FLEXOGRAPHY:
Principles & Practices

5th Edition

VOLUME

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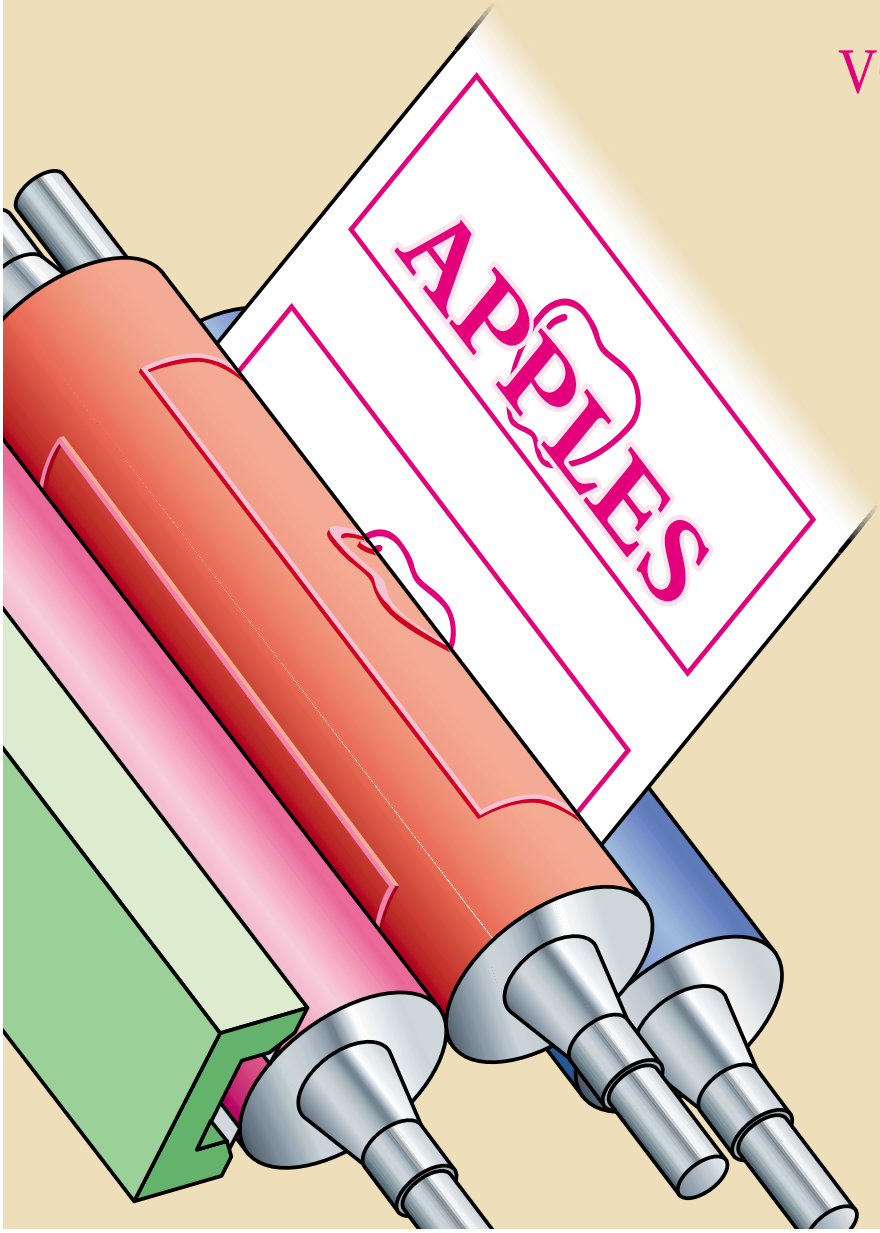

Flexography: Principles And Practices

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Fifth Edition

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Preface

The fifth edition of *Flexography: Principles & Practices* represents the efforts and contributions of many people in the flexographic printing industry. In fact, we can thank all those contributors that date back to the publication of the first edition in 1962. The text book has served the industry well as a reference work on all aspects of flexographic printing. Our belief is that this publication will continue to be highly valued as we enter the next millennium.

This fifth edition introduces a new format. Six volumes contain the various chapters on specific topics of flexography. The motivation for this change was twofold: First, the text has continued to expand with each edition and has outgrown a convenient size for one volume. The second and perhaps a more important motivation was the desire to be able to update the material in more manageable pieces. In the future, select topics, particularly some of the more rapidly changing areas of our industry, can be updated in specific volumes. This will make the process more timely and also will not necessitate the purchase of the entire six volume set at each update.

Another major change in format will be immediately apparent by inspecting any of the books – all of the illustrations are now in color. We have standardized the use of illustrations in order to give the work a unified and easy to understand appearance. We hope you enjoy the new format!

As each volume and its chapters are reviewed, please notice the credit list of people who authored or edited that particular section. However, several people played an overall role with their work. Michael Wiest, technical manager of the FTA/FFTA, was the leader of the project, coordinating the input from many sources, as well as editing each chapter. Michael also authored select chapters or parts of chapters. Involved with several of the other chapters was George Cusdin, president of Flexographic Printing Services, Smyrna, GA, a respected consultant, who created manuscripts from the beginning, or modified and updated those areas from the Fourth Edition where appropriate.

Coordinating the layout, imposition, and graphics was Kelley Callery, director of marketing and creative services for the FTA/FFTA, and handling the production and design was freelance publication graphic designer, Sonja Huie, of H+A Productions. Illustrations were done by Shane Kelley of Kelley Graphics in Maryland.

The editorial staff of *Flexo*® magazine, Glenn Koch, the former editor, Ed Rogers, associate editor, and Bob Moran, publisher, read and edited each manuscript to generate consistent readability from one chapter to another, as well as to ensure language and word appropriateness. Kim Berk, marketing coordinator for the FTA/FFTA also assisted with the proofreading.

Due to the enormity of the effort to produce "FP&P", we want to acknowledge the history and people who have brought us to this point. The fourth edition of *Flexography: Principles & Practices* was an exceptional effort, as it was also not intended to be merely a revised copy of the third edition, but rather a completely-new general

resource book. Frank Siconolfi of Matthews International Corporation dedicated an enormous amount of time, as did his committee of industry volunteers (*committee listed below).

In 1980, the third edition was published with Joe W. Cotton as chairman. Members of this revision committee were: Don Vanden Branden, Robert Demetrician, Don Donelan, James K. Ely, Gerald J. Gartner, Charles R.Heurich, Vernon R Johnson, Joseph B. Lankford, Wallace D. Nard, Henry F. Salmaggi, Fred Shapiro, Howard K. Sheldon Douglas E. Tuttle, Bruce Weaver and George Wilfling.

The second edition was released in 1970 under the chairmanship of Howard K. Sheldon. Committee members included: George H. Anthony, E. Howard Grupe, Jack Kemerling, John M. Miller, Ned E. Mitchell, Frederick K. Moss, George J. Parisi, Daniel A. White and Robert Zuckerman.

The first edition of *Flexography: Principles & Practices* was printed in 1962 under the overall leadership of Norman H. Abrams and F. Henry Wittel as co-chairmen. Members serving on this first committee were: Calvin Balcom, James J. Deeney, Peter M. Fahrendorf, Jr., Richard E. Jansing, Heinz P. John, Mel Kester, David Killary, Franklin Moss, Frank Murphy, Christopher Shepherd, Douglas E.Tuttle and Robert Zuckerman.

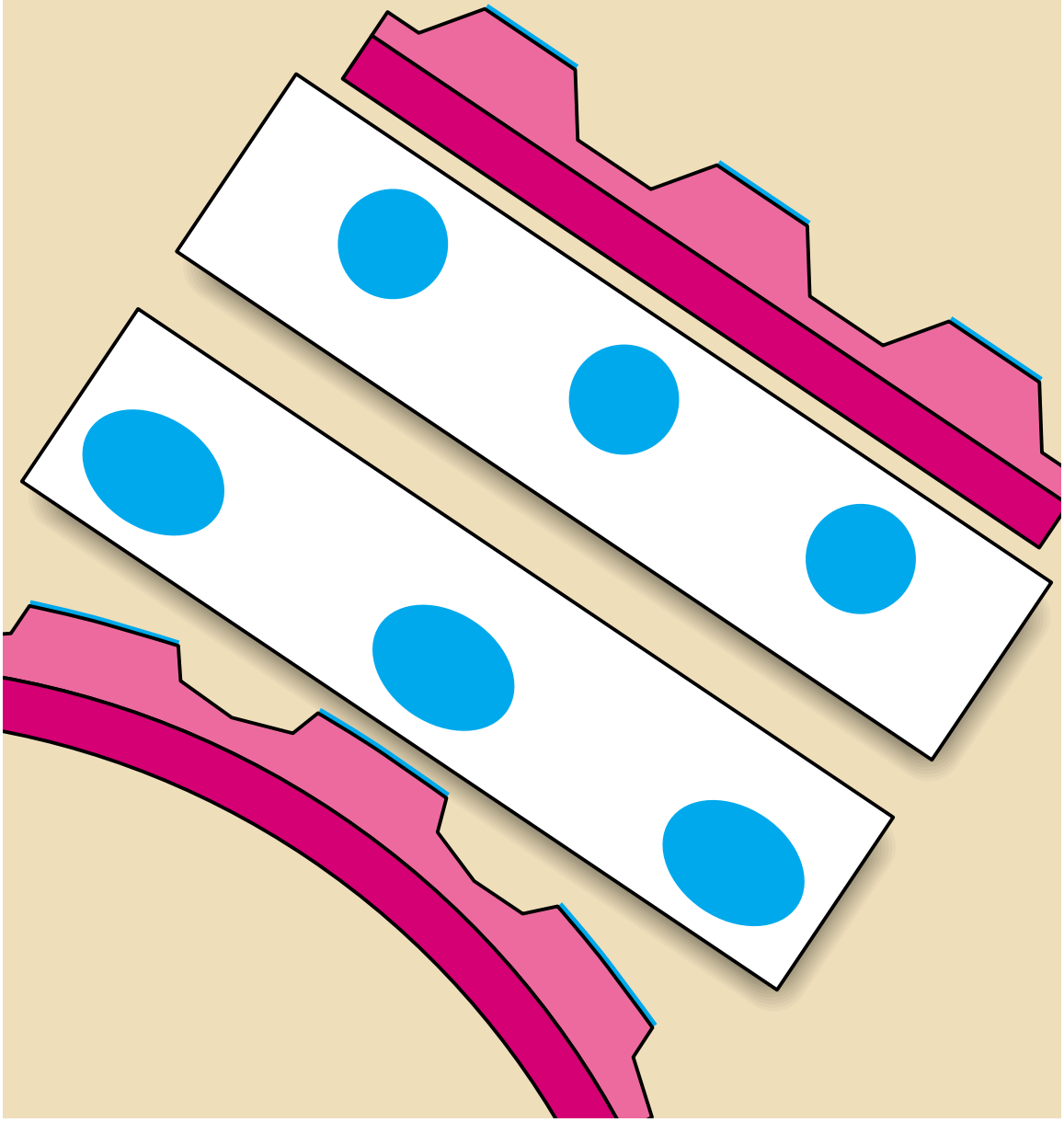
All of the above-named individuals are recognized for their exceptional dedication and forethought in preparing the respective editions. It is through their laying of the groundwork that a project of this size and scope can be undertaken. At this point, we should also acknowledge the pioneering efforts of Frank E. Boughton whose book entitled *Flexographic Printing* was published in 1958. To our knowledge, this was the first book to be dedicated solely to flexography.

George Parisi, former president of the FTA/FFTA, who maintained a spirit of continuation, updating, and energy to foster the educational mission of the organization, directed previous issues. To all our contributors, past and present, we extend thanks and appreciation for the work and effort that has resulted in a most significant product.

William C. Dowdell
President
Foundation of Flexographic Technical Association

CHAPTER 1

Introduction



ACKNOWLEDGEMENTS

Author/Editor: George Cusdin, Flexographic Printing Services

What is Flexography?

Flexography is a method of direct rotary printing, similar to letterpress, that uses resilient relief-image plates of rubber or photopolymer material. The plates are affixed to plate cylinders and are inked by a cell-structured, ink-metering "anilox" roll carrying a fast-drying fluid ink to plates that print onto virtually any substrate, absorbent or nonabsorbent. For every revolution of the printing-plate cylinder, an image is produced.

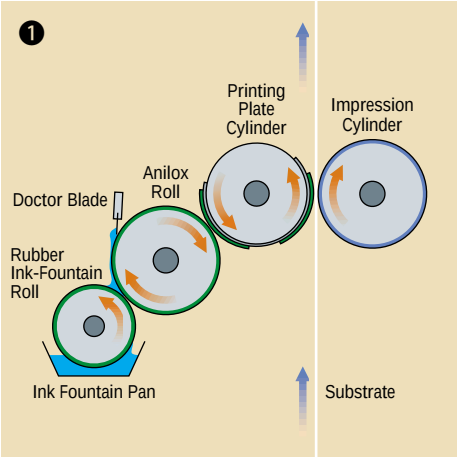
The process was developed primarily for printing on packaging substrates – board, paper, foil and film. Materials are commonly supplied in roll form for feeding into form-and-fill, over-wrapping, bag making and other continuous web-processing machinery. For these applications, roll-to-roll or roll-to-cut printing is required.

The four most common flexographic press designs are central impression, stack, in-line and sheetfed.

Many operations can be performed in line after the substrate has been printed and dried, while still unwound. Some types of flexo presses are equipped with a shearing and stacking device that delivers sheets instead of wound rolls; others are equipped with a die-cutting operation which delivers finished individual cartons, rolls of labels, or other finished products.

In the corrugated postprint converting operation, the flexographic presses are sheetfed, in-line units and are generally coupled to other in-line processes such as die cutting or folding and gluing.

The heart of the flexographic printing process is its simple inking system (*Figure* ❶).



❶ A typical flexographic print station, configured as a two-roll inking system with doctor blade.

The ink-fountain pan supplies ink to a rubber ink-fountain roll, which supplies ink to the ink-metering (anilox) roll and may come equipped with a reverse-angle doctor blade. The anilox roll transfers a precise amount of ink onto the printing plate, which is mounted onto the printing cylinder. The printing plate on the printing-plate cylinder and the impression cylinder form a nip where the ink is transferred onto the substrate.

The fact that flexo printing plates are inked directly by the anilox roll makes the system simple and unique. To a flexographic press operator, the ink-metering system is a means of controlling the amount of ink being presented to the plates and subsequently to the substrates. On the most sophisticated presses the ink fountain, fountain roll and doctor blade have been replaced by a chambered ink applicator.

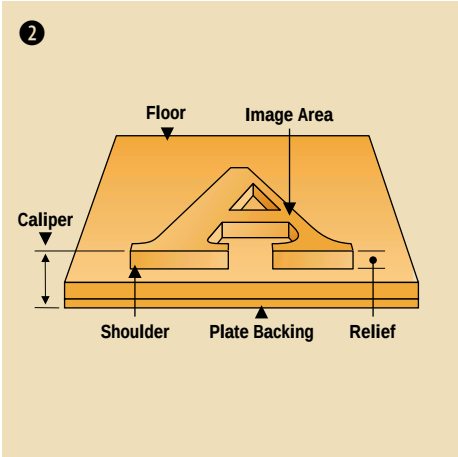
Flexography uses low-viscosity inks, either solvent- or water-based, which dry very quickly between the print stations of a press. The viscosity of the ink is like that of a free-

flowing, liquid, such as light oil or a light syrup. In the early 1990s, pigmented, UV-curable flexo inks became commercially available from a number of suppliers. Since that time, UV-flexo printing has grown rapidly among narrow-web converters.

Flexographic printing plates can be made of either vulcanized rubber or a variety of ultraviolet-sensitive, curable-polymer resins. The plates have a base-relief (raised image) and print directly to the substrate with a very light impression.

The key component of the plate is, of course, the raised image area, which carries the image to be printed. *Figure* ❷ illustrates the additional components of the printing plate, and are summarized as follows:

- image area – the printable surface;
- caliper – the total thickness of the plate;
- floor – the nonprintable area of the plate;
- relief – the distance from the floor to the top of the image area;
- shoulder – the support for the printable area; the edge of the image area;.
- plate backing – the material on the back of the plate to provide stability.



❷ This diagram of a flexographic relief printing plate shows the components of the plate: image area, floor, caliper, shoulder, plate backing and relief.

❸ A wide variety of packaging is produced using the flexographic printing process.

Unlike the hard metal plates that are used in letterpress work, flexo plates are resilient and displaceable. The plates are attached to the plate cylinders with double-sided adhesive tape called "stickyback" which may be solid vinyl or cushion type.

ADVANTAGES OF FLEXOGRAPHY

Flexographic printing is an efficient, cost-effective and versatile printing method. By the end of the 1990's, approximately one quarter of all printing is flexographic; in the packaging segment of the printing industry, flexo enjoys a market share of over 65%. Growth throughout the 1990s has been steady, estimating an increase of 6% to 8% for the final year of the decade. *Table 1* summarizes the positive points of using flexography.

FLEXOGRAPHIC PRINTING APPLICATIONS

Figure ❸ shows the variety of products printed and vivid colors produced by flexography. For any manufacturer, flexography is a logical and economical choice.

Consumers, of course, are usually unaware of the process used to reproduce the graphics on products they use every day. Ordinarily, the product is opened, the contents used and the packaging discarded.

As new products are manufactured, additional package printing requirements are generated. This has a lot to do with the steady growth of flexography. In fact, flexo-

CHARACTERISTICS AND ADVANTAGES OF FLEXOGRAPHY

- Prints on a wide variety of absorbent and nonabsorbent substrates.
- Prints on the reverse side of stretchable, transparent films.
- Prints using resilient rubber or photopolymer image carriers – millions of impressions can be printed.
- Allows printing of 10 or more colors because of multiple print stations.
- Allows continuous pattern printing (giftwrap, wallpaper, floor coverings) because of its near-total variable-repeat-length system.
- Can achieve press speeds of 2,000 feet per minute or more (certain segments of the industry).
- Prints process color jobs 175-lpi and higher (smooth-coated substrates).
- Uses fast-drying solvent, water-based or UV curable inks.
- Eliminates back-trap contamination, setoff and trapping problems by allowing wet ink to print over dry ink.
- Can deliver a predetermined amount of ink with minimum on-press adjustments with its inking system.
- Can print using flourescent and metallic inks.
- Allows printing-plate cylinders to be taken out of the press to enable printing plates to be mounted and proofed as a prepress operation.
- Can perform coating and in-line operations such as laminating and diecutting as a continuous operation.
- Can produce the complete package, such as folding cartons, displays, multiwall bags, labels, in-line.
- Is cost effective for many applications.
- Offers high investment return on equipment.
- Enables fast turnaround time between jobs.
- Can make short-run work more profitable.

graphy is now the fastest growing printing process in the world.

Successful packaging catches the customer's eye. Manufacturers know that established brands need consistent color matching and print quality to attract attention on store shelves and to help assure customer loyalty.

To boost sales, manufacturers are relying heavily on full process-color printing. Full process-color printing is a system of reproducing a variety of colors by printing three standard-color inks in various combinations and proportions, usually with black added. For example, the process color images depicted on frozen food packages must look real, appear appetizing. If the color looks artificial because of poor printing, sales could suffer. It is evident that flexographers and manufacturers will continue to be partners, especially in the printing of plastic bags for food packaging.

Until recently, flexography was rarely involved in the printing of publications, but the process is now making inroads in this area. Flexographically printed comics and inserts are being produced with excellent results. Water-based inks that produce a no-

rub-off image on thinner newsprint have been well received. Interest in flexography is now global. The 1990s have seen major improvements in flexo print quality.

New products and new packaging continue to evolve. It is a challenge for flexography to keep pace. Makers of presses and related equipment are designing with state-of-the-art advances in mind. Vendors and supplies also are obliged to keep abreast of new technology as standards for print quality get tougher.

In the corrugated area, many companies are preprinting linerboard, roll-to-roll, using process colors with great success. The preprinted rolls are then combined with traditional corrugated medium and die cut, folded and glued, either in-line, or later, off-line. The finished carton has enhanced eye appeal and excellent print quality.

Traditionally, corrugated printers used sheetfed letterpress presses when working with combined board. It has always been difficult to achieve decent print quality and image sharpness without crushing the flutes, which reduced the strength of the case. But flexo, using water-based inks to print directly onto combined board, has been on the rise.

The quality of corrugated postprint using flexography is limited only by the initial quality of the combined board. The quality of graphics printed on combined corrugated board, using state-of-the-art presses, is rivaling that of offset preprinted labels.

Flexography can expand in many different directions. It has grown into a sophisticated, high-quality process of choice.

OTHER PRINTING METHODS

Flexography is the predominant method of printing in the packaging industry and is expanding in other printing segments. This section provides a short overview of other major printing methods, including some hybrid ones, such as those that combine different printing methods on one print station.

Letterpress

Letterpress was the first printing method, and its name pretty much describes how it works. The relief printing surface of the type is inked with a paste ink and literally pressed onto the paper. The main characteristics of letterpress are clear, crisp impressions and strong, vibrant colors.

It made its first mark in history, when Johann Gutenberg, in the 15th century, produced a two-volume Bible. Ironically, this venture bankrupted him, but the printing process continued its growth.

During the 1700s, America's independence was owed in part to the use of letterpress, as Ben Franklin and Peter Zenger were printing materials that supported our freedom.

Until the late 1800s, letterpress was the only printing method around. Offset, gravure and screen printing did not appear until after the turn of the century. In the 1950s, offset printing got started and eventually became the major printing process of our time. In the 1980s, letterpress' share of the market declined, and web-offset replaced it at most newspapers and magazines. In general, small jobs could be done on high-speed offset duplicators or electrostatic copiers.

Letterpress is now limited mainly to specialty work, such as numbering, embossing, hot stamping and hot-wax carbonizing (spot-carbon printing). It is also used for die cutting, perforating, slitting and scoring.

Since the introduction of photo-compositioned type, hard photopolymer or rubber plates took the place of the old hot-metal linotype casting machines. Most letterpress type forms were replaced by one-piece aluminum or steel backed photopolymer materials. Today, very few printers use handset foundry or hot-metal type.

In the press, lead- and trail-sheet lockup systems, magnetic bases or magnetic cylinders are used to hold plates in place. Most letterpress printers are using photopolymer or rubber plates instead of the original hard

metal plates. Letterpress is also used for hot foil stamping, where a heated metal printing plate melts glue on the back of the foil sheets transferring the characters to the substrate being printed.

Typical letterpress configurations are platen, flat-bed with impression cylinder and rotary (*Figure* ❹).

On a typical rotary letterpress print station used mainly on newsprint presses, the print station includes an ink fountain and a steel fountain roller turning in contact with the thick paste ink (*Figure* ❺). Notice the many rollers in the inking train. The ink is picked up by a roller that conducts the ink to a series of oscillating/rotating steel rollers with rubber rollers in between. The ink is thinned out and transferred by the rubber form rollers which in turn ink the type or printing plates. The image is pressed into the substrate against an impression cylinder, which is covered with a rubber blanket or tympan paper (a soft, makeready packing paper).

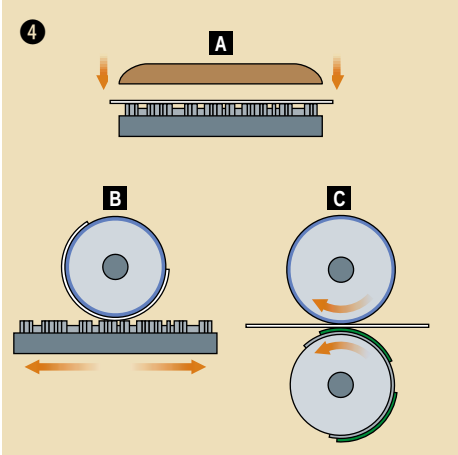
The sharp image for which letterpress is noted is slightly embossed below the surface of the substrate. For fine-line screen printing, a smooth substrate is essential; the smoother the substrate, the greater the detail. Letterpress is limited to 150-line screen work.

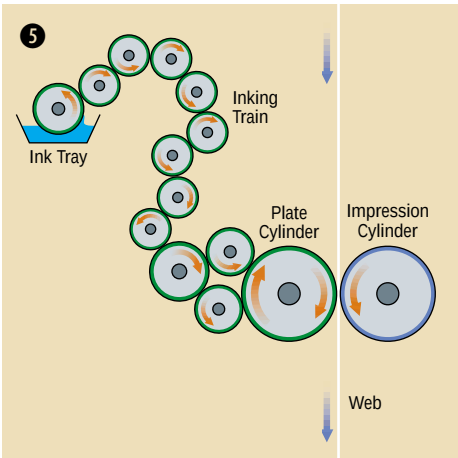
As with flexo printing, letterpress requires some pressure to the substrate to transfer the image. While flexo plates are relatively soft and displaceable, letterpress plates are hard and require more pressure than flexo.

Many printers mistake flexography as a form of rotary letterpress. Flexo plates look like relief-letterpress plates, but that's where the similarity ends. Flexo uses a "kiss" impression with fast-drying fluid inks. Letterpress uses slow-drying paste inks and cannot print on plastic films or many of the other materials that flexo handles with ease.

Lithography

Lithography prints from a flat (planographic) surface.





❹ Typical letterpress configurations are platen (a), flatbed (b), and impression cylinder (c).

❺ A typical rotary letterpress print station used mainly on newsprint presses. The print station includes an ink fountain and a steel fountain roller turning in contact with the thick paste ink.

In 1798, Alois Senefelder discovered the basic principle of lithography, when he wrote on a flat stone with a grease pencil. He dampened the limestone surface with water and inked the writing with a greasy ink, then pressed the paper against the stone, transferring the inked image to the paper. The image, of course, printed in reverse.

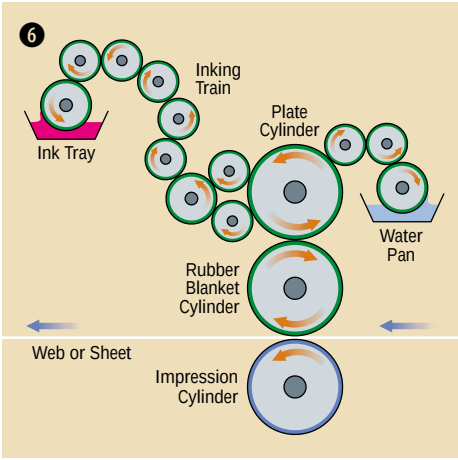
What happened was this: The water wetted the nonimage areas on the stone but was repelled by the greasy image areas. Conversly, the greasy ink was repelled by the wetted areas of the stone and was only attracted to the image areas. Later, Senefelder wrote on paper with a greasy ink and then pressed the image to the dry stone surface. In doing so, the image reversed itself when transferred to the stone. He wet-

ted the stone and inked the reversed greasy image. When he pressed paper to the stone, the image it produced was the first readable, direct stone lithographic print ever.

For generations, a special Bavarian limestone was used for the image-carrying "plate" from which the process got its name, taken from the Greek words "litho" (stone) and "graphein" (to write).

Today, stone lithography is very rare and is only being utilized by a small group of professional artists who produce limited edition prints. At one time, zinc coated with a photoemulsion was widely used. The images were rubbed off the zinc plate with abrasives, dried, recoated with emulsions and reused. Most modern lithographs are made from thin aluminum plates.

Printers buy presensitized aluminum plates that they expose through negatives, using vacuum contact, under bright light. After exposure, the latent image is developed with a greasy developer and dried. On press, the aluminum plate is dampened with a water fountain solution and inked by rubber form rollers. Faithful to the process, only the ink is attracted to the image, since the water repels it from the nonprinting areas. The thin-gauge aluminum plates are relatively inexpensive and are not reuseable but may be recycled for the aluminum content.



6 A typical offset lithography print station. The print station includes the inking train and water rollers, the plate, rubber blanket and impression cylinders.

In some cases for short-run jobs, plastic-coated-paper printing plates covered with a photo emulsion are used.

The image is positive-reading on the plate surface. Both the inked image and nonprinting areas are on the same plane, hence the name planography. The plates are attached to the plate cylinder by clamping the plate's leading and trailing edges, leaving a gap between the clamps, which makes continuous-design patterns impossible to print with this process. Only flexography and gravure use an uninterrupted cylinder surface that allows continuous patterns to be printed.

As the plate cylinder turns, it is dampened with a water-wetted roller and immediately inked (*Figure* 6). The plate cylinder then comes in contact with a rubber-blanketed cylinder. The positive printing plate image is transferred or "offset" to the blanket surface in reverse. The blanket in turn transfers the image to the substrate against an impression cylinder in positive, readable copy. Offset presses can be either sheetfed or web-fed.

Historically, offset presses have been sheetfed. Web-fed offset presses first appeared in the 1960s. Out of a need for higher press speeds, most publication worktoday is being done with web-offset. Lithography has been a favored process because it can reproduce soft tonal values on coated substrates. Another highly-prized feature of lithography is its ability to print 300-line screen images with excellent fidelity.

Rotogravure

True intaglio or steel-die process prints from sunken lines or grooves are connected and cross each other. Ink is then applied to the engraved areas and doctored or wiped off the smooth nonimage areas. The resulting inked image is then impressed onto the substrate to be printed. Our paper currency is printed from steel dies capable of reproducing very fine lines that no other process can duplicate. Rotogravure is a form of

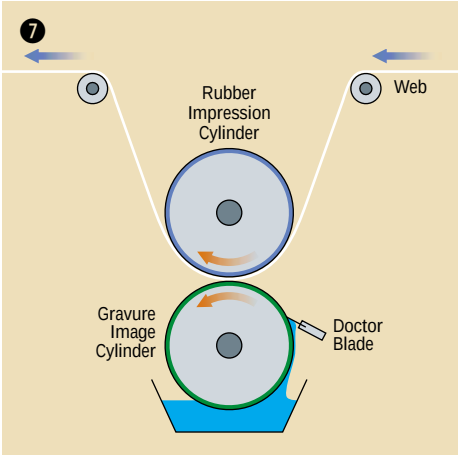
"intaglio" (cut-in or sunken) printing and prints directly from unconnected cells engraved into the plate cylinder.

The print cylinders in gravure are machined, electroplated with copper, ground and polished. For photo-etching the cylinders are then coated with a light-sensitive emulsion. After drying, negatives are contacted completely around the cylinder and exposed to light. The sunken cells are etched into the cylinder with an iron chloride solution. To increase the run length of the copper cylinder, chrome plating is applied over the copper to protect and harden the surface. For short runs, the copper cylinder may be used without chrome plating.

In place of the photo-etching process, an electronic scanning machine with a diamond stylus can be used to mechanically "deboss" copper cylinders in place. Most recently the use of computer-driven laser etching images directly to the surface of ceramic coated cylinders is replacing the former technology.

In gravure, the cells holding the ink are not interconnected, therefore a checkerboard or saw-tooth pattern shows up around print edges – a characteristic of gravure printing. To overcome this deficiency, very fine screen sizes are used to make the rough edges as inconspicuous as possible. The cylinder's print areas are etched as microscopic, cup-like cells, while nonprint areas remain untouched. The larger and bolder the copy, the larger and deeper the etched cells. Fine tonal areas have a smaller cell size and depth.

Gravure inks are fluid and have very low viscosity. They are formulated of resins dissolved with solvents, pigments and additives. On press (*Figure* ❼), the image-bearing cylinder is either flooded with an applicator roll or rotates in an ink pan, or fountain, in order to fill the cells with ink. Excess ink on the surface of the cylinder is wiped off with a steel doctor blade. As the cylinder makes contact with the substrate, ink leaves the cells by capillary action to transfer the image to the substrate. Often the ink will not release from the cells to the web substrate, causing print "skipping." To overcome this deficiency, a rubber roller provides an electrostatic charge to the system. This helps eliminate skipping by allowing the electrostatically charged ink in the cells to be attracted by an opposite charge in the roller.



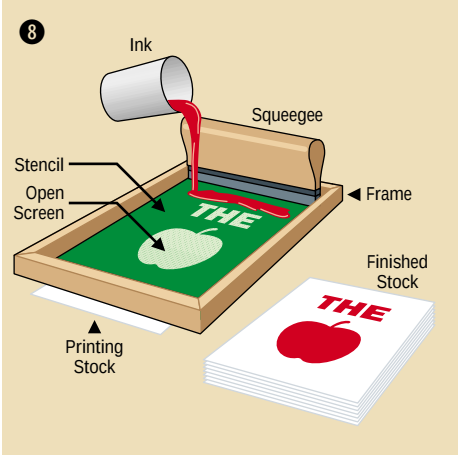
❼ In a typical gravure print station, the ink station includes a gravure cylinder flooded with low-viscosity ink, which is doctored and then transfers the ink to the substrate.

Gravure inks must be free of foreign particles. These can cause streaking on the cylinder surface, resulting in doctor-blade streaking on the printed web. If streaking does occur, the cylinder has to be removed from the press and refinished. If the doctor blade has nicks or other defects, the blade must either be replaced or reground to a smooth finish.

Most gravure presses are web-fed (rotogravure). But some are sheetfed and have a flat plate that clamps to the plate cylinder. Other gravure systems use removable sleeve-type cylinders. Presses are mostly inline, designed with a dryer unit above each print station. The web travels from one print station to another with wet ink overprinting dry ink throughout the process. Six- to eight-color presses are common.

Gravure is used to print line work and fine halftones at relatively high speeds, and print runs can go into millions of impressions. Run length depends on the condition or wear of

❽ For a typical screen print station, the ink station includes a screen in a frame and squeegee to force ink through the screen onto the substrate.



the print cylinder, and the streaking mentioned above would certainly shorten a cylinder's life.

Ideal substrates for gravure are smooth-finish, clay-coated papers, super-calendered papers, rigid films and foils. Since effective ink transfer depends on thorough cell contact with the substrate, irregular or "toothy" rough surfaces are generally not printed gravure. Stretchable substrates also present problems with registration and print quality, while thick or rigid films print quite well.

Gravure is used for packaging, magazines, newspapers, and other specialty printing applications. It has been an outstanding choice for printing process color for mass-circulation magazines and newspapers. Gravure-printed postage stamps are another example of the fine print results of rotogravure. Many plants have blended flexography with gravure to produce exceptional print results on packaging materials.

Screen Printing (Serigraphy)

Screen printing or screen process printing, originally known as silk screen printing, first appeared in ancient China, where silk was abundant. Today, man-made fabrics and stainless steel are used for the mesh screens, so the word "silk" has been dropped.

The basic equipment includes a table, a rigid frame, a finely meshed screen, a semi-rigid squeegee, stencil materials and heavy, viscous ink (*Figure* ❽). The process involves using a squeegee made of wood or rubber to force ink through a porous, screen stencil to a substrate beneath.

In the beginning, screen stencils were hand-cut from a special, lacquered film material, but the process was slow and inefficient. Today, there is a choice of using either computer-aided, mechanically produced stencils or the more popular direct photo-emulsion variety. In the latter process, the screen is strectched tightly over the frame, and a photo-emulsion is applied to it. Film with a positive image is put into vacuum contact with the screen's dry emulsion and exposed to white light. After exposure, the image is washed out with a water spray. The unexposed areas are insoluble and wash out cleanly; while the exposed areas are painted with a block-out solution to prevent ink from bleeding through the screen. The screen is attached to a table on one side by clamps or hinges, or installed in an automatic press location. The screen becomes the image carrier. Printers currently use durable, ultra-fine stainless-steel mesh screens that are capable of reproducing remarkable readable 6 pt. type, along with intricate designs.

The substrate is positioned under the screen and frame. Register tabs are located on the table, or press guides are set in place on the feed table of the press to register each sheet for printing. The screen is lowered and ink is deposited at one end. Then, the squeegee is pressed down and across the length of the screen, forcing the ink through and printing the image.

The ink-film thickness on the substrate is approximately equal to the thickness of the screen's fabric filaments. For fine-line process color work, fine threads or filaments are used, and multiple colors can be printed. The photo stencils can be removed with solvent sprays after use and the screens reused.

Both single and multicolor presses are used. Many require an operator to insert and remove the sheets by hand. Some have automatic squeegee impression cycles. The fully automatic machines feed the sheets, register colors, lower the screen and squeegee the print. The sheets are removed to a dryer and then stacked at the other end of the press.

Some presses use round, brass screens. These print dyes to fabrics from a roll. In-line presses print from one station to another for eight or more colors. The process is simple and lends itself to many specialty applications.

Through the use of specially built jigs and printing frames with flexible screens, the silkscreen process is widely used for printing rounded and irregular surfaces such as bottles, tubes, plastic and metal objects. The chief advantage of screen printing is its versatility on many different surfaces, irregular or flat. Screen printing also lays down a smooth, heavy ink-film thickness. Many outdoor reflective signs, like those used on highways, are screen printed on metal. Indeed, many items are screen printed because they can not be printed any other way. The process is ideal for short-run jobs.

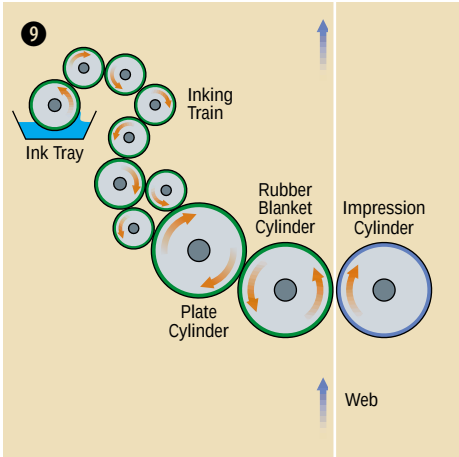
Letterset (Dry Offset)

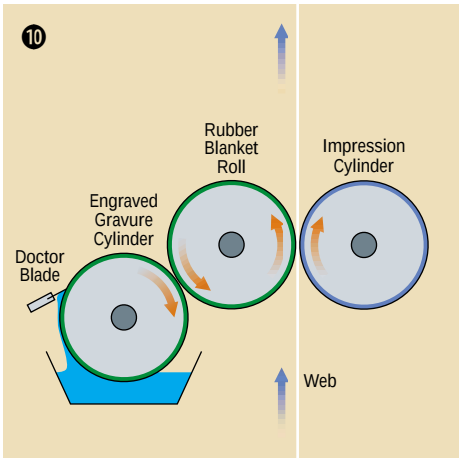
Water used in the offset process sometimes causes problems because of the critical balance that must be kept between it and the oil-based ink. The letterset or dry offset plate system was introduced to eliminate the need to dampen the plate with water. A hard, shallow-relief letterpress plate is used to print to the blanket on an offset press. (*Figure* ❾). As the name implies, letterset means the use of letterpress plates on an offset press.

Offset Gravure

Offset gravure is a combination of offset lithography and rotogravure. In conventional offset, the flat offset-plate image has a limited life and can wear off during long runs. To overcome this, a longer-wearing gravure cylinder can be used instead. The gravure cylinder transfers its image to an offset blanket with excellent fidelity (*Figure* ❿). The image on the gravure cylinder must be positive so it can transfer a reversed image to the offset blanket. In turn, the blanket's image prints positive on the substrate.

Coarse surface substrates or even woven fabrics are printed with surprising fidelity overcoming the need to print on super-calendered or coated papers using standard rotogravure. With or without electrostatic help, the ink easily transfers its image to the smooth rubber blanket. In doing so, the image from the blanket faithfully delivers its minute dots to the substrate.





❾ The typical letterset – also called dry offset – print station is similar to offset but eliminates the use of a dampening (water) system by using a shallow relief plate.

❿ In a typical offset gravure print station, the gravure cylinder transfers ink to the offset blanket.

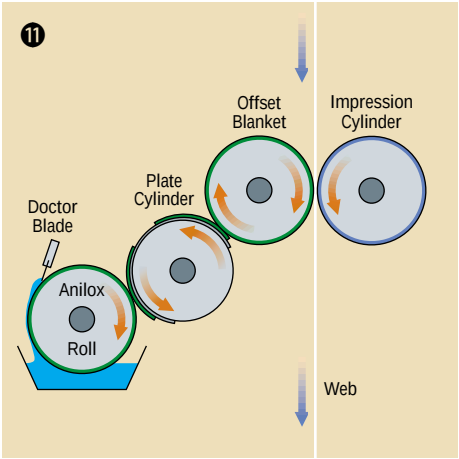
⓫ The typical flexo offset print station requires the flexo plate to transfer ink to the offset blanket.

Flexo Offset

In this process, a flexographic printing plate is used in place of the gravure cylinder. The flexo plate, with a positive image, prints to the offset blanket, which reverses it and prints a positive image to the substrate, as shown in *Figure* ⓫.

Round, plastic containers are printed this way. Some special presses have three- or four-color stations around the offset blanket cylinder. All the colors are registered on the surface of the blanket, which transfers the multicolored image directly to the rotating container during each revolution.

The containers are held by vacuum on a printing spindle. After one is printed, the next, on its own spindle, comes into position and is printed. Aluminum cans with a clear-base coating and tapered drinking cups can also be printed this way. There are still many untapped applications for flexo offset.



The Evolution of Flexography

There have been many critical events, inventions and other factors that influenced the evolution of flexography. What follows reflects some of the known milestones in the development of flexographic printing.

ANILINE PRINTING

Aniline printing, as flexography was known until 1952, evolved out of rotary letterpress. Its name was taken from the aniline dyes in the inks that were used at the time.

Early forms of the aniline press were in use in Europe as far back as 1860, and historians trace the first modern style of aniline press to 1890, when Bibby Baron and Sons of Liverpool, England, built what resembled a central-impression cylinder press, with printing units around the drum.

The first patented aniline press was produced by C.A. Holweg of Alsace-Lorraine, who was granted British patent #16519 on November 7, 1908. Holweg built the stack-type press in 1905 as a tail-end printer unit, in-line with a bag-making machine. Since the alcohol dyestuff ink dried so quickly, it was possible to produce bags in a continuous operation after printing. Another key player during the infancy of aniline printing was Strachan and Henshaw in Great Britain, producing central-impression presses.

Windmoeller & Hoelscher GmbH of Germany sold presses for printing bags. These machines used inline with aniline presses that produced paper bags in one continuous operation.Its popular bag-making machine, introduced in 1914, was called the “Matador.”

Also in the late 1800s, Francis X. Hooper designed and built a press for stamping ink identification marks onto the wooden planks of shipping crates, using metal type known as “printing dies.” Hooper’s presses were very much like the more modern printer-slotter. Around the turn of the century, the George W. Swift Company developed aniline presses that could print on fiberboard.

By 1900, combined corrugated board was being considered as a shipping box material. In 1914, the Interstate Commerce Commission decided to allow the use of corrugated boxes for interstate commerce, thus inaugurating a huge industry in the United States. Presses soon appeared that could die cut after printing and add slots and creases to the corrugated box. Previously, dried, printed corrugated boxes were folded without an overlap on the corner and automatic taping machines were marketed during the 1920s and 1930s.

The early corrugated printers saw the need for flexible, displaceable plates that would not crush the fluted material. Presses had to be built to handle the various calipers of fluted board and 0.250" thick printing plates which were nailed or tacked in place on the wooden print cylinders. For many years, only letterpress paste inks were used. Ink drying was slow, causing die-cutting and

finishing delays. The need for a faster-drying ink system became apparent.

Ink metering for early aniline printing was achieved using two rubber rolls; one to draw the ink from the ink fountain, the second to doctor the ink film and transfer the ink film to the printing plate. At this time, printing plates were either wooden or metal, similar to those used in letterpress or hand-engraved designs, drawn or traced on sheets of prepared vulcanized rubber compounds.

EARLY DEVELOPMENT

The early development of aniline printing ran head-on into the "do-it-yourself" age. Many converters designed and built their own equipment using local machine shops to fabricate their designs. Most presses were simple and followed the design for stack presses. Many made their own rubber plates and dyestuff inks. These homemade presses were of light construction, with the printing stations consisting of an ink pan, a rubber fountain roller, rubber ink-transfer roller and a plate cylinder with an impression cylinder.

Ink metering was crude and uncontrolled. Two rubber rollers, or an aluminum together with a rubber roller, were used to ink the plates. Ink-film thickness on the plates varied and was unpredictable. An increase in press speed caused more hydraulic force between the rollers and over-inking, resulting in crude and fuzzy printed images.

In the 1920s, aniline ink was made from water-soluble, coal-tar dyestuffs. The dyes were dissolved in alcohol, with tannic and acetic acids added, to make them smear-proof. They had very poor light-fastness and a short shelf life; they also bled into the surface of paper substrates and migrated with uncoated cellophane. Even after drying on the substrate, they had a very unpleasant residual odor which could contaminate food.

In the early 1930s, titanium-dioxide-white-pigmented ink, pigmented yellow and orange inks appeared. Metallic inks also arrived, in addition to colors such as red, green, blue and black. By 1938, water-type opaque inks were developed for printing on paper, paperboard and combined corrugated board. Until the 1950s, only dyestuff, alcohol, water-soluble and some pigmented inks were available to the aniline or flexographic printer.

By the 1940s, aniline presses were printing about 150 feet per minute. Within 10 years, press speeds increased, forcing ink-drying speeds to increase through new ink technology.

INTRODUCTION OF THE ANILOX ROLL

In 1939, a mechanically engraved, chrome-plated, ink-metering roll was introduced in the aniline industry. Similar to rotogravure print cylinders, anilox rolls were produced by mechanically engraving the surface of copper-coated rolls with a controlled pattern of ink-carrying cells. Chromium was then electroplated over the copper layer to prevent corrosion and increase wear resistance. The name anilox roll was derived from the aniline process.

Then, as now, the anilox roll is the heart of the flexographic printing system. Its introduction was a milestone in the development of an accurate inking system, and the older rubber-roll-to-rubber-roll system began to disappear.

IMPACT OF MAN-MADE PLASTICS

The introduction of polyethylene to the packaging industry as an alternative to cellophane marked another milestone in the industry. New substrates affected press design. Once polyethylene came along in the 1940s, presses had to be refined to work with this stretchable material. It caused radical changes in web-tensioning devices, unwind and rewind controls, edge-guiding equip-

ment, automatic splicing, hydraulics and air-pressure devices. More controllable drying systems had to be developed.

The new substrates also demanded even better ink formulations. Ink manufactures found alternatives to the aniline dies and co-solvent inks appeared, using a mixture of aliphatic hydrocarbons and alcohol as a solvent. Ink chemists then began using other coloring agents that everybody considered safe but even though printers were using these newer inks, the name aniline printing stuck.

OFF-PRESS MOUNTING AND PROOFING

In the 1940s, the first plate-mounting and proofing machine was introduced to mount plates accurately and completely off-press. The mounter-proofer boosted production by minimizing downtime between jobs. Accurate proofs of each cylinder and of the complete multicolor job became a reality, with the prepress proofs showing whether each job would print in register. The costly trial and error of correcting misregister became but a bad memory from the days of on-press mounting.

ANILINE PROCESS NAME CHANGE

In 1949, the Federal Bureau of Animal Industries recognized that the dyes and pigmentation being used in the new aniline ink formulations were the same as those in other printing processes, and removed the ban for use on food packaging. Aniline printing could not shake the stigma, however, especially in the minds of customers, and it was not long before people objected to the name aniline because of the bad connotations and plain inaccuracy.

In March 1951, a campaign to change the name "aniline printing" to a more suitable one was started. The industry's response was enormous, with well over 200 submissions. A subcommittee of the Packaging Institute's Printed Packaging Committee was specially formed to pick the best submission. On October 21, 1952, at the 14th Packaging Institute Forum, the announcement was made that the "flexographic process" had been the overwhelming choice. The industry world-wide embrace the new name, and aniline's bad reputation was history.

MOLDED-RUBBER PLATES

The introduction of phenolic-resin molding boards for rubber-platemaking in the 1950s marked another breakthrough. Mechanically etched or photo-etched graphics on a metal master plate could be transferred to a phenolic-resin molding board. This board was then used to vulcanize rubber copies of the metal master. Using this technique, finer, more accurate print copy could be produced.

Charts were developed for figuring the stretch of rubber plates when curved and mounted onto round cylinders, and a special camera was developed for accurate image distortion of photographic negatives to allow for image elongation.

PHOTOPOLYMER PLATES

The 1970s saw the introduction of photopolymer printing plates. By the mid-1970s, five companies in the United States began selling photopolymers for the production of photopolymer plates.

Photopolymers began to replace the molded rubber previously used for the manufacture of printing plates. At first, these photopolymer plate materials were not very chemically stable and often became brittle from ozone exposure or tacky from ink additives. Since then, plate manufacturers have improved platemaking materials and research in the photopolymer plate field is ongoing.

PLATE MOUNTING

More aggressive adhesives were necessary to keep the polyester plate backings from pulling free. In 1975, stickyback was developed to attach photopolymers to plate cylinders. Several companies came out with cushion-foam stickyback at that time. These add more cushioning under the plates and help improve on-press impression.

INK AND DRYING SYSTEM

Before 1940, dryers in general were a problem, and gas-flame dryers were dangerous. By the early 1950s, safer, more adequate dryers appeared.

One major contribution to productivity was the introduction of hot-air circulating systems for presses. While these initial dryer designs were crude compared to our modern drying systems, they set the pace for today's units and allowed the use of highly pigmented inks that dried at higher press speeds. Stack presses had greater distances between stations, allowing space for inter-station dryers. The new dryers allowed press speeds to be increased substantially.

In the 1950s, the main resin in many inks was shellac. However, shellac is a natural resin that can vary in quality and characteristics, and therefore a substitute had to be found. Polyamide resins were developed and inks based on them appeared in 1955. Polyamides give superior gloss and adhere well to polyethylene. An alcohol-ester solvent added to the resins kept the ink stable and fast-drying on the press, and made wide-web speeds up to 750 feet per minute possible. Polyamides are still called the "all purpose ink" because they print well on most substrates, absorbent or nonabsorbent.

In the corrugated arena, flexographic printing with water-reducible inks began in 1957. The first flexo press was shipped to Columbus, Ohio.

ACCURATE MULTICOLOR REGISTRATION

Among the first corporations to develop modern registration systems were the Harley Company, which came out with a mechanical mounter and an optical mounter and proofing machine, and Mosstype, which introduced an optical mounter-proofer machine in the 1960s. These optical mounters created a reflected image from a proofing cylinder onto the cylinder. The centerlines reflected on the cylinder made plate mounting more accurate. Tighter registration was made possible and, in turn, better results were obtained.

The 1960s saw the overall design refinement of aniline press into the flexographic press seen today. Several European press manufacturers continued their development of the central-impression press design, which evolved in the early 1940s and was used in the United States and Canada. It was not until the 1950s, when polyethylene and polypropylene began to replace cellophane, that demand really took off. The central-impression press enabled more control over stretchable substrates than the stack press with its unsupported web between print stations.

Early narrow-web label presses were built using the three main types of flexo press designs: stack, central impression and in-line. Label-press web widths of 4" to 6" dominated the market for many years. During the 1970s, though, label printers wanted wider web widths so they could print larger labels and more of them across and around cylinders, and more color stations. Manufacturers responded to this demand.

Today's narrow-web, in-line label presses vary in web width capacity from 4" to 20" and six- to eight-color stations are very common. By the 1980s, most label presses were of the in-line type and currently, they continue to dominate this market.

RECENT DEVELOPMENTS

The past two decades have seen an explosion of technology in the flexographic printing industry. Without doubt, the biggest development has been the digital revolution, which has impacted all aspects of the flexo process, from the initial design to production and printing.

Prepress

Today, nearly all prepress is electronic, including design generation, image capture and manipulation, page assembly, and final output to film or directly to plate. A recent development has been the lower cost of measurement devices, particularly in the measurement of color. This is leading to entirely new workflows, in which color is controlled or "managed" from initial creation to final ink-on-paper.

Presses

Computer control has revolutionized the operation of the modern press. Digital drives on the print decks allow for precise, repeatable-impression setting. Video web inspection is common and automatic registration between color stations is available.

In the 1980s, preprinted linerboard emerged. Rolls of kraft linerboard with white-coated surface can now be printed on advanced stack and CI presses in one to nine or more colors. Excellent process-color print quality, with screen sizes of 85- to 150-line can be printed. The finished rolls are then combined on a corrugator and finished. These are high-quality printed boxes – something that was not possible on traditional sheetfed combined board.

The introduction of high-tech presses to corrugated postprint in 1995 has had a marked effect on the quality of graphics. Sheetfed presses printing on combined corrugated board can produce multicolored graphics that rival the quality found on preprint linerboard.

Anilox

Ceramic plasma-coating, developed for the aerospace industry, has been adapted for use on anilox rolls, replacing the chromium plating. Fine, ceramic powder heated to nearly 9,000° F is sprayed onto anilox cells to make them tough and long-wearing. The use of reverse-angle steel doctor blades, possible because of the increased durability of ceramic coating, gives a more precise control of ink metering.

Since in the 1980s, lasers have been used to etch ceramic-coated anilox rolls, and improvements in this technology continue. Today, precisely engraved ceramic anilox rolls, with up to 1,200 cells per linear inch, are available to the flexographic printer, allowing flexo to challenge most other forms of printing.

Printing Plates

New polymer plates are being developed for all areas of flexography, including newspapers. In the past decade, water processing of photopolymer plates was introduced.

In the early 1990s the use of electronic prepress in flexo began to grow. During the early 1990s, most graphics were still being produced using cut-and-paste art boards and photographic negatives to produce the flexographic printing plates. By the end of 1997, all graphics were computer-generated and laser-engraved directly to the platemaking negative. This computer and laser technology has led to the development of direct imaging using a laser driven from a computer for both laser-engraved rubber plates and computer-to-plate (CTP) systems for photopolymers. For rubber plates, the laser ablates away the rubber in the nonimaged areas and creates the finished rubber plate directly. In the photopolymer CTP system, a mask is applied to the uncured photopolymer. This mask is ablated away in the non-image area by the laser and the plate is then processed conventionally.

Plate Mounting

In the 1980s, pin-register systems for photopolymer plates came along, and many firms introduced accurate register systems for both narrow- and wide-web press cylinders. The following is just a sampling of the different solutions available.

- pin register with drilled holes in negatives and plates ;
- microscopically controlled, one-piece plate mounter;
- macro-lens video camera system with plate-hole puncher.;
- macro-lens video camera system with micro-dot register.

Today, we see new and improved systems for mounting individual small plates across and around cylinders with pin-register speed and efficiency. Currently, one-piece plate mounting is only limited by the sizes of prepared photopolymer sheets provided by suppliers. Wide-web presses may require more than one plate to be mounted accurately and quickly. Prepress plate-registration systems have been perfected and introduced.

Mounting plates on sleeves continues to grow in popularity. Sleeves come in a variety of materials, such as metal or composites, and different constructions, such as varying wall thickness or cushioned sleeves. Some advantages of using sleeves are:

- quick, on-press plate remounting when a job is rerun;
- flexibility of different repeat length with the same gearing; and
- the ability to change to a thinner plate using the same undercut plate cylinder.

Sleeves are also used in computer-to-sleeve (CTS) systems. In these systems, the sleeve is coated with uncured photopolymer. In one method, the photopolymer is exposed on the sleeve using a film negative. In a second method, the photopolymer is masked and a laser ablates the mask similar to a computer-to-plate (CTP) system.

Inks and Dryers

Growing concern about the environment has focused national attention on the industry's impact, and flexo printers have had to keep a close eye on air emissions from plants. The Clean Air Act of 1980 mandated a 35% cutback in these emissions and the current Environmental Protection Agency controls are even more stringent.

Catalytic incineration has been introduced to cut down on emissions; a heat exchanger allows the hot air from the incinerator to heat incoming air. This double use of the hot air slashes energy costs. Another way to cut back on emissions is to use water-soluble inks or to reduce solvent content of the inks. Ink chemists have developed a means of providing water-soluble inks that work well on nonabsorbent substrates. Scuff resistance and good adhesion to nonabsorbent substrates using water-based ink can still be a problem. On-press corona discharge units are used after the in-feed web guide to treat the web immediately before printing, increasing the adhesion of water-soluble inks. Many converters are reverse-side printing on transparent films, in which in-line lamination seals the ink between the laminations where it can not be scratched.

The Flexographic Process

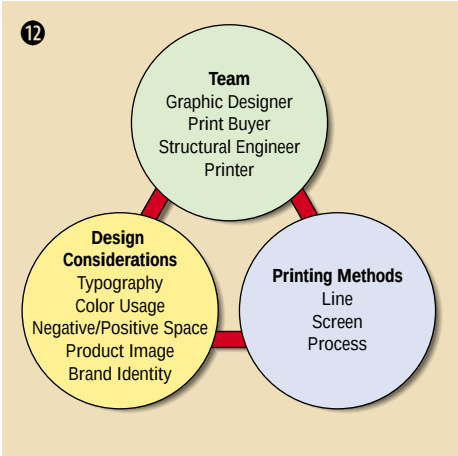
This section gives an overview of the flexographic process. The process starts with the design itself, which must take into account the particulars of flexo printing in order to assure a smooth, trouble-free work flow all the way to the final conversion of the printed piece.

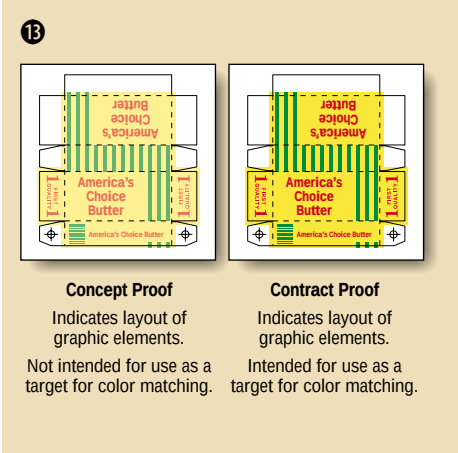
BASIC ELEMENTS OF FLEXOGRAPHY

Starting with the design to be reproduced, each flexographer involved in the process must understand the techniques of handling the different elements of flexo printing as they relate to a commercially acceptable job (*Figure* ⓬). The complete printing job starts with a team of people which includes the graphic designer, print buyer, structural engineer – in the case of a package design – and printer. The printer may handle the prepress function, but many times this is a separate company or team member. The team selects the appropriate printing method, whether it will be a line job only, contain screens or will be a full process-color job. The printing method, in turn, will be determined by the design considerations for the particular job. These considerations include the product and product image, use of space and brand identity, typography and color usage.

Artwork Design and Prepress

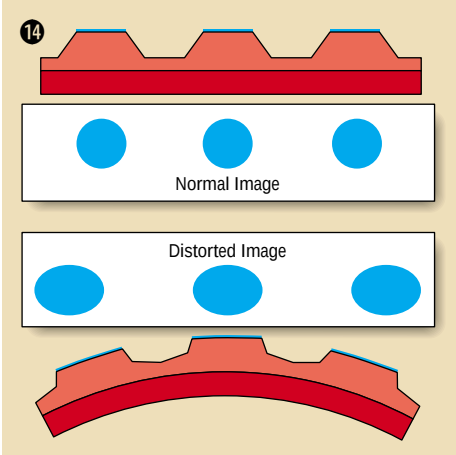
Design and production art (mechanicals or black-and-white art) for flexographic printing are prepared largely the same way as art for other printing processes. But there are some differences that must be kept in mind. With the advent of computer graphics, direct digital-imaging, digital proofs, laser-imaged films and in some cases digitally imaged printing plates, the design copy is often not seen until it is on the actual package. What is seen on the computer screen or on the color proof is not necessarily the same as the finished printed image. The concept proof is used to indicate the graphic alignment and general layout of the design. To see a true representation of the final





⓬ A successful flexo printed piece results from a team effort that works within the parameters of design considerations and printing processes.

⓭ The concept proof is used to indicate alignment of graphic elements in the package layout, while the contract proof is used to show accuracy in color.



⓮ Flat images tend to elongate or distort when printed, caused by the curvature created by the flexible plate.

product, a contract proof is generated which accurately shows the colors in the final printed piece (*Figure* ⓭).

To do a competent job, the designer and production artist must be thoroughly familiar with the requirements of the flexographic printing process, especially in the way it differs from other printing processes. Most of these differences relate to:

- choice of printing plate (molded or photopolymer, thick or thin, hard or soft, digital or conventional);
- distortion characteristics of the plate material (*Figure* ⓮);
- shrinkage in molded-rubber plates;
- choice of line screens for halftone and process color (below 65 lpi to 150 lpi and above);
- print-element growth (dot and bar code gain, minimum highlight dot, maximum shadow dot);
- press design (narrow or wide web, sheet or roll fed, stack, central impression or in-line);
- two-roll or doctor-blade inking system; and
- type of substrate (i.e. film, foil, paper, paperboard, corrugated, newsprint).

Each industry segment (wide web, narrow web and corrugated postprint) has different requirements. Properly prepared designs, appropriate electronic prepress adjustments, image gain allowances, calibrated and consistent negatives and plates all make high quality flexo printing possible. Nevertheless, it should always be kept in mind that the final print result can be no better than the original copy.

Inks

Flexography uses low-viscosity inks which dry very quickly between the print stations of a press. Solvent-based, water-based and ultraviolet-curable inks are used in flexo for a wide variety of requirements. The viscosity, or thickness of the ink is like that of a free-flowing liquid such as light oil or a light syrup. Paste inks have been tried in the anilox system where quick drying was not so important, but a doctor blade was found to be a necessity.

Solvent- and water-based printing inks are composed of a colorant and a liquid vehicle. The colorant, whether pigment or dye, provides the visual sensation of color, and hence appearance, readability and aesthetic value. A flexographic ink vehicle, consisting of resin, solvent and additives, does several jobs: One is to carry color from the ink fountain to the substrate; others include setting viscosity, drying speed, pigment strength, tack and surface tension. It also binds the colorant to the printed surface in a phenomenon known as adhesion.

Pigments are small particles that are insoluble in the ink vehicle. They are usually more opaque than dyes, which are soluble. Pigments also have better lightfastness than dyes and are more resistance to materials likely to come in contact with printed matter.

Many different resins are used, either alone or in combinations, to give adhesion to different substrates and the ability to withstand specific processing and end-use requirements, such as heat resistance, rub resistance, etc. Types of inks for different

uses can therefore be classified by the resins they contain. Examples include polyamides, nitrocellulose, water-based and acrylics. Additives provide special effects, such as slip, low or high coefficient of friction, or rub resistance.

A printer has to be very careful in choosing and using ink. Adhesion, block resistance, heat resistance, rub resistance and lightfastness may be fine on one substrate but terrible on another. Different ink systems require different control. For example, when using solvent-based inks, selecting the right solvent is essential. Viscosity control is important for maintaining color intensity and print quality for both solvent- and water-based inks. Other ink considerations:

- Water-based inks require good pH control and balance.
- Metallic and flourescent inks lead to different problems since they are generally weak and don't dry as well.
- UV inks are more forgiving in terms of viscosity control. The wise printer selects ink with the total job in mind.

UV Flexo

Narrow-web presses have incorporated ultraviolet-curing equipment into their design since the 1970s. These units were originally used for the setting of UV-curable overprint varnishes. At the beginning of the 1990s, pigmented UV-curable flexo inks became commercially available from a number of suppliers. Since that time, UV-flexo printing has grown rapidly among narrow-web converters.

UV-curable inks are 100% solids in the sense that there is no solvent to dry or evaporate. The entire ink film deposited on the substrate remains and is cured or hardened by the UV light. Their fluid character is obtained by the use of low molecular-weight oligomers that are diluted with reactive monomers. Typically, UV-flexo inks have a viscosity between 500 and 1,700 centipoise. Some may have an appreciably higher viscosity. Since they do not have any volatile dilutents, such as alcohol or amines, they are more stable than other flexo inks. This characteristic gives them greater color consistency and requires less attention from the press operator while the job is being run.

UV inks are hardened, or set, through a process of polymerization or curing initiated by a sufficient quantity of ultraviolet energy. Liquid inks are converted into solid-colored polymers or plastics. Since they are are hardened through a process of polymerization, they do not release volatile organic compounds (VOCs) when they are used. In areas of strict environmental regulation, this may be a significant benefit.

Substrates

Flexography is unique because it was developed primarily for printing packaging materials. Board, paper, foil and film packaging substrates are commonly supplied in roll form for feeding into form-and-fill, overwrapping, bag-making and other continuous web-processing machinery. For these applications, roll-to-roll or roll-to-cut printing is required.

Because there are so many kinds of paper, board, plastics, foil and film, the term "substrate" applies to any surface to be printed. If the material is reasonably smooth and comes in roll form, chances are it can be printed by flexography. As a matter of fact, the vast number of substrates on which flexography can print is one of its greatest advantages. Naturally, for high-quality images, the smoother the substrate the better.

The Printing Plate

As the first chapter pointed out, flexography is like letterpress in that both print from a raised-image surface (see *Figure* ❷). Flexographic printing plates, whether molded from natural or synthetic rubber compounds, or imaged using light-reactive

photopolymer resins, are generally made from flexible, elastomeric materials. The ink is carried by the raised portion of the plate and transferred to the substrate. The raised image is obtained by removing and lowering the nonprinting areas through cutting, molding, etching, dissolving or laser engraving.

Molded Printing Plates. Using a mold, uncured plate gum is vulcanized under heat and pressure. This mold or matrix is made by vulcanizing an uncured phenolic-coated board with a magnesium etching or other suitable original. Numerous duplicate plates can be made from a cured mold.

The molded printing plate must evolve through several stages that include camera-ready art, photographic negative, a master engraving, mold and finally, printing plate. The many steps involved in the manufacture of molded plates may substantially reduce the image quality. The increased use of computerized electronic prepress and high definition photopolymer plates has made the molded-rubber plate almost obsolete.

The Photopolymer Printing Plate. Unlike rubber printing plates, photopolymer plates are not molded. The light-reactive polymer resin is exposed to ultraviolet light to selectively cure the resin to a solid and processed using either an aqueous or solvent-based solution.

The term photopolymer refers to a range of polymers that react to ultraviolet light energy. These come in precast sheets of varying size and thickness, or in liquid form for custom sizing and gauging. Photopolymer materials are available in varying levels of durometer. Ordinarily, the printing plates are backed with a dimensionally stable polyester support sheet that helps control plate distortions during processing, plate-mounting operations and repeated use.

In making the relief-printing plates, film negatives of the art are positioned in contact with the plate material. In the case of digital plates, the image is created by laser ablation of an opaque mask on the surface of the photopolymer. The image is transferred to the plate material by exposing to ultraviolet radiation. The portions of the raw material that receive light through the clear areas of the negatives or mask are rendered “set” or hardened, or, more properly, polymerized. The areas protected from the UV light by the opaque portions of the negative remain uncured and are brushed or washed away by either a water- or solvent-based solution, leaving the hardened, raised printing areas.

The photopolymer plate becomes the final printing plate, eliminating the need for an original and mold of any sort. Each photopolymer plate is a faithful copy of the image on the negative film and is therefore an original plate, thus reducing any loss of image fidelity.

Photopolymer resins are made specifically for use with alcohol, water, oil or glycol inks, or combinations of these. Because of their good print performance and ink-transfer qualities, photopolymer plates are quite popular for halftone and process color jobs.

Design Rolls

Design rolls are mainly used to produce continuous-repeat designs. The procedure involves vulcanizing rubber to a bare cylinder and grinding the rubber to a desired diameter for the exact print repeat length needed, then hand-cutting the face of the rubber to remove the nonprinting areas. A far more popular method laser engraves the image into a ground rubber roll directly from the computer generated art work. Seamless imaged photopolymer rolls are also available.

Mounting and Proofing Devices

Usually, rubber or photopolymer printing plates are mounted to double-sided stickyback that comes in a variety of adhesive strengths and are up to 18" wide. Some are suitable for photopolymer plates, while others work better with rubber.

Off-press plate mounting and proofing

devices are a basic requirement for good flexo printing practices. These machines provide a means for mounting multicolor jobs in exact register. They are also used to makeready the printing plates to achieve uniform impression across and around the cylinder before installing the job in the press. Furthermore, full-color proofs can be made that graphically indicate color trapping, print copy, print positioning and plate height uniformity. The proof can also be folded into a mockup of the finished job to confirm that all copy is in the right place when the product is enclosed in three-dimensional form.

Mounting and proofing registration systems are generally:

- optical, using a split-mirror principle;
- punched hole and pin; or
- video microscope.

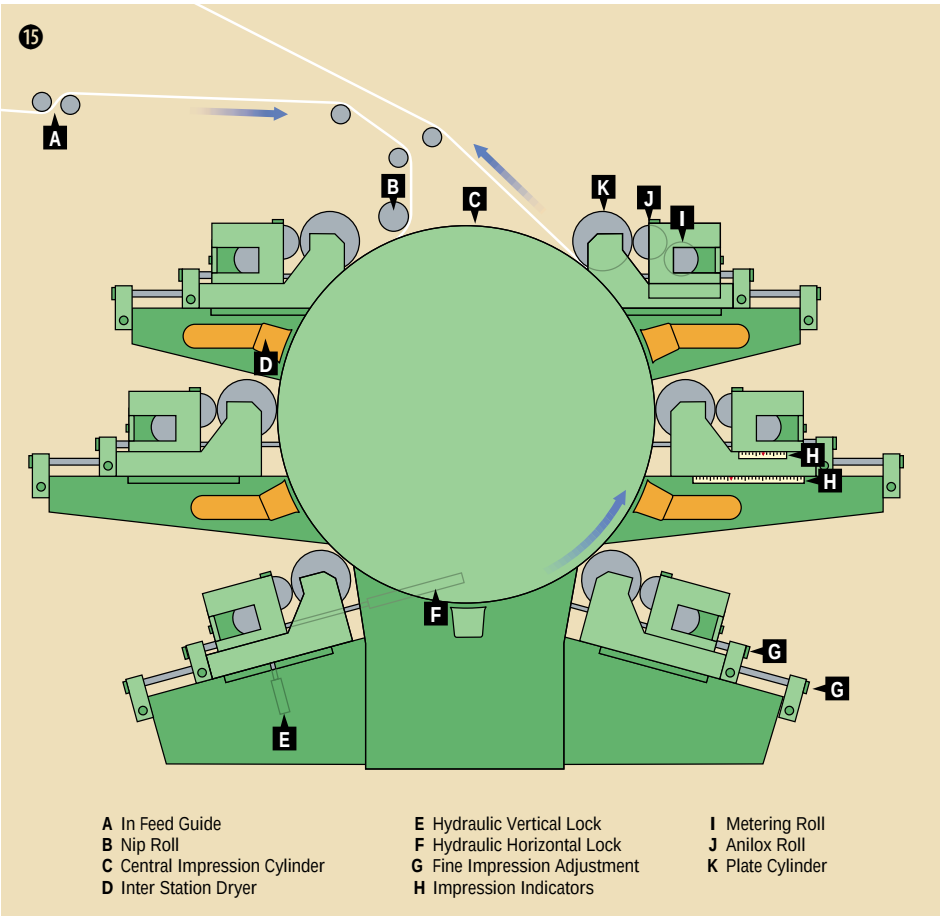
Mounting plates on sleeves enables jobs to be remounted on press quickly and with excellent, repeatable registration.

PRESSES

The four most common press-frame designs are:

- central impression or CI (*Figure* ⓯)
- stack (*Figure* ⓰)
- in-line (*Figure* ⓱)
- sheetfed (*Figure* ⓲).

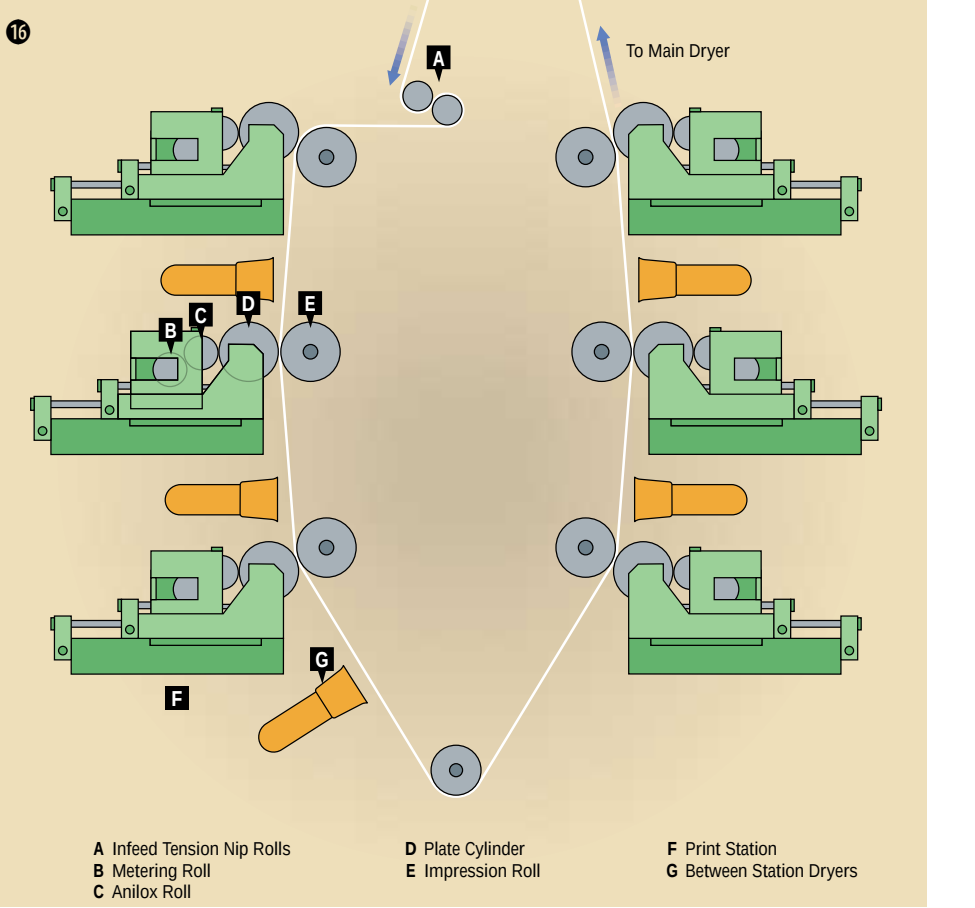
The central-impression press has a common impression cylinder around which two to eight print stations can be positioned. The most common CI press in use today is six colors. The stack press is built with print stations literally "stacked" one above the other.

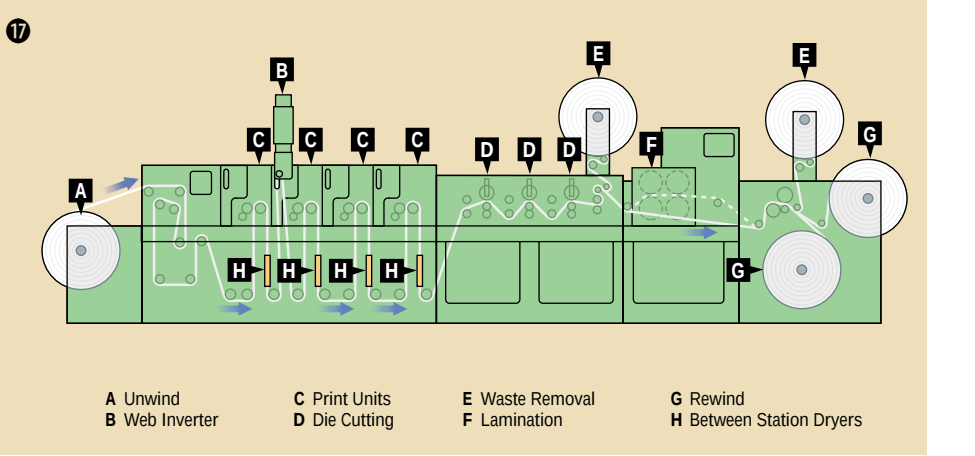


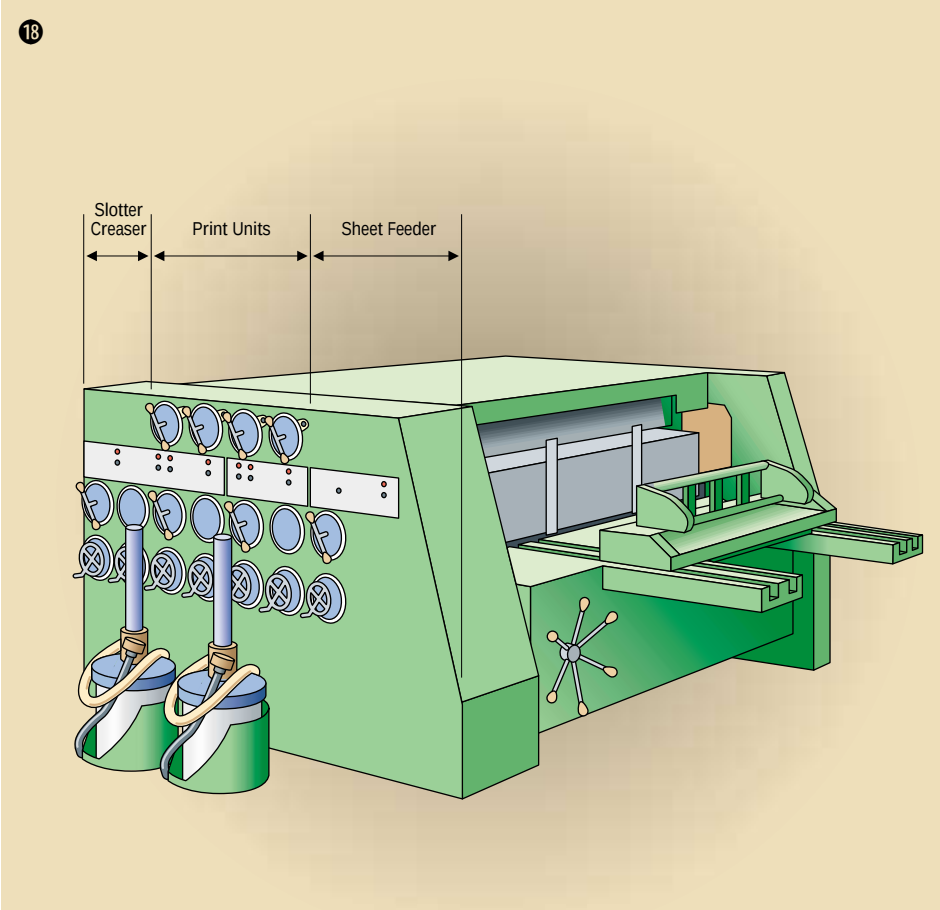
⓯ A typical six-color central impression press supports all of its color print stations around a single, large impression cylinder.

⑯ A typical six-color wide-web stack press, where individual color print stations are stacked one over the other on one or both sides of a main press frame.

⑰ In a typical narrow-web in-line press, color print stations are configured horizonatally, providing versatility and access-ability to the printing stations.







18 A typical sheet-fed press for corrugated postprint.

One to four individual print stations can be mounted on both sides of a vertical frame. The in-line press has its print stations positioned in tandem (a straight row). Six to nine colors are possible with this type of press.

Parts of a Web Press

Flexographic web-fed presses generally consist of four parts:

- unwind and in-feed section;
- printing section;
- drying section; and
- out-feed and rewind section (or subsequent in-line operation)

Unwind and In-feed Section. The roll stock to be printed must be held under control, so the web can unwind into the press with proper alignment and sufficient tension to prevent slack and wrinkles. If web tension is too great, stretching and breakage could occur.

An effective unwind and infeed system may include some or all of the following:

- multiple unwind positions;
- rotating turrets to make reloading easier;
- semi-automatic chucking;
- precision bearings;
- automatic side-guide control;
- automatic tension control with tension-sensing devices;
- driven in-feed rolls; and
- automatic (flying) roll splicing.

Printing Section. A single-color station consisting of a fountain roll (or wipe roll), anilox roll, printing plate roll and impression roll

are sufficient to constitute a flexo printing unit. But most presses are multicolor, with two to eight stations in the printing section.

Drying Section. The drying section usually includes between-color drying capacity to print color-on-color. An after-dryer is added to remove any remaining liquid vehicle before winding the substrate into a roll. The most common method of drying is by high-velocity heated air, although other methods, such as infrared heating, may be used.

Out-feed and Rewind Section. In many ways, this is identical to the unwind section, but with one important difference: The unwind shaft is braked to apply the necessary tension to the web, while the rewind shaft must be driven. As always, the web tension must be controlled and limited to the minimum amount necessary to keep the substrate level, unwrinkled and taut – not necessarily tight – as it winds on the finished roll. A rewind section may include:

- multiple rewind positions;
- rotating turrets to facilitate unloading;
- semi-automatic chucking;
- anti-friction bearings;
- web-tension sensing devices;
- tension controls (often programmed to reduce web tension as the roll diameter increases);
- driven out-feed rolls;
- chill roll(s);
- automatic transfer;
- side guides;
- slitting devices;
- static eliminators; and
- moving web-inspection devices that "freeze" the image for close examination.

THE SHEETFED FLEXO PRESS

Combined corrugated board is supplied in sheet form. It requires a sheetfed press, which is generally attached to an in-line die cutting or slotting and gluing converting section.

Combined corrugated sheets are rigid enough to be pushed into the printing station and to remain horizontal from in-feed to finished stacking. The sheets can be fed into a pair of feed rolls at speeds as high as 400 sheets or "kicks" per minute without disrupting register. The machines are adjustable and can run many different sheet sizes. Each press has a plate cylinder with a set size and therefore a repeat cycle that cannot be changed.

The corrugated postprint press is also a tandem press and generally has its units close coupled, in-line, on roll-away tracks for plate mounting and servicing. Some modern corrugated presses have permanently spaced units that allow constant access to the print stations.

Sheetfed presses can be "bottom printers" (printing is done on the underside of the sheet) or "top printers" (printing on the topside of the sheet). In bottom printing, a normal ink fountain is used. With top printing, the ink fountain is actually a puddle of ink kept between the wipe and anilox rolls by one or more applicators that supply a constant flow to the nip. The overflow runs off at the ends of the rolls into a container and recycles through the system.

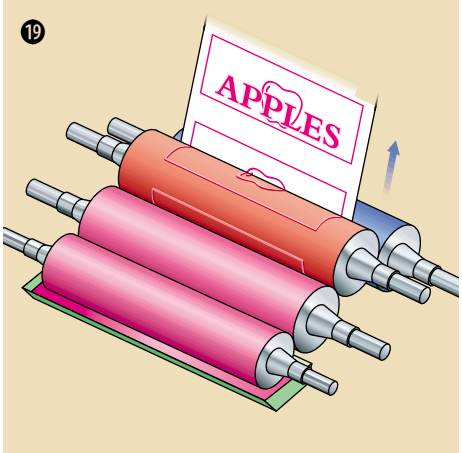
THE BASIC FLEXO PRINT UNIT

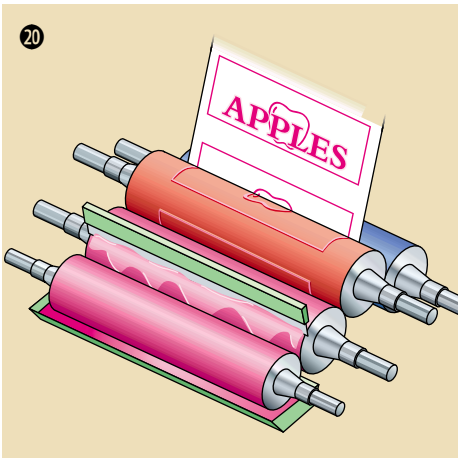
In its simplest and most common form, the flexographic printing system consists of four basic parts:

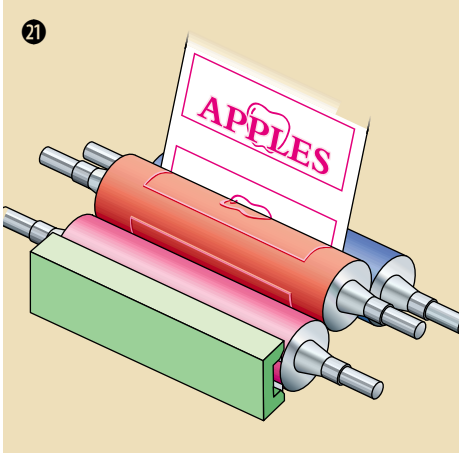
- fountain roll;
- ink-metering (anilox) roll;
- plate cylinder; and
- impression cylinder.

Fountain Roll

The fountain roll is generally covered with natural or synthetic rubber. It is positioned to rotate in a reservoir of flexo ink, and its purpose is to pick up and deliver a relatively heavy flow from the reservoir or "fountain"







to the metering (anilox) roll. The ink on the land areas of the anilox roll must be removed to ensure that only the cells carry ink to the plates. The fountain and anilox rolls are set to rotate against each other in such a way as to allow excess ink to form a puddle behind the nip (point of contact) while only the ink in the engraved cells transfers to the printing plates.

The fountain roll, sometimes referred to as a wiper roll, is usually driven slower than the metering anilox roll. This has the effect of "wiping" the latter, and thus, doctoring the ink to an even film.

The fountain roll is subjected to fairly high nip pressures, either from the roll-loading system or from the hydraulic pumping action caused by the excess ink at the nip between the fountain roll and the anilox roll. Because of these pressures, the fountain roll design is critical to the operation of the two-roll system.

Whatever the press configuration, the roller grouping of a typical flexo print station consists of either:

- Two-roll ink-metering system. This consists of four rolls: ink-fountain roll, anilox roll, plate cylinder and impression cylinder (*Figure* 19);
- Two-roll with a doctor-blade ink-metering system. This consists of four rolls: ink-fountain roll, anilox roll with doctor blade, plate cylinder and impression cylinder (*Figure* 20);
- Chambered doctor-blade ink-metering system. This consists of three rolls: anilox roll with enclosed doctor blade chamber, plate cylinder and impression cylinder (*Figure* 21).

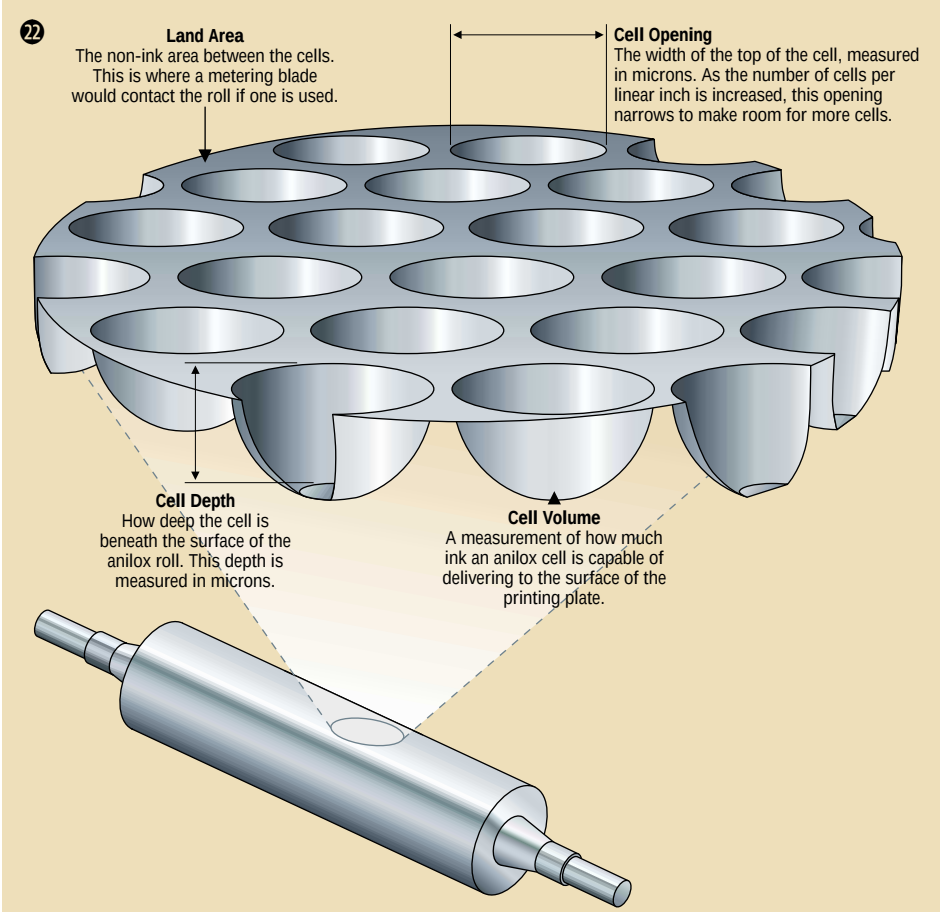
To a flexographic press operator, the ink-metering system is a means of controlling the amount of ink being presented to the plates and subsequently to the substrates.

19 The two-roll ink-metering system shown consists of, from front to back, an ink-fountain roll, anilox roll, plate cylinder and impression cylinder.

20 The two-roll with doctor-blade ink-metering system shown consists of, from front to back, an ink-fountain roll, anilox roll with doctor blade, plate cylinder and impression cylinder

21 The chambered doctor-blade ink-metering system shown consists of, from front to back, an enclosed doctor-blade chamber, anilox roll, plate cylinder and impression cylinder.

㉒ An enlarged section of anilox roll shows the cells and the cell parameters of land area, cell opening, cell depth, cell volume.



Ink Metering and Anilox Rolls

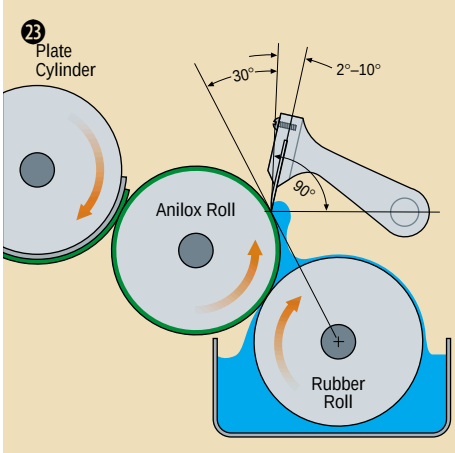
The purpose of the anilox roll is to transfer a measured amount of ink to the surface of the printing plate.

The surface of the anilox roll is covered with tiny engraved cells spaced anywhere from 80 to 1,200 per linear inch. The amount of ink delivered to the plates is metered by the screen size of the cells. The coarser the cell count, the larger and deeper the cells are engraved into the roll. Conversely, the higher the screen count, the smaller the cells. The volume of ink contained in the cells is measured in billion cubic microns (BCM) per square inch of surface area.

For example; a 200-line screen anilox with 200 cells per linear inch, has 200 x 200, or 40,000 cells per square inch. Similarly, an anilox with 400 cells per linear inch would have 400 x 400, or 160,000 cells per square inch. As cell counts vary, so do the ink volumes delivered and this affects the color printed.

Special attention must be given to the selection (screen count and cell volume) and quality of the anilox rolls. For any given use, the substrate on which the printing is done, the type of work (solids, type, halftones, etc.) and type of ink will be factors in the selection of the engraved transfer roll. Choosing the correct anilox roll for a particular application may be the most difficult task faced by the flexographic press operator (*Figure* ㉒).

Control over the anilox-to-printing-plate-transfer is very important. A light contact



23 The doctor blade should ideally make contact with the anilox roll at a 30° angle.

between the anilox roll and the printing plate surface prevents over-inking and keeps ink from being pressed down on the shoulders of the raised image areas of the printing plate. It is also important that the anilox roll and plate cylinder are geared to travel at the same surface speed.

The construction of the anilox roll may be:

- plain, steel-chromed coarse matte finished;
- chrome-plated, mechanically engraved cells;
- ceramic-coated, mechanically engraved cells;
- coarse, random-coated plain ceramic; or
- ceramic-coated, laser engraved cells.

The number of cells per linear inch achievable by mechanical engraving is limited and either chrome plating or ceramic coating reduces the cell volume.

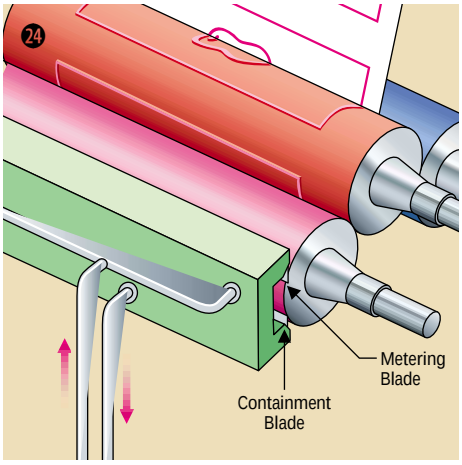
Recent developments in laser engraving of ceramic-coated rolls have been very successful. Roll life has been lengthened, cell volumes are consistent and cell count increased to as high as 1,200 cells per linear inch. Experimental rolls have been produced with cell counts as high as 2, 000 per linear inch.

Two-Roll System with Doctor Blade. In order to eliminate a number of the deficiencies associated with a fountain-roll system, press manufacturers have developed a number of doctor-blade devices to assist the operator in controlling the distribution of ink. The purpose of the doctor blade is to remove excess ink (or fluid) from the surface of the engraved anilox or transfer roll, allowing better control of ink transfer to the plate cylinder. The device is particularly useful when printing halftone screens and process colors.

Ideally, the doctor blades should make contact at a 30° angle with the tangent point of the anilox roll (*Figure* 23). At this angle, the blade shaves, or doctors, off the excess ink, leaving the precise amount of ink contained in the engraved cells of the anilox rolls. Also, the Total Indicated Runout (TIR) of the anilox roll must not exceed 0.0005" in order to maintain proper blade pressure and doctoring of the ink. To obtain good doctoring in any application, a number of requirements must be satisfied:

- The anilox roll should be manufactured for use with a doctor blade.
- The anilox roll must be in reasonably good condition.
- The doctor blade must be designed and manufactured for the specific application, taking into account machine width and speed, the function and location of the roll being doctored, the location of the doctor blade on the roll and the surface material of the roll (chrome or ceramic).
- The doctor blade must be accurately aligned and adjusted to the anilox roll in the designed location.
- The doctor blade should be set at the minimum blade pressure to accomplish its task.
- The doctor blade and anilox roll must be given sufficient maintenance to prevent deterioration and misalignment.

Chambered Doctor-blade System. Two doctor blades usually make up this system. One is a



㉔ This chambered doctor-blade shows the reverse-angle metering blade and the trailing containment blade.

reverse-angle metering blade and the second a trailing containment blade (*Figure* ㉔). The reverse-angle metering blade is typically made of steel and the trailing containment blade is often plastic. These blades are set about 2" apart, but this may vary between manufacturers. The blades are connected in a box-like enclosure with flexible sealing material at both ends. This is then fit snugly against the sides of the anilox rolls. Ink is usually pumped into the system at the middle of the ink pan, but can be pumped in several locations on wider presses. A pan is generally placed beneath the anilox roll for cleanup purposes. The advantage of this method: The entire inking system from ink kit to anilox roll is never exposed to the air and, the volume of ink flowing through the pumped system is reduced. This makes tight viscosity control possible. The system is quite popular on high-speed, wide-web and corrugated postprint presses.

Continuous Inking. Since most flexographic inks are fast-drying, with the exception of UV-curable inks, the anilox roll in the ink distribution system must continue rotating when the press is in a non-printing mode. If not, the inks will dry in the cells, and controlled transfer will no longer be smooth. Therefore, when the press is idling, if the fountain roll and anilox roll are to continue to rotate the anilox roll must be separated from the plate cylinder. Otherwise, the anilox roll will wear the plate along the line of contact with the stationary printing plate.

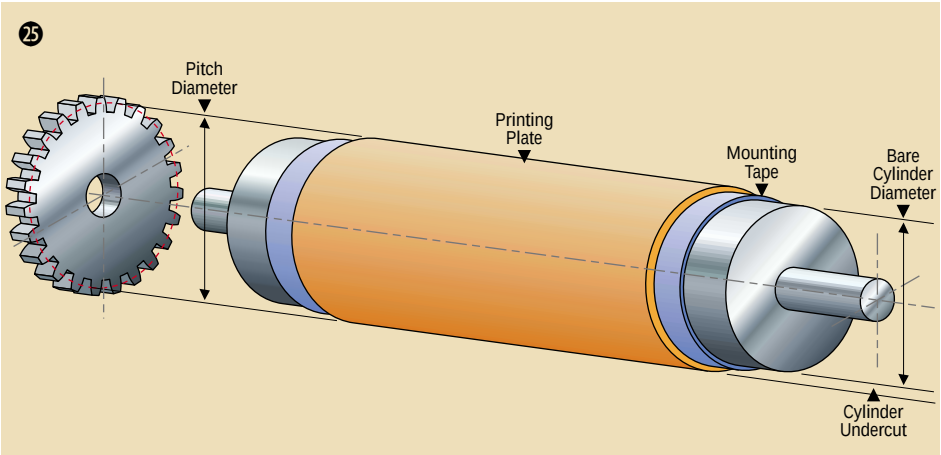
In addition, it is essential to separate the plate cylinder from the web when in the stop mode. If not, the ink from the plate will dry on the web, and when the press is restarted, the web will stick to the plate and may break. If ink has been applied to the plates before the press is stopped, it may be necessary to clean the dried ink from the plates before restarting the press again. After the plates have been cleaned, the press can be restarted and the impression-control sequence commenced; the anilox roll comes in contact with the plate cylinder and the plate cylinder in contact with the web, and printing resumes.

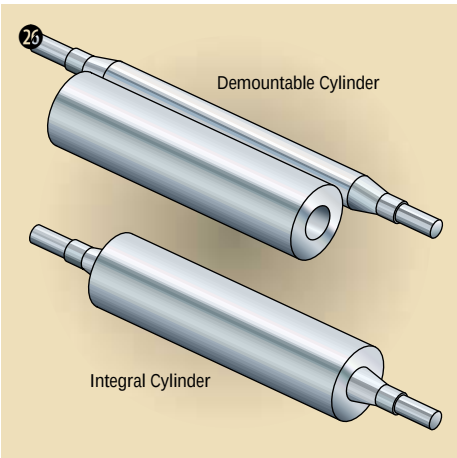
Plate Cylinders and Sleeves

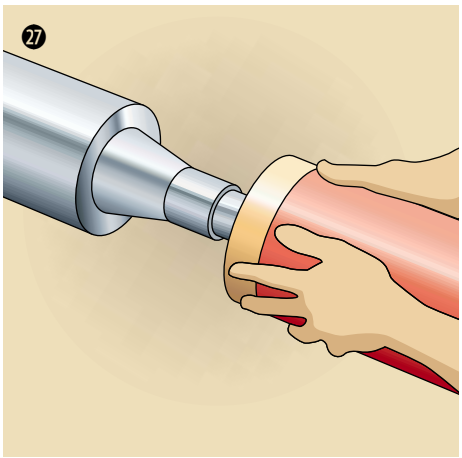
The plate cylinder is usually steel and is installed between the ink-metering roll and the impression cylinder. Printing plates are mounted to the plate cylinder with stickyback. The raised impression areas on the printing plate pick up ink from the ink-metering roll and transfer it to the substrate. Other kinds of printing plates include ferrous (containing iron), metal-backed plates mounted to a magnetic cylinder, and magnetic-backed plates mounted to a steel cylinder.

The total plate-cylinder diameter, including stickyback and printing plate, has to equal the pitch diameter of the driving gear (*Figure* ㉕). Therefore, for a given print-repeat length, the bare cylinder diameter of the plate cylinder must be reduced or "undercut" to accommodate the combined thickness of the stickyback and printing plate. A trend toward thinner printing plates, designed to reduce distortion and cupping, requires the correct plate cylinder diameter to accommodate the change.

Printing plates are mounted on the printing-plate cylinder. There are four types of plate cylinders: integral, demountable, mag-







25 The total plate-cylinder diameter, including stickyback and printing plate, has to equal the pitch diameter of the driving gear

26 An integral plate cylinder is one piece, while a demountable plate cylinder consists of the cylinder face and mandrel.

27 The plate cylinder is ready to accept the sleeve-mounted plate.

netic and sleeved. The following is a brief description of each.

Integral. The cylinder body or face, end-caps and shaft are all one unit. Most cylinder bodies are tubular, with end-caps shrunk-fit into the tube ends. Small cylinders (less than 3" in diameter) are generally made from one solid piece of steel (*Figure* 26).

Demountable. The cylinder face (or core) is made (without the shaft) to any desired diameter, but to fit a prescribed shaft or mandrel. Mounting or demounting of the cylinder core on shafts can be done in different ways (*Figure* 26).

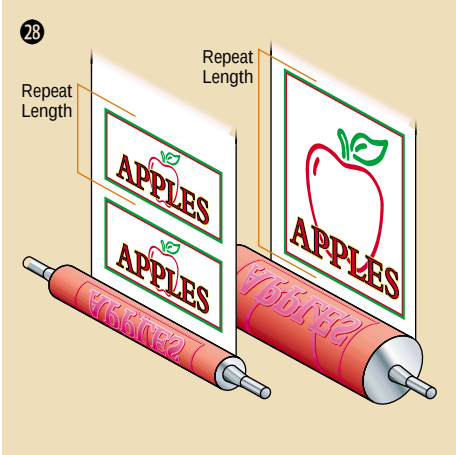
Magnetic. This integral cylinder is built to generate a magnetic field to receive and hold printing plates made with steel backing. This eliminates stickyback.

Sleeves. Sleeves slide onto specially bored cylinders by allowing high-pressure air to enter through the side and exit through holes in the face of the cylinder (*Figure* 27). The introduction of air slightly expands the resilient sleeve and permits it to float into position.

Impression Cylinder

The impression cylinder is smooth, highly polished and supports the substrate when it contacts the printing plate. On most stack and in-line presses the impression cylinder is a plain steel roller that supports the web or substrate within each print station. On a central impression (CI) press the impression cylinder is a single large drum with an arrangement of satellite print stations. In

㉘ The repeat length is determined by the plate cylinder diameter; the smaller the cylinder diameter, the shorter the repeat length.



both cases the total indicated runout (TIR) of the support surface will effect the print quality. TIR's of better than 0.0005" are common on most high-quality presses.

The surface speed of the substrate on the impression cylinder must match the surface speed of the printing plate and the anilox roll. Otherwise, slurring, halos, smearing and reduced plate life will result. For high-quality printing, the accuracy of cylinder diameters, concentricity, gearing and bearing fit cannot be overstressed.

Repeat Lengths and Gears

In any printing process, it is necessary to print cleanly at each color station, with each station registering properly with one another. To prevent smearing, the surface speed of the plate cylinder, anilox roll and impression cylinder must be identical; therefore, the three rolls are geared together to create equal surface speeds. Keep in mind, the following are necessary for good results:

- The pitch diameter of the plate cylinder gear must be equal to the diameter of the top of the printing plate mounted to the plate cylinder (see *Figure* ㉕)
- The plate cylinder will have a diameter that is governed by the repeat length of the image. (*Figure* ㉘)
- The pitch diameter of the anilox roll gear must be identical to the outer diameter of the anilox roll.
- The pitch diameter of the impression-roll gear must be equal to the impression roll diameter plus twice the thickness of the substrate to be printed. In most applications, the substrate thickness may vary and therefore a compromise is made.

Pitch Diameter. The pitch diameter is the dimension of a circle through the gear teeth, where the space between the teeth equals the thickness measured along the arc of the pitch circle. Gear pitch is the spacing of gear teeth measured around the pitch circle. In the United States, flexographic presses use either a one-quarter inch (0.025") circular pitch or 10 diametrical pitch gearing.

Here are some useful equations:

$$\text{Pitch Circle Diameter} = \frac{\text{Number of Teeth} \times \text{Circular Pitch}}{3.1416}$$

$$\text{Diametrical Pitch} = \frac{\text{Number of Teeth}}{\text{Pitch Diameter (inches)}}$$

When using metric gears, the following holds true:

$$\text{Module} = \frac{\text{Metric Pitch Diameter (mm)}}{\text{Number of Teeth}}$$

Station Control

The setting of the impressions of the anilox roll to the plate cylinder and plate contact with the web requires a certain amount of "feel" from the operator. To help the operator, most press manufacturers design the adjustment to work through very finely threaded screws.

With a fine-thread adjustment, it's easier to set impression for tone work. Also, the combination of fine threads, and, very often, gear

reduction on the adjusting screw makes it possible for a press operator to have a read-out system to visually tell the amount of squeeze or impression being set on the plate. That is, it is preferable to have a dial indicator gauge to visually and repeatably set the impression to a specified value.

When the print cylinder is stationary and impression is "off", the fountain and anilox will separate from the plate cylinder and the plate cylinder from the web, both by roughly 1⁄32". If impression settings were made with impression "off", then when impression is activated and the plate cylinder moves the 1⁄32" toward the impression cylinder, the plate would be damaged. Therefore, it is mandatory that station setups are done when the impressions are set to the "on" position.

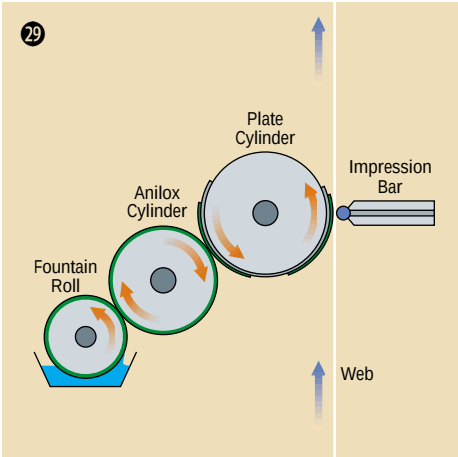
VARIATIONS ON THE FLEXOGRAPHIC PROCESS

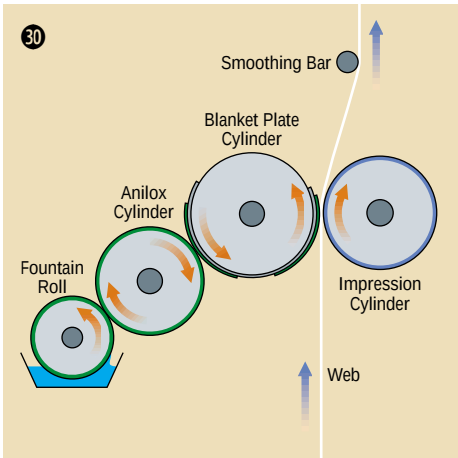
There are many variations on the basic flexo press, each developed for a specific purpose.

The Impression Bar (Tympan Bar)

The printer, tor example, may face the problem of printing on very thin or porous papers. Ink strike-through onto the impression cylinder, especially on CI presses, becomes a daunting obstacle. Ink buildup on the impression cylinder not only affects print quality, but can also damage printing plates. Replacing the impression cylinder with an impression (Tympan) bar is a solution (*Figure* ㉙).

The bar is usually a length of steel drill rod measuring one-quarter inch (0.25") to one-half inch (0.5") in diameter (depending on the press width) mounted in a sturdy, properly aligned clamp or holding device. In some cases, the bar is actually hollow and water-cooled to prevent nonuniform expansion from overheating near the middle of the web. With this system, ink that penetrates the substrate can't accumulate on the bar because the moving web constantly wipes it clean.





㉙ A variation of flexo printing uses a thin impression bar, to print on very thin or porous papers.

㉚ This flexo print station is adapted for use as a coating station.

The Flexographic Press as a Coating Section

Coating is the process of laying down overprint varnishes on top of printing or the application of adhesives to substrate surfaces. Properly adapted, the flexographic printing process is can be used as a coating station. *Figure* ㉚ illustrates the arrangement for a typical coating application.

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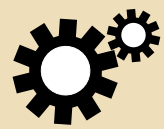
CHAPTER 2

Glossary



Glossary

This glossary shows a key symbol for each term. Many terms have specific meaning depending on the context or subject in which they are used. For terms with a specific context, the key is used to identify the relevant subject chapter. Terms which span more than one category or subject will have the "general" icon.

A

Abrasion Resistance
The ability to withstand the effects of repeated rubbing and scuffing. Also called scuff or rub resistance.

Abrasion Test
A test designed to determine the ability of a substrate to withstand the effects of rubbing and scuffing.

Absolute Density
The density measurement where the densitometer is calibrated on air for tranmission and on a white standard supplied by the manufacturer for reflection. *See also relative density.*

Absolute Humidity
The actual weight of water vapor contained in a unit weight of air. *See also Relative Humidity*.

Absorption
Taking in or the penetration of one substance into another; taking in of liquids or vapors such as moisture by a porous material like paper.

Absorption
1. The selective removal of some of the wavelengths of white light, producing colored light. 2. The reduction that occurs when light incident on an object is not reflected.

Accelerate
To hasten or quicken the natural progress or process of ink drying or curing. Achieved by the addition of a faster drying solvent or by increasing the temperature or volume of hot air applied to the printed surface.

Accelerate
To speed rewind shafts during flying splices and to take up web slack.

Accelerator
A substance added, or method used, to hasten or quicken the natural progress or process of ink drying or curing.

Acceptance Inspection
The evaluation of a definite lot of material or product that is already in existence to determine its acceptability within quality standards.

Acceptance Sampling
See Acceptance Inspection.

Accumulate
To temporarily store hazardous waste at a place of business for a limited amount of time. The time allowed for storage depends on the amount of hazardous waste produced per month. Satellite accumulation allows a facility to completely fill a container over a longer period of time, as long as some simple, additional storage requirements are met.

Acetate
1. A family of solvents also known as esters; an example is normal propyl acetate. It can also refer to a particular cellulose acetate or film in general. 2. In multilayer artwork, it is often used as an overlay, often referred to as mylar or clear layout base. 3. The material used for "overhead" transparency printing.

Acetone
A very active solvent used mainly in gravure inks. The fastest drying solvent in the ketone family.

ACFM
Actual cubic feet per minute of air flow; i.e., air flow in drying systems or catalytic/thermal oxidizers.

Achromatic Color
Colors that have no hue or chroma; i.e., black, white, gray.

Acid
Any chemical that undergoes dissociation in water resulting in the formation of hydrogen ions. Acids have a pH less than 7.0; lower number indicating greater acidity. Among its properties: corrodes many materials, tastes sour, turns litmus paper red. *See also pH*.

Acid Number
The amount of potassium hydroxide (in milligrams) required to neutralize free acids in one gram of oil, wax or resin.

Across Web
See Cross Direction.

Acrylic
A general chemical term for a particular family of thermoplastic resins based on acrylic acid and its derivatives.

ACT
Alternative Control Techniques.

Actinic Rays
Those rays of light which cause the most intense chemical reactions.

KEY:

Barcode
Design
Environment
General
Ink
Mounting/ Proofing
Plates
Prepress
Press
Process Color
Quality
Substrate

Activated Carbon
A highly absorbent form of carbon used to remove odors and toxic substances from liquid or gaseous emissions.

Activator
A chemical solution used on exposed photographic paper or film emulsion to develop the image.

Acute Effect
An adverse effect on any living organism in which severe symptoms develop rapidly and often subside after exposure stops; a health exposure that is evident at time exposure takes place, i.e., irritation, rash, burn.

Additive Primaries
The colors red, green, blue. When the lights of these colors are added together in equal proportion, they produce the sensation of white light.

Additives
Ink components used during formulation and at press-side to manipulate chemical ink balance and performance properties.

Add-on Control Device
An air-pollution control device such as an oxidizer, solvent recovery or carbon absorption system that reduces the pollution in an exhaust gas.

Addressable Output Resolution
The maximum number of images positioned along a 1" straight line, that can be addressed by a bar code designer. This resolution would exclude further resolution-enhancing techniques performed by the imaging device or software that are beyond the control of the designer.

Adhesive
Any material which is applied to one or both surfaces to form a bond between the two.

Administrative Order
A legal document signed by a government agency directing an individual, business or other entity to take corrective action or refrain from an activity.

Adsorption
The accumulation of a material with which it has contact (typically gas-solid or liquid-solid), such as the adsorption of organic compounds onto activated carbon.

Afterburner
In incinerator technology, a burner located so that the combustion gases are made to pass though its flame in order to remove smoke and odors.

After-tack
The condition of an ink, whereby after it has been left to dry naturally or from a heat-drying operation, develops a stickiness.

Agglomerate
A cluster of undispersed particles of ink pigment.

Aggregate
A series of clusters of undispersed ink pigment.

Agitation
A stirring action; violent or irregular in motion.

Air Brush
1. A colorant sprayer, operating on compressed air, capable of producing subtle gradations of tone. It is used in rendering various types of artwork, in retouching photographs and for smooth backgrounds. 2. A method of creating continuous tone artwork using an airbrush.

Air Quality Standards
The level of selected pollutants set by law that may not be exceeded in outside air. Used to determine the amount of pollutants that may be emitted by industry.

Air Stripping
A treatment system that removes volatile organic compounds from contaminated ground water or surface water by forcing an airstream through the water and causing the compounds to evaporate.

Air Toxics
Air pollutants for which a National Ambient Air Quality Standard (NAAQS) does not exist that may be reasonably anticipated to cause cancer, developmental effects, reproductive dysfunctions, neurological disorders, heritable gene mutations, or other serious or irreversible chronic or acute health effects in humans.

Alcohol
A family of volatile organic solvents, commonly used in flexographic inks, containing the grouping C-OH. The most common members of this group are methyl alcohol, ethyl alcohol, propyl and isopropyl alcohols.

Aliphatic Hydrocarbons
Solvents obtained by fractionation of crude petroleum oil. Examples are textile spirits, VMP Naphtha, gasoline and kerosene. Frequently used as part of the solvent mixture in co-solvent and polyamide-type flexo inks, in conjunction with Buna-N plate.

Alkali
Any chemical that undergoes dissociation in water with the formation of hydroxyl ions. Alkalis have a pH greater than 7.0—a higher number indicates greater alkalinity. Alkalai properties include causticness, bitter taste and turning litmus paper blue. *See also pH*.

Alkali Resistance
The relative ability to withstand the action of alkalis; to be distinguished from soap resistance.

Alkali Test
A test to evaluate resistance of printed packages, labels, etc. to alkali.

Alkalinity
In testing paper for alkalinity, the specimen is extracted with water at a definite temperature, and the extract is tested to determine its pH value. The condition that results in an alkaline solution when paper is extracted with water.

Alumina Hydrate
Also known as hydrate, it is a white, inorganic pigment used as an extender in inks and noted for its transparency.

Aluminum Coating
A coating composed of aluminum paste or powder and a mixing varnish or vehicle.

Aluminum Foil
A solid-sheet section of aluminum metal, rolled to a thickness of less than 0.006".

Ambient Conditions
A term used to denote the existing temperature, pressure, etc. of the surrounding air.

Amines
A nitrogen-containing component of water-based inks and coatings that, when mixed with acrylic resins, allows them to go into and remain in solution.

Anchor Coat
A coating (primer) applied to the surface of a substrate to effect or increase the adhesion of subsequent ink coatings.

Anchoring
The bonding or fusing of inks to the material on which they are printed.

Anhydrous
Free from water; i.e., anhydrous alcohol is free from water.

Aniline
The former term for flexography; the name was derived from aniline dyes obtained from coal tar (an obsolete technology).

Aniline Dyes
Derivatives of coal-tar, classified by chemical composition. Basic dyes have extreme brightness, but are not lightfast, while acid dyes are less brilliant, but are lightfast.

Anilox Roll
An engraved ink-metering roll used in flexo presses to provide a controlled film of ink to the printing plates that print the substrate. The ink film is affected by the number of cells per linear inch and volume of the individual cells in the engraving.

Anode
The positively charged electrode.

Anti-aliasing
In a digitized image, diagonal lines are treated as short horizontal and vertical lines that approximate the path of the desired line, At lower resolutions, this will produce a stair-stepped effect known as aliasing. Anti-aliasing algorithms remove these "jaggies" to produce smoother lines.

Antifoaming Agent
An additive used in ink to prevent or break down foam that has already formed.

Antifriction Bearings
A bearing used to reduce frictional drag, by such means as the use of narrow wheels, rollers, balls or air to support the rotating shaft.

Antipenetrant
Any material that reduces penetration into the stock.

Antique
With reference to paper, a finish rougher than normally used on bond paper.

Anti-skid Compounds
Ink additives used to retard slippage factors during the stacking and handling of packaging.

Anti-skid Varnish
A generally clear, resin coating formulated and applied to large flexible packaging to retard slippage during stacking and handling.

Apparent Trap
See Ink Trap Percent.

Applicator Roll
Examples are coating roll, print roll, tint roll, lacquer or varnish roll.

AQL
Acceptable Quality Level.

Archival
Pertaining to the long-term storage of data.

Area Source
Smaller sources of air pollutants that emit less than 10 tons per year (TPY) of a single air toxic or less than 25 TPY of a combination of air toxics.

Aromatic Hydrocarbons
Petroleum-based solvents characterized by benzene or a closed-ring molecular configuration. Used sparingly in flexographic inks.

Artwork
The original design, including drawings, photos and text produced by the artist.

Artype
A mechanical way to make up lettering from prepared sheets of preprinted alphabets.

ASAP
Acryonym for "as soon as possible."

As Applied
The condition (formulation) of an ink after its dilution to proper viscosity, just prior to applying to the substrate.

ASCII
See American Standard Code for Information Interchange.

ASCII File
A file encoded in the industry-standard representation for text, ASCII. An ASCII file contains only plain text and basic text-formatting characters such as spaces and carriage returns, but no graphics or special character formatting.

Ash
The inorganic or mineral filler used in paper. Determined by weighing the residue after ther complete combustion of a weighted sample.

Asphaltum (asphalt)
A dark-colored, resinous substance, soluble in hydrocarbon solvents, and used as a moisture barrier in heavy laminations.

KEY:

Barcode
Design
Environment
General
Ink
Mounting/ Proofing
Plates
Prepress
Press
Process Color CMYK
Quality
Substrate

AST
Above Ground Storage Tank.
See also UST (Underground Storage Tank).

ATSDR
Agency for Toxic Substances and Disease Registry.

Axis
The line about which a rotating body such as a roll or cylinder rotates.

Azeotropic Mixture
A liquid mixture of two or more substances that behaves like a single substance, in that, the vapor produced by partial evaporation of the liquid has the same composition as the liquid. This means the mixture cannot be separated by distillation. An example is ethyl and methyl alcohol.

B

Backlash
When looseness in gear teeth or a screw mechanism causes movement of one or more components without corresponding movement in the connected mechanisms.

Back-side Printing
See Reverse Printing.

Backup Copy
A copy of a file or data set that is kept for reference in case the original file or data set is destroyed.

Backup Roll
See Impression Cylinder.

BACT
See Best Available Control Technology.

Balance
Even distribution of the mass or a cylinder or roll about its axis.

Balancing
A procedure to bring a cylinder or roll into balance.

Baler
A machine used to compress recyclables into bundles to reduce volume. Balers are used often on newspapers, plastic, corrugated cardboard and other sorted paper products.

Banding
The undesirable effect occuring in blends or gradients where the image exhibits bands when printing because the color transition is too long or has too many steps.

Bar Code
A symbol consisting of an alternating series of thick and thin lines and may also include human readable characters, used to encode product and other information. Bar codes are readable with an optical scanner.

Bare Cylinder Diameter
The diameter of the actual plate cylinder before the stickyback and plates are mounted.

Barrier
An obstructing agent serving to separate one element from another or limit the migration or infiltration of one into the other.

Bar Width Reduction
A prepress function of decreasing the bar code image width to compensate for normal image growth as predetermined by press fingerprinting and production monitoring; it is analogous to dot gain for halftone dots.

Base
See Alkali.

Base
1. A full strength ink or toner; 2. The major ingredient used in a clear lacquer, varnish or ink. May refer to either the solvent or binder system; 3. A coating applied to a substrate to enhance subsequent application of inks or coatings.

Base
Film before the addition of a coating.

Base
1. The anilox roll before it is engraved. 2. The core of a design roll before the application of elastomer.

Base Alignment
On a typesetter or printer, a mode specifying that the lower reference edge of all letters in a line of mixed sizes or styles should be horizontally even; also called baseline alignment.

Base Cylinder
The cylinder used to accept a sleeve-mounting system.

Baseline Monitoring Report **BMR**
A report required to be submitted to POTWs by all CIUs within 180 days of the promulgation of new Categorical Standards, or 90 days prior to the commencement of discharge (for new sources), which defines the nature of the discharge and provides analytical data characterizing that discharge.

Basis Weight
The weight, in pounds, of a ream (usually 500 sheets) of paper at a given sheet size (usually the basic size for a given grade).

BCM
The abbreviation for one billion cubic microns per square inch, which is the measurement of the volume of ink in an average engraved anilox cell.

Bearer
Type-high supports mounted around each end of a plate cylinder to help carry part of the impression load and to help prevent bounce.

Bearer
When vulcanizing rubber plates or matrices, the metal spacers used to separate the platens, in order to produce finished, molded and vulcanized plates or matrices of the desired thickness. In photoengraving, bearers are the dead metal remaining on a plate that support and protect the printing surface during molding operations.

Beater
A large mixer used to mix the pulp to make paper.

Beater Dyed
A paper produced from the pulp colored in the beater.

Ben Day
A system of dots or patterns used to effect shading.

Benchmark
A point of reference from which measurements can be made, such as the use of a program to evaluate the performance of a computer. It is any standard against which products can be compared.

KEY:

Design
Environment
General
Ink
Plates
Prepress
Press
Process Color
Substrate

Best Available Control Technology **BACT**
An emission limitation based on the maximum degree of emission reduction (considering energy, environmental and economic impacts) achievable through application of production processes and available methods, systems and techniques. BACT does not permit emissions in excess of those allowed under any applicable Clean Air Act provision. Use of the BACT concept is allowable on a case-by-case basis for new or modified emission sources in attainment areas, and applies to each regulated pollutant.

Best Management Practices **BMP**
Procedures or controls other than emission or effluent limitations to prevent or reduce pollution, e.g., ink management, inventory control and purchasing or clean-up procedures.

Binary
A coding or counting system with only two symbols or conditions, such as on/off or zero/one. It is the format for storing data in computers.

Binder
The adhesive components of an ink, normally supplied by the resin formulation.

Binder
In paper, an adhesive component used to bond inert filler, such as clay, to the sheet, or to affix short fibers firmly (securely) to paper or board stock.

Biochemical Oxygen Demand **BOD**
A measure of oxygen required to break down organic materials in water.

Biodegradability
The ability of a substance to be broken down physically and/or chemically by microorganisms.

Bit
A binary digit, the smallest information entity. It is expressed as 1 or 0, meaning on or off, yes or no, positive or negative, something or nothing.

Bit map
A computerized image consisting of dots. Images are "mapped" directly from corresponding bits in memory, whereby each dot is represented by a binary digit (bit) that is "on" (1) or "off" (0). Also referred to as a paint format.

Black
See Process Black.

Black Body
A term describing a well-defined, theoretical light source used to specify the spectral composition of light.

Black Heat
See Infrared Light.

Blanking
The process where each individual image or product is cut out of the press sheet before forming is done.

Bleach
The method of measuring the tinctorial strength of an ink or toner, usually by mixing a small portion of ink or toner with a large amount of white base, and then evaluating its tinctorial strength vs. a control standard.

Bleed
To print beyond the cut edge or score so that the design is either cut off or folded under, resulting in a printed area that extends to the edge.

Bleed
In certain substrates, when the ink is partially dissolved by the liquid or solvent plasticizers, it causes the ink to run or migrate into unwanted areas adjacent to the printed area. It can also describe the condition resulting from insufficient drying of the preceding printed color, causing the trapping color to lose its color value – such as red printing over a wet white, resulting in pink.

Block Test
A test to measure the tendency of surface-to-surface sticking.

Blocking
1. An undesired adhesion between touching layers of material caused by moderate pressure and/or temperature change. 2. The extent to which damage to at least one surface is visible upon their separation.

Bloom
A term describing the condition when solid materials migrate to the film's surface. *See also Exudation.*

Blueline
Proofs that are blue image photoprints made from film negatives or positives. They are used to check the position of image elements and to show color breaks (by varying exposure time to produce light and dark blue images) but not process color.

Blushing
A milky, foggy or flat appearance in an ink or coating caused by excessive moisture condensation or incompatibility of one of the ingredients.

BMP
See Best Management Practices.

BMR
See Baseline Monitoring Report.

Board
A heavy-weight, thick sheet of paper or other fiber substance, usually 0.012" in thickness or more. The distinction between board and paper is not definite.

BOD
See Biochemical Oxygen Demand.

BOD5
Five Day BOD.

Body
Refers to the viscosity or flow characteristics of an ink or vehicle.

Bodying Agent
A susbstance added to an ink to increase its viscosity.

Body Type
The type face used in the majority of the copy in reading matter, as opposed to headline or display type.

Bold Face
A heavy typeface, in contrast to a light typeface, used to create emphasis in the body text.

Bold Face
The original name of the paper used for printing stock and bond certificates. Bold face now refers to a paper grade that is free of fuzz.

Bounce
The abnormal reaction to compression, resulting from the cylinder's erratic, rotational movement, causing missed or imperfect impressions. These imperfections are evident as horizontal lines or bands of decreasing intensity on the leading edge. In extreme cases, the horizontal lines will also appear on the trailing edge.

Boundary Layer
A layer of saturated air that accumulates above the substrate surface as the ink's liquid components evaporate.

Bourges
A patented masking medium on a dimensionally stable base.

Boxboard
A paperboard of sufficient caliper and test to be used in the manufacture of paperboard boxes. Commonly used grades are news, filled news, chip, straw, jute, patent coated and clay-coated. Specifications for boxboard are designated by kind, finish, caliper, dimensions, regular number (for standard sizes 25" x 20") and count (for odd sized sheets).

Brass Mounted Plates
Printing plates, which are premounted onto thin-gauge brass, ready to be clamped onto the plate cylinder.

Brayer
A hand-held roller used to apply ink to a mounted plate for proofing during the mounting process.

Bridging
A print defect of halftone or screen where the individual dots join or bridge together.

Brightness
The quality of whiteness and intensity as emitted from printed or unprinted surfaces.

British Thermal Unit **BTU**
A unit of energy, it is the quantity of heat required to raise one pound of water by 1° F. *See also Calorie*.

Brittleness of Ink
A condition where ink printed on foil decomposes or peels from folding the substrate.

Bronze
A metallic sheen characteristic of some printed inks where the appearance of the print depends on the viewing angle and illumination.

BTU
See British Thermal Unit.

Bubble
Existing sources of air pollution within a facility(ies), which may control air emissions for a number of different types of processes, where reduction in pollution can be more than is required at one emission point, or where control costs are higher or more difficult to achieve.

Buckle Folder
A folding unit consisting of moving tapes or belts to carry the substrate through fold-plates, where it buckles slightly. The buckle is pulled downward by rotating rollers, creating a fold. Buckle folders are often used for parallel folds.

Bulk
A term denoting the thickness (or the relative thickness) of a sheet, expressed as the number of pages (two pages per sheet) or the number of sheets (multiplied by two) needed to become 1" thick. It is an important factor where a volume of paper will be converted into a product, such as books, envelopes and business forms, and must fit into a specified shipping container.

Buna-N
A synthetic rubber, made from butadiene and acrylonitrile, used in the manufacture of flexo plates and rolls. It is resistant to aliphatic hydrocarbons, alcohols, cellosolve and water, but not resistant to aromatic hydrocarbons and esters (acetate).

Burn
Exposure of uncured photopolymer to ultraviolet light duringthe plate production process.

Bursting Strength
Paper's resistance to rupture under pressure, indicated in pounds per square inch on a Mullen or pop tester.

Butt Register
The condition where two colors touch each other without an allowance for overprint trap.

Butt Splice
An end-to-end joining of two similar materials to achieve continuity of surface, design, etc. Butt splicing is also used to join stickyback, printing plates and webs of substrate in process, such as heavy papers and boards, at the unwind or rewind, in which case, the thickness or the substrate prevents using the lap (overlap) splice.

BWR
See Bar Width Reduction.

By-product
Materials, other than the intended product, generated as a result of an industrial process.

KEY:

Barcode
Design
Environment
General
Ink
Mounting/ Proofing
Plates
Prepress
Press
Process Color CMYK
Quality
Substrate

C

C (°C)
Degrees Centigrade; °C = 5/9 x (°F – 32)

CAAA
Clean Air Act Amendments of 1990.

Caking
When dried ink collects on the rollers and plates.

Calender
The equipment used in heat transfer printing where designs on the transfer paper are vaporized into the fabric.

Calender Stack
A group of rolls through which material is passed in the calendering operation.

Calendering
A process that increases density and improves surface smoothness and gloss in paper.

Calibration
The process of setting a device to conform to a standard or preset condition; often used to correct for drift or change in the device's performance characteristics and to bring it back to norm.

Caliper
The thickness measurement of a single sheet of paper as defined by TAPPI Method T411 and reported in mils or thousandths of an inch (1 mil = 0.001"). Multiply inches by 25.4 micrometers and round to the nearest whole number to find metric thickness. Also used to identify thickness of other printing materials such as plates, mounting tape, etc. *See "gauge" for flexible film substrate thickness and "point" for paperboard thickness*.

Caliper Gauge
A micrometer used to measure the thickness of a sheet of material.

Calorie
A unit of energy, described as the amount of heat required to raise one gram of water by 1° centigrade. *See also British Thermal Unit.*

Camera-ready
Copy and/or artwork that is ready for the photography step to make a film negative for platemaking in the printing process.

Canadian Environment Protection Act **CEPA**
A federal law which regulates the release of pollutants into Canada's environment.

Cap
See Emission Cap.

Capillary Action
Surface tension which causes liquid to rise or fall when it comes in contact with a solid. Examples are liquids rising in capillary tubes, blotting paper, wicks. In printing it is the force that transfers inks and coatings from engraved cells of an anilox roll to a contacting surface.

Capture Device
A drying system, hood, enclosed room, floor sweep or other method of collecting solvent or other pollutants into a duct. The pollutant can then be directed to a pollution control device such as an incinerator or carbon absorber, or to atmosphere.

Capture Efficiency
The fraction of organic vapors generated by a process that is directed to an abatement or recovery device. The percentage of air emissions that is removed during the transfer of ink and movement of the web by the drying system and exhausted out or to a control device.

Carbon Absorber
An add-on device using activated carbon to absorb volatile organic compounds from a gas stream.

Carbon Adsorption
A process of removing contaminants through a system containing activated carbon treated to attract the contaminants.

Carbon Monoxide **CO**
A colorless, odorless, poisonous gas produced by incomplete burning of carbon-based fuels, including gasoline, oil and wood.

Carcinogenic or Carcinogen
A chemical capable of causing cancer.

CAS
See Chemical Abstract Service.

Casein
A protein usually obtained from milk used to make sizings, adhesive solutions and coatings. Also acts as the binder for aqueous dispersions of pigments for a variety of trades.

Catalyst
A substance that causes an increase in the rate of a chemical reaction without being permanently altered by the reaction.

Catalytic Incinerator
A control device that oxidizes volatile organic compounds by using a catalyst to promote the combustion process. Catalytic incinerators require lower temperatures than conventional thermal incinerators, thus saving fuel and other costs.

Categorical Industrial User (CIU)
A nondomestic discharger into a POTW that is subject to one of the National Categorical Discharge Standards found in 40 CFR 405-471; a facility that falls under the jurisdiction of regulations written to cover that specific process, i.e., photoprocessing.

Caustic
See Alkali.

CBEP
See Community-Based Environmental Protection.

cc
Cubic centimeter.

CCD
See Charged Coupled Device.

CCN
See Clay-coated News.

CEAA
Canadian Environmental Assessment Act.

Cell Count
The number of cells per linear inch (or centimeter) in either a laser or mechanically engraved anilox roll.

Cell Volume
The volume delivery capability of a single anilox cell or group of cells in a given area.

Cellophane
A transparent, flexible sheeting consisting of regenerated cellulose plus plasticizers, with or without functional coatings, such as moisture-proof, etc. Cellophane gained widespread use in the early 1930s and is credited with helping the flexo printing process to flourish.

Cellosolve
Union Carbide Corp.'s trade name for ethylene glycol mono-ethyl ether, a retarding solvent in flexographic inks.

Cellulose Acetate
A clear, thermoplastic material, usually in film form, made from cellulose and acetic acid.

Cellulose Acetate Butyrate
A clear, thermoplastic material made from cellulose, reacted with both acetic and butyic acid. It is used as a packaging film and in coatings, such as lamination.

Cellulose Fiber
In paper-making, the fibrous material remaining after the nonfibrous components of wood have been removed by the pulping and bleaching operations.

CEMS
See Continuous Emission Monitoring Systems.

Center
To establish an equal amount of space on both sides of the type copy or image.

Center Line
A line added to indicate the center of an object.

Centipoise
A measure of viscosity, conveniently and approximately defined, relative to the viscosity of water at room temperature, which is 1.0. Higher values indicate a "thicker" liquid.

Central Impression (CI) Cylinder Press
A type of printing press. The web being printed is in continuous contact with a single large diameter impression cylinder and the color stations are arranged around the circumference of the central impression cylinder.

CEPA
See Canadian Environmental Protection Act.

CEPS
See Color Electronic Prepress System.

CERCLA
See Comprehensive Environmental Response, Compensation and Liabilities Act; see also Superfund.

CD
See Cross Direction.

CFC
See Chlorofluorocarbon.

Chalking
Occurs when the pigment in the printed ink is not properly bound to the paper, becoming powdery and easily rubbed off.

Change Over
The process or processes that take place when the printer changes from one production order to the next. Often includes changing ink, anilox roll, printing plates, metering system, substrate and any in-line finishing equipment.

Character
Each individual letter, symbol or punctuation mark that makes up a full typeface.

Character Count
The number of characters included in a block of text. In graphic arts, spaces are counted but other nonprinting characters are not. In information processing, both printing and nonprinting characters are usually included.

Character Set
The entire set of characters that can be either shown on a monitor or used to code computer instructions. In a digital printer, it is the entire set of characters that the printer is capable of printing.

Characteristic Waste
Wastes that are defined as hazardous because they exhibit one or more of the following general qualities: ignitable, oxidizing, corrosive, reactive, lethal and toxic.

Charged Couple Device **CCD**
Photosensitive CCD's are used in scanners, digital cameras, video cameras. The CCD basically reads the image by storing a group of charges based on the image that it is exposed to. These charges are analog charges, as opposed to simple digital on/off charges. Thus, you can grab degrees of light and color to transfer a visual image into a group of electrical charges, and then to your computer screen, video tape or printer.

Chattering
Horizontal lines or bands in printed solids or screens of varying color intensity.

Check Digit
Built into bar codes, an algorithm which verifies the valid combination of characters.

Checking
The short, shallow cracks on the surface of a rubber product caused by exposure to extreme environmental conditions, such as exposure to ozone.

KEY:

Barcode
Design
Environment
General
Ink
Mounting/ Proofing
Plates
Prepress
Press
Process Color CMYK
Quality
Substrate

Chemical Oxygen Demand (COD)
The measure or capacity of oxygen consumption in inorganic and organic matter present in water.

Chemical Substance
Any inorganic or organic substance of a particular molecular identity; any element of uncombined radical.

Chill Roll
A metal roll or drum cooled internally with a solution, such as water or brine; these rolls are normally used after the press dryer to cool the printed web prior to rewinding.

China Clay
A natural, white, mineral pigment used for coating paper and extending ink.

Chipboard
A low-quality nontest paperboard made of waste paper used when specified strength or quality are not necessary.

Chlorofluorocarbons (CFCs)
A family of chemicals used in air conditioners and refrigerators as coolants, and also as solvents and aerosol propellants. They drift into the upper atmosphere where their chlorine components destroy the ozone layer.

Choke Roll
The printing roll carrying the background or overall pattern. *See also Design Roll*.

Choke Trap
The intentional overlap of a lighter background onto a darker object needed to ensure that a slight misalignnment or movement of separations on press will not affect the final appearance of the job, i.e., color or white fringes or borders around image detail. Called trapping in digital imagng systems. *See trapping.*

Chroma
See Lch Value.

Chromatic Scale
The colors of the spectrum; red, orange, yellow, green, blue and violet.

Chrome Green
A fairly light-resistant, opaque-green pigment made by mixing freshly precipitated iron blue and chrome yellow.

Chrome Yellow
A light-resistant opaque yellow pigment composed essentially of lead chromate.

Chromium Plate
A thin covering of chromium, usually electroplated, over a copper or nickel base to increase the surface-wear properties.

Chronic Effect
An adverse effect on a human or animal in which symptoms recur frequently or develop slowly over a long period of time, i.e., medical conditions stemming from the ingestion of lead, nicotine and solvents.

CI Press
See Central Impression Press.

CIE
See Commission Internationale de l'Eclairage.

CIELab
Adopted by CIE, it is a standard, objective color measurement system, widely used for quantitative color measurement and control. "L represents the "lightness" of the sheet and varies from 100 for a perfect white to 0 for absolute black; "+a" indicates redness; "–a" indicates greenness; "+b" indicates yellowness; and "–b" indicates blueness.

CIE'94
One of several methods for calculating color differences in CIELab Color Space.

CIE Standard Illuminant
Common lighting conditions used to evaluate color as defined by the CIE in terms of relative spectral power distributions, or color temperature; lower numbers are warmer/redder, higher numbers are colder/bluer.

CIE Standard Observer
A hypothetical, average human observer who sees color at a 2° viewing angle as defined in a 1931 CIE study. A supplementary observer for a larger viewing angle of 10° was adopted in 1964. The 2° standard observer should be assumed if not otherwise specified. If the field of view is larger than 4°, the 10° standard observer should be used.

Circumferential Register Control
See Running Register.

C1S
See Coated One Side.

CIU
See Categorical Industrial User.

Clamp Marks
Marks produced by clamps holding the stock in position for guillotine trimming.

Class I Area
Under the Clean Air Act, a Class I area is one in which visibility is protected more stringently than under the NAAQS; includes national parks, wilderness areas, monuments and other areas of special natural and cultural significance.

Clay-coated Board
A high quality paperboard whose surface is coated with pigment or pigment-like solids and appropriate binders.

Clay-coated News **CCN**
Paperboard made from recycled newsprint-based fiber with a clay-coated surface to improve printability.

Clean Air Act
The original Clean Air Act was passed in 1963, but the United States air pollution control program is actually based on the 1970 version of the law. The 1990 Clean Air Act Amendments are the most far-reaching revisions of the 1970 law.

Clean Water Act (CWA)
The basic federal law governing water pollution control in the United States.

Cling
The tendency of adjacent materials to adhere to each other, as in blocking, except that the surfaces can be separated without any visible damage. Also polar static attraction.

Clip Art
Copyright-free, raster or vector illustrations, figures and designs, commerically available in book format or in various file formats on disk.

CMYK
Denotes cyan, magenta, yellow, and black in that order. *See Process Black, Process Cyan, Process Magenta, Process Yellow.*

CMS
See Color Matching System.

CNK™
See Coated Natural Kraft.

CO
See Carbon Monoxide.

Coated Natural Kraft™ **CNK™**
Unbleached paperboard, usually clay-coated on the side to be printed for folding cartons.

Coated One (1) Side **C1S**
Paper which is coated on one side, widely used for labels.

Coated Recycled Board
Unbleached paperboard, usually clay-coated on the side to be printed for folding cartons.

Coating
The outer covering of a film or web. The film may be coated on one side or both.

Coating
A uniform layer of adhesives, varnishes or similar materials applied across the entire width of a web.

Cockling
A rippling effect occurring on surface of a sheet of paper that has not been properly dried. Moisture pickup of the sheet can also cause the cockling or wavy edges.

COD
See Chemical Oxygen Demand.

Code 128
This bar code has the ability to encode the full 128-character ASCII set. It can encode variable-length data and permits numeric data to be encoded as two digits per symbol character. This "double-density" mode makes it one of the most efficent symbols used, especially in such industries as healthcare, retail, food/grocery and transportation.

Code 3-of-9
Also referred to as Code 39, a bar code consisting of nine elements—five bars and four spaces—with three of the nine elements always being wide for each character encoded. It has the ability to vary in length as required.

Code Color
The color used to differentiate select items in a product line of very similar packages.

Code of Federal Regulations **CFR**
A periodic publication of the regulations established by United States law.

Code of Management Practices **CMP**
The site-specific plan implemented by the individual processing facility for the purpose of controlling and reducing silver discharged to the POTW.

Coefficient of Friction **COF**
A measure of the slip resistance between two surfaces.

Coefficient of Friction Tester
A device consisting of inclined plane and block to measure the coefficient of friction of various flexible substrates.

Co-extrusions
Film that is produced by more than one extruder through a common die. Films have been made with as many as 13 layers.

Cohesion
That form of attraction by which the particles of a body are united throughout its mass.

Cold-Flow
See Creep.

Collateral Materials
Accompanying or auxiliary material such as advertising and promotional items.

Color
A visual sensation produced in the brain when the eye views various wavelengths of light. Light is transmitted, reflected and/or absorbed. For example, if a printed sheet of paper is sufficiently thick, all light will be either absorbed or diffusely reflected; there should be no significant amount of light transmitted. Color viewing is a highly subjective experience that varies from individual to individual. Lighting and viewing standards help ensure the accuracy of color reproduction in the graphic arts industry. TAPPI methods T524 and T515 are common sources of paper color measurement protocol.

Color Balance
See Gray Balance.

Color Burn-out
An objectionable color change of a printing ink that may occur in bulk or on the printed sheet. In bulk, it is associated primarily with tints and is caused by a chemical reaction between certain components in the ink formulation. In the printed sheet, it is generally caused by heat generated from the pile of printed material during the drying of an oxidizing type of ink.

Color Break
The designation of ink colors to be used for specific image areas.

KEY:

Barcode
Design
Environment
General
Ink
Mounting/ Proofing
Plates
Prepress
Press
Process Color
Quality
Substrate

Color Comprehensive
Design work, which illustrates in detail: size, layout, color, copy, copy positioning, type style, etc. of the proposed finished reproduction.

Color Correction
A photographic or electronic process used to alter the colors in an image, done to compensate for the limitations of the output device or to achieve the result desired by the customer. Colors can be altered globally or selectively in the image.

Color Difference
The degree of nonmatch between two colors which can be calculated mathematically in CIELab color space. Also called delta (Δ) E.

Color Electronic Prepress System **CEPS**
A high-quality, proprietary computer-based system that may include equipment for page make-up, scanning color separations and making color corrections. PC-based color scanning and manipulation systems, often referred to as desktop publishing systems (DTP), usually lack the capabilities and sophistication of CEPS.

Color Fastness
See Lightfastness.

Color Key
A proof consisting of acetate or polyester overlays attached in register to a backing substrate. Each overlay carries the colored image from a film negative. Color breaks and traps can be judged, but exact color match to the final printed product can not be made.

Color Matching
To duplicate the hue, chroma and lightness of a given color sample, usually by blending base mixing inks.

Color Matching System **CMS**
A system of managing color to achieve consistency between devices. Ideally, colors on the monitor should accurately represent the colors in a scanned image and the colors on the final output. This consistency is accomplished by creating ICC profiles of one device into a device-independent color model, and then mapping those colors to the the color gamut of another device.

Color Model
See Color Space.

Color Monitor
An RGB or composite monitor which uses separate video signals of red, green, and blue – the three primary additive colors. It uses these signals to display almost any number of hues, depending upon the computer software and calibration. This type of monitor usually produces clearer, sharper colors and images than can be reproduced by printing CMYK process inks. Composite monitors use one signal to combine the three primary colors.

Color Overlap
See Trapping.

Color Overlay
A transparent overlay, usually acetate, on a black-and-white drawing on which each additional color is indicated as a guide for reproduction. A term sometimes used at press-side referring to the number of colors that overprint each other.

Color Proof
A printed or simulated printed image of each process color (cyan, magenta, yellow and black) using inks, toners or dyes to give a representation of the final printed reproduction.

Color Resolution
The number of different colors or gray-scale values a system can work with or present. The value is usually given in bits; each added bit doubles the number of available colors. For example, 8-bit color displays show 256 colors (or shades of gray).

Color Rendering Index **CRI**
An indexed number used to indicate the degree to which a real light source matches the ideal D50 source. The higher the number, the better the match – 100 denoting a perfect match. For color evaluating in a light booth, an index of 90 or higher should be used.

Color Saturation
A measure of the amount of white light in a hue. High saturation means there is no white-light component and the color is intense or of good quality.

Color Sequence
See Ink Rotation.

Color Scanner
See Scanner.

Color Separated Art
See Preseparated Art.

Color Separation
The process of exposing an original color image through RGB filters to produce complementary images which will be printed with CMYK inks. The final digital file includes masking (color modification) for specific inks and substrates, as well as halftone screening to enable printing a uniform tone scale with proper gray balance from extreme highlights through midtones and shadows to maximum solid color. This can be accomplished through the use of a digital camera, digital or analog scanner, or photographically.

Color Space
Also known as color model; in graphics applications, the manner in which colors can be defined or modifed. Common color spaces are RGB, HSB, CMY and spot (custom) colors. CIELab is the widely used perceptual color space.

Color Standard
A color sample which serves as the target for the color to be reproduced.

Color Stations
The individual section of the press or set of rollers used to print each individual color.

Color Strength
The effective concentration of colorant per unit weight or volume of ink.

Color Target Proof
A proof that is not profiled using the output source file; however, it represents the customer's color expectations.

Color Temperature
The temperature assigned to any light source by matching it against light radiating from a heated black body. The spectral distribution emitted by the heated black body depends on its Kelvin temperature. The higher the color temperature, the bluer the light; the lower the temperature, the redder the light. A standard viewing light, which should be neutral, is obtained with equal amounts of red, green and blue lights at a color temperature of approximately 5,000 °K (D50).

Color Theory
The systems and science of color usage (physical, chemical and emotional factors).

Color Transparency
A full-color photographic positive image on a transparent support, viewed with the aid of a backlit transparency viewer.

Colorant
That which renders color; it may be a pigment or dye or a combination of the two.

Colorimeter
An optical measuring device that responds to color in a manner similar to the human eye by filtering reflected light into its dominant regions of red, green and blue. This determines a color's numeric CIELab value.

Colorway
A specific combination of colors in a pattern of a transfer type print design.

Combination Folder
A folding unit which incorporates the characteristics of both a knife and buckle folder.

Combination Plate
In flexo, the printing of halftones or screen tints and solid line or text copy using the same plate. It may compromise print quality because halftone dots require minimum impression and ink film thickness, whereas solids need maximum impression and ink film thickness for optimum printability. In offset litho, it is the ganging of several designs on the same plate with no concern about mixing halftone and line copy.

Combination Run
A common image that remains throughout a press run. Plate or color changes are made for different design elements such as weight marks, UPC codes, ingredients, nutritional labeling, etc.

Combustible
Any substance that will burn. Combustible liquids have a flash point of 100° F (73.8° C) to 200° F (93.9° C).

Comment Period
The time provided for the public to review and comment on proposed action or rulemaking after publication in a Federal or State Register.

Commercial Chemical Product
A chemical substance that is manufactured or formulated for commercial or manufacturing use but becomes hazardous waste when discarded. Examples include some pesticides and pharmaceutical products.

Commission Internationale de l'Eclairage CIE
International standard body for color specifications.

Common Impression Cylinder Press
See Central Impression Cylinder Press.

Common Sense Initiative CSI
A program initiated by the USEPA to promote less environmental pollution by involving all parties that are affected by industrial activity. It represents a fundamentally different system of environmental protection, replacing the pollutant-by-pollutant approach of the past with an industry-by-industry approach for the future. Its goal is to help industry operate "cheaper, cleaner and smarter."

Community-Based Environmental Protection CBEP
A holistic approach to environmental protection that is sensitive to local conditions and employs multi-level, cross-sector partnerships to achieve results; environmental pollution and control programs that respond to the health and safety needs of the surrounding community.

Comp
See Comprehensive Layout.

Compatible
Refers to the ability to mix differing solutions or materials together into a homogenous mixture, without kick-out or haziness.

Compliance Monitoring
The collection and evaluation of data, including self-monitoring reports and verification, to show whether pollutant concentrations and loads contained in permitted discharges are in compliance with the limits and conditions specified in a permit.

Complementary Colors
A pair of contrasting colors that, when mixed in proportions, produce a neutral hue.

Composite Art
Artwork, where all colors are drawn on one piece of copy (not color separated), indicated by white and different shades of black.

Composite Film
Complete separations ready for printing; usually created by a process called stripping.

Comprehensive Environmental Response Compensation and Liability Act CERCLA
Enacted in 1980, CERCLA is a U.S. law that provides broad federal authority to respond to releases or threatened releases of hazardous substances that may endanger public health or the environment.

Comprehensive Layout (Comp)
A mock-up of a printed piece showing all type and pictures in rough form but in the right size

KEY:

Barcode
Design
Environment
General
Ink
Mounting/ Proofing
Plates
Prepress
Press
Process Color
Quality
Substrate

and in the correct position. It is used to evaluate a design before final type and artwork are produced.

Compression Set
The extent to which the rubber becomes distorted permanently, after subjecting a test sample to a known load, for a specified time. It is expressed as percentage of the original thickness.

Computer-to-Plate **CTP**
See Direct-to-Plate.

Computer-to-Sleeve **CTS**
A system where the plate is mounted on a sleeve and imaged in the round directly from a computer system using laser ablation.

Concentricity
A circle or sphere, one within another, having a common center. For example: When the outside diameter (O.D.) of a roll or cylinder and the diameters of journals, bearing steps, bore, etc., have a common rotational axis.

Concept Proof
A proof that is not profiled and is not used for matching color. It is used to show the design layout and type, but not the expected color.

Condensed Type
Proportionally narrow or slender typefaces.

Conditionally Exempt Generators
Small-quantity facilities that produce fewer than 220 pounds of hazardous waste per month that are not considered acute hazardous wastes.

Consent Decree
A legal document submitted by the Department of Justice on behalf of USEPA for approval by a federal judge to settle a case.

Consistency
The general body characteristics of an ink, (e.g., viscosity, uniformity) used to describe the rheological property of an ink – i.e., thick, thin or buttery.

Contaminant
Any physical, chemical, biological or radiological substance or matter that has an effect on air, water or soil.

Continuous Emission Monitoring Systems **CEMS**
Machines that measure, on a continuous basis, pollutants released by a source.

Continuous Tone **CT**
An image which has not been screened and contains a range of light to dark color tones, but must be converted to halftone dots in order to be printed.

Contract Analog Proof
A proof that is made to manufacturer's recommendations for exposing and processing by a specific analog proofing system, representative of what the finished product will look like before the design goes on press, and has been profiled according to FIRST specifications.

Contract Digital Proof
A proof that is profiled to a specific digital proofing system, representative of what the finished product will look like before the design goes on press, and has been made according to FIRST specifications.

Contract Proof
A proof output to FIRST specifications, using a press profile, and is representative of what the copy will look like when reproduced on press. For images, it does not have to be a dot-for-dot reproduction, but instead, must be an overall simulation of the expected print results. The subsets of a contract proof are defined: contract analog, contract digital and profiled contract.

Contrast
The difference between extreme highlight and shadow areas of continuous tone original or halftone reproduction. Image contrast is usually compressed to bring an original's density range to that can be reproduced on a printing press.

Control Chart
A visual record of quality performance in a statistical process, produced by plotting the value of each sample drawn from the process in graph form with the number of observations along the horizontal axis and the value of the observation along the vertical axis.

Control Target
The standard set of graphic elements placed outside the live area of each of the pieces of film, used to monitor makeready, and if possible, the entire production run. When printed, they superimpose to form a colored bar in various densities that enables the platemaker and printer to to check by eye or instrument the nature of each ink film, the strength and eveness of ink and the registration of color. It is specifically defined in FIRST and available from the FTA. *See also Run Target.*

Control Technique Guideline **CTG**
USEPA documents designed to assist states in defining reasonable available control technology for sources of VOCs. The CTG for flexography is "Control of Organic Emissions from Existing Stationary Sources Volume VIII: Graphic Arts – Rotogravure and Flexography".

Converter
A manufacturer who takes raw materials – such as resin, polymer, paper pulp – to produce the final package (box, pouch, bag, envelope). Printing may or may not be included in the process.

Copolymer
A polymer produced from a combination of two or more dissimilar monomers. *See also Polymer.*

Copy
Manuscript, type, transparency, artwork or computer disk from which a printed piece is to be prepared. The term is also used to refer to the final printed result.

Copy Boards
The part of a process camera where the original artwork is placed on to be reproduced onto photographic paper or film.

Copy Range
See Dynamic Range.

Coquille Boards
Pattern-surfaced drawing boards that allow the artist to produce tone effects directly onto the original drawing.

Core
A tube on which paper, film or foil is wound for shipment.

Core
The metal body of a roller covered with rubber.

Core Holder
A device for affixing the core to shaft.

Corona Treatment
To improve a film surface's ink wettability, the dyne level or surface tension is increased by applying a concentrated electrical discharge.

Corrosive Waste
Water-based waste having a pH of 2.0 or less (strong acids) or 12.5 or more (strong bases); also any liquid able to corrode 3" of steel per year.

Corrugated Press
A sheet-fed in-line press used to print sheets of combined corrugated board. These presses often have folding, gluing, creasing and stacking equipment located in-line after the printing stations.

Cosolvent
One of two or more solvents in a mixture which together dissolve a solid.

Cost/Benefit Analysis
A quantitative evaluation of the costs that would be incurred by implementing an environmental regulation versus the overall benefit to society of the proposed action.

Cover Sheet
A clear overlay taped or laminated over artwork to provide surface protection.

Cover Sheet
In reference to liquid photopolymer, a thin sheet of clear film used to protect the negatives during platemaking. In reference to sheet photopolymer, a protective polyester sheet laminated to the image surface of the polymer sheet.

Coverage
The extent or degree a base material is covered, colored or hidden by an ink or coating; the hiding power.

CPS
See Computer to Sleeve.

Cradle-to-Grave System
A procedure in which hazardous materials are identified and followed as they are produced, treated, transported and disposed of by a series of permanent, linkable, descriptive documents (e.g., manifests). Also a concept in which the generator of waste is reused or destroyed and no longer exists. *See also Manifest System*.

Crash
A halo or double outline effect caused by excessive plate impression to the stock or the transfer roll to the plate.

Crash Finish
A surface finish of paper similar to coarse linen.

Craters
See Pock Marks.

Crawling
An ink-film property. If surface wetting is very poor, it prevents the ink from contracting into drops, leaving an uneven covering. *See also Surface Energy*.

CRB
See Coated Recyled Board.

Creep
Cured or uncured rubber which deforms over time and under stress. With rubber-covered rolls, the metal roll body is subject to creep, as well as the rubber. Creep can also occur when a roll is kept in storage without turning.

Creepage
The slight, continuous and cumulative tendency of a color to drift out of register or position in the running direction.

CRI
See Color Rendering Index.

Crimp Seal
A seal formed with a corrugated, pressure-type heat-seal mechanism. The seal has a wavy appearance.

Crinkle
To wrinkle or wad the printed film severely in order to determine ink flexibility.

Criteria
Descriptive factors taken into account by USEPA in setting standards for pollutants.

Criteria Air Pollutants
A group of very common air pollutants regulated by USEPA on the basis of criteria. Criteria air pollutants include ground level ozone, carbon monoxide, particulate matter, nitrogen dioxide, sulfur dioxide and lead.

Crop Marks
Marks made on the outer edges of artwork to designate the area to be printed or cut.

Cropping
To trim unwanted areas of an illustration, photo, or other artwork.

Cross Direction
The direction at a right angle to the paper grain or flow of material through a machine (paper machine, extruder, printing press, etc.). *See also Machine Direction.*

Cross Press
See Cross Direction.

Cross Web
See Cross Direction.

Crown
The difference in diameter between the center of a roll and reference points at or near the ends of the face.

KEY:

Barcode
Design
Environment
General
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Prepress
Press
Process Color
Quality
Substrate

Crushed Board
A condition where corrugated board is crushed on the edges.

CSI
See Common Sense Initiative.

CT
See Continuous Tone.

CTG
See Control Technique Guideline.

CT Merge
The function of combining two CT files in such a manner that they apperar to vignette together smoothly without noticeable break between images.

CTP
See Computer to Plate.

CTS
See Computer to Sleeve.

Cumulative Impact
The combined effects of all chemical exposures on human health and the environment over time.

Cure
The process of hardening a heat-set or photo-reactive material. For example hardening photopolymers requires exposing the photoinitiator to UV light.

Curl
Distortion of an unrestrained sheet due to differences in structure from one side of the sheet to the other. The curl side is the concave side of the sheet. It may occur in substrates and printing plates.

Curve Direction
The direction of web travel on a flexo press.

Cut
An expression commonly used to designate an engraving.

Cut
To dilute or thin an ink, lacquer, varnish, etc. with solvents or with clear base.

Cut-back Curve
Data which indicates the halftone dot areas need to be compensated for normal dot gain throughout the entire tone scale during the printing process. The data is specific to particular materials and process conditions.

CWA
See Clean Water Act.

Cyan
See Process Cyan.

D

D50
A standard light source used in graphic arts for critical color evaluation, whose color temperature is 5,000° K.

D65
A standard light source used by the textile, paint and ink industries, whose color temperature is 6,500° K.

D-max
The highest measured density on a sample. This is not to be confused with the maximum density achievable by the material.

D-min
The lowest measured density on the clear/non-image area of a sample. This is not to be confused with the minimum density achievable by the material.

Damper
Usually a pivoted gate or valve used to control the flow of air or other gases, as in the dryer.

Dancer Roll
A web-tensioning device in the form of a roller that uses weights or springs which monitors web tension by controlling the unwind brake or rewind tension.

DCS
See Desktop Color Separation.

DDCP
See Direct Digital Color Proofs.

DDES
See Digital Data Exchange Standards.

Deep-relief Powder Molding **DRPM**
The rubber plate-making process where the finished plate relief is more than 0.125".

Deflection
Deviation from a straight line under load, e.g., fountain-roll pressure against the anilox roll, causes both to bend or bow slightly. Excessive bending of both or either one will result in uneven ink metering and subsequent nonuniform printing.

Delamination
The partial or complete separation of the layers in a laminate.

Deliquescence
The property of a material to absorb moisture from the air and to become a liquid. A best known example is calcium chloride.

Delist
Use of the petition process to have a facility's toxic designation rescinded, or a particular waste stream declared nonhazardous for disposal.

Delta (Δ) E
The calculated color difference between the highlights and shadows of an image. It is also the tonal, density and copy range.

De Minimis
A quantity that is small enough and with insignificant impact that it serves as a trigger to exempt firms/facilities with actual exposure below the specified level from one or more provisions of the various environmental and OSHA regulations.

Densitometer
A photoelectric instrument that measures the optical density of images or colors. A reflection densitometer measures the amount of incident light reflecting from the surface of a substrate, such as ink on paper or film. A transmission densitometer measures the amount of light transmitted through film from a measured light source.

Densitometer Response
The aim spectral response as contained in ISO 5-3: 1995, Photography Density Measurements – Part 3: Spectral Conditions. The status responses pertaining to the graphic arts are Status E, Status I and Status T. *See also Spectral Response.*

Density
A measure of the amount of light reflected from the printed sheet or transmitted through a plate-making film.

Density
The mass per unit volume of a substance, commonly measured in g/cc.

Density, Absolute
The optical density referenced to a perfect reflecting diffuser through calibration procedures. Typically referred to as "density with paper/film included."

Density, Reflection
The light-absorbing property of a material, expressed as the logarithm of the reciprocal of the reflectance. A higher density indicates more light is absorbed or a darker surface. Also referred to as print density.

Density, Relative
The absolute (optical) density of a sample minus the absolute (optical) density of the substrate. Typically referred to as "density minus paper."

Density, Transmission
The light-absorbing property of a material, expressed as the logarithm of the reciprocal of the transmittance.

Density Range
See Dynamic Range.

Dermal Toxicity
Adverse effects resulting from skin exposure to a substance.

Desiccant
1. A dehydrating agent – absorbs moisture by physical or chemical means. 2. A drying agent.

Design for the Environment **DFE**
A cooperative effort between USEPA and industry to incorporate environmental consideration into the design and redesign of products, processes and technical and management systems for the purpose of promoting pollution prevention.

KEY:

Barcode
Design
Environment
General
Ink
Mounting/ Proofing
Plates
Prepress
Press
Process Color
Quality
Substrate

Design Motif
1. A distinctive feature, shape or figure or other thematic element in a work of art. A dominant idea or central theme. 2. A single or repeated design element or color.

Design Roll
A printing cylinder with an elastomeric material affixed in position and engraved with a design. Used for seamless printing.

Desktop Color Separation **DCS**
A preseparated digital EPS file consisting of five files: one is the originally named file that is the PICT preview to be imported into page layout programs; the other four end with .C, .M, .Y and .K respectively. In OPI settings, the PICT image is replaced with the high resolution file during the RIPping process.

Destruction Removal Efficiency **DRE**
A percentage that represents the number of molecules of a compound destroyed in an oxidizer.

Detergent
A surface-active agent that, by lowering the surface tension of water and by its emulsifying action, increases the wetting power and cleansing ability of water.

Dew Point
1. The temperature at which air or other gasses become saturated with vapor, causing the vapor to deposit as a liquid. 2. The temperature at which 100% relative humidity is reached.

Dextrin
A carbohydrate derived from starch, usually by treatment with heat, acids or enzymatic action.

DFE
See Design for the Environment.

Dial Indicator
A watch-like instrument used to measure concentricity, run-out, deflection and the relative position of mechanical components.

Die Cut
1. To punch out with a sharp tool. 2. A cleft, gash, slit or notch left from a punching-out operation.

Dies
Any sharp cutting forms, rotary or flat, used to cut shapes from paper, paperboard or other stocks.

Diffusion
A spreading out or equalized dispersion of a material, force or condition into the surrounding medium; e.g., the diffusion of heat by conduction; the diffusion of light through a translucent material or reflection from a rough surface; the diffusion of gases, liquids or granular solids into the surrounding medium.

Digital Data Exchange Standards **DDES**
A body of standards developed for the graphic arts industry by the ANSI-accredited Image Technology Committee (i.e., ANSI IT8) and the ISO-accredited graphics technology committee (i.e., ISO TC130). DDES provides standardized exchange formats for the digital information developed and used in printing, design and production.

Digitizing
The process of converting graphic representations (images, line drawings, etc.) into digital data that can be processed by a computer system.

Dilatent
Having the property of an increase in viscosity with increase in shear. Dilatent liquids are solid or highly viscous when stirred, and fluid when undisturbed. The condition can occur in flexo inks but is normally considered highly undesirable and one to be avoided through formulation.

Diluent
A liquid with no solvent action, used to dilute or thin an ink or lacquer.

Dimensional Stability
Indicates a material's resistance to dimensional change caused by ambient, atmospheric or other conditions.

DIN
German industrial standards (*Deutsche Industrie-Normen*).

DIN Cup
An eflux cup used to measure viscosity.

Direct Digital Color Proof **DDCP**
A prepress color proof that is imaged directly from digital data without the intermediate steps of film and contact exposure.

Direct-to-Plate
A system designed to image printing plates directly from computer data, eliminating the need for film production and the use of contact plates.

Dithering
A technique used by some input and output devices to simulate grays by varying the pattern and proximity of black pixels to each other.

Dirty Print
A print defect, characterized by the bridging of dots and dirty edges on a solid print. It can often be caused by dry ink accumulating on the printing plates, or by applying a very thick ink film to the printing plate, or by using too much impression.

Disc
See Disk.

Discharge
Any spilling, leaking, pumping, pouring, emitting, emptying or dumping of liquid wastes into a sewer, storm drain or body of water.

Disk
A magnetic device for storing information and programs accessible by a computer. A disk can be either a rigid platter (hard disk) or a sheet of flexible plastic (floppy disk).

Disperse Dye
A textile dyestuff which is technically defined as a water insoluble dye.

Dispersion
A uniform distribution of solid particles in a vehicle by mixing or milling.

Display Type
See Headline Type.

Disposal Facility
A landfill, incinerator or other facility that receives waste for disposal.

Distillation
The act of purifying liquids through boiling, whereby steam condenses into a pure liquid and the pollutants remain concentrated in the residue.

Distorted
To Intentionally change width and/or height dimension in order to compensate for shrinkage, stretch, etc., of the printing plates.

Distortion Copy
Copy which is intentionally distorted in preparation.

Distortion Factor
A multiplier which compensates for normal flexo image-shrinkage with rubber plates and image-stretch when any type of flexo plates are made flat and mounted around a cylinder for printing.

Distortion Plate
Plates made from distorted copy.

Dividing Head
Device put on a plate cylinder to mount jobs requiring multiple repeats around the cylinder.

Doctor Blade
A thin, flexible blade mounted parallel to and adjustable against an engraved roll, for the purpose of scraping off excess material.

Doctor Roll
The fountain roll in a flexographic press which wipes against the anilox roll to remove excess ink.

Donut
A print fault where the impression pressure is so great that the ink of the printed dot is squeezed out from the center to the edges producing a ring-like print. The ink density is lighter in donut's center.

Dot
The individual printing element of a halftone.

Dot Area
1. The area of a printed halftone, expressed as a percent value, computed from the reflection densities of the printed element and its area of solid, continuous coverage using the Murray-Davies equation (or in special cases, the Yule-Nielson equation.) Also referred to as apparent dot area;
2. The area that will print as the final dot on the substrate. The film printing dot area for positive separations in that value measured as the opaque dot on the input film. The film printing dot area for negative separations is that value measured as the opaque dot in the input film substracted from 100;
3. In ISO documentation, it is the "tone value."

Dot Gain
A physical and/or optical measurement and theoretical calculation of the apparent increase in dot area from one medium to another. Normally expressed as the difference between a midtone (nominal 50%) dot area on a film negative and the printed dot area. For example, a 50% film dot area which prints as a 78% dot has a 28% dot gain. Dot gain (and loss) are normal and must be controlled throughout the prepress and printing process.

Dot Gain Curve
The graphic illustration of dot gain throughout the entire highlight (nonimage) to extreme shadow (solid image) tone scale.

Dot Percent
See Dot Area.

Dots per Inch
A measure of the resolution of a screen image or printed pate. Dots are also known as pixels. Screen displays are 72 dpi; laser printers 300-1,200 dpi; and imagesetters, up to 2,540 dpi.

Dot Growth
See Dot Gain.

Double Bump
The application of two layers of ink to achieve greater opacity or more intense color.

Double Face
The outside, or printing face, of combined corrugated board.

Double Inking
A specific corrugated print fault where too much ink is printed because a sheet was not properly fed, causing the next sheet to receive all of the ink from the plate.

Double-tone Ink
A printing ink that produces a two-color printing effect with a single impression. These inks contain a soluble toner that bleeds out to produce a secondary color.

dpi
Dots per inch.

Dragging
The removal and redepositing of wet ink from the web by a stationary object in contact with the web. *See also Scratches.*

Draize Value
A system of rating a chemical's harmfulness to the human eye, on a scale of one to four. The higher the value, the more hazardous the material. Values of two or less do not pose any major health and safety concerns, providing all handling and guidelines for that material are followed.

Drawdown
A swatch of color or coating made by spreading a small amount of coating across a sheet of stock. The purpose is for visual analysis or testing, to check the formulated ink color or coating before going on press.

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DRE
See Destruction Removal Efficiency.

Drift
1. The continued deformation of rubber under strain; 2. The change in a given durometer reading after a specified period of time.

Drift
A gradual out-of-register movement.

Driving Side
That side of a flexographic press on which the main gear train(s) are located; also gear side; opposite of operating side.

Dropped Dots
The condition of missing print, related to missing dots. *See also Skipout.*

Dropout
A halftone in which the extreme highlights have been eliminated (dropped out) to produce more contrast, as in a specular highlight.

DRPM
See Deep-relief Powder Molding.

Drum Scanner
See Scanner.

Dry Color
A pigment in dry or powder form.

Dry Ink Film
The thickness or weight per unit area of dry ink or coating on a substrate.

Dryer
That auxiliary unit of a flexographic printing press through which the printed web travels and is dried prior to rewinding. Drying units are placed as required between color stations.

Dummy
A preliminary mock-up showing the color, size, shape, general form, positioning of text and artwork on preparation and production of a printed piece.

Duotones
Two-color halftones.

Duplicate Transparency
A copy of an original transparency prepared from a special color film.

Durometer
A measure of hardness, by using a durometer gauge, either Shore A (for soft rubber) or Shore D (for harder, less resillient materials).

Dwell
The time interval during which elements remain in contact or in a static position; pause.

Dyes
The coloring material which is soluble in an ink vehicle. *See alsoPigment.*

Dynamic Balance
The state when rotating masses are in equilibrium.

Dynamic Range
The density difference between highlights and shadows of an image, also known as tonal, density or copy range.

Dyne
The unit of force in the centimeter-gram-second system equal to the force that would give a free mass of one gram an acceleration of one centimeter per second per second. In printing, a unit of measure concerning surface tension.

E

EAN/UPC Symbol
See European Article Number Association.

EB
See Electron Beam.

EC
See Environment Canada.

Eccentricity
Off-center or out-of-round condition, such as a roll or cylinder which does not rotate in a true concentric circle in relation to its axis. *See also Concentricity.*

Edge Guide
A device that detects and controls the position of substrate's edge as it passes through the press, maintaining the side-to-side register.

Editing
The process of reviewing original copy and making necessary changes or corrections before the type is finally set.

Efflorescence
A specific form of spontaneous desiccation (drying up). The property of a crystalline substance to become dehydrated or anhydrous when exposed to air and to crumble to a powder. Opposite of deliquescence.

Effluent
Waste water discharged from a point source, such as a pipe.

Effluent Guidelines
Technical USEPA documents that set effluent limitations for given industries and pollutants.

Efflux Cup
A cup of specific volume with an orifice in the bottom of specific size, used for comparing the viscosity of fluids. The length of time the volume of fluid runs out of the orifice is a measure of viscosity. Specific efflux cups are DIN Cup, Shell Cup or Zahn Cup.

Eggshell Finish
A paper finish similar to an eggshell in texture and color (light cream or off-white color).

EIS
See Environmental Impact Statement.

EJ
See Environmental Justice.

Elastic Elongation
The ability of a material to stretch without breaking. To describe this property as measured, it is more accurate to speak of ultimate elongation or elongation at break, since its value, expressed as percent of original length, is taken at the moment of rupture.

Elastic Modulus
See Modulus of Elasticity.

Elasticity
The property of a substance which enables it to return to its original size or shape after being stretched or deformed.

Elastomer
Any rubber-like substance or polymer.

Electrolytic Silver Recovery
A method of recovering silver by applying a direct current across two electrodes immersed in a silver-rich solution. Silver plates onto the cathode and the thiosulfate is oxidized at the anode.

Electron Beam (EB) Curing
Converting a wet coating or printing-ink film to a solid film by using an electron beam. Electrons are small, negatively charged particles that penetrate the material; thus using EB for curing pigments is more efficient.

Electrophotography
See Xerography.

Elementary Neutralization Unit
A tank, tank system, container, transport vehicle or vessel (including ships) designed to contain and neutralize corrosive waste.

Elmendorf Test
A test to determine a paper's tear resistance.

Elongation
Longitudinal deformation resulting from an applied stress, i.e., stretching.

Embossed
A finish or design imparted by means of compressing a material between matched rigid surfaces or a rigid and a ductile surface having the desired raised or depressed surface pattern. The process ususally occurs between rollers, although it may be done in the flat.

Emergency and Hazardous Chemical Inventory
An annual report by facilities having one or more extremely hazardous substances, or hazardous chemical above certain weight threshold limits, as specified in Section 311 and 312 of EPCRA, or by local regulatory agencies.

Emergency Planning and Community Right-to-Know Act
Title III of the Superfund Amendments and Reauthorization Act of 1986.

Emergency Response
Response from outside the immediate release area or by other designated responders to an occurrence that results, or may result, in an uncontrolled release of a hazardous substance, i.e., spills, explosions or fire.

Emission Cap
A limit designed to prevent projected growth in emissions from existing and future stationary sources from eroding any mandated reductions.

Emission Inventory
A listing, by source, of the amount of air pollutants discharged into the atmosphere; used to establish emission standards.

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Emission Reduction Credit (ERC)
Certified reductions of air emissions that are over and above the amount required by regulatory standards. The amount of reduction that is in excess is credit. While the concept is part of the CAAA of 1990, each state passed its own enabling legislation.

Emission Trading
The transfer of ERCs between facilities or industries that require the offsets to establish new sources of air transmissions.

EMS
See Environmental Management System.

Emulsifying Agent
A material which is added to hold two or more immissable materials in suspension, forming an emulsion.

Emulsion
A type of mixture wherein two or more immiscible (or unmixable) materials are held together in a homogenous mixture by the action of a third, the emulsifying agent. Differs from a solution in which one material is dissolved in another.

Encapsulated PostScript **EPS**
A file format that carries both a description of an image in the PostScript page-description language and an optional bitmap equivalent for screen display. EPS is commonly used for image interchange on the Macintosh.

Endprinter
Printing section(s) added to an in-line process. *See also In-line Press.*

End Product
The final package or printed piece, after all blanking, folding, gluing or heat sealing is done, ready for customer use.

Enforcement Response Plan **ERP**
A USEPA-mandated plan, developed by the local control authority, that details the procedures a POTW will use to investigate and respond to industrial user non-compliance.

English Finish
A paper finish that falls between machine and supercalendered finish by degree of smoothness.

Engraved Roll
A roll having a mechanically or laser engraved surface. *See also Anilox Roll, Design Roll.*

Engraving
A general term normally applied to any pattern which has been cut in or incised in a surface by hand, mechanical, laser or chemical etching processes.

Environmental Accounting
An approach to the financial analysis of business decisions which recognizes that many environmental costs are often overlooked.

Environmental Audit
An independent assessment of a facility's compliance policies, practices and controls.

Environmental Impact Statement **EIS**
A document prepared by or for USEPA that identifies and analyzes, in detail, environmental impacts of a proposed action.

Environmental Indicator
A measurement, statistic or value that provides a proximate gauge or evidence of the effects of environmental management programs or of the state or condition of the environment.

Environmental Justice
A government policy that provides for the fair treatment to all people with respect to the development and enforcement of environmental laws, regulations and policies.

Environmental Management System **EMS**
A management approach, through policy and procedure, that serves to reduce exposures to liability, manage environmental affairs with the elimination of duplicative efforts, improve employee and community relations, partner with regulatory staff, and offers the very real possibility of bottom-line savings.

EPA
See USEPA.

EPA I.D.
See Identification Code.

EPCRA
See Emergency Planning and Community Right-to-Know Act.

Epoxy Resins
Plastic or resinous materials used for strong, fast-setting adhesives, as heat-resistant coatings and binders, etc.

EPS
See Encapsulated PostScript.

Equalizer Rod
See Meyer Rod.

Equivalent Method
Any method of sampling and analyzing for an air pollutant that has been demonstrated to the administrator's satisfaction to have a consistent and quantitatively known relationship to the reference method under specific conditions.

Equivalent Weights
Indicates weights of papers of different dimensional sizes and different ream weights of identical basis or substance weights, e.g., 25 x 38@50/R is equivalent in substance to 32 x 44@74/R.

ERC
See Emission Reduction Credit.

ERP
See Enforcement Response Plan.

Ester
A group of solvents made by reacting an acid with an alcohol, e.g., ethyl acetate, isopropyl acetate; acetate solvents.

Etch
To dissolve the nonprinting areas of a metal plate

by the action of an acid, as in the engravings used to mold the matrix.

Ethyl Cellulose
A cellulose ether, soluble in most organic and hydrocarbon solvents, available as a transparent, flexible packaging film. Also used as an ingredient in inks, coatings and adhesives.

European Article Association **EAN**
A standards organization, which together with the UCC, manage the UPC product identification system.

Evaporation
The changing from the liquid to the gaseous or vapor stage, as when the solvent leaves the printed ink film.

Exempt Solvent
Specific organic compounds not subject to regulation because they are deemed by USEPA to be of negligible photochemical reactivity.

Expose
To subject (a sensitive film, plate, etc.) to light.

Exposure
The state of being open and vulnerable to a hazardous chemical by inhalation, ingestion, skin contact, absorption or any other course; includes potential (accidental or possible) exposure.

Extenders
Any material added to an ink to reduce its color strength and/or viscosity.

Extensible
Stretchable packaging materials, such as polyethylene, which elongate during processing.

Extreme
A category of nonattainment where sources of NOx of VOCs of 10 TPY (tons per year) or more are affected.

Extremely Hazardous Substance
Any of 406 chemicals identified by USEPA as toxic and listed under SARA Title III.

Extrusion
Continuous sheet or film (or other shapes not connected with flexography) produced by forcing thermoplastic material through a die or orifice.

Extrusion Coating
This process uses an extruder to apply plastic coating (i.e., polyethylene) at elevated temperatures to a moving web of paper.

Exudation
When solid material migrates to the film's surface. *See also Bloom.*

Eye Mark or Eye Spot
A small, rectangular printed area usually located near the edge of a web or design, to activate an automatic electronic position regulator for controlling register of the printed design with subsequent equipment or operations.

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F

F (°F)
Degrees Fahrenheit; °F = (9/5 x °C) + 32.

Face Printing
Printing on the outer surface of a transparent film, contrary to printing on the back (reverse) of the film.

Face Stock
In label printing, it is the part of the substrate which is printed opposed to the disposable release liner that carries the facestock through the press.

Facility
All buildings, equipment, structures, and other stationary items located on a single, contiguous or adjacent site and which are owned or operated by the same person (or by any person who controls, is controlled by, or is under common control with such person). A facility shall include man-made structures, as well as natural structures, in which chemicals are purposefully placed or removed by human means, such that it functions as a containment structure for human use. For purposes of emergency release notification, the term includes motor vehicles, rolling stock and aircraft.

Fade
See Vignette.

Fadeometer
An instrument that measures light fastness or resistance to fading.

Fading
The change in hue from exposure to light, heat or other influences.

False Body
See Thixotropic.

Fast Solvent
A solvent that has a low boiling point, allowing rapid evaporation; a fast-drying solvent.

Fastness
A term denoting the stability or resistance of stock or colorants to influences such as light, alkali, etc.

Feathering
Irregular edges around a print, often undesirable.

Feathering on Trailing Edges
Marks made on the image's trailing edges, generally caused by excessive ink buildup.

Federal Register **FR**
A publication of proposed U.S. regulations. The final regulations are then codified in the Code of Federal Regulations.

Feet per Minute **FPM**
A measure of surface speed.

Felt
A fabric used to carry the web of paper between press and dryer rolls on the paper machine.

Felt Mark
An imperfection in a paper's surface caused by a coarse felt or the warp of a felt, leaving a textured impression in the surface.

Felt Side
That side of the paper web which has been in contact with the felt during manufacture. It is the top side of the sheet.

Fiberboard
1. Fibered sheets produced or laminated a certain thickness, providing stiffness. Fiberboard used for container production may be corrugated board, or solid board of 0.060", 0.080", 0.100", 0.0120", or 0.140". 2. A generic name applied to many products made of fiberboard.

Fibreboard, Solid
A heavy, solid board, usually 3 or 4 ply, comprised of two liners and a chipboard filler, used in shipping containers.

File Server
A computer on network with special software so that all the network users can access the applications and documents stored on it.

Filler
An inert substance in a composition to increase bulk, strength and/or lower cost, etc.

Fill-in
Generally used to refer to the open portions of small type and half-tones filled by ink.

Film
Unsupported, basically organic, nonfibrous, thin, flexible material, 0.010" thick (maximum), is usually called sheeting. A variety of special designation, such as gussetted film, J film, U film, W film, etc. refer to film wound with a single or double fold or gusset on one or both sides; the designations describing the shape of a cross-section.

Film Former
A type of resin with qualities of forming a tough continuous film. Usually refers to such plastics as nitrocellulose, vinyl, etc.

Film Gauge
1. A number indicative of the thickness of films. 2. A micrometer for measuring film thickness.

Film Treatment
The surface oxidation of film to increase ink adhesion.

Film, Cast
Generally refers to films made by coating, or casting, a solution of a film former on an endless belt, drying the solvents, stripping the film from the belt and winding it up. Polyethylene cast film refers to the film made by extruding the molten polyethylene.

Film, Tubular
Generally used to mean polyethylene tubular film produced by extruding the molten polyethylene through a round die, cooling the plastic and flattening the tube so formed by means of nip rolls, and winding it up.

Fineness of Grind
The degree of grinding or dispersion of a pigment

in a printing ink or vehicle. The extent to which particle size has been reduced to the finest granular structure.

Fingerprint
See Press Characterization.

Finish
The degree of a surfaces's gloss or flatness .

Finish, Calender
A finish obtained by passing a material through the calender stack.

Finish, Dry
A paper or paperboard finish that has not been dampened or steamed before going through calender stack.

Finish, Matte
A dull finish; flat.

Finish, Satin
A type of dull finish, somewhat finer than matte.

Finish, Supercalender
A smooth, high finish applied to paper by running it through a calender stack. This finish provides a better printing surface, finer than a calender finish.

Finish, Water
A very high finish produced by passing paper and paperboard through the calender stack and applying water on one or both sides.

FIRST
Flexographic Image Reproduction Specifications & Tolerances. A set of specifications and communication protocols for the industry developed by the FIRST Committee and the FTA Consumer Advisory Council. This platform should establish common communication and identify the responsibilty of the provider(s). These are not standards, but when adhered to, are meant to produce a predictable, consistant result.

First-down Color
In multicolor printing, it is the initial color printed on the substrate and overprinted by other colors.

Fish-eyes
A print defect. A pinhole in the ink film, looks like an eye. It is often the result of dirt on the surface of the printing plate; or the result of too much defoamer added to the ink causing de-wetting.

Fixer
The chemical used to stop the developed photographic image from developing further.

Flag
A small piece of paper or board inserted in a roll of stock being run, so that it extends beyond the edge, to indicate the location of a splice, imperfection, etc., or to designate some change from the standard of quality, speed, condition. It serves as a warning to the operator in the converting process.

Flame Resistant
The capability to burn when in contact with a flame, but not to continue burning when the flame is removed.

Flame Retardant
A chemical used in treating a material so that it will not support combustion.

Flameproof
Not readily ignited and does not propagate flame under test conditions. Flameproof materials are usually combustible materials treated or coated to modify its burning properties.

Flammable
Describes any material that can be ignited easily and that will burn rapidly.

Flammable Liquid
Liquids which have a flashpoint of less than100°F.

Flashpoint
The lowest temperature at which evaporation of a substance produces enough vapor to form an ignitable mixture with air.

Flat
1. Lacking in contrast and definition of tone. Opposite of glossy; dull, matte. 2. A full-size sheet of engraving metal.

Flat-bed Press
A press-like piece of equipment used in transfer printing to transfer the design by sublimation from paper to fabric.

Flat-bed Scanner
See Scanner.

Flat Seal
A heat seal characterized by being flat, compared to a crimp seal.

Flex
Another term for roll or cylinder deflection in press. Also, describes the bending qualities or characteristics of any material including printing substrates.

Flexible Glue
Animal glue, plasticized to enable permanent flexible films to be formed. Commonly used to denote any flexible adhesive.

Flexing Strength
The ability of a sheet or film to withstand breakage by folding. Flexing strength may be measured and tested by determining the number of folds required to cause failure.

Flexographic Printing
See Flexography.

Flexography
A method of direct-rotary printing, using resilient raised-image printing plates, affixed to variable-repeat plate cylinders, inked by a roll or doctor-blade-wiped engraved metal roll carrying fluid or paste type inks to virtually any substrate.

Flocculation
Pigment particles collecting together in the ink to form clusters or chains that can cause loss of color strength and a change of hue.

Flooding
The growth of a print area from the master copy

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on the printed sheet, caused by excessive ink applied to the substrate.

Floppy Disks
See Disk.

Flow
1. The property of an ink causing it to level out as would a true liquid. Inks of poor flow are classified short in body, while inks of good flow are said to be long. 2. The rheological properties of an ink.

Flow Chart
A graphical diagram used to show the key steps in a process. Special symbols are used to show inputs, outputs, decisions and process steps.

Fluidity
The ease in which an ink flows. Opposite of viscosity, the greater the viscosity the less the fluidity.

Fluorocarbons
Organic compounds in which fluorine atoms are bonded to carbon atoms.

Flying
Ink thrown off the press by the inking rollers, causing splashing.

FM Screening
See Stochastic Screening.

Foil
An unsupported, thin metal membrane, less than 0.006" thick. Above 0.006" thick, it is called a sheet.

Folder
A unit that creases and scores the substrate to preset specifications. *See also Buckle Folder, Combination Folder, Knife Folder*.

Font
A complete set of characters in one design, size, and style. In traditional typography usage, a font may be restricted to a particular size and style or may comprise multiple sizes, or multiple sizes and styles, of a typeface design.

Form Roll
The obsolete reference to an inking roller. *See also Transfer Roll, Anilox Roll*.

Formation
An arrangement of the fibers in a sheet of paper. Irregular arrangement is wild, while uniform formation is close.

Fountain
A pan, trough or other ink-supply system on a flexographic press in which the fountain roll revolves. Sometimes loosely applied to the entire printing station.

Fountain Roll
The roll that picks up the ink or coating material from the fountain and applies it to the transfer roll.

For Position Only
An image that will be replaced in production, (usually on the film imagesetter) with the high-resolution image.

Four-Color Process
Printing with yellow, magenta, and cyan color inks plus black by using screens to create all other colors. *See Process Black, Process Cyan, Process Magenta, Process Yellow.*

Fourdrinier Wire
The wire belt on which a web of paper is initially formed from the liquid fiber pulp (furnish) on the paper machine.

FPM
See Feet Per Minute.

FPO
See For Position Only.

FR
See Federal Register.

Freuqency Modulated Screening
See Stochastic Screening.

Fugitive
Refers to a dye or pigment having very poor permanence, and is likely to deteriorate, change or fade.

Fugitive Emissions
Air pollutants released to the air other than those from stacks or vents; typically released from open containers and ink fountains, as well as small releases from leaks in plant equipment.

Full-scale Black
Printing with black in all tonal areas of the reproduction from highlight to shadow. *See also Gray Component Replacement.*

Furnish
The ingredients that make up a particular paper.

Fusible
Capable of being melted or liquefied by action of heat.

Fuzz
Fibrous projections on the surface of a sheet of paper. Lint appears in much the same manner but is not attached to the surface.

G

gb
See Gigabyte.

g/cc
Grams per cubic centimeter.

g/cm³
Grams per cubic centimeter.

g/kg
Grams per kilogram.

g/m²
Grams per square meter. *See Grammage.*

GACT
See Generally Available Control Technology.

Gamut
The range of colors available to a device. An input device, for instance, such as a scanner interprets color using RGB; while an output device, such as a press, interprets colors with process inks.

Gas Chromatography
An analytical, instrumental method of accurately determining the composition of volatile solvents and oils, and of determining their residual presence in inert materials such as paper, board or film.

Gauge
The thickness of flexible packaging film. 100 gauge equals 1 mil (0.001").

GCR
See Gray Component Replacement.

Gear Chart
A handy reference, it is a compilation of the various printing lengths, or repeats, obtainable within the different gearing systems.

Gear Marks
A defect in flexographic printing appearing as uniformly spaced, lateral variations in tone corresponding exactly to the distance between the gear teeth.

Gear Selector
See Gear Chart.

Gear Side
Opposite to the operator side. *See also Driving Side.*

Generally Available Control Technology GACT
Controls for area sources that can be as stringent as MACT, but tend to be more flexible.

General Permit
A single permitting document that can cover a category or class of many similar sources.

General Requirements for Applicatins in Commercial Lithography (GRACoL)
Guidelines for sheetfed offset litho prepress, press and binding/finishing operations, introduced in 1996. The 1999 or third edition is available from the Graphic Communications Association, subsidiary of Printing Industries of America, Inc.

Generator
1. A facility or mobile source that emits pollutants into the air; 2. Any person who produces a hazardous waste listed by USEPA and therefore subject to regulation.

Generic Designs
Artwork not protected by trademark registration.

Ghosting
The presence of a faint image of a design in areas which are not intended to receive that portion of the image. Usually a repeat pattern in the press machine direction.

GIF
See Graphic Interchange Format.

Gigabyte
A unit of measure, equal approximately to 1,048,576,000 bytes, or 1,024 megabytes. Commonly used to specify the capacity of computer memory.

Glassine
A type of translucent, flexible paper that is highly dense and resistant to the passage of oil, grease and air. Common uses are for envelopes, candy wrappers, liners for cereal and cookie boxes.

Gloss
A surface's ability to reflect light.

Gloss Finish
A finish of paper or paperboard that is smooth and shiny or lustrous in appearance.

Gloss Meter
An instrument used to measure gloss.

Goldenrod
A specially coated, yellow or orange, masking paper used by strippers to assemble and position negatives for exposure on plates.

GPD
Gallons per day.

GRACoL
See General Requirements for Applications in Commercial Lithography.

Grade
Paper classification based primarily upon end-use and brightness.

Gradient
A gradual transition or blending – linear or radial – from light to dark, or from one color to another.

Grain
The arrangement or direction of fibers in a fibrous material such as paper or wood, or the direction of molecular orientation in a nonfibrous material.

Grain Direction
The direction of paper parallel with the direction of movement on the paper machine.

Grammage
A term in the metric system for expressing the basis weight of paper as the weight (in grams) of a square meter of the paper – g/m².

KEY:

Barcode
Design
Environment
General
Ink
Mounting/ Proofing
Plates
Prepress
Press
Process Color
Quality
Substrate

Graphic Arts
The technology and practice of converting ideas and originals (i.e., photographs, drawings, computer-generated images and designs) into visual form. Not restricted to, but often associated with, printing in its various forms.

Graphic Interchange Format **GIF**
A widely used bitmap-image format that originated on the CompuServe network and supports black, white and color.

Gravure
A printing process in which the image area is etched below the surface of the printing plate. The ink is carried below the printing surface in small wells or lines etched or scribed into a metal plate. The surface of the plate is wiped clean so nonimage areas carry no ink and the image is transferred directly to the paper by means of pressure.

Gravurescope
A type of microscope designed for inspecting and measuring the engraved cells on an anilox roll or a gravure cylinder. Measures both vertically for depth and horizontally for width.

Gray Balance
The proper combination of cyan, magenta and yellow ink dot area, hue/density, trap, transparency and register on a specific substrate under normal printing conditions which reproduce as a neutral gray.

Gray Component Replacement **GCR**
1. The replacement of an unwanted color (i.e., cyan in reds, magenta in greens, yellow in blues) in whole or in part by black; 2. The system to reduce overprinted halftone dot sizes of C, M or Y when it acts as a graying component by increasing the appropriate black halftone dot sizes to achieve a color parity with less process ink and improved printing conditions.

Grayness
See Hue Error.

Grayscale
A tonal scale, printed in steps of no-color through to black, used for quality control in both black-and-white and photographic processing.

Grease Proofness
A material's resistance to grease.

Groundwater
Subsurface sources of water that comprise a large percentage of the water supply.

Groundwood Papers
A general term applied to a variety of papers made of mechanical wood pulp.

Guard Bars
The start-and-stop pattern in bar codes, particularly UPC-A, EAN-13 and EAN-8 versions of the EAN/UPC symbol family. Formed by twin narow elements at the beginning, center and end of the symbol, they divide the symbol into left and right decodable segments that are then combined by the scanner into a single symbol.

Guillotine
A cutting machine in which the cut is made by a long knife that descends vertically on the material to be cut.

Gum
1. A water-soluble, amorphous substance exuded by or prepared from plants, which is sticky when moist but hardens upon exposure to air; 2. Any material having the above properties, natural or synthetic, regardless of source. Loosely used in reference to unvulcanized rubber.

Gusset
The bellows fold or tuck on the side or bottom of a bag. The bag's capacity is measured with the gusset unfolded.

H

Halftone
A pictorial which has been converted from a continuous tone original image, such as a photograph, into dots of appropriate size which, when printed, give the visual illusion closely resembling the original over a gradation range from highlight to shadow.

Halftone Dot
The small image element in a halftone placed in a regular pattern with set spacing, angle and shape. Flexography uses a round-shaped dot.

Halftone Screen
1. The specific pattern of halftone dots;
2. Originally, the engraved glass through which continuous-tone copy is photographed to produce a halftone.

Halftone Tint
An area of approximately equal-sized halftone dots producing a uniform optical density.

Halo
An undesirable peripheral outline of the printed image.

HAP
See Hazardous Air Pollutant.

Hard-sized
Refers to a type of paper which has been treated with considerable sizing to resist water.

Hazard Communication Standard **HCS**
An OSHA regulation that requires chemical manufacturers, suppliers and importers to assess the hazards of the chemicals they make, supply or import, and to inform employers, customers and workers of these hazards through a material safety data sheet (MSDS). Users are required to inform, train and provide MSDSs and labels in the workplace.

Hazardous Air Pollutant **HAP**
Air toxics or hazardous air pollutants include chemicals that may cause serious health effects, such as birth defects and gene mutations. Under Section 112 of the CAAA, 189 chemicals/chemical families were listed as toxic air pollutants, and according to USEPA, about 30 are used in the printing industry. These chemicals are managed under the National Emission Standards for Hazardous Air Pollutants (NESHAP) regulations. The following are sometimes used in the flexographic industry: methanol, toluene, hexane, ethylene glycol and methyl ethyl ketone. Some states have additional lists of HAPs.

Hazardous Chemical
USEPA's designation for any hazardous material that requires a material safety data sheet (MSDS).

Hazardous Product Act **HPA**
A law restricting advertising, sale or import of products in Canada.

Hazardous Waste
A subset of solid wastes that pose substantial or potential threats to public health or the environment.

Hazardous Waste Codes
A four-digit classification system used by USEPA to identify hazardous waste on labels, shipping papers and other records. All federal hazardous waste codes begin with a letter and are followed by numbers. All listed wastes begin with the letters F, K, U or P, and all characteristic waste begins with the letter D.

Hazardous Materials Information System
A system developed under RCRA for the collection, maintenance and dissemination of data on hazardous material.

Hazardous Waste Minimization
Reducing the amount or toxicity of waste produced by a generator, either by source reduction or environmentally sound recycling.

HCFC
Hydrochlorofluorocarbon.

HCS
See Hazard Communication Standard.

HDPE
See High-density Polyethylene.

Header
An identifying line at the top margin of a document, it can appear on every page and can include text, pictures, page numbers, the date, and the time. Headers that are repeated throughout a document are called running headers or running heads.

Headline Type
In composition, type set larger than the main reading body text, to attract attention, e.g., a headline.

Heat Resistance
The ability to withstand the effects of high temperature exposure. Care must be exercised in defining degree.

Heat Seal
A method of uniting two or more surfaces by fusion, either of the coatings or of the base materials, under controlled conditions of temperature, pressure and time (dwell).

Heat-seal Lacquer
A lacquer, applied to a stock and then dried, is capable of softening under heat, causing the stock be sealed to itself or another surface.

Heat Sealing Paper
Any paper coated with heat-sealable materials.

Heavy Body
Having a high viscosity.

Heavy Metals
Metallic elements with high atomic weights, e.g., mercury, chromium, cadmium, arsenic and lead; can damage living things at low concentrations and tend to accumulate in the food chain.

KEY:

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Press
Process Color
Quality
Substrate

Hickey
A common printing defect, visible as a spot surrounded by a blank halo, caused by a speck of dirt pushing the paper away from the printing plate.

High Bulking Groundwood
This term refers to low cost printing papers made primarily from mechanical pulps, characterized by relatively high bulk-to-weight ratios, high opacity, and high speed printability.

High-density Polyethylene **HDPE**
Film that has excellent moisture barrier and stiffness, used in applications such as cereal and cracker packaging. It is frequently coextruded with heat-seal layers, such as Surlyn, to make a finished packaging material. Blown HDPE film has better stiffness and moisture barrier than cast HDPE, but is hazier. Extrusion-coated HDPE resins are generally used to improve grease resistance.

Highlight
The lightest or whitest parts in an image represented in a halftone reproduction by the smallest dots or no dots.

Histogram
A graphical representation, usually in the form of a bar graph, of a series of measurements. The horizontal axis represents small sub-ranges of the total range of the measured value, starting at the smallest value and progressing to the maximum value. The vertical axis represents the number of times the measured value is in that particular range.

HMIS
See Hazardous Materials Information System.

Holding Line
See Keyline.

Holland Cloth
The protective, starch-linen cover sheet used in rubber-plate molding to prevent the plate from sticking to the mold.

Homogeneous
Of the same uniform composition or construction throughout.

Homopolymer Polypropylene
Pure polypropylene.

Hot Type
When a casting method of melted metal is used to set type copy instead of using the original type characters or a photographic process.

HPA
See Hazardous Products Act (Canada).

Hue
*See L*C*h*.*

Hue Error
A measure for the purity of process inks, how close they are to the ideal of absorbing light only one third of the spectrum.

Humidity
See Absolute Humidity and Relative Humidity.

Hydrocarbon
An organic compound containing exclusively the elements carbon and hydrogen.

Hydrometer
An instrument for measuring the specific gravity of a liquid or solution.

Hydrophilic
Having a strong affinity for water; hygroscopic.

Hydrophobic
Lacking affinity or attraction for water; opposite of hydrophilic.

Hygroexpansivity
The change in dimension of paper that results from a change in the ambient relative humidity. This property is a great importance in applications where the dimension of paper sheets are critical.

Hygrometer
An instrument for measuring the relative humidity of air.

Hygroscopic
See Hydroscopic.

Hysteresis
A loss of energy due to successive deformations and relaxation.

I.D.
Inside diameter.

ICC Profile
A complete description of a color space, specific to a particular device, by identifying or mapping the device-independent CIELab color values to the color values of that specific device. Used to characterize monitors; input devices, such as scanners; and ouput devices, such as proofers, presses, ICC profiles match one device to another to achieve color consistency.

Icon
A tiny, on-screen symbol that simplifies access to a program, command, or data file. For example, a waste basket may represent the command to delete a file. It is activated by moving the cursor onto the icon and pressing a button or key.

Identification Code
The unique code assigned to each generator, transporter and treatment, storage or disposal facility by regulating agencies to facilitate identification and tracking of chemicals or hazardous waste.

Idler Rolls
Roller mechanisms on converting machines used to support, smooth or direct, not drive, the web in its course of travel through a machine.

Ignitable Waste
A liquid waste having a flash point of less than 140° F; or a nonliquid waste, under standard temperature and pressure, that is capable of igniting through friction, moisture absorption, or spontaneous chemical changes. When ignited, they burn so vigorously and persistently, creating a hazard or an ignitable compressed gas.

Image Areas
1. The area of the printing plate which transfers ink to the substrate; 2. The printed area of a receiving surface.

Image Capture
The process of acquiring live action or still life images and converting that into a digital file, so it can be displayed, edited, and possibly output from a computer. *See Scanning.*

Imagesetter
A high-resolution output device used to produce reproduction-quality copy for printing, either as camera-ready artwork on photographic paper or as film negatives or positives.

Imposition
The process of laying out pages in a press form so that they will be in the correct order after the printed sheet is folded.

Impression
The image transferred from the printing plate to the substrate and the adjustment required to achieve that.

Impression Bar
A small diameter rod or bar, supported by a backup member of sufficient rigidity, mounted in place of the impression cylinder for running certain types of work, such as porous tissue.

Impression Cylinder
The roller or cylinder which backs up or supports the substrate at the point of impression.

Imprint
A secondary marking containing additional information imposed on a primary printing.

Inching
See Jog.

Incineration
The destruction of solid, liquid or gaseous wastes by controlled burning at high temperatures.

Industrial Pollution Prevention
The reduction of pollution in the workplace and environment by means of process design (machinery, materials and methods), substitution of safer chemicals and technology and recycling of waste products for reuse.

Industrial Pretreatment Program **IPP**
The approved program of the Control Authority that monitors and controls industrial discharges.

Industrial Source Reduction Environment
Practices that reduce the amount of any hazardous substances, pollutants or contaminants entering any waste stream or otherwise released into the environment. Product and equipment design, chemistry requirements and working methods are typical.

Industrial Waste
Unwanted materials produced in, or eliminated from, an industrial operation, and categorized under a variety of headings, such as liquid wastes, sludge, solid wastes and hazardous wastes.

Infeed
A mechanism designed to control the forward travel of the web into the press.

Influent
The solution entering a process or piece of equipment.

Infrared Light
Radiation in the infrared part of the spectrum – the longer wavelengths beyond the visible red end of the spectrum. Also called black head because it is not visible yet produces a warm sensation suitable for use as a heat source.

Inhibitor
A chemical added to another substance to prevent an unwanted chemical change.

Ink, Flexographic
Fast-drying fluid or paste-type inks used in flexographic printing.

Ink Balance
The chemical relationship between the different ink components.

Ink Film
The wet layer of ink on the anilox, printing plate

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or substrate surface; its weight or volume per unit area; as opposed to dry ink film.

Ink Fountain
The ink pan or trough or other ink supply system on a printing press.

Ink Jet
A printing technology which utilizes liquid ink which is sprayed through miniature nozzles onto the substrate in dot matrix patterns, forming text and graphics. For color printing, several nozzles connected to containers of colored inks are used.

Ink Kickout
The condition where some of the ink's ingredients go out of suspension, causing loss of ink properties, such as color, fluidity, printability. Some causes: high pH, introducing additives without agitation.

Ink Laydown
The visual appearance of the ink on the substrate surface.

Ink-metering Roll
A roll that allows the amount of ink (or coating) to be applied to the plate in a thin, even layer.

Ink Rotation
The sequence in which inks are printed. For process colors, it is commonly Y, M, C, K.

Ink Souring
See Ink Kickout.

Ink Starvation
A print defect characterized by large vertical or irregular lines in what should be the solid print area. It can be caused by poor anilox cell rewetting, trapped air in chambered doctor-blade systems, and/or poor ink balance.

Ink Trap Percent
A measure of how well one ink prints over another, calculated from measured print densities, using the filter for the second ink printed to form the overprint. Higher numbers are desirable, indicating the ink's ability to transfer equally to the unprinted substrate and to a previously printed ink film. A "perfect" 100% trap is rarely achieved due to the inherent measuring geometry and data additivity failure.

Ink Trapping
Overprinting and adhering one ink over another to produce the desired secondary and tertiary colors required in process printing.

Inking System
In flexographic presses, the system consisting of an anilox roll, an ink supply and a doctoring system. Ink is flooded into the engraved cells of the metering roll, excess ink is doctored off by the wiping or squeezing action of the fountain roll, or a doctor blade, and what ink that remains in the cells of the anilox metering roll is transferred to the printing plates.

In-Line Press
1. A press coupled to another operation such as a bag making, sheeting, diecutting, creasing, etc;
2. A multicolor press in which the color stations are mounted horizontally in a line.

In-Line Printing
Printing, as part of a continuous process of producing a finished product.

In-Line Processing
A continuous process of producing a finished product from basic materials.

Intaglio
An engraved or etched design which is below the surface as cells in an anilox roll or gravure cylinder.

Intensity
See Saturation.

Interleave
To insert separate sheets of paper, etc., between foil, printed paper or other stacked sheet material to facilitate handling or to prevent blocking or smudging.

Interleaved 2-of-5 **ITF**
Commonly encountered as the bar code specified for UCC/EAN products when they are packaged about the unit level in corrugated case, each symbol character contains five data elements (bars or spaces) two of which are wide (2-of-5). The "interleaved" reference comes from the way the symbology takes digit pairs and interleaves them into its symbol characters, one in the bars and one in the spaces. It is widely used in the airline industry.

Interpolation
The term describing the technique of recreating the color values of pixels in bitmapped images which have been modified (i.e., dimenion, resolution, orientation).

Inventory Form
Tier I and Tier II emergency and hazardous chemical inventory forms set forth in subpart D of EPCRA.

Inverted Pyramid Cell
The most commonly used engraved anilox roll cell formation in flexographic printing, it is literally an engraved, inverted-pyramid-shaped cell that carries the ink or coating within an anilox roll.

Ion Exchange
A reversible exchange of charged atoms between a solid and a liquid. When used with photo-processing solutions, ion exchange removes silver and replaces it with ionized salts.

IPA
Isopropyl Alcohol.

IPP
See Industrial Pretreatment Program.

Iridescent
The property where materials exhibit shimmering, rainbow-like colors.

Irradiation
To be treated with ultraviolet light or other high energy radiation.

Irritant
A noncorrosive chemical that causes a reversible inflammatory effect on living tissue by chemical action at the site of contact.

Ishihara Charts
Color-vision sensitivity charts containing irregular and varicolored spots arranged in a way around numbers or shapes that can be read by the observer with normal color vision but not by an observer with a color-vision deficency.

ISO
See International Standards for Organization.

ISO 9000
A set of standards on quality systems for companies with design, manufacturing and service capabilities. They were first developed by the International Organization for Standardization (ISO), subsequently, a similar approach was adopted by the American National Standards Institute (ANSI) and the American Society of Quality Control (ASQC).

ISO 14000
Similar to ISO 9000 except with a focus on environmental management standards.

ITF
See Interleaved 2-of-5.

J

Jelling
The thickening of an ink or other liquid which cannot be reversed by stirring.

Jet Black
A term used to describe the blackness or intensity of the mass tone of black or near black surfaces.

Jog
To intermittently operate a press for very short increments of web travel.

Journals
The end shafts on which a roll rotates.

JPEG
Joint Photographic Experts Group. A picture compression standard/algorithm developed by this group, designed for highly effective compression of either full-color or gray-scale continuous-tone digital images. Not for compression of black-and-white (1-bit-per-pixel) images or moving pictures.

Jumbo Roll
A roll of web material, the outside diameter of which is larger than standard diameter.

Justify
To justify copy means to letter or word space the type characters on each line so they will line up vertically on the left, right or both margins.

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K

K (°K)
Degrees Kelvin; the absolute temperature scale. Absolute zero is –273.13° C.

K Film
The tradename of polymer-coated cellophanes manufactured by DuPont.

kb
See Kilobyte.

K.B. Value
See Kauri-Butanol Value.

Kaolin
See China Clay.

Kauri-Butanol Value
A measurement of the solvent strength of a hydrocarbon solvent.

Kelvin
See K (°K).

Kerning
Modifying the normal space between letters during typesetting to achieve more readable and eye-pleasing word forms. Traditionally, this meant reducing the space between only selected characters, such as the "L" and "Y" in "only"; 2. Adding or subtracting a small amount of space between each letter or character to adjust (justify) the length of a line of copy. *See Tracking.*

Ketones
A class of organic compounds which are generally colorless, volatile liquids, such as acetone, methyl ethyl ketone, etc.

Keyline
1. An outline, usually in red, drawn on artwork, which may or may not form part of the artwork, indicating the shape, size and position for elements such as halftones, line art, UPC symbols; 2. The outline on artwork that, when transferred to a printing plate, will provide a registration guide for the other colors.

Keyline Art
The black-and-white production art for designs containing two or more colors, in which all color plates are shown on one surface in composite form. The trap width or overlapping colors is shown by white lines within black solids.

Key Plate
The plate of a set of color plates which carries the major area of detail and to which the other plates are registered.

Kilobyte
Equilvalent to 1,024 bytes.

Kiss Impression
The lightest possible impression which will transfer a film of ink from the anilox roll to the entire print surface of the printing plate, or from the entire print surface of the printing plate to the material being printed.

Kiss Register
See Butt Register.

Knife Folder
A folding unit with moving tapes or belts that feed a sheet along a flat plane until it is stopped by a gauge and positioned against a side-guide. A metal knife presses at a right angle to the sheet, forcing it between two rollers to create a fold.

Knock-Out
See Reverse.

Knurled Roll
See Engraved Roll.

Kraft
1. A chemical-based wood pulp made by the sulphate process; 2. Paper or paperboard made from such pulp.

Kraft Linerboard
A paperboard made on a fourdrinier or cylinder machine and used as the facing material in the production of corrugated and solid-fiber shipping containers.

Kromecote
A highly polished, mirror-like paper finish.

Kurtosis
A statistical measure of the abnormal amount of data around the mean. More data around the mean indicates a kurtosis of greater than 1; less data around the mean indicates a kurtosis of less than 1.

L

L*a*b* Value
Values that identify or define a color in three-dimensional CIELab color space. L=lightness, a=red/green component, b=yellow/blue component.

Lacquer
Originally used to denote a nitrocellulose-type of fast-drying inks and varnishes, now used as a term for any fast-drying, clear varnish with a plastic film-former base.

Ladder Orientation
Positioning the UPC symbol, so that the bars in the artwork are printed running in the cross direction. *See also Picket Fence Orientation.*

LAER
See Lowest Achievable Emission Rate.

Lake
An insoluble compound of a dye colorant.

Lake
A depression or dishing in the surface of a rubber plate.

Laminant
An adhesive to combine and bond a combination of films, foils, plastics, papers or other material in sheet or web form.

Laminate
1. A product made by bonding together two or more layers of material or materials;
2.To unite layers of materials with adhesives.

Land Disposal Restrictions **LDR**
A set of regulations that prohibit the land disposal of untreated hazardous wastes.

Landfill
Disposal facilities where waste is placed in or on land. Properly designed and operated landfills are lined to prevent leakage.

Lap
The portion of a material which covers or overlaps another portion, at which the two thicknesses of material are bonded together.

Large Commercial-imaging Facility
A facility that produces, on average, more than 20 gallons per day of silver-rich solution.

Large-quantity Generator **LQG**
Person or facility that generates more than 2,200 pounds of hazardous waste per month.

Layer
In some applications, a level to which you can consign an element of the design you are working on.

Layout
The preliminary arrangement of an artwork showing position, sizes, color and other details for the final design.

LCA
See Life Cycle Analysis.

L*C*h° Value
The perceptual values of a color in CIELab color space. It is an approach to describing color numerically, expressing the color in terms of L for lightness, C for chroma or saturation, and h for hue or shade.

LD 50/Lethal Dose
The dose of a toxicant that will kill 50 percent of the test organisms within a designated period. The lower the LD 50, the more toxic a compound.

LDPE
See Low Density Polyethylene.

LDR
See Land Disposal Restrictions.

Leading
The vertical spacing between base lines of type, measured in points or point units, but is referred to as leading or a given number of lead points. *See Point.*

Leafing
The process whereby the metal flakes contained in metallic inks float to the surface of the ink, causing metallic luster.

LEL
See Lower Explosive Limit.

LFL
See Lower Flammable Limit.

LEPC
See Local Emergency Planning Committee.

Letterpress
A method of printing that uses hard-relief plates as an image carrier. The image area of the plate, raised above the nonprinting area, receives the ink and is then transferred directly to the substrate.

Lettering Spacing
See Kerning.

Life Cycle Analysis **LCA**
The analysis of all energy resources and emissions used and produced in any and all of the processes of manufacturing, using, distributing and ultimately disposing of a product.

Light Fastness
That property which renders a material resistant to change in color. Depending upon its use, it may be required to show good resistance (fastness) to change in color after exposure to destructive influences such as light, acids and alkalines.

Lightness
*See L*C*h° Value.*

Light Stability
A measure of the ability of a pigment, dye or other colorant to retain its original color and physical properties, either alone or when incorporated into plastics, paints, inks and other colored surfaces, upon exposure to sun or other light.

Linear Blend
See Gradient.

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Linear Low Density Polyethylene **LLDPE**
A film having the same features as LDPE but is stronger, with better hot-tack strength. The film resins a re more expensive than LDPE, and extrusion coating grades are even more so.

Linear Medium Density Polyethylene **LMDPE**
A film similar to LLDPE, but provides improved stiffness, gloss and reduced flavor adsorption.

Line Art
See Line Copy.

Line Color
Any color that is not part of the process-color image, printed on a separate print station. Often, it is a special ink formulation, but it can be a second print station using process inks, especially black.

Line Copy
Copy made up of solids and lines in contrast to halftones or shadings made up of a series of dots.

Line Cut
An engraving made from line copy.

Line Drawing
See Line Copy.

Line Films
Photographic film that converts all tones of gray to just black or white granular solids.

Line Growth
The growth of a printed line as a result of pressure between the printing plate and the substrate.

Liner
One of the outer, smooth members of corrugated board.

Linerboard
Paperboard used for the flat facings in corrugated board.

Linear Medium Density Polyethylene **LMDPE**
Paperboard used for the flat facings in corrugated board.

Lines per Inch **LPI**
The number of dots per linear inch in a halftone. Dot size varies from very small highlight dots to large shadow dots. More lines per inch increases resolution detail and dot gain. Lines per centimeter are specified outside the U.S.A.

Linetone
A form of halftone composed of lines instead of dots.

Line Work
See Line Copy.

Liquid Photopolymer
See Photopolymer Plate.

Listed Waste
Contains any number of toxic constituents that have been shown to be harmful to human health and the environment. Listed wastes include waste solvents that are classified as “F” wastes, while unused, discarded, or off-specification materials may be classified as “U” wastes.

Lithography
A method of printing from a plane surface (as smooth stone or metal plate) on which the image to be printed is ink-receptive and the non-printing area ink repellent. *See also Planography.*

Live
Indicates a scan or illustration in an electronic document that is ready for production of the platemaking-film negative.

Livering
An irreversible increase in the body of inks as a result of gelation or chemical change during storage. *See also Jelling.*

LLDPE
See Linear Low Density Polyethylene.

LMDPE
See Linear Medium Density Polyethylene.

Load
1. The total weight supported by the journals of a roll; 2. The force exerted by one roll on another usually expressed in pounds per linear inch (PLI).

Local Emergency Planning Committee **LEPC**
A committee appointed by the State Emergency Response Commission, as required by SARA Title III, to formulate a comprehensive emergency plan for its jurisdiction.

Local Limits
Discharge limits developed by the local control authority for non-domestic indirect dischargers designed to prevent interference with or pass through of the POTW.

Logo
A mark or symbol designed for an individual, company or product that translates the the impression of of the body it is representing into a graphic image.

Logo Color
Colors that signify a brand name or corporate identity. To ensure its consistency from package to package, press run to press run, logo colors should be treated as a line color.

Logotype
An alphabetical configuration designed to identify by name an individual, company or product. Also trademark.

Loose Color Proof
A process-color proof with no line copy or special (custom) ink colors.

Loupe
A small, hand-held magnifying device used to check the dot structure and line thickness of the film and printed piece.

LDPE
See Low Density Polyethylene.

Low Density Polyethylene **LDPE**
A low-cost resin, LDPE film has good moisture barrier, heat sealability and strength. Extrusion LDPE has an excellent bond to paper and varying bonds to other substrates.

Lower Explosive Limit **LEL**
The concentration of a compound in air above which the mixture will ignite; it relates to percentage of explosive vapors in air or around the press. Atmospheres with a concentration of flammable vapors at or above 10% of the LEL are considered hazardous.

Lower Flammable Limit **LFL**
See Lower Explosive Limit.

Lowest Achievable Emission Rate **LAER**
The most stringent emission limitation derived from either the most stringent emission limitation contained in the implementation plan of any state for such class or category of source; or the most stringent emission limitation achieved in practice by such class or category of source. Required of new sources in nonattainment areas.

LPI
See Lines per inch.

LQG
See Large Quantity Generator.

LZW
(Lempel-Ziv-Welch). A lossless compression scheme that uses an algorithm to compress digital image files to save disk space without sacrificing any data in the image.

KEY:

Barcode
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Ink
Mounting/ Proofing
Plates
Prepress
Press
Process Color
Quality
Substrate

M

M2P2
See Multimedia Pollution Prevention.

Machine Direction **MD**
The flow or movement of material through a machine. Cellulose paper fibers are oriented somewhat parallel to the direction of flow through a papermaking machine. *See also Cross Direction.*

Machine Finish
A dry or wet finish obtained on a paper machine. It can be achieved as the sheet leaves the last dryer or the calendar stack.

Machine Glazed
The finish produced on a Yankee machine, where paper is pressed against a large, highly polished, steam-heated revolving cylinder, causing the sheet to dry with a highly glazed surface on the side next to the cylinder, leaving the other side rough.

Machine Guard
A device or method that prevents the equipment/machine operator from placing any part of his/her body in a hazardous zone.

Machine Set
Type that is set by using a keyboard on a machine instead of setting each character by hand into a typestick.

Machine Wire
The continuous copper or bronze wire which is the traveling surface upon which the web of paper is formed. It is usually referred to as the Fourdrinier Wire.

MACT
See Maximum Achievable Control Technology.

Magenta
See Process Magenta.

Major Modification
This term is used to define modifications of major sources of emissions with respect to Prevention of Significant Deterioration and New Source Review under the Clean Air Act.

Major Source
Any source that emits or has the potential to emit 10 TPY of any hazardous air pollutant, 25 TPY of any combination of hazardous air pollutants or 100 TPY of any air pollutants. For ozone non-attainment areas, major sources are sources with the potential to emit 100 TPY or more of VOCs in marginal and moderate areas, 50 TPY or more of VOCs in serious areas, 25 TPY or more in severe areas, and 10 TPY or more in extreme areas.

Makeready
The preparation and correction of the printing plate before starting the print run, to ensure uniformly clean impressions of optimum quality.

Makeready
Techniques used in mounting plates to plate cylinders in order to achieve thickness uniformity or controlled variation in thickness, such as a lower area for fine screens in a combination plate.

Makeready
All preparatory operations preceding production on press.

Mandrel
A shaft upon which cylinders, or other devices, are mounted or affixed.

Manifest
A multicopy shipping form used to identify the type and quantity of waste, the generator, the transporter and the TSDF to which the waste is being shipped. The manifest includes copies for all participants in the waste shipment chain and is often obtained

Manifest System
See Cradle-to-Grave System.

Marginal
A category of nonattainment where sources of NO_X of VOCs of 100 tons per year or more are affected.

Mark
A print fault characterized by a localized pattern that repeats. The mark can be in printed or non-printed areas, positive or negative.

Markets
Generally, a recycling business (i.e., a buyer) or municipal recycling facility that accepts recyclable materials for processing and final sale to an end user, either for their own use or resale.

Mask
To block out part of an image to prevent reproduction or to allow for alterations.

Mass Tone
The color of a bulk of ink.

Material Safety Data Sheet **MSDS**
Printed material concerning a hazardous chemical or extremely hazardous substance, including its physical properties, hazards to personnel, fire and explosion potential, safe handling recommendations, health effects, fire fighting techniques, reactivity and proper disposal.

Materials Exchange
A mutually beneficial relationship whereby two or more organizations exchange materials that otherwise would be thrown away. In some areas, computer and catalog networks are available to match up companies that wish to participate in exchanging their materials.

Matrix
An intermediate mold, made from an engraving or type form, from which a rubber plate is subsequently molded.

Matte Finish
A low-gloss, dull finish. Compared to coated box paper, a finish with a gloss test less than 55%.

Maximum Achievable Control Technology **MACT**
A standard for source categories that emit hazardous air pollutants. It is generally the best available control technology, taking into account cost and technical feasibility.

Maximum Uncontrolled
Emissions calculated at maximum operating capacity of source, based on 8,760 hours per year without control equipment.

mb
See Megabyte.

MDPE
See Medium Density Polyethylene.

Mean Quality
See Average.

Mean (Arithmetic)
The value or statistic that is the result of the sum of the statistical observations in a sample divided by the number of observations in the sample.

Mechanical
Camera-ready pasteup of artwork and type on one piece of artboard; may be accompanied by overlays.

Media
Specific environments – air, water, soil – that are the subject of regulatory concern and activities.

Median
The value of the variable in a statistical sampling which exceeds half of the observations and is exceeded by half.

Medium
The corrugated or fluted portion of combined corrugated board, supporting the outer linerboard.

Medium Commercial Imaging Facility
A facility that produces, on average, more than two but less than 20 gallons per day of silver-rich solution, and uses less than 10,000 gallons per day of process wash water.

Medium Density Polyethylene
A film that provides better barrier and chemical resistance than LDPE.

Medium-density Tape
A foam mounting-tape, more firm and resillient than the standard double-sided tape.

Megabyte **Mb**
A unit of measure equivalent to 1,024 kilobytes or 1,048,576 bytes, commonly used to specify the capacity of computer memory.

Metallic Inks
Inks composed of aluminum or bronze powder in varnish to produce gold or silver color effects.

Metallic Replacement
A method of recovering silver from silver-rich solutions by an oxidation-reduction reaction with elemental iron and silver thiosulfate to produce ferrous iron and metallic silver.

Metamerism
When two colors match under one source of illumination but not under another.

Method 24
See Test Method 24.

Method 24A
See Test Method 24A.

Method 25
See Test Method 25.

Method 25A
See Test Method 25A.

Methyl Ethyl Ketone **MEK**
A relatively fast drying, organic solvent of the ketone family. A good solvent for nitrocellulose and vinyl lacquers. Small amounts will swell natural rubber. Its boiling point is 175°F. Highly flammable – its flash point is 24°F.

Metric ton
Unit of weight equivalent to 2,204.6 pounds.

Meyer Rod
A metal rod wound with fine wire around its axis so that liquids can be drawn down evenly at a given thickness across a substrate.

Mezzotint
An irregular, random dot halftone.

mg/kg
Milligrams per kilogram.

mg/L
Milligrams per liter; equivalent to ppm.

MIBK
See Methyl isobutyl ketone.

Micro Dot
Typically used in video-mounting devices, they are 0.010" diameter dots placed on the left and right side of the printed material, and in the center of the web direction. When printed, the dots will overprint each other and appear to be an almost perfect dot.

Micrometer
An instrument (caliper) for measurement in terms of small dimensions, usually in 0.001" and 0.0001".

Mil
1. Military specifications; 2. 1/1000 of an inch; 0.001".

Mileage
The usage factor of any ink, referring to the amount of ink used to cover a certain area of printed surface.

Mill Roll
A roll of paper, film or foil as received by the converter from the mill.

Min/Max Rule
The minimum and maximum type or line width a press is capable of reproducing, usually determined by press characterization data.

Mineral Spirits
Hydrocarbon petroleum distillates having a boiling range of approximately 300° F to 350° F.

Minimum Dot
The smallest dot size a press is capable of reproducing, usually determined by press characterization data.

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Misregister
A condition where printing is out of or not in register. *See Register.*

Misting
A mist or fog of tiny ink droplets thrown off the press by the rollers. *See also Flying.*

Mixing White
A white ink, either transparent or opaque, used in making tints.

Mixture
Any combination of two or more chemicals if the combination is not, in whole or part, the result of a chemical reaction.

mmHg
Millimeters (mm) of mercury (Hg); a unit of measurement for low pressures or partial vacuums.

Mode
The value of the variable in a set of statistical data at which the greatest concentration of observations occur.

Mode Quality
The value in a series of measurements which occurs most frequently.

Moderate
A category of nonattainment where sources of NO_X of VOCs of 100 TPY or more are affected.

Modulus of Elasticity
The ratio of stress produced in a material corresponding to the strain producing the stress, within the elastic limit of the material.

Moiré
An interference pattern caused by the out-of-register overlap of two or more regular patterns such as dots or lines. In flexographic printing, it can be caused by incorrect relative screen of the anilox rolls and halftone plate. Screen angles are selected to minimize this pattern.

Moisture-proof
Not affected by the moisture. A barrier to moisture. Although materials which resist passage of moisture are often called moisture-proof, their preferable designation is moisture barrier.

Molding Bearing Bars
See Bearer.

Mold
1. A female form used for production of desired shapes; 2. To form a matrix or rubber plate, using heat and pressure. *See Matrix.*

Molding Press
A platen press in which matrices or rubber plates are formed.

Monochrome
Consisting of a single color or hue. In printing, this refers to imaging in shades of gray, used interchangeably with black and white.

Monomer
A chemical combination of molecules corresponding to the individual units of a polymer. It is capable of being incorporated (polymerized) into polymers.

Mottle
A nonuniform ink lay resulting in a speckled or indistinctly spotted appearance, also known as orange peel, flocculation, striations.

Mounting
The process of affixing plates on a cylinder or base in proper position to register color to color as well as to the product form to be printed.

Mounting and Proofing Machine
A device for accurately positioning plates to the plate cylinder and for obtaining proofs for register and impression, off the press.

MSDS
See Material Safety Data Sheet.

msi
One thousand square inches.

Mullen Bursting Strength
The measure of a material's strength to resist burst, expressed in pounds per square inch. The test is made on a motor-driven Mullen tester.

Mullen Tester
The equipment which tests bursting strength of paper.

Munsell Color System
A prorietary color system where color is defined in terms of h (hue), c (chroma) and v (lightness).

Multicolor Overprinting
The technique of overprinting a given number of transparent colors to produce additional colors without using halftones. For example, to produce orange, green, purple and brown, cyan, magenta and yellow are overprinted to make seven colors from three.

Multimedia Pollution Prevention **M2P2**
Actively identifying equipment, processes and activities that generate excessive wastes or use toxic chemicals, and then making substitutions, alterations or product improvements, taking into account the impact on all media.

Murray-Davies Equation
A formula for calculating dot area based on density measurments. This measurement approximates the total of physical dot size plus optical dot gain due to insufficient light absorption of the ink and extra light absorption of the substrate, thus the term "apparent dot area." Under visual examination with a 10X magnifying glass, the printed dot would appear smaller than the calculated apparent dot area which correlates well with visual perception when holding the printed piece at normal viewing distance.*See also Dot Area, Yule-Nielson Equation.*

MVT Rate
Moisture vapor transmission rate. *See Water Vapor Transmission Rate.*

Mylar
A DuPont® tradename for a tough, polymeric polyester produced in the form of a clear film.

N

NAA
See Nonattainment Area.

NAAQS
See National Ambient Air Quality Standards.

NAFTA
North American Free Trade Agreement.

NAICS
See North American Industrial Classification System.

Naphtha
An alipathic hydrocarbon solvent, characterized by low K.B. values, derived from petroleum, such as hexane, V M & P naphtha, etc. It swells natural or butyl rubber and has slight effect on Buna-N or Neoprene.

National Ambient Air Quality Standards NAAQS
Maximum air pollutant standards that USEPA set under the Clean Air Act for attainment by each state.

National Emission Standards for Hazardous Air Pollutants NESHAP
Emission standards set by USEPA for an air pollutant not covered by NAAQS that may cause an increase in deaths or serious, irreversible or incapacitating illness.

National Environmental Policy Act NEPA
A U.S. federal law that ensures that public officials consider the environmental effects of proposed actions, to foster better decision-making and to encourage public participation. It also requires environmental impact statements for any major federal action that may significantly affect the quality of the human environment.

National Pollution Discharge Elimination System NPDES
The primary federal permitting program under the Clean Water Act that regulates discharges to surface waters.

Native File Format
The process in which an application program saves data.

Natural Drying Time
The amount of time it takes the ink to dry as it leaves the last printing unit and before the web dryer temperature begins rising.

Negative
A photographic image of originals on paper, film or glass in reverse from that of the original copy. Dark areas appear light and vice versa.

Neoprene
A synthetic, chlorinated butadiene rubber used in making flexo rollers, that are resistant to alcohols, cellosolve, water, aliphatic hydrocarbons and to a limited extent, esters (acetates), but not resistant to aromatic hydrocarbons.

NEPA
See National Environmental Policy Act.

NESHAP
See National Emission Standards for Hazardous Air Pollutants.

Neutral
The absence of acid or alkaline activity in a material. The presence of an equal concentration of hydrogen and hydroxyl ions; a pH of 7.

Neutral Tone
The absence of color. An achromatic tone produced by balancing the ink densities of yellow, magenta and cyan.

New Source
Any stationary source built or modified after publication of final or proposed regulations that prescribe a given standard of performance.

New Source Review NSR
Clean Air Act requirement that State implementation plans must include a permit review that applies to the construction and operation of new and modified stationary sources in nonattainment areas to assure attainment of NAAQS.

N Factor
See Yule-Nielson Factor.

Nigrosine
A deep blue or black aniline, or coal tar dye-stuff.

Nip
The line of contact between two rolls.

Nitrocellulose
A film formerly widely used in flexography and with gravure inks, also known as nitrated cellulose. *See also Pyroxylin.*

nm
Nanometer. A unit measure of length, equivalent to one billionth (10–9) of a meter.

Nodule
A small lump, round or irregular shaped, such as chrome projections on an anilox roll, needing additional polishing for removal.

Nonattainment Area
An area that does not meet one or more of the NAAQS for the criteria air pollutants designated in the Clean Air Act.

Nonferrous Metals
Metals not containing any sizable proportion of iron.

Nonfogging Film
A film that does not become cloudy from moisture condensation caused by temperature and humidity changes.

Nonhazardous Industrial Waste
Wastes and waste waters from manufacturing facilities regulated under Subtitle D that are not considered to be MSW, hazardous waste or other waste under Subtitle C and D.

Nonincrement Press
A flexo press capable of printing infinite variable repeats, and is not dependent on standard gear pitch increments.

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Nonpoint Source
Any source of pollution not associated with a distinct discharge point.

Nonscratch
Inks which have high abrasion and mar-resistance when dry.

Nonspecific Source Wastes Environment
This list identifies wastes from common manufacturing and industrial processes. These include solvents that have been used in cleaning or degreasing operations.

Nonvolatile
That portion of a material which does not evaporate at ordinary temperatures.

North American Industrial Classification System **NAICS**
Updated change to the standard industrial classification (SIC) code system which began phase-in during 1997.

Notice of Violation **NOV**
A formal notification by a government agency to an emission source indicating violation of a regulation.

NOV
See Notice of Violation.

NOx
See Oxides of Nitrogen.

NPDES
See National Pollutation Discharge Elimination System.

NSR
See New Source Review.

Nylon
A synthetic resin, part of the polyamide family.

O

O.D.
Outside diameter.

Object-oriented
An approach in drawing and layout programs that treats graphics as line and arc segments rather than individual dots. Also referred to as vector-oriented.

OCC
Old Corrugated Containers, used for recycled pulp.

Occupational Safety and Health Act (OSH Act)
A Federal law that provides protection to employees by specifying requirements for industry to safeguard the worker from accidents, exposure and other health endangering conditions. According to this Act, inspectors may at any time or when requested by employee examine any company for violations of occupational safety and health standards set by the Act."

OCR
See Optical Character Recognition.

Off-press Proof
A simulation of the printed job produced directly from digital information or photographic films.

Offset
The transfer of printing inks, or coatings, from the surface of a printed sheet to other surfaces.

Offset
A method used in the 1990 Clean Air Act Amendments to give companies that own or operate large (major) sources in nonattainment areas, flexibility in meeting overall pollution reduction requirements when changing production processes. If the owner or operator of the source wishes to increase release of a criteria air pollutant, an offset must be obtained either at the same plant or by purchasing offsets from another company.

Off-Spec
A chemical that does not meet specifications to perform a particular function.

Opacity
1. Having the quality of being impervious to light rays; 2. The degree of light unable to transmit through a material.

Opaque
1. A paint exhibiting light obstructive qualities used to block out areas on a photographic negative not wanted on the plate; 2. To apply opaque materials.

Open Prepress Interface **OPI™**
An extension of the PostScript page-description language, it is a workflow where the high-resolution images are stored in a central location on a flie server, and the low-resolution files with the same name are sent to the individual workstations to be used for layout. When the completed file is sent for output, the high resolution images are automatically swapped out with the low-resolution images.

Operating Side
That side of a flexographic press on which the printing unit adjustments are located, opposite of driving side or gear side.

Operation and Maintenance Plan
A plan describing the planned/scheduled maintenance of equipment.

OPI™
See Open Prepress Interface.

OPP Substrates
See Oriented Polypropylene.

Optical Character Recognition **OCR**
A means of inputting copy, without the need to key it in, by using software which, when used with a scanner, converts the type into editable computer text.

Optical Density
The light-stopping ability of a photographic film or printed image; it is mathematically expressed as the logarithm of opacity.

Optical Disk
A high-density storage device that uses a laser to burn a pattern of holes into a tellurium film on the disk's surface. A single optical disk can hold billions of bytes of data. In fact, one optical disk storage system can store the entire Encyclopedia Britannica if necessary.

Optical Distortion
To change an object's appearance when viewed through a transparent material, adding certain defects such as waviness of surface, etc.

Optical Scanner
A device which analyzes the light reflected from or transmitted through copy, art, or film and produces an electronic signal proportional to the intensity of the light or color.

Orange Peel
See Mottle.

Organic
Refers to the compounds in the field of chemistry containing carbon.

Organosol
A suspension of particles in an organic solvent, mostly made with vinyl resins, solvents and plasticizers.

Oriented Polypropylene
A clear, stiff film with good heat resistance and good moisture barrier. Coated grades also have good oxygen barrier or good heat sealability.

Original
The material that is required to be reproduced in the printing process, such as a photograph, transparency, artist's drawing or merchandise sample.

Ortho Response
Specified as Type 2 in ISO 5-3:1995: Photography – Density measurements – Part 3: Spectral conditions. This is generally used for measuring densities when printing to orthochromatic (blue/green sensi-

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tive) materials with sensitivities between 350 nm to 520 nm, with a peak at approximately 435 nm.

OSH Act
See Occupational Safety and Health Act.

OTR
See Ozone Transport Region.

Out-of-Gamut
The condition where the gamut of one device is less than that of another device. For example, many colors that are displayed on a monitor can not be reproduced on a press using C, M, Y, K process color inks.

Overlay
The transparent sheet attached to copy used to indicate changes, color separation, etc.

Overprint
The printing of one ink impression over another.

Overtone
Modifying the hue or tone of a color.

Overwrap
A wrapper applied over a product, package, carton, box, etc.

Oxidation
The use of heat to burn VOCs in a solvent-laden gas stream.

Oxides of Nitrogen (No_x)
A criteria air pollutant that is produced from burning fuels.

Ozone
The three oxygen molecule compound (O_3) found in two layers of the earth's atmosphere. One layer, beneficial ozone, occurs seven to 18 miles above the surface and shields the earth from UV light. Ozone also concentrates at the surface as a result of reactions between volatile organic compounds, oxides of nitrogen and UV light.

Ozone Depleter
A type of air pollutant regulated by the Clean Air Act that includes the emissions of substances that deplete the upper (stratospheric) ozone layer.

Ozone Transport Region **OTR**
Encompasses the east coast of the United States, including Connecticut, Delaware, Maine, Maryland, Massachusetts, New Hampshire, New York, New Jersey, Pennsylvania, Rhode Island and the District of Columbia. All existing sources in the ozone transport region with potential emissions greater than 50 TPY have to adopt RACT even if they are located in a less severely polluted area.

P

P2
See Pollution Prevention.

PAL
See Plantwide Applicability Limit.

Pantone Matching System® **PMS®**
The brand name of a system for specifying colors, a standard in the printing industry.

Paper Direction
The direction that the paper web is produced. *See also Machine Direction.*

Paperboard
The distinction between paperboard and paper is not clear, but generally, paperboard is heavier in basis weight, thicker and more rigid than paper. Sheets 12 pts (0.012") thick or more are classified as paperboard. There are a number of exceptions based upon traditional nomenclature. For example, blotting paper, felts and drawing paper are classified as paper while corrugating medium, chipboard and linerboard less than 12 pts are also classified as paperboard. Paperboard is made from a wide variety of furnishes on a number of types of machines, principally cylinder and fourdrinier.

Pareto Analysis
A graph of the number of occurrences of different items, usually problems or faults and used as a tool to analyze and pinpoint the significant few from the insignificant many.

Particulate Matter **PM**
A criteria air pollutant that includes dust, soot and other tiny bits of solid materials that are released and move around in the air.

Parity Checking
Built into bar codes, a method of error checking the graphic design of the symbology itself, such as an odd number of narrow bars in every properly encoded character or an even number of dark modules for each character.

Pastel
A tint or masstone to which white has been added.

Pattern or Pattern Plate
The engraving or combination of plates used for making the matrices from which rubber plates are made.

PCB
See Polychlorinated biphenyls.

PCE
See Perchloroethylene.

PDF
See Portable Document Format.

PE
See Polyethylene.

PEL
See Permissible Exposure Limit.

PFL
See Permissible Flammable Limit.

Penetration
The ability of a liquid (ink, varnish or solvent) to be absorbed.

Perc
See Perchloroethylene.

Percent Volatile
The percentage of a liquid or solid (by volume) that will evaporate at an ambient temperature of 70° F.

Perceptual Color Space
A color space or model based on how people see color. *See also CIELab.*

Perchloroethylene **PCE**
A colorless, nonflammable liquid. It is an irritant, and extended exposure can adversely affect the human nervous system.

Perfumed Ink
A printing ink with a small percentage of concentrated scents to impart a desired aroma or fragrance to the printed sheet.

Permanent Total Enclosure **PTE**
An enclosure that completely surrounds an emission source, as defined by USEPA guidelines, such that all VOC emissions are discharged to a control device, resulting in a capture efficiency of 100%.

Permissible Exposure Limit **PEL**
An occupational exposure limit established by OSHA's regulatory authority. It may be a time-weighted average (TWA) limit or a maximum concentration exposure limit.

Permit
A legal document issued by state and/or federal authorities containing a detailed description of the proposed activity and operating procedures as well as appropriate requirements and regulations.

Permit to Construct
May be required before any new facility can be built or before any new piece of equipment can be installed or modified (contact your state regulatory agency).

Permit to Operate
Contains all applicable and enforceable control requirements and has a definite period of effectiveness.

PET
See Polyethylene Terephthalate.

pH
The measure of acidity or alkalinity of an aqueous solution; 7 on the scale is neutral; less than 7 is acidic and greater than 7 is alkaline. Strong acids have a pH of 1–3; weak acids about 6. Strong bases have a pH of 12–13, weak bases about 8.

Phenolic
The generic name for phenol-formaldehyde plastic.

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Photo Composition
The process of setting type copy photographically, as opposed to using the method of inking and proofing lead-type characters.

Photoengraving
A metal plate prepared photochemically, from which the matrix or rubber mold is reproduced.

Photoinitiator
A substance which, by absorbing light, becomes energized into forming free radicals which promote radical reactions and polymerization.

Photomultiplier Tube **PMT**
A light-detection device traditionally used in high-end drum scanners. PMTs are highly light sensitive, and are physically larger in size compared to CCDs. *See also CCD.*

Photopolymer Plate
A flexible, relief-printing plate, used in flexography, made of either precast sheet or liquid light-sensitive polymers. Photopolymer plates require exposure to UV light during the platemaking process.

Photopolymers
The generic name for a mixture of materials which are sensitive to UV or visible light exposure. With image-wise exposure, they are used extensively in off-press proofing materials and printing plates.

Photostat
See Stat.

Physical Hazard
A chemical for which there is scientifically valid evidence that it is a combustible liquid, a compressed gas, explosive, flammable, an organic peroxide, an oxidizer, pyrophoric, unstable or water-reactive.

pi (π)
The ratio of a circle's circumference to its diameter. The value, rounded to four decimal places, is equal to 3.1416.

Pica
A unit of type measure equivalent to 1/6". One pica equals 12 points.

Picket Fence Orientation
The positioning the UPC symbol, so that the bars in the artwork are printed running in the machine direction. *See also Ladder Orientation.*

Pick Resistance
The ability of the paper's surface, i.e., the coating, film or fibers, to resist lifting from the surface when struck during printing.

Picking
The lifting of any portion of a surface during the printing impression.

PICT
A standard file format for storing object-oriented images. PICT data can be created, displayed on screen, and printed by routines incorporated in the Macintosh system, so a program need not contain graphics-processing routines in order to incorporate PICT data generated by other software.

Pigment
An insoluble coloring material dispersed in a liquid vehicle to impart color to inks, paints and plastics. *See also dyes.*

Pigment Load
The amount of pigment in an ink formulation as a percentage of the total liquid volume.

Pigments, Inorganic
A class of pigments consisting of various metallic compounds, e.g, titanium oxide, iron blue.

Pigments, Organic
A class of pigments which are manufactured from coal tar and its derivatives. These pigments are generally stronger, brighter and more transparent than inorganic pigments.

Piling
The buildup of ink on a roller, plate or blanket.

Pinholing
When a printed ink fails to form a complete, continuous coverage, evident by the random formation of small holes in the printed area.

Pin-on Temperature
The temperature when an ink adheres to the substrate.

Pitch Diameter
The measurement of a gear, determined by dividing the tooth pitch line circumference by pi (π).

Pitch Line
An imaginary circle on the gear at the point of true mesh with the mating gear. The circumference of the pitch line determines the repeat of the gear on the print cylinder.

Pixel
The abbreviation for picture element. It is the smallest unit (cell, dot, square) on a color monitor display screen grid that can be displayed, stored or addressed. An image is typically composed of a rectangular array of pixels.

PPI
See Pixels per Inch.

Planography
See Lithography.

Plasticizers
Materials, usually liquid but sometimes solid, that impart flexibility to an ink or lacquer.

Plastisol
Particle suspension of in an organic liquid, similar to an organosol, but containing no solvents.

Plate Break
The nonprint area where the two ends of a flexographic plate butt together after being wrapped around the plate cylinder on the printing press.

Plate Cylinder
The press cylinder on which the printing plates are mounted. There are two types. Integral, the shaft is a permanent part of the body. Demountable, the shaft is removable to receive a multiple of bodies of varying diameters and, in some cases, face widths.

Platen
1. The heated plates of a printing plate vulcanizer that press the engraving into the matrix or matrix into the rubber during the platemaking process; 2. The heated plate on a flat-bed transfer-printing press, which presses the heat-transfer paper onto the fabric to produce the finished design.

Platesetter
See Imagesetter.

Plate Staggering
A mounting technique whereby multiple plates are staggered or offset with respect to each other on the plate cylinder, usually done to prevent plate and cylinder bounce.

Ply
Each layer in a multilayered structure.

PM
See Particulate Matter.

PM 10
Particulate matter greater than 10 microns in diameter.

PMS
See Pantone Matching System®.

PMT
See Photomultiplier Tube.

Pock Marks
A print defect, also referred to as craters or volcanoes, often caused by solvent retention.

Point
A unit of type measurement, equivalent to 0.0139". There are 12 points to a pica and 72 points to the inch.

Point
A unit of measure to specify paperboard thickness, equivalent to mils or 0.001"; i.e., 20 pt equals 0.20".

Point Source
A stationary location or fixed facility (such as an industry or municipality) that discharges pollutants into the air or water surface through pipes, ditches, lagoons, wells or stacks.

Points
Meaurement of caliper; 0.001".

Pollution
Any substance in water, soil or air that degrades the natural quality of the environment, offends the senses of sight, taste or smell or causes a health hazard.

Pollution Prevention **P2**
Actively identifying equipment, processes and activities that generate excessive wastes or use toxic chemicals, and then making substitutions, alterations or product improvements.

Pollution Prevention Act **PPA**
A law enacted in 1990 which establishes a U.S. national policy that pollution should be prevented or reduced at the source whenever feasible. Pollution that cannot be prevented should be recycled in an environmentally safe manner. Pollution which cannot be prevented or recycled should be treated in an environmentally safe manner and its disposal or release into the environment should be employed as the last resort.

Poly
See Polyethylene.

Polyamide
Polymers containing amide groups; for example nylon, versamid resins, etc.

Polychlorinated biphenyls **PCBs**
Mixtures of a certain class of carcinogenic, synthetic, organic chemical regulated by OPPT and other agencies.

Polyester
See Polyethylene Terepthalate.

Polyethylene
A polymerized ethylene resin used for packaging films or molded for a wide variety of containers, kitchenware and tubing. *See also HDPE, LDPE, LLDPE, LMDPE, MDPE.*

Polyethylene Terephthalate **PET**
An oriented PET film that has excellent stiffness, clarity, heat resistance and dimensional stability, good oxygen barrier, and some moisture barrier.

Polymer
A compound formed by linking simple and identical molecules having functional groups that permit their combination, to proceed to higher molecular weights under suitable conditions.

Polymerization
A chemical reaction in which the molecules of a monomer are linked together to form large molecules whose weight is a multiple of that of the original substance.

Polypropylene **PP**
A class of plastics which includes a wide variety of packaging, such as yogurt containers, shampoo bottles, margarine tubs, cereal box liners, rope and strapping, combs and battery cases.

Polystyrene
A class of plastics which includes Styrofoam® coffee cups, food trays and "clamshell" packaging, as well as some yogurt tubs, clear carry-out containers and plastic cutlery. Foam applications are sometimes called Expanded Polystyrene (EPS). Some recycling of polystyrene is taking place, but is limited by its low weight-to-volume ratio and value as a commodity.

Polyvinylidene Chloride **PVDC**
A film that has excellent water, oxygen and flavor barriers. In emulsion form, it can be used as a barrier coating.

Pop Test
The slang term for the bursting test, originating from the popping sound when the paper bursts. *See also Mullen Tester.*

Population
In statistics, the total of all possible observations of the same kind from which the statistical sample is drawn.

KEY:

Barcode
Design
Environment
General
Ink
Mounting/ Proofing
Plates
Prepress
Press
Process Color
Quality
Substrate

Porosity
A property of paper that allows the permeation of air, an important factor in ink penetration.

Portable Document Format **PDF**
A file format invented by Adobe Systems as a solution to transporting digital files cross-platform. PDFs are independent of the original application software, hardware, and operating system used to create those documents, capturing all the elements of a printed document as an electronic image which can then be forwarded, viewed, navigated and printed. PDFs are also device-independent, resolution independent and page independent. Manipulation and page routing can occur, which characterize the editable component of the PDF file. Files in this format are based on the same imaging model as PostScript, but are optimized and compressed for transport and delivery (portability).

POS
Point of Sale.

Positive
A photographic image on paper, film or glass which exactly corresponds to the original subject in all details.

PostScript
A computer language created by Adobe® Systems, Inc., which allows a programmer to create complex pages using a series of commands. Text and graphics can be controlled with mathematical precision and image output to laser printers and high-resolution imagesetters.

Potential to Emit **PTE**
The maximum capacity of an air contamination source to emit any air contaminant under its physical and operational design, operating every hour of the year.

POTW
See Publicly Owned Treatment Works.

Powdering
See Chalking.

PP
See Polypropylene.

PPA
See Pollution Prevention Act.

ppb
Parts per billion.

PIxels per Inch **PPI**
The unit used to measure the resolution of a digital image.

ppm
Parts per million.

PPO
See Pollution Prevention Officer.

Preflight
A process of determining the completeness and correctness of an electronic design file prior to commencement of production.

Precipitate
An insoluble substance that forms in a solution.

Premakeready
Varying the surface height of printing plates before going to press in order to achieve better printability.

Preseparated Art
Artwork in which the basic layout, register marks and major color is prepared on illustration board and each additional color plate is drawn on a separate sheet or film overlay.

Press Characterization
The procedure to quantify and document the printing process and use the data to adjust upstream systems and provide data to monitor the printing process for consistency.

Press Direction
The direction of paper parallel to its forward movement on the press. The direction at right angles to this is called the cross press direction.

Press Proofs
Printed sections of substrate material made on a press to allow for approval or final corrections before the production printing run is made.

Pretreatment
Methods used by industry and other non-household sources of waste water to remove, reduce or alter the pollutants in a waste water before discharge to a POTW.

Preucil
See Ink Trap Percent.

Prevention of Significant Deterioration **PSD**
USEPA program in which state and/or federal permits are required to restrict emissions from new or modified sources in places where air quality already meets or exceeds primary and secondary air quality standards.

Primary Colors
Those from which all other colors may be derived, but which cannot be produced from each other. The additive primaries (light) are blue, green and red. The subtractive primaries (colorant) are cyan, magenta and yellow.

Primary Standards
To set limits to protect public health, including the health of people sensitive to air pollution, such as young children, the elderly and those with asthma.

Prime Coat
The initial base coating applied to enhance subsequent printing.

Printability
The collective term used to describe the substrate properties required for acceptable print-image quality.

Print Contrast
A ratio of the difference between the printed solid area density and a printed shadow tint area (traditionally 75% as measured on the platemaking file or film negative for offset lithography; 70% for flexography) to the density of the solid, expressed as a percentage. This indicates the printing sys-

tem's capability to hold image detail in the upper tone region. Most desirable (highest) print contrast occurs with the simultaneous highest solid print density and the lowest dot gain.

Printed Dust
A print fault where dust appears on the solid areas. It is more common on thin substrates, such as film.

Printing, Flexographic
See Flexography.

Printouts
A fascimile, from an output device such as a laser or ink-jet printer, of the copy programmed into the computer for review.

Print Voids
A print defect resulting from the nontransfer of ink to the substrate.

Process Black
One of the four ink colors used in four-color process printing. Like all process inks, this ink must be a transparent. This will allow for the blending of varying amounts of each of the process colors, to achieve the visual appearance of the many thousands of shades capable of being printed by flexography.

Process Color
Cyan, magenta, yellow, and black inks used in four-color process printing; hue may be modified to meet specific needs.

Process Cyan
One of the four ink colors used in four-color process printing. Like all process inks, this ink must be a transparent. This will allow for the blending of varying amounts of each of the process colors, to achieve the visual appearance of the many thousands of shades capable of being printed by flexography.

Process Magenta
One of the four ink colors used in four-color process printing. Like all process inks, this ink must be a transparent. This will allow for the blending of varying amounts of each of the process colors, to achieve the visual appearance of the many thousands of shades capable of being printed by flexography.

Process Yellow
One of the four ink colors used in four-color process printing. Like all process inks, this ink must be a transparent. This will allow for the blending of varying amounts of each of the process colors, to achieve the visual appearance of the many thousands of shades capable of being printed by flexography.

Process Control
That procedure for examining a process which aims at evaluating future performance through the use of statistical quality control methods.

Process Inks
A set of transparent inks for high reproduction illustrations by halftone color separation process. Colors are yellow, magenta, cyan with or without black. *See Process Black, Process Cyan, Process Magenta, Process Yellow.*

Process Printing
Printing from a series of two or more halftone plates to produce intermediate colors and shades. In the four-color process, yellow, magenta, cyan and black are used.

Production Run
The final printing requested by the customer from the original artwork.

Programming
To establish such things as type styles, point sizes, spacing, etc. in a computer application.

Profile
See ICC Profile.

Progessive Color Bar
See Control Target.

Progressive Proofs (Progs)
Prints of individual color plates of a multicolored design or illustration, applied to color separation negatives or as individual plate cylinder print repeats from a plate proofer or a printing press, to evaluate color balance and printability.

Progs
See Progressive Proofs.

Proof
A prototype of the printed job that is made from plates, film, or electronic data, for in-house quality control and/or for customer inspection and approval.

Proof, Color Target
See Color Target Proof.

Proof, Concept
See Concept Proof.

Proof, Contract
See Contract Proof.

Proof, Contract Analog
See Contract Analog Proof.

Proof, Contract Digital
See Contract Digital Proof.

Proof, Profiled Contract
A proof that is profiled on a specific date using a specific color management system and is prepared based upon profiles provided by the proofing system's manufacturer.

Proofing Paper
A white paper with a machine glaze or finish, commonly 0.003" thick, such as 50# super-calendered paper, used during the proofing and mounting process.

Proprietary Alcohol
Denatured ethyl alcohol.

PSD
See Prevention of Significant Deterioration.

KEY:

Barcode
Design
Environment
General
Ink
Mounting/ Proofing
Plates
Prepress
Press
Process Color
Quality
Substrate

PTE
See Potential to Emit and Permanent Total Enclosure.

Publicly Owned Treatment Works **POTW**
A municipal or public service district sewage treatment system.

Pulldown Ink
See Drawdown.

PVDC
See Polyvinylidene Chloride.

Pyroxylin
The name given to the more soluble types of cellulose nitrate and confined roughly to those containing less than 12.4% nitrogen. Also called nitrocellulose.

Q

Quality
Those characteristics of a product that allow manufacture at a given cost-price relationship; uniformity to meet parameters of customer specifications; and caliber of competitive performance.

Quality Control
The systematic planning, measurement and control of the combination of personnel, materials and machines with the objective of producing a product which will satisfy the quality and profitability of the enterprise.

Quiet Zone
Print-free zones or areas in a bar code that are used to separate the bars and spaces from any surrounding graphics or text; used to help the scanner locate the symbol.

R

Rack-jobber
One who displays items on a vertical rack with pins, hooks, etc.

RACT
See Reasonably Available Control Technology.

Radiation-vured Inks
These inks consist of mixtures of low-molecular-weight polymers or oligomers dissolved in low-molecular-weight acrylic monomers. They typically do not contain organic solvent carriers. Electron beam or ultraviolet light sources are used to cure these inks.

Random Copolymer Polypropylene
A small percentage of ethylene added to HDPE while being polymerized.

Random Sample
In statistics, a sample of a population obtained by a process which gives each possible combination of "n" items in the population the same chance of being the sample actually drawn.

Range
In a statistical sampling, the amount of the values covered by the frequency distribution from the highest value to the lowest value.

Raster Display
A video display that sweeps a beam of light through a fixed pattern, building an image with a matrix of points.

Raster Graphics
The manner of storing and displaying data as horizontal rows of uniform grid or picture cells (pixels). Raster scan devices recreate or refresh a display screen 30 to 60 times a second in order to provide a clear image for viewing. Raster display devices are generally faster and less expensive than vector tubes and are therefore gaining popularity for use with graphics systems.

Raster Image File Format **RIFF**
A file format for paint-style graphics, developed by Letraset USA. RIFF is an expanded version of the TIFF format used by many scanner makers.

Raster Image Processor **RIP**
A computer device or program that translates digital information in the page description language to the pattern of dots to be delivered by the output unit of the system.

Rasterize
To convert images into a bitmap (raster) form for display or printing. All output of a display screen or printer is in raster format.

Raster Scam **RIP**
The generation of an image on a display screen made by refreshing the display area line by line.

RCF
See Refractory Ceramic Fibers.

RCRA
See Resource Conservation and Recovery Act.

Reaction
A chemical transformation or change. The interaction of two or more substances to form new substances.

Reactive
Potentially explosive or produces toxic gases when mixed with water, air or other incompatible materials.

Reactive Waste
Unstable or explosive waste; wastes which react violently in the presence of water; and sulfide- or cyanide-bearing wastes which liberate toxic vapors when exposed to pH conditions between 2.0 and 12.5. Printers do not normally generate reactive wastes.

Ream
The unit of quantitative measure used in the marketing of paper, consisting of a specified number of sheets of the basic size for a given grade. Generally, it is 500 sheets; wrapping tissue is 480 sheets, sometimes 1,000 sheets.

Reasonably Available Control Technology **RACT**
Control technology that is reasonably available and both technologically and economically feasible. Usually applied to existing sources in non-attainment areas; in most cases it is less stringent than new source performance standards. RACT is normally described in the CTGs for the process.

Reclaimed Material
Material that is regenerated or processed to recover a usable product. Examples are recovering lead values from spent batteries and the regeneration of spent solvents.

Recovered Material
A material or by-product that has been recovered or diverted from solid waste and does not include materials or by-products generated from, and commonly used within, an original manufacturing process.

Recycled Medium
Paperboard used in forming the fluted portion of corrugated board, made from recycled fiber, such as old corrugated boxes.

Recycled Paperboard
A term which refers to paperboard manufactured using recycled paper, usually old newspaper or waste paper, that has very little refining.

Recycling
Recovering and reusing materials and objects in original or changed forms rather than discarding them as waste.

Reducers
Materials used to alter the body, viscosity or color strength of ink.

Reflection Densitometry
The practice of characterizing the amount of light absorption of materials by measuring reflectance and calculating and reporting optical density.

KEY:

Barcode
Design
Environment
General
Ink
Mounting/ Proofing
Plates
Prepress
Press
Process Color
Quality
Substrate

Reflective Art
Art which must be photographed by the light reflected from its surface.

Reflective Copy
An opaque original that is photographed with reflected light.

Reflective Process Camera
A camera that is capable of reproducing an original image that has been prepared on an opaque substrate.

Refractive Index
The relative measure of the speed of light in a medium (air's refractive index is equal to one). The change in refractive index from one matrial to another causes light to change direction at the material interface. This property enables a glass prism (refractive index of about 1.5) to separate white light into its constituent colors.

Refractory Ceramic Fibers **RCF**
Manmade fibers produced from melting and blowing or spinning of kaolin clay or alumina and silica. They are used primarily for high temperature industrial insulation applications, most frequently as lining in high temperature furnaces, heaters and kilns.

Regenerated Cellulose
The basic ingredient used in the manufacture of cellophane.

Regenerative Thermal Oxidizer **RTO**
An air pollution control device that destroys organics by thermal oxidation. Heat from the oxidation process is captured and reused to heat the influent vapor stream.

Register
In printing, the alignment of two or more images when printed sequentially on top of each other.

Regular Slotted Container
A container usually made from a single piece of corrugated board and shipped flat. All flaps are the same length and the outer flaps meet at the center of the box. RSC's are used more than any other style because they are more economical to manufacture and use.

Regulatory Agency
Federal, state/provincial or local agencies responsible for implementing, monitoring and enforcing regulations.

Related Colors
Neighboring colors in the spectrum.

Relative Density
The density measurement where the densitometer is calibrated on a clear film substrate for transmission and on an unprinted substrate for reflection. *See also absolute density.*

Relative Humidity
The ratio of actual humidity to the maximum humidity which air can retain without precipitation at a given temperature and pressure. *See also Absolute Humidity.*

Release
Any spilling, leaking, pumping, pouring, emitting, emptying, discharging, injecting, escaping, leaching, dumping or disposing into the environment of a hazardous or toxic chemical or extremely hazardous substance.

Releases to Air
(Point and Fugitive Air Emissions)
Includes all air emissions from industry activity. Point emissions occur through confined airstreams as found in stacks, ducts or pipes. Fugitive emissions include losses from equipment leaks or evaporative losses from impoundments, spills or leaks.

Releases to Land
Includes disposal of toxic chemicals in waste to on-site landfills, land treatment or incorporation into soil, surface impoundments, spills, leaks or waste piles. These activities must occur within the facility's boundaries.

Releases to Water (Surface Water Discharges)
Encompasses any releases going directly into streams, rivers, lakes, oceans or other bodies of water. Any estimates for stormwater runoff and non-point losses must also be included.

Remedial Action
The actual construction or clean-up phase of a Superfund site cleanup.

Rendering
Producing or the finished production of a design drawing, painting, etc. by hand using any of various tools, i.e., pencils, pens, knives, brushes, air brushes, etc.

Repeat
The printing length (circumference of the printing surface) of a plate cylinder, determined by one revolution of the plate cylinder gear. The pitch circle circumference of the plate cylinder gear.

Reportable Quantity **RQ**
Amount of a hazardous or extremely hazardous substance that, if released into the environment, must be reported under EPCRA.

Resins
Generic name for photopolymers.

Resins
Natural or synthetic complex organic substances with no sharp melting point which, in a solvent solution, form the binder portion of flexo inks.

Resource Conservation and Recovery Act **RCRA**
Environmental law in the U.S aimed at controlling the generation, treating, storage, transportation and disposal of hazardous wastes.

Release Agents
Solutions and sprays applied to the back of photopolymer and rubber plates to facilitate their removal from the stickyback. These should only be used with great care by experience personnel.

Release Liner
In printing labels, the part of the substrate which

carries the facestock through the press and is ultimately discarded.

Resample
To change the digital image's resolution while keeping its pixel dimensions constant.

Resolution
A measure of sharpness in a digital image, expressed as dots per inch (or millimeter), pixels per inch or lines per inch.

Resource Recovery
The extraction of useful materials or energy from solid waste.

Retarders
Low-volatile solvents added to ink to slow the rate of evaporation.

Reticulation
A print fault where the ink runs into lines, possibly caused by over-thinning the ink with solvent.

Retrofit
The addition of a pollution control device or the modification of a piece of equipment on an existing facility without making major changes.

Reuse
The act of using a material over again for the same or some other beneficial purpose. *See also Recycling.*

Reverse
To change the tonal orientation of an image, making the darker elements lighter and the lighter darker. Note that physically reversing the spatial orientation of an image is known as "flopping" the image.

Reverse Printing
Printing on the underside of a transparent film.

Rewetting
The process of refilling the anilox cells with ink after they are emptied on the surface of the printing plate. It is also subsequent printed ink dissolving previously applied ink.

Rewind
After the substrate has been printed with the desired images, it is taped to a shaft and wound back into the original roll form for further processing.

RGB
Red, green and blue, the primary additive colors, which are the backbone of computer color display monitors and prepress color separation. They also are the complementary or secondary subtractive ink colors which produce red by overprinting magenta and yellow, green by trapping cyan and yellow, and blue by overprinting cyan and magenta.

RH
See Relative Humidity.

RHEM Light Indicator
A test strip which indicates whether or not a light source is D50. A version is available from GATF.

Rheology
1. The science dealing with the deformation and flow of matter. 2. The ability to flow or be deformed.

Rhodamine Reds
A class of clean, blue shade organic red pigment, possessing good light fastness and often called magenta in process printing.

RIFF
See Raster Image File Format.

Right Reading, Emulsion-Side Down **RRED**
The description of positive or negative paper/film on which the text, if any, can be read as normal, i.e., from left to right.

Right Reading, Emulsion-Side UP **RREU**
The description of positive or negative paper/film on which the text, if any, can not be read as normal, i.e., from left to right.

Ring Crush
A test to establish the amount of force required to crush a narrow specimen of paperboard that is inserted into a special holder with a circular groove. This test establishes a number corresponding to the on-edge stiffness of materials and is applicable to linerboard and corrugated medium.

RIP
See Raster Image Processor.

Risk
A measure of the chance that damage to life, health, property or the environment will occur.

Risk Assessment
A process to determine the increased risk from exposure to environmental pollutants, together with an estimate of the severity of the impact.

Risk Management
The process of identifying, evaluating, selecting and implementing actions to reduce risk to human health and the environment. The goal of risk management is to select scientifically sound, cost-effective, integrated actions that reduce or prevent risks.

Roll-Out
Fluid ink printed on a substrate using a Meyer rod applicator. Also known as bardown.

Ross Boards
Pattern-surfaced drawing boards which permit the artist to obtain a variety of tones between pure white and black directly on the original drawing.

Rough Sketch
An artist's impromptu drawing of a picture or design, often in color, that can develop into comprehensive artwork.

Rounding Error
The process of allocating imaging-device dots to bar or space modules in an uneven manner.

RQ
See Reportable Quantity.

KEY:

Barcode
Design
Environment
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Mounting/ Proofing
Plates
Prepress
Press
Process Color
Quality
Substrate

RRED
See Right-Reading, Emulsion-Side Down

RREU
See Right-Reading, Emulsion-Side Up

RSC
See Regular Slotted Container.

RTO
See Regenerative Thermal Oxidizer.

Rub Test
See Abrasion Test.

Rubber
An elastomer material capable of recovering from large deformations quickly and forcibly.

Rubylith
A hand-cut , red or orange, masking film.

Run Chart
A chart showing successive values of a measured variable. The horizontal axis represents successive measurements, usually but not always at equal time intervals.The vertical axis represents the value of the measurement.

Run Target
The minimal set of graphic elements placed, if possible, in the live image area, used to monitor the production run process. It is a specific target as specified by FIRST, available from the FTA. *See also Control Target.*

Running Register
That control on a flexographic press which accurately positions the printing of each color station in the direction of the web travel. Also called circumferential register and longitudinal register.

Runout
See Total Indicated Runout.

S

Sampling
The statistical process of collecting data or observations.

Sans Serif
Letterforms or type that does not contain the short crossline or spiral-like terminals at the ends of the stroke.

SARA
Superfund Amendments and Reauthorization Act; *see Superfund.*

Satin Finish
A smooth finish of paper or paperboard, suggestive of satin.

Saturation
Purity of hue or the degree of hue as seen by the eye; color saturation.

Saturation
1. The extreme degree of concentration beyond which a solute can no longer be dissolved into a solvent, or, similarly, in which a substance can no longer be absorbed into another medium;
2. The point beyond which air can no longer absorb water vapor.

SBAP
See Small Business Assistance Program.

SBO
See Small Business Ombudsman.

SBREFA
See Small Business Regulatory Enforcement Fairness Act.

SBS
See Solid Bleached Sulfate.

Scanner
An optical device which uses a laser beam to "read" the encoded data in a bar code by optically detecting the bars and spaces.

Scanner
A digitizing device using light sensitivity to translate a picture or typed text into a pattern of dots which can be understood and stored by a computer. Some types of scanners are flatbed, sheet-fed, hand-held, slide and drum scanners.

Scatter Diagram
A graph used to show the correlation between two measurements or variables. The value of one variable is plotted against the value of the second. Values plotted and falling in a straight line indicate a correlation, whereas values plotted randomly or scattered in the graph indicate no correlation.

Score
To make an impression or a partial cut in a material to facilitate its bending, creasing, folding or tearing.

Score Cut
To make a cut by rotating a pressure-loaded blade against a smooth, hard backup surface.

Scratches
Ink that is removed by a stationary object in contact with the web. *See also Dragging.*

Scratchboards
Plain, white, coated boards which may be covered with India ink or some other black coating, to "draw", a scratchboard tool is used to scratch through the ink, exposing white lines or areas.

Screen Angle
The angle of the rows of dots in a halftone.

Screen Printing
In flexo, refers to any tone printing work, whether halftone or Ben Day.

Screen Resolution
1. A measure of the number of colors that can be displayed on a monitor, such as 8-bit (256) or 16-bit (63,536); 2. The number of horizontal and vertical lines on a raster display.

Screen Ruling
The number of lines per inch in a halftone.

Screen Sizes
See Screen Ruling.

Screen Tint
See Halftone Tint.

Scribe Lines
The fine lines on the surface of the plate cylinder in an evenly spaced horizontal and vertical position to aid in mounting rubber plates accurately. Center lines or other positioning guide lines applied to the nonprinting areas of a rubber printing plate to facilitate mounting on a cylinder.

Scrubber
An air pollution device that uses a spray of water or reactant, or a dry process, to trap pollutants in emissions.

Scuff
1.The action of rubbing against with applied pressure. 2. The damage which has taken place through a rubbing.

Secant Modula
A measure of stiffness used for polymeric films.

Secondary Colors
Those obtained by mixing any two of the primary colors in equal proportions. Subtractive secondary colors are red, green and blue. Additive secondary colors are cyan, magenta and yellow.

Secondary Standards
Limits set to protect plants, wildlife, building materials and cultural monuments.

Section 313 Toxic Chemical List
A list of approximately 320 specific chemicals and chemical categories subject to CERCLA requirements.

Sell Copy
The text on the package, which describes and the promotes the product, opposed to bar code and nutrition information.

KEY:

Design
Environment
General
Ink
Plates
Prepress
Press
Process Color
Substrate

Semichemical Medium
A corrugated medium made from a furnish which is 75% or more of virgin wood pulp produced by a semichemical process.

SEP
See Supplemental Environmental Project.

Separations
A set of three or four continuous tone or halftone photographic films made photographically or electronically from an original subject. Each film represents one of the printer colors abstracted and are used to make printing plates in color process printing.

Serif
The short crossline or spiral-like terminals at the ends of the stroke of a Roman-style type face.

Serigraph
A color print made by the silk screen process – especially when printed by the artist.

Serious
A category of nonattainment where sources of NO_X or VOCs of 50 tons per year or more are affected.

Set
The strain remaining after complete release of a load, producing the deformation in rubber.

Set Off
An unintended transfer of an ink or a coating from the surface of one sheet to the back of another sheet.

Setup
The process or processes that take place when the printer changes from one production order to the next. Often includes the changing of ink, printing plates, metering system, and substrate, as well as any in-line finishing equipment.

Severe
A category of non-attainment where sources of NO_X or VOCs of 25 tons per year or more are affected.

Sewer
A channel or conduit that carries waste and storm waters to a treatment plant for receiving water.

Sewer Use Ordinance **SUO**
The local control authority document that sets forth the conditions under which domestic and nondomestic users may discharge to a POTW.

SG
See Specific Gravity.

Shade
1. A color produced by adding black to a pigment or dye, therefore darkening it; opposite of tint; 2. In ink manufacture, a commonly used synonym for hue.

Shading
The addition of a color, shade or tone to suggest three-dimensionality, shadow or diminished light in a picture or design.

Shadows
The darkest area of a reproduction.

Sharpen
1.To decrease in color strength, as when halftone dots are made smaller; opposite of dot gain; 2. To bring out the detail in an image by enhancing the edges.

Shear
The relative movement of adjacent layers in a liquid or plastic during flow.

Shear Thickening
See Dilatent.

Shear Thinning
See Thixotropic.

Sheeter
1. A unit on press that converts forms into smaller sheets; 2. A specific web press delivery unit that cuts the printed web into individual sheets; 3. A separate device used in screen printing to cut cloth or other substrates into sheets.

Shelf Life
The length of time that a container, or a material in a container, will remain in an acceptable condition under specified conditions of storage.

Shelf-talkers
Small signs affixed to the display shelf edge.

Shell Cup
A device to measure viscosity. *See also Efflux Cup.*

Shellac
An alcohol-soluble, natural resin widely used in flexo inks.

Shore A
The A-type gauge, on a scale from zero (softest) to 100 (hardest), used to measure durometer of photopolymer plates. Shore D is used for harder products.

Shore D
The D-type gauge, on a scale from zero (softest) to 100 (hardest), used to measure durometer of photopolymer plates. Shore A is used for soft, resilient compounds.

Short-term Exposure Limit **STEL**
The concentration to which workers can be exposed continously for a short period of time without suffering from irritation, chronic or irreversible tissue damage or narcosis of sufficient degree, to increase the likelihood of accidental injury, impair self-rescue or materially reduce work efficiency.

Show-through
The undesirable condition where the print on the reverse side of a sheet can be seen through the sheet under normal lighting conditions.

SIC Code
See Standard Industrial Classification Code.

Side Guide
See Edge Guide.

Sidelay
In web printing, the lateral placement of a substrate as it travels through the printing unit and subsequent in-line devices. *See also Edge Guide*.

Side Weld
In bag-making, it is the seal formed by a hot knife cutting through two layers of a thermoplastic material, like polyethylene, and sealing that edge.

Sigma
See Standard Deviation.

Significant Industrial User **SIU**
A nondomestic indirect discharger to a POTW, which is either a CIU, who discharges more than 25,000 gallons per day, contributes more than 5% of the POTW's hydropic or organic load, or has the potential to adversely affect the POTW.

Significant Noncompliance **SNC**
One who is seriously deficient in adhering to the National Pretreatment Standards.

Silver Recovery
The process of reclaiming silver from silver-rich solutions such as fixers and low-flow washes.

Silver-Rich Solution
A solution containing sufficient silver that cost-effective recovery could be done either on-site or off-site. Silver-rich solutions include fixers and low-flow wash.

Singlefacer
The part of a corrugator which takes a roll of linerboard and medium, and combines them into singleface board. The corrugating rolls in the singlefacer form the medium into flutes, then adheres the fluted medium to the linerboard with adhesive applied to the flute tips.

SIU
See Significant Industrial User.

Sizing
The addition of materials to a paper-making furnish or the application of materials to the surface of paper and paperboard, in order to provide resistance to liquid penetration.

Skeleton Black
A black-and-white printer that prints only the middle tone to shadow portion of the gray scale.

Skip-out
Poor or no ink transfer onto the substrate, evident as a partial image or a missing portion of it, possibly caused by low areas of the plate.

Skips
Missing print, often caused by plate bounce, gear chatter or poorly set impression.

SKU
See Stock-keeping Unit.

Slip Compound
An ink additive which imparts lubricating qualities to the dried ink film.

Slip Film
A thin film remaining on the surface of sheet photopolymer after the removal of the cover sheet, to prevent adhesion of the polymer to the plate-making negative during exposure.

Slip Sheet
A material between sheets of film, foil, paper, board, etc. to prevent blocking, by keeping them separate from one another. It facilitates removal of sheets.

Slit
To cut rolls of stock to specified widths. Either rotary or stationary knives or blades are used with mechanical unwinding and rewinding devices.

Slitter
A machine to cut roll stock in the long direction. Three types are widely used: razor blade slitter, shear slitter and score cutter.

Sludge
Any solid, semisolid, or liquid waste generated from a municipal, commercial or industrial wastewater treatment plant, water supply treatment plant or air pollution control facility, exclusive of the treated effluent from a wastewater treatment plant.

Slug
A rubber-plate section, usually type, used as an insert.

Slur
A condition caused by slippage at the moment of impression between substrate and plate.

Small Business
There are a variety of definitions. Under the CAAA, a small business is defined as a non-major source having 100 or fewer employees. The Small Business Administration defines a small business as having 500 or fewer employees.

Small Business Assistance Program **SBAP**
Provides technical assistance needed by small businesses to comply with the Clean Air Act. For more information, call (919) 541-5437.

Small Business Ombudsman **SBO**
Acts as the small business community's representative in matters that affect them under the Clean Air Act. For more information, call (800) 368-5888.

Small Business Regulatory Enforcement Fairness Act **SBREFA**
Federal law enacted in 1996 to protect small business from potentially excessive regulatory burdens imposed by federal agencies.

Small Business Stationary Source Technical and Environmental Compliance Assistance Program
Established by Section 507 of the Clean Air Act Amendments of 1990 to help small businesses contend with new air-pollution control responsibilities. In each state, it consists of a Small Business Ombudsman and Small Business Assistance Program.

Small Commercial Imaging Facility
A facility that produces, on average, less than two GPD of silver-rich solution.

KEY:

Barcode
Design
Environment
General
Ink
Mounting/ Proofing
Plates
Prepress
Press
Process Color
Quality
Substrate

Small Quantity Generator **SQG**
Persons or facilities that produce 220 to 2,200 pounds per month of hazardous waste.

Smog
A mixture of pollutants, principally ground-level ozone, produced by chemical reactions in the air involving smog-forming chemicals exposed to sunlight. Smog formers include VOCs and NO_X.

SNC
See Significant Noncompliance.

Soap Resistance
The relative ability of an ink to withstand the action of detergent agents in soap, to be distinguished from alkali resistance.

Softening Point
The temperature at which plastic material will start to deform without an externally applied load.

Softwood
Wood from coniferous trees.

Solid Bleached Sulfate **SBS**
Paperboard made from bleached wood pulp, usually clay-coated, on one or both sides, to improve printability.

Solid Waste
As defined under RCRA, any solid, semi-solid, liquid or contained gaseous materials discarded from industrial, commercial, mining or agricultural operations and from community activities.

Solid Waste Management System
Any disposal or resource recovery system; any system, program or facility for resource conservation; any facility for the treatment of solid waste.

Solids Content
The percentage of nonvolatile matter of which a compound or mixture is composed, based on weight of the entire mixture.

Solvent
A substance that is liquid at standard conditions and is used to dissolve or dilute another substance. This term includes, but is not limited to, organic materials used as dissolvers, viscosity reducers, degreasers or cleaning agents. Water is considered the universal solvent.

Solvent Coating
A tthin layer or covering, applied in liquid form, which dries by evaporation.

Source Reduction
The design, manufacture, purchase or use of materials (i.e., products and packaging) to reduce the amount or toxicity of garbage generated.

Source Separation
Separating waste materials such as paper, metal and glass by type at the point of discard so that they can be recycled.

Source-specific Wastes
This list includes certain wastes from specific industries. Certain sludges and waste waters from treatment and production processes are examples.

Souring
See Ink Souring.

SO_X
See Sulfur Dioxide.

SPC
See Statistical Process Control.

Specific Gravity **SG**
The ratio of the weight of a body to the weight of an equal volume of water at the same specified temperature.

Specifications for Web Offset Publications
A set of production specifications developed for those involved in heatset, web-offset litho magazine publication printing, available from SWOP Incorporated.

Spectral Curve
A graphic plot indicating the amount of light energy reflected, emitted or transmitted by an object for each wavelength in the visible spectrum.

Spectral Data
The data used to plot the spectral curve.

Spectral Response
In an instrument such as densitometer, it is the measure of its signal during exposure to radiation of a constant power level and varying wavelength. *See also Densitometer Response.*

Spectrophotometer
A photoelectric device for measuring the relative intensity of wavelengths in the visible spectrum. Usually the intensity is measured in 10 or 20 nm increments from 380 to 740 nm.

Spectrophotometric Curve
See Spectral Curve.

Spectrum
The series of color bands diffracted and arranged in the order of their respective wavelengths by passing white light through a diffracting medium, shading continuously from red (the longest wavelength visible) to violet (the shortest wavelength visible).

Specular Highlight
A small, clear area in a tone field indicative of high-gloss reflection or sparkle.

Spent Material
Any material that has been used and, as a result of contamination, can no longer serve the purpose for which it was produced without first processing it.

Splashing
When ink is thrown off the press by the inking rollers.

Splice
The joining of the ends of rolled material to form a continuous web.

Splitting
See Flying, Misting.

Spontaneous Combustible
A material that ignites as a result of retained heat

from processing, or that will oxidize to generate heat and ignite, or that absorbs moisture to generate heat and ignite.

Spot Color
See Line Color.

Spread
The enlargement of a printed image from the plate film to the printing plate or the printed image. *See Dot Gain*.

SQG
See Small Quantity Generator.

Stabilizer
See Fixer.

Stable Overlays
A transparent sheet of material used as part of the finished art that will not stretch or shrink.

Stack Press
A flexo press, where the printing stations are placed one above the other, each with its own impression cylinder.

Staining
When two different colored inks touch or overlap each other, the result is a third color, or stain.

Standard Deviation
A statistical measure of the deviation of a measured value from its mean or average value. Also called sigma.

Standard Industrial Classification Code **SIC**
A method of grouping industries with similar products or services and assigning codes to these groups for use by government in identification of similar industry activities, outreaching for information, collecting statistics and evaluating performance by industry sectors.

Standard Reference Material
A physical sample with characteristics traceable to an accepted primary standard or set of standards. It is commonly used for densitometer calibration or calibration verification. One standard reference material of interest is the SWOP™ Hi-Lo Color and Single Color References. These references may be obtained from the International Prepress Association.

Starvation
A print defect, apparent as voids or light shades of the intended color being printed. It is caused by either poor anilox cell rewetting, by trapped air in chambered doctor-blade system and/or ink balance problems.

Stat
A thermal proof or copy of final art before making platemaking film. *See Photostat.*

Static
Electricity contained in or produced by stationary charges. With reference to films, static causes them to cling to one another or to other insulating surfaces.

Stationary Source
A place or object from which pollutants are released and which does not move around, i.e,. a printing press or coating/laminating line.

Statistical Process Control
The use of statistics and statistical tools to characterize a process, predict its future behavior and optimally control the process.

Statistics
A collection of quantitative data useful for analyzing, interpreting and establishing a course of action.

Statutes
The acts or amendments (laws) that give authority to regulation.

STEL
See Short-term Exposure Limit.

Step and Repeat
Positioning and exposing multiple complete images on film in preparation for platemaking.

Stickyback
The double-faced adhesive-coated material used for mounting elastomeric printing plates to the plate cylinder.

Still Bottom
Solid or sludge residue or by-product of a distillation process, such as solvent recycling.

Stippling
Artwork in which a series of miscellaneous and usually random dots are used instead of lines.

Stochastic Screening
An alternative to conventional halftone screening by placing same-size microdots (typically 12 to 30 microns diameter) in a computer-controlled random order within a given area. Also known as frequency modulation (FM) screening.

Stock
Paper or other material to be printed; substrate.

Stock-keeping Unit **SKU**
An assortment or variety of wholesale items shipped in one physical case.

Storage Life
See Shelf Life.

Stormwater Permit
Required for areas where material handling equipment or activities, raw materials, intermediate products, final products, waste materials, by-products or industrial machinery are exposed to storm water that drains to a municipal separate storm water system or directly to a receiving water.

Stormwater Pollution Prevention Plan **SWPPP**
Often required by a stormwater permit, a written plan that identifies good engineering practices to maximize control of pollutants and reduce levels of pollutants in stormwater discharges.

Strength
The color intensity of (flexographic) ink.

Stretch
Extensibility of web materials under tension. The

KEY:

Barcode
Design
Environment
General
Ink
Mounting/ Proofing
Plates
Prepress
Press
Process Color CMYK
Quality
Substrate

elongation of a design in an elastomeric relief-printing plate when mounted around a cylinder.

Stretch/Shrink Factors
Calculations of dimensional change, which occur in rubber-plate molding and in all plate mounting, when a flat plate is applied to the curve of the plate cylinder.

Striations
A printing defect characterized by light and dark streaks parallel to the direction through the press.

Strike-Through
The penetration of ink through the substrate visible from the reverse side.

Stringiness
The property of an ink to draw into filaments or threads.

Stripping
Job assembly, where all the elements for the job are brought together to produce the final output files. The term is derived from the traditional process, where separate film negatives were manually assembled onto a carrier sheet.

Stylus
A hard, pointed pen-shaped instrument used in marking, writing, incising, tracing, etc.

Sublimable Dyes
Dyes that exhibit sublimation.

Sublimation
The process in chemistry whereby a solid is volatilized by heat and then converted back into a solid without passing through a liquid phase.

Substance
The weight in pounds of a ream (either 480 or 500 sheets) of paper cut to a given size.

Substrate
The material which is printed upon, i.e., film, paper, paperboard.

Subtractive Primaries
The colors yellow, magenta, cyan. These colors are the result of substracting one of the additive primaries (red, green, blue) from white light. Yellow subtracts blue, magenta subtracts green, cyan subtracts red. Combining all three in a subtractive process, such as ink on paper, yields black.

Sulfate
See Sulphate.

Sulfite
See Sulphite.

Sulfur Dioxide SO_2
A criteria air pollutant that is a gas produced from burning coal.

Sulphate (Sulfate)
An alkaline process of cooking pulp. It is often referred to as Kraft process; pulp cooked by this process.

Sulphite (Sulfite)
An acid process of cooking pulp. Also the pulp cooked by this process.

SUO
See Sewer Use Ordinance.

Supercalendared Finish
A finish obtained by passing paper between the rolls of a supercalendar under pressure. Supercalendars used for uncoated paper are usually composed of alternating chilled, cast iron and paper rolls. For coated paper, the rolls are usually chilled cast iron and cotton. Papers supercalendared to a very high gloss are sometimes referred to as “plate finished”.

Superfund
The program operated under the legislative authority of CERCLA and SARA that funds and carries out USEPA solid waste emergency and long-term removal and remedial activities. These activities include establishing the National Priorities List, investigating sites for inclusion on the list, determining their priority and conducting and/or supervising the cleanup and other remedial actions.

Supplemental Environmental Project **SEP**
A voluntary environmental project performed in lieu of monetary penalty for noncompliance that will benefit the industry and community at large.

Surface Energy
A force existing at various solid, liquid and gas interfaces which tends to bring the contained volume into a form having the least superficial area. Surface energy units are expressed in dynes/cm.

Surface Impoundment
Double-lined, natural or fabricated, depressions or diked areas that can be used to treat, store or dispose of hazardous waste. Surface impoundments may be any shape and any size and are sometimes referred to as pits, ponds, lagoons and basins.

Surface Print
Conventional flexo printing resulting with a right-reading image on the top surface of the web. *See reverse print*.

Surface Tension
See Surface Energy.

Swatch
A small piece of material cut for a sample.

SWOP
See Specifications for Web Offset Publications.

SWPPP
See Stormwater Pollution Prevention Plan.

Synthetic Minor
Source with limited potential to emit below major source thresholds by having federally enforceable limitations that are approved by a regulatory agency.

T

Tabulate
To set or arrange copy in symmetrical rows and columns.

Tack
The resistance between two surfaces when pulled apart.

Tail-End Printer
See In-Line Press.

Tailprinter
See In-Line Press.

Tagged Image File Format **TIFF**
A file format for graphics developed by Aldus, Adobe and Apple that is particularly suited for representing scanned images and other large bitmaps. The original TIFF saved only black-and-white images in uncompressed forms. Newer versions support color and compression. TIFF is a neutral format designed for compatibility with both Macintosh and MS-DOS applications.

Tagged RGB
An RGB file which includes the image data and ICC profile of the input device which generated the file.

Tank
A stationary device designed to contain an accumulation of hazardous waste that is constructed primarily of non-earthen materials (e.g., wood, concrete, steel, plastic).

TCLP
See Toxicity Characteristic Leaching Procedure.

TCRIS
See Toxic Chemical Release Inventory System.

Tear Strip (Tape)
A narrow ribbon of film, cord, etc., usually incorporated mechanically in the wrapper or overwrap during the wrapping operation to facilitate opening of the package.

Tearing Bond
A type of bond in which it is necessary to tear fibers of one of the other adhered sheets in order to separate them, while at the same time there is no failure in adhesion or cohesion of the adhesive.

Teflon®
A inert polymer of fluorinated ethylene, and in the form of a film, or an impregnator, is used for its heat-resistance and nonsticking properties.

Telescoping
Transverse slippage of successive winds of a roll of material, so that the edge becomes conical rather than flat.

Tempera
1. A water-reducible, opaque, matte-finish paint in which an albuminous or colloidal medium, such as egg yolk, is the vehicle instead of oil or varnish; 2. A showcard or poster color.

Temporary Total Enclosure **TTE**
A temporary enclosure that completely surrounds an emission source such that all VOC emissions can be measured during capture efficiency testing. Used for testing only, in lieu of having source(s) in a permanent total enclosure.

Tensile Strength
The maximum load in tension that a material can withstand without failure.

Tension Control
The mechanical control of unwinding, processing and rewinding paper, film, foil and other roll materials.

Tertiary Colors
Those obtained by mixing two secondary colors.

Test Method 24
A method that applies to determination of volatile organic matter content, water content, density and weight solids of surface coatings. Refer to 40 CFR 60, Appendix A.

Test Method 24A
A method that applies to the determination of the VOC content and density of solvent-borne (solvent reducible) printing inks and related coatings. Refer to 40 CFR 60, Appendix A.

Test Method 25
A method that applies to the measurement of VOCs as total gaseous nonmethane organics as carbon in source emissions. The minimum detectable for the method is 50 ppm as carbon. Refer to 40 CFR 60, Appendix A.

Test Method 25A
A method that applies to the measurement of total gaseous organic concentrations of vapors consisting of alkanes, alkenes and/or arenes (aromatic hydrocarbons). The concentration is expressed in terms of propane (or other appropriate organic calibration).

Thermal Conductivity
The physical property of a material relating its ability to conduct thermal or heat energy.

Thermoset
A material which hardens when heated, but does not soften when reheated.

Thinners
Liquids, solvents, and/or diluents added to ink for dilution or thinning.

Thixotropic
When viscosity decreases with agitation and returns to its original value when agitation ceases. Also called false body.

Thread
The initial passage of a web between the various rollers or other parts of a machine.

Threshold
The lowest dose of a chemical at which a specific measurable effect is observed, and below which, it is not observed. Also, the level specified in regulations above which a facility must comply with specific components of the regulations or file reports on a periodic basis.

KEY:

Barcode
Design
Environment
General
Ink
Mounting/ Proofing
Plates
Prepress
Press
Process Color
Quality
Substrate

Threshold Level
Time-weighted average pollutant concentration values, exposure beyond which is likely to adversely affect human health.

Threshold Limit Value **TLV**
As defined by the American Conference of Governmental Industrial Hygienists, it refers to the recommended maximum airborne concentrations of substances under which it is believed that nearly all workers may be repeatedly exposed to without experiencing adverse health effects.

Threshold Planning Quantity
The amount of a listed EHS present at a facility that triggers Section 302, 311 and 312 reporting requirements.

Throwing
See Flying.

Thumbnail
A rough, pencil drawing of a concept for a finished piece of artwork, to convey the positioning of relevant elements.

Tier I Form
A chemical inventory form established under Section 312 that groups chemicals into five hazardous categories.

Tier II Form
A chemical inventory form established under Section 312 that provides specific chemical information and is preferred by most states.

TIFF
See Tagged Image File Format.

Time Weighted Average
The airborne concentration of a material to which a person is exposed, averaged over the total exposure time (generally, the total workday).

Tinctorial Strength
See Color Strength.

Tint
A means of making a given color appear lighter in value by printing it in a dot or line pattern of less than 100% coverage in any given area.

Tint
Colors of a lighter value obtained by adding white to the basic color; opposite of shade.

TIR
See Total Indicated Runout.

Titanium Dioxide **TiO_2**
A filler or pigment made from titanium ores, which has great opacity and brightening properties and is of minute particle size.

Title III
The title of the Clean Air Act Amendments of 1990 that establishes standards controlling hazardous air pollutants.

Title V
The title of the Clean Air Act Amendments of 1990 that defines major source permitting.

TLV
See Threshold Limit Value.

Tonal Range
See Dynamic Range.

Tone
1. A color quality or value; 2. A tint or shade of color; 3. A predominant hue in a nearly neutral value.

Tone Reproduction
The relative density of every reproduced tone to the corresponding original density.

Toner
A dispersion of highly concentrated pigment or dye, used to manufacture, strengthen or modify the color of an ink.

Tone Value
See Dot Area.

Total Enclosed Treatment Facility
A facility for the treatment of hazardous waste that is directly connected to an industrial production process that is constructed and operated to prevent the release of hazardous waste into the environment during treatment. An example is a pipe in which waste is neutralized.

Total Indicated Runout **TIR**
A measure of the out-of-trueness of a cylindrical surface.

Total Suspended Solids **TSS**
A measure of the turbidity of water.

Toxic
Capable of causing severe illness, poisoning, birth defects, disease or death when ingested, inhaled or absorbed by a living organism.

Toxic Release Inventory **TRI**
A database of annual toxics released from certain manufacturers compiled from EPCRA Section 313 reports.

Toxic Release Inventory Facilities
Manufacturing facilities that have 10 or more full-time employees and are above established chemical throughput thresholds. Facilities must submit estimates for all chemicals that are on the USEPA's defined list and are above throughput thresholds.

Toxic Substance Control Act **TSCA**
Regulates the manufacture, handling and use of materials classified as toxic substances.

Toxic Substances
A chemical or mixture that can cause severe illness, poisoning, birth defects, disease or death when ingested, inhaled or absorbed by living organisms.

Toxicity Characteristic Leaching Procedure **TCLP**
A testing procedure used to determine whether a waste is hazardous. The procedure identifies waste that might leach hazardous constituents into groundwater if improperly managed.

Toxicity Characteristic Waste
Wastes which release toxic metals, pesticides or volatile organic chemicals above specified limits under a test procedure called the Toxicity Characteristic Leaching Procedure (TCLP).

TPQ
See Threshold Planning Quantity.

Tracking
See Kerning.

Tracking
A print defect where an unwanted image appears, often as a dark line in a light or solid print area. Tracking always occurs when two print stations, which are often next to each other, interact.

Trademark
A distinctive name, symbol or figure adopted by a manufacturer or other firm to identify the company and/or its products.

Transfer Roll
A plain roll rotating in contact with another plain roll, transferring variable amounts of ink in an inking system.

Transfer Screens
Halftone screens of different sizes that can be transferred from its original carrier sheet to the artwork by rubbing it with a stylus.

Transfer Sheets
Carrier sheets of type characters, design elements or halftone screens that will release the image when pressure is applied.

Transfer Type
Type characters of different sizes and styles that can be transferred from its original carrier sheet to the artwork by rubbing it with a stylus.

Transfers
A transfer of toxic chemicals in wastes to a facility that is geographically or physically separate from a facility reporting under TRI. The quantities reported present a movement of chemicals away from the reporting facility. Except for off-site transfers for disposal, these quantities do not necessarily represent entry of the chemical into the environment.

Transfers to Disposal
Wastes taken to another facility for disposal generally as a release to land or as an injection underground.

Transfers to Energy Recovery
Wastes combusted off-site in industrial furnaces for energy recovery. Treatment of a chemical by incineration is not considered to be energy recovery.

Transfers to POTWs
Waste waters transferred through pipes or sewers to a POTW. Treatment and chemical removal depend on the chemical's nature and treatment methods used. Chemicals not treated or destroyed by the POTW are generally released to surface waters or landfilled.

Transfers to Recycling
Substances sent off-site for the purposes of regenerating or recovering still valuable materials. Once these chemicals have been recycled, they may be returned to the originating facility or sold commercially.

Transfers to Treatment
Wastes moved off-site for either neutralization, incineration, biological destruction or physical separation. In some cases, the chemicals are not destroyed but prepared for further waste management.

Transmission Densitometry
The practice of characterizing the light absorption of materials by measuring transmittance, and calculating and reporting optical density.

Transparency
The photographic positive on a clear or transparent support, viewed by transmitted light. Commonly, the term is applied to full-color transparencies such as Kodachrome.

Transparent Inks
Inks which do not have hiding power (opacity), permitting light to pass through and selectively absorb light of specific wavelengths; essential to process printing.

Trapping
The overlapping of various colors in a design to prevent their separating and not touching as a result of registration variables during printing.

Trapping
The condition of printing ink on ink or superimposing one color on another, in which the first down ink film is sufficiently dry that when the next is printed over it optimum ink transfer is achieved.

Treatment, Storage and Disposal Facility TSDF
The facility where hazardous wastes are treated, stored and/or disposed.

TRI
See Toxic Release Inventory.

TRI Facilities
See Toxic Release Inventory Facilities.

TRIS
Toxic Release Inventory System.

Tristimulus
The magnitudes of three standard stimuli needed to match a given sample of light. A method for communicating or generating a color using three stimuli (colorants such as R, G, B or C, M, Y) or three attributes (such as lightness, chroma and hue).

Truncation
The process whereby a bar code is compressed in the height dimension beyond the allowable height and width specification.

TSCA
See Toxic Substances Control Act.

TSDF
See Treatment, Storage and Disposal Facility.

KEY:

Barcode
Design
Environment
General
Ink
Mounting/ Proofing
Plates
Prepress
Press
Process Color
Quality
Substrate

TSS
See Total Suspended Solids.

TTE
See Temporary Total Enclosure.

Tunnel
The compartment through which the web passes for final drying after printing.

Turning Bars
An arrangement of stationary bars on a flexo press which guide the web in such a manner that it is turned front to back, and will be printed on the reverse side by the printing units located subsequent to the turning bars.

TWA
See Time Weighted Average.

Two-roll System
The inking system commonly employed in flexographic presses, consisting of a fountain roll running in an ink pan and contacting the engraved anilox roll; the two as a unit, meter the ink being transferred to the printing plates.

Type
See Typeface.

Typeface
Variation of a font such as regular, italic, bold, condensed, extended.

Typography
The style, arrangement or appearance of typeset matter. The art of selecting and arranging typefaces.

U

UCA
See Undercolor Addition.

USC
See United States Code.

UCR
See Undercolor Removal.

ug/L
Micrograms per liter.

UIC
See Underground Injection Control.

Ultra-high Density
Refers to polyethylene resin with density above 0.965 g/cc.

Ultraviolet **UV**
Radiant energy in the wavelength band of 180 to 400 nanometers (nm), wavelengths shorter than visible light.

Ultraviolet (UV) Curing
Conversion of a wet coating or printing ink film to a solid film by the use of ultraviolet light.

Ultraviolet (UV) Light
Commonly called UV light. UV-A has a wavelength bandwidth of 320 to 400 nanometers, UV-B has a wavelength bandwidth of 280 to 320 nanometers and UV-C has a wavelength bandwidth of 180 to 280 nanometers. UV activates the photoinitiator in photo-cureable polymers.

Ultraviolet (UV) Response
Refers to that response specified as Type 1 in ISO 5/3. This is generally used for measuring densities when printing to UV/blue sensitive materials. Type 1 (UV) printing density was standardized to provide printing density values for use when exposing diazo and vesicular films normally sensitive in a narrow band of the blue and ultraviolet region of the spectrum, between 380 nm and 420 nm with a peak at 400 nm.

Unbalance
The uneven distribution of weight or forces in a roll. There are two types of unbalance: static and dynamic.

Unbleached
A term applied to paper or pulp which has not been treated with bleaching agents.

Uncoated Free Sheet
An uncoated paper used for printing, writing, and related application, made almost entirely from chemical wood pulps.

Undercolor Addition **UCA**
A prepress method of intensifying dark, neutral gray areas in process color reproduction by selectively increasing cyan, magenta and yellow dot areas.

Undercolor Removal **UCR**
The balanced reduction of cyan, magenta and yellow in ann image's shadow areas, with an increase of the black to maintain the dark and near neutral shadows.

Undercut
Engraving, where side-wall areas have been etched under the printing surface.

Underground Injection Well
Steel and concrete-encased shafts into which hazardous wastes are deposited by force or under pressure.

Undertone
See Overtone.

Undistorted Artwork
Artwork that has been prepared without compensation for the distortion that takes place after the printing plate has been mounted on the printing cylinder.

U.P.C.
See Universal Product Code.

United States Code **USC**
Prepared and published by the Office of the Law Revision Counsel, it is a consolidation and codification by subject matter of the general and permanent laws of the United States.

Universal Product Code **UPC**
A 12- or 8-digit code number that identifies a wide range of products, printed on packages as the UPC bar code symbol which can be read electronically by a scanner at retail store checkout counters.

UST
Underground Storage Tank. *See also AST (Above Ground Storage Tank).*

UV
See Ultraviolet.

KEY:

Barcode
Design
Environment
General
Ink
Mounting/ Proofing
Plates
Prepress
Press
Process Color
Quality
Substrate

V

Vacuum Back
The top or back of a process camera with a vacuum system used to hold the photographic paper or film in place during exposure.

Vacuum Forming
The process of heating a plastic until it is soft, placing it over a mold and then creating the form by means of a vacuum.

Vacuum Frame
In platemaking, a vacuum device for holding copy and reproduction material in contact during exposure.

Vapor
The gas given off by substances that are solids or liquids at ordinary atmospheric pressure and temperatures.

Vapor Capture System
Any combination of hoods and ventilation systems that captures or contains organic vapors so they may be directed to an abatement or recovery device.

Vapor Phase Inhibitor **VPI**
See Volatile Corrosion Inhibitor.

Vapor Pressure
The pressure exerted by a saturated vapor above its own liquid in a closed container.

Vapor Transmission
1. The passage of vapor (usually water vapor) through a material. 2. The properties of a packaging material permitting the passage of vapor.

Variance
Government permission for a delay or exemption in the application of a given law, ordinance or regulation.

Varnish
The binder component of an ink. Also resin.

Vector
A line between two points. Vectors are created and displayed on the screen with drawing software. Vector drawings can be processed as a series of points and connections that are compact for a computer to store and manipulate.

Vector Display
A cathode-ray tube (CRT) that moves the electron beam randomly to trace figures on the color monitor screen, as compared with raster display.

Vehicles
The liquid components of a printing ink.

Vellum
High quality translucent paper used for tracing.

Velox
A black-and-white photographic paper print (proof) made from a negative film; originally an Eastman Kodak Company chloride printing paper and today used erroneously as a generic term for similar proofs.

Vertical Process Camera
A large, vertical camera used for making enlargements or reductions on photographic film or paper.

Vignette
A halftone image in which the background gradually fades away until it blends into the unprinted substrate or a solid print. Also called “fade”. The term is occasionally used to indicate a conventional halftone.

Vinyl
Informal, generic term for any of the vinyl resins, or for film or other products made from them.

Vinyl Plastics
Plastics based on resins made from vinyl monomers, except those specifically covered by other classifications such as acrylic and styrene plastics. Typical vinyl plastics are polyvinyl chloride, polyvinyl acetate, polyvinyl alcohol, polyvinyl butyral, copolymers of vinyl monomers and unsaturated compounds.

Viscometer
An instrument used to measure the viscosity of an ink, varnish or other solution.

Viscosimeter
See Viscometer.

Viscosity
A measure of a fluid’s (ink, coating) resistance to flow which influences the amount of ink (color) printed.

VOC
See Volatile Organic Compound.

Voids
The undesirable absence of ink or presence of dirt within a bar of a bar code symbol.

Volatile
Easily passing from a liquid into a gaseous state. Subject to rapid evaporation. Having a high vapor-pressure at room temperature.

Volcanoes
See Pock Marks.

Volatile Corrosion Inhibitor
A chemical which slowly gives off a vapor that reduces or inhibits corrosion. It is uusually applied to paper.

Volatile Organic Compound **VOC**
Any organic compound that evaporates readily into the atmosphere. Examples include isopropyl alcohol and toluene.

Vulcanization
A curing process to change the physical properties of a rubber.

Vulcanizing Press
See Molding Press.

W,X,Y,Z

Washboarding
A print fault in corrugated, characterized by darker lines appearing at the flutes from the uneven surface of the corrugated board. It is caused by the liner as it dips lower where there is no flute and higher where there is a flute.

Wash Drawings
Drawings which contain a thin coat of paint, such as watercolor.

Waste Prevention
The design, manufacture, purchase or use of materials or products to reduce their amount or toxicity before they enter the municipal solid waste stream. Because it is intended to reduce pollution and conserve resources, waste prevention should not increase the net amount of toxicity of wastes generated throughout the life of a product.

Waste Stream
The total flow of solid waste from homes, businesses, institutions and manufacturing plants that are recycled, burned or disposed of in landfills, or any segment thereof.

Wastewater Treatment Unit
A tank or tank system that is subject to regulation under either Section 402 or 307(b) of the Clean Water Act, and that treats or stores an effluent waste water that is hazardous waste, or that treats or stores a wastewater treatment sludge that is hazardous.

Water Vapor Transmission Rate **WVTR**
The actual rate of water vapor transmission used to compare water vapor barriers; formerly called moisture vapor transmission rate.

Water-based Ink
An alternative to solvent-based inks, these contain a vehicle whose binder is water-soluable or water dispersible.

Water-borne Ink
According to the control techniques guidelines (CTG) for flexography, water-borne inks should consist of a volatile portion of 75% of water and 25% organic solvent by volume. Note, however, that the definition of a water-borne ink can vary depending on the regulatory agency.

Watermark
A translucent mark made in paper while it is still set for purposes of identification.

Web
The paper, foil, film or other flexible material, from a roll, as it moves through the machine in the process of being formed or in the process of being converted, printed, etc.

Web Guide
The device which keeps the web traveling in a straight or true path through the press.

Web Temperature
The temperature of the web in the oven as differentiated from the oven temperature.

Wet Strength
A measure of the physical strength properties of paper when saturated with water (i.e, wet tensile strength, wet bursting strength).

Wettability
See Wetting Out.

Wetting
Surrounding the pigment particles with varnish during the ink-making process. Pigments that wet out easily will, in general, grind more easily, form better ink bodies and result in a finer dispersion.

Wetting Agent
A chemical agent used to overcome the reluctance of a liquid to coat the surface of a dissimilar material by reducing surface tension of the liquid.

Wetting Out
The ability of an ink to lay down smoothly and evenly on the substrate as opposed to laying down in beads on the surface.

Whip
See Bounce.

White Opaque Polyethylene **WhOPE, WITE**
A film frequently used for frozen foods packaging.

Whole Effluent Toxicity **WET**
This test measures the total toxic effect of discharges on aquatic organisms.

WhOPE
See White Opaque Polyethylene.

Wicking
The absorption of moisture into paperboard through the raw edge.

Wire Mark
The impression left in a web of paper by the wire of a Fourdrinier machine.

Wire Side
The side of a sheet of paper or paperboard that was formed in contact with the wire of the paper machine during the process of manufacture.

WITE
See White Opaque Polyethylene.

Work Area
A room or defined space in a workplace where hazardous chemicals are produced or used, and where employees are present.

Workplace
An establishment at one geographical location containing one or more work areas.

WVTR
See Water Vapor Transmission Rate.

X-Dimension
The specified width of the narrow element in a bar code symbol.

Xerography
An imaging process in which electrostatically charged powder (toner) is boned to paper using

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heat. It is the method used by laser printing systems to create an image onto document media. Also called electrophotography.

Yellow
See Process Yellow.

Yield
The amount of substrate that can be covered with a given volume of liquid ink.

Yield
The number of square inches of film per pound or product per mil.

Yield Strength
The value at which permanent deformation takes place in an elastic material under stress.

YMC
Yellow, Magenta, Cyan.

Yule-Neilsen (Y-N) Factor
Used to calculate the physical dot area or actual dot size, usually for analytical purposes. It eliminates the optical dot gain with an “n” factor.

Zahn Cup
A device for measuring viscosity. *See Efflux Cup.*

Organizations

ACGIH
See American Conference of Governmental Industrial Hygienists.

AFPA
See American Forest and Paper Association.

AICC
See Association of Independent Corrugated Converters.

AIM
Automatic Identification Manufacturers.

American Conference of Governmental Industrial Hygienists **ACGIH**
An organization of professional personnel in governmental agencies or educational institutions engaged in occupational safety and health programs.

American Forest and Paper Association **FPA**
A national trade association of the forest, paper and wood products industries.

American National Standards Institute **ANSI**
The USA member of the International Standards Organization (ISO) that develops voluntary standards for business and industry.

American Society for Testing and Materials **ASTM**
The world's largest source of voluntary consensus standards for materials, products, systems and services. It is a resource for sampling and testing methods, health and safety aspects of materials, safe performance guideline, and effects of physical and biological agents and chemicals.

ANSI
See American National Standards Institute.

Association of Independent Corrugated Converters **AICC**
An international trade association whose purpose is to protect and represent the business interests of the independent sector of the corrugated packaging industry.

ASTM
See American Society for Testing and Materials.

Canadian Council of Ministers of the Environment **CCME**
Works to promote cooperation on and coordination of interjurisdictional issues such as waste management, air pollution and toxic chemicals. Its members propose nationally consistent environmental standards and objectives so as to achieve a high level of environmental quality across Canada.

CAS
See Chemical Abstract Service.

CCME
See Canadian Council of Ministers of the Environment.

CGATS
See Committee for Graphic Arts Technologies Standards.

Chemical Abstract Service **CAS**
An organization that assigns identification numbers to chemicals registered through them. A number is used to identify chemicals which may go under a variety of technical and common commercial names.

CMC
Color Measurement Committee.

Committee for Graphic Arts Technologies Standards
Formed in 1987, this group reports to ANSI and is charged with the overall coordination of graphic arts standard activities and the development of graphic arts standards where no applicable standards developer is available. The IT8 Committee, developer of digital data exchange standards, was merged under CGATS in 1994. Information about existing and pending CGATS activities is available from the NPES The Association for Suppliers of Printing and Publishing Technologies.

Consumer Products Safety Commission CPSC
Responsible for regulating hazardous materials when they appear in consumer goods.

CPSC
See Consumer Products Safety Commission.

DOT
See United States Department of Transportation.

Environment Canada **EC**
Federal environmental regulatory agency in Canada.

EPA
See United States Environmental Protection Agency.

FBA
See Fibre Box Association.

FDA
See United States Food and Drug Administration.

Fibre Box Association **FBA**
A nonprofit organization representing and serving the corrugated industry.

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Flexographic Technical Association **FTA**
A technical society incorporated in 1958, whose membership is composed of flexographic printers and companies furnishing equipment and supplies to flexographic printers. FTA promotes, develops and maintains the advancement of flexography; works cooperatively with the industry; assists with the development and maintenance of quality standards; works to improve flexography by fostering research, technical development and training; provides a forum for information and discussion, and acts in the best interest of the flexographic industry.

FlexSys™
The FlexSys™ training corporation is a "for profit" business subsidiary of Foundation of FTA.

Foundation of Flexographic Technical Association **FFTA**
Incorporated in 1974, the FFTA conducts educational meetings; publishes educational materials; participates in or initiates research, and provides scholarships to students.

GAA
See Gravure Association of America.

GATF
See Graphic Arts Technical Foundation.

Glass Packaging Institute **GPI**
GPI serves as the voice for the glass container industry in Washington, D.C. and across the country. It serves its member companies through legislative, public relations, promotional and technical activities.

GPI
See Glass Packaging Institute.

Graphic Arts Technical Foundation **GATF**
A nonprofit technical and education organization serving the graphic communications industries. GATF is consolidated with PIA.

Gravure Association of America **GAA**
An association which promotes the use of gravure printing for publication, package and product printing.

IARC
See International Agency for Research on Cancer.

International Agency for Research on Cancer **IARC**
Part of the World Health Organization, IARC's mission is to coordinate and conduct research on the causes of human cancer, the methods of carcinogens and to develop scientific strategies for cancer control.

International Color Consortium **ICC**
The International Color Consortium was established in 1993 by eight industry vendors for the purpose of creating, promoting and encouraging the standardization and evolution of an open, vendor-neutral, cross-platform color management system architecture and components.

International Organization for Standardization **ISO**
A worldwide federation of national standards bodies from some 100 countries. Their mission is to promote the development of standardization and related activities in the world, with a view toward facilitating the international exchange of goods and services, and to developing cooperation in the spheres of intellectual, scientific, technological and economic activity.

International Prepress Association **IPA**
A trade association consisting of over 300 of the world's leading graphic communications companies and 60 graphic arts suppliers. Members take advantage of IPA resources to make well-informed decisions for a productive and profitable future.

IPA
See International Prepress Association.

National Institute for Occupational Safety and Health **NIOSH**
A federal agency that tests and certifies respiratory protective devices and air-sampling detector tubes, recommends occupational exposure limits for various substances and assists in occupational safety and health investigations and research.

National Institute of Standards and Technology
Established by Congress to assist industry in the development of technology needed to improve product quality, to modernize manufacturing process, to ensure product reliability and to facilitate rapid commercialization of products based on scientific discovery.

National Response Center
The federal operations center that receives notification of all releases of oil and hazardous substances into the environment. The phone number is 1-800-424-8802.

NESCAUM
See Northeast States for Coordinated Air Use Management.

NIOSH
See National Institute for Occupational Safety and Health.

NIST
See National Institute of Standards and Technology.

Northeast States for Coordinated Air Use Management
An interstate association of air quality control divisions in the northeast United States.

Occupational Safety and Health Administration **OSHA**
US Department of Labor agency that sets health and safety regulations.

OSHA
See Occupational Safety and Health Administration.

PIA
See Printing Industries of America.

PNEAC
See Printers' National Environmental Assistance Center.

Printers' National Environmental Assistance Center **PNEAC**
A technical assistance center that provides information about environmental impacts of printing and effective means to achieve compliance with environmental regulations. For more information, go to http://www.pneac.org.

Printing Industries of America **PIA**
A trade association devoted to promoting programs, services and an environment to help its printer members operate profitably.

TAPPI
See Technical Association of the Pulp and Paper. Industry.

Technical Association of the Pulp and Paper Industry
The world's largest professional organization dedicated to the paper and pulp industries.

Underwriters' Laboratories of Canada **ULC**
A safety, certification, testing, quality registration and standards development organization dedicated entirely to the protection of life and property.

ULC
See Underwriters' Laboratories of Canada.

United States Department of Transportation DOT
Federal agency that promotes safe and efficient transportation system.

United States Environmental Protection Agency **EPA**
An independent regulatory agency of the executive branch of the United States government. The USEPA's mission is to control and abate pollution in the area of air, water, solid waste, pesticides, noise and radiation. Offices include:
OAQPS: Office of Air Quality Planning and Standards.
OAR: Office of Air and Radiation.
OECA: Office of Enforcement and Compliance Assurance.
OPPT: Office of Pollution Prevention and Toxics.
OSW: Office of Solid Waste.
OSWER: Office of Solid Waste and Emergency Response.
OW: Office of Water.

United States Food and Drug Administration **FDA**
The government agency responsible for the approval of food additives. Inks, coatings and other packaging materials coming in direct contact with food or drugs must be shown to be non-migrating, or must be made only from raw materials that are known to be harmless and are listed in the Code of Federal Regulations, Title 21.

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CHAPTER 3

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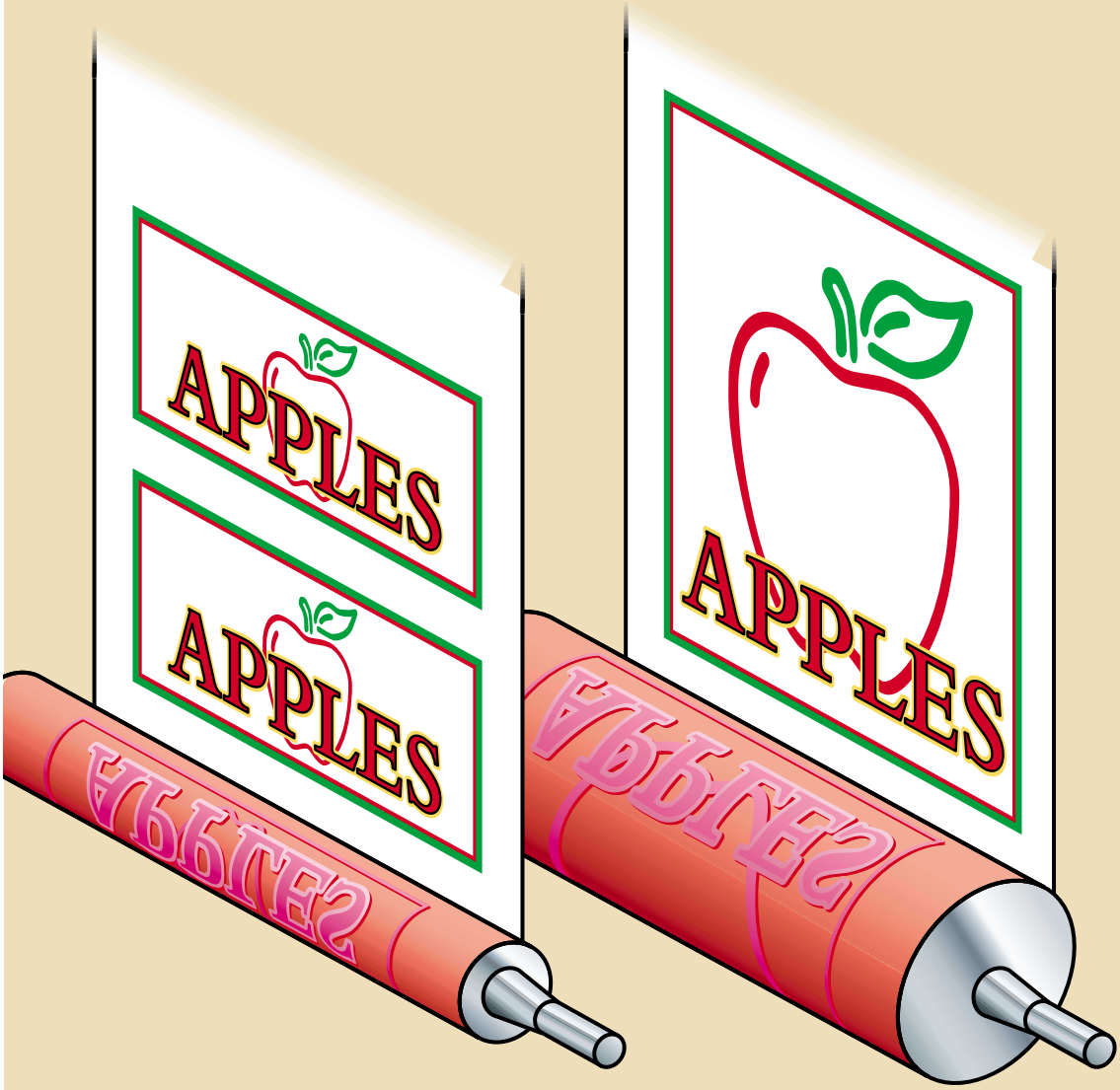

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Principles & Practices

5th Edition

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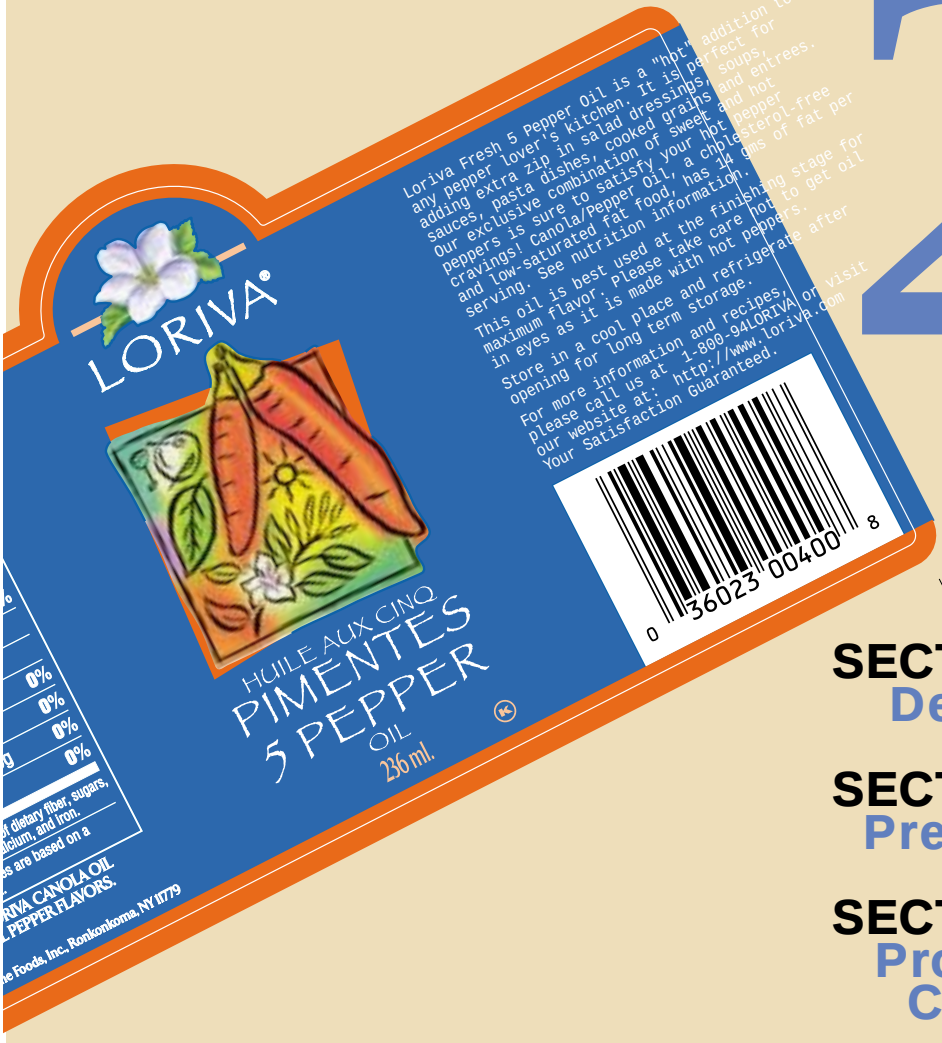

SECTION 1
Design

SECTION 2
Prepress

SECTION 3
Process Color

Flexography: Principles And Practices

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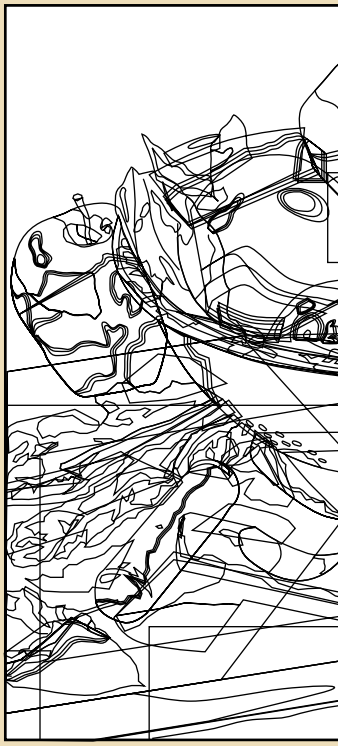
CHAPTER 1

Design



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Introduction

Graphic design for packaging is the process of translating the image that the customer has in mind into a finished package. In order to accomplish this task successfully, a designer requires a great deal of information before and during the entire design process.

To accomplish its many objectives, flexographic design has to play a number of roles. This chapter talks about how fabrics, paper products, packaging, shipping cases, labels and any other flexo-printed product can be designed most effectively.

Over the past 20 years, the graphics arts industry has seen fundamental changes in the way color is reproduced. Every aspect of color reproduction has undergone a complete transformation as the industry has moved from traditional mechanical prepress to digitally-based methods of production. The work involved in preparing color artwork for printing has transitioned from dedicated high-end equipment at specialized trade shops to standard desktop computers used by the designer. The roles once filled by typesetters, camera personnel, strippers and color separators have dramatically changed, and in some cases even disappeared with the advent of electronic prepress (*Figure* ❶).

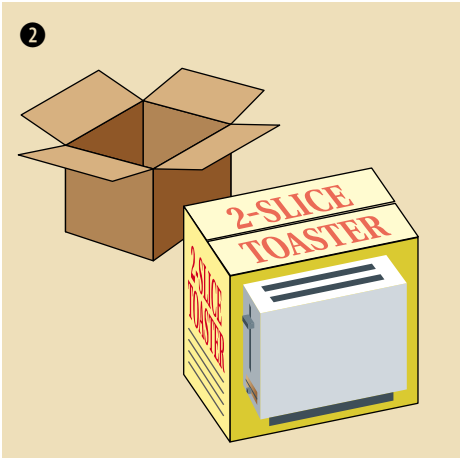
When a designer develops packaging graphics, many considerations relating to the type of package printing must be reviewed and applied in order to achieve success and meet the customer's marketing needs. A successful design is eye catching and stands out. It is achieved within the proposed budget, and the final printed piece must look as good as the approved contract proof.

DEFINITION OF DESIGN

Design is an orderly combination of formal elements that produces a composition. In flexography and other printing processes, design is the visual plan of line, mass and color, selected and assembled to accomplish a designated goal. That goal may be to convey beauty, or simply to provide information by the arrangement of copy on a label. Often, the goal is to sell a product. In that case, the design has to have impact and it must provide identification and information about the item. Sometimes the design goal involves the printed product itself, as with giftwraps, textiles, cups and containers.

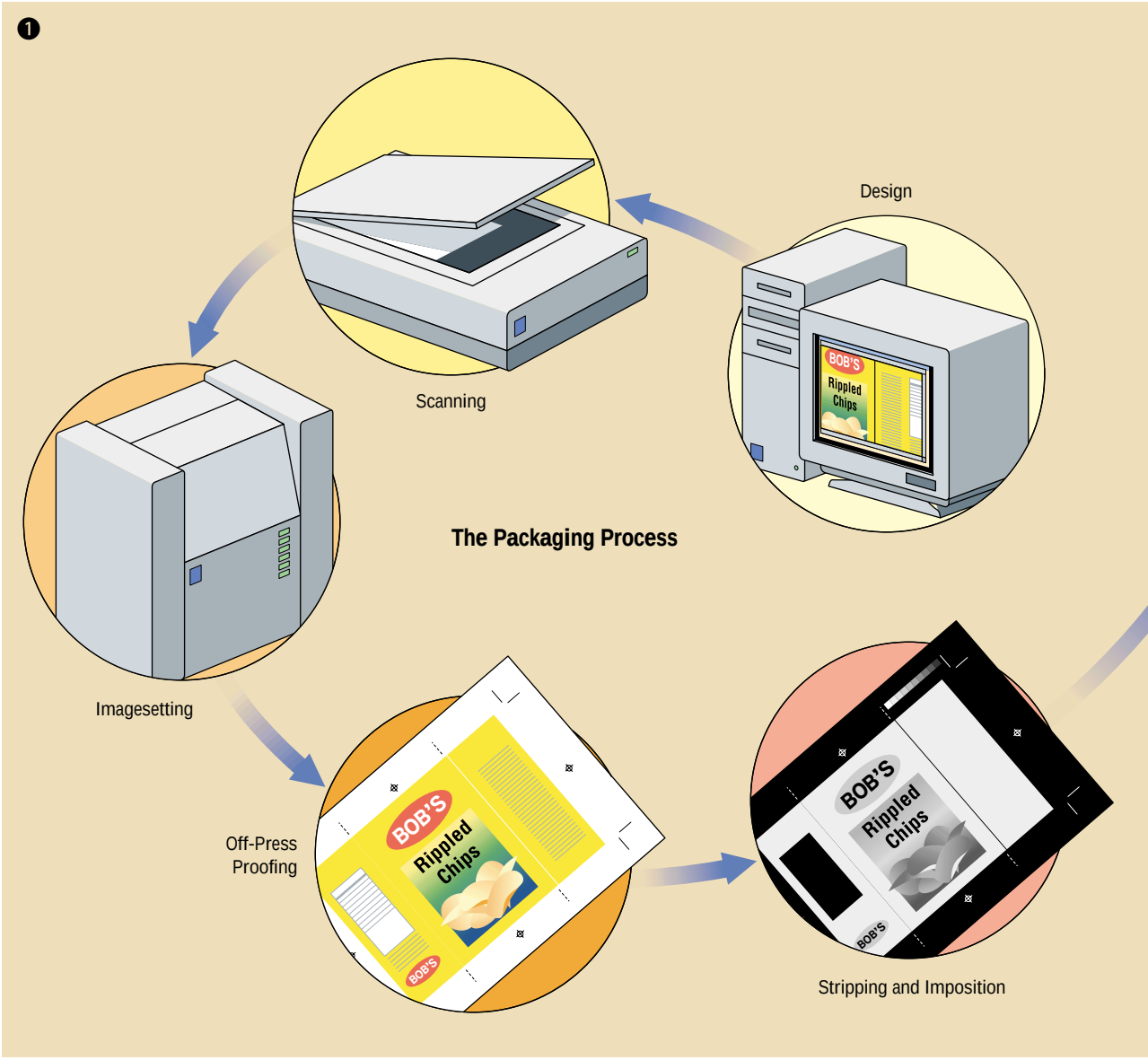
A designer's job is to translate the client's ideas into a finished product that will satisfy consumer preferences. In the case of labeling, packaging and shipping containers, design is often the only means that identifies the product, the brand and the manufacturer or packer. In addition, many products depend heavily on package design to establish their image for merchandising, advertising and promotion (*Figure* ❷).

❷



❶ (Following pages) The package printing process from start to finish.

❷ Most products depend on package designs to identify the product and to establish their image for merchandising, advertising and promotion.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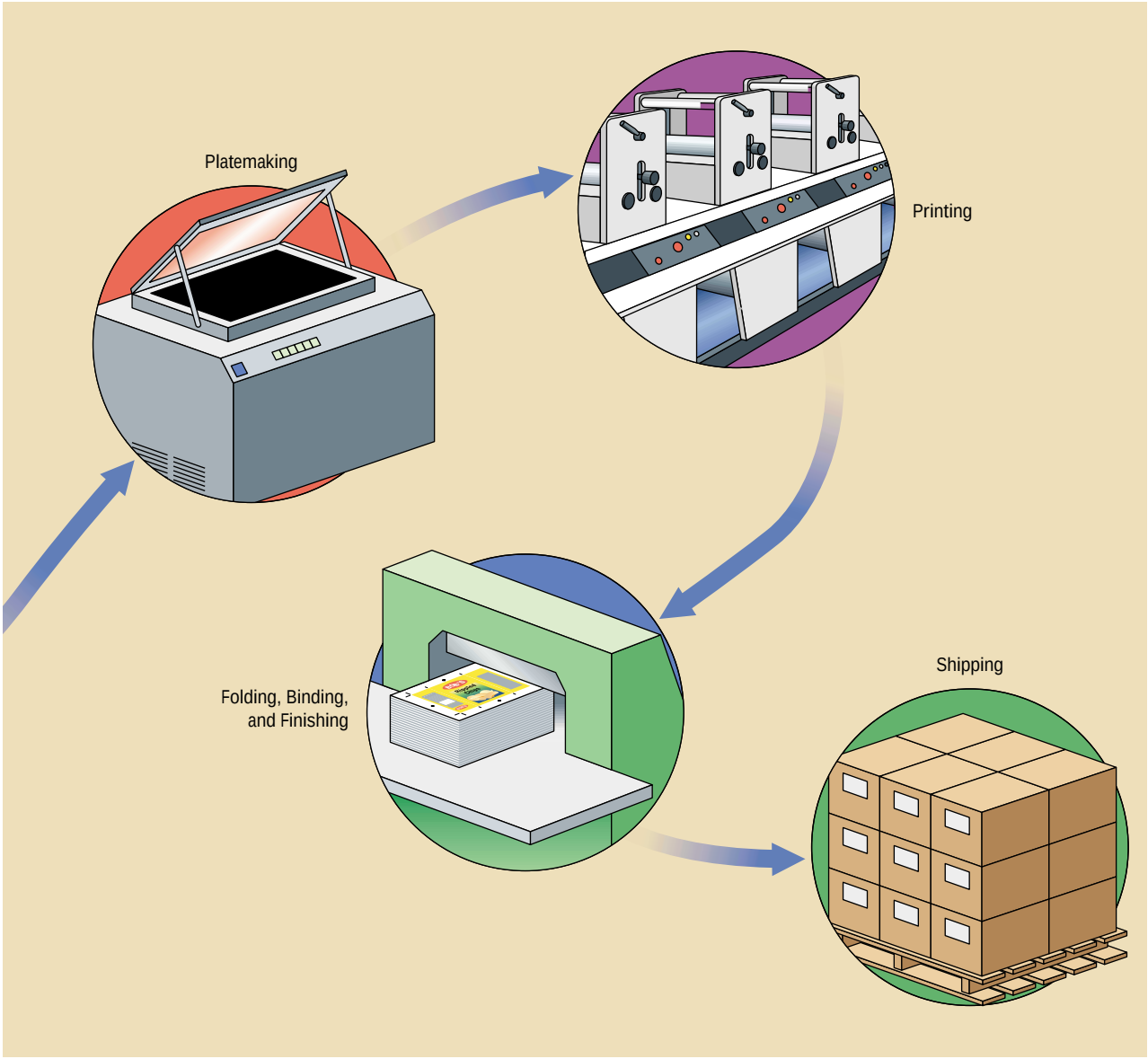
Design
Scanning
Imagesetting
The Packaging Process
Off-Press
Proofing
Stripping and Imposition
BOB'S
Rippled
Chips

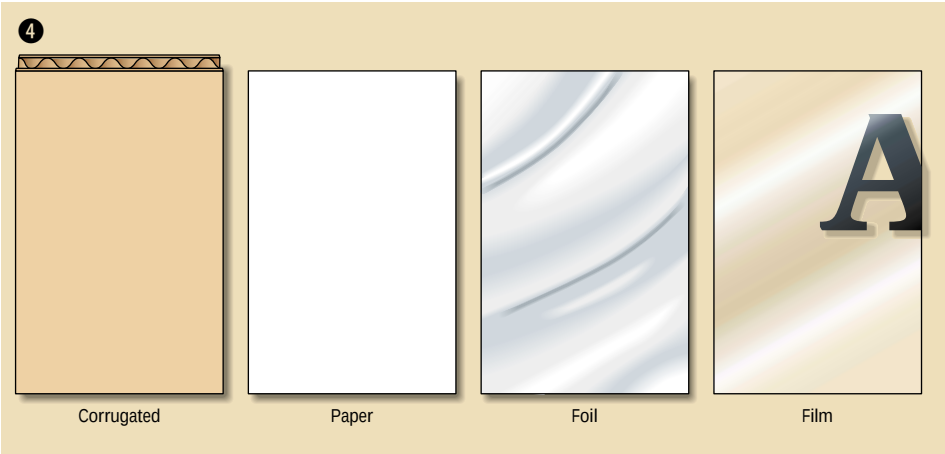

Platemaking
Printing
Folding, Binding,
and Finishing
Shipping

Design Considerations

The printer or separator must supply the designer with specific information about print parameters. This is usually part of the press characterization information, and is best furnished very early in the design process. The designer's understanding of the flexo criteria should be used creatively to maximize the many benefits of the flexographic print process (*Figure* ❸). Advantages of flexo include: the use of many colors, including metallic and fluorescent inks, a wide variety of substrates with unique characteristics (*Figure* ❹), and many special finishing effects like embossing, foil stamping, holograms, varnishing and UV coating.

In addition to meeting with the printer, the designer must also work closely with the consumer product company to meet its marketing objectives, requirements and goals. For the consumer product company and the

❸ Successful design creatively utilizes the many unique features of the flexographic print process.



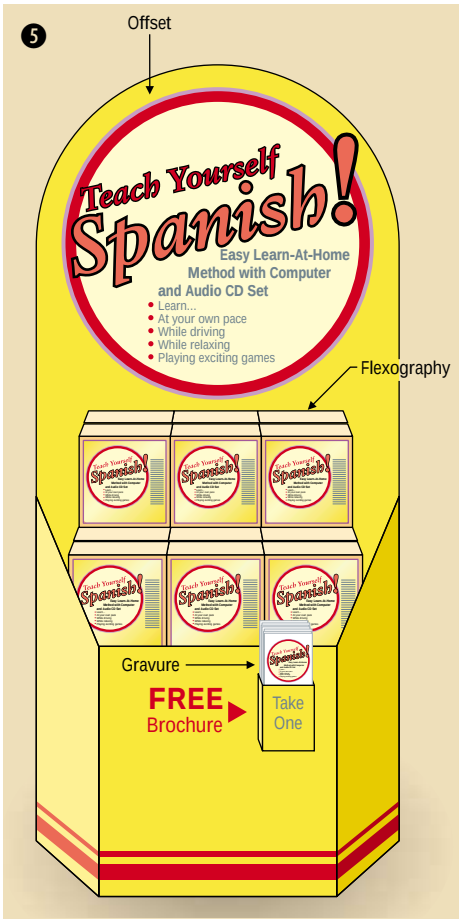
4 One of the advantages of flexography is the large variety of substrates that can be printed on.

5 Combination printing makes use of offset, flexography and gravure to maximize the benefits of each process.

designer, meeting marketing objectives is the highest priority. Print parameters are taken into account only after a comprehensive proof of a design is approved and the marketing objectives are met. Most marketing goals are oriented toward making the package more appealing than competing products.

Marketing objectives can also take the form of helping a consumer product company solve a particular problem. This could be a problem with an existing package, a specific product to be packaged or tight budget constraints. The services of a designer and a structural engineer may be enlisted to create a package design that solves the problem, is printable for the specified print process and meets the allocated budget. Staying within budget can be a difficult task and both the design and production costs must take into consideration. Since the designer is not always knowledgeable about all the costs of prepress and print production, it is advisable to discuss these issues with the separator and printer prior to beginning the package design.

Many consumer product companies develop their packaging using a combination of gravure, offset, flexo and other print technologies within one product line. (*Figure* 5) The customer expects the product line to be aesthetically cohesive in design and color.



Producing a product line combining different print technologies can be difficult, especially when trying to achieve consistent colors and special effects. When combining print technologies, it is best to create the

❻ The label or tag on a product provides the visual essence of its character and end-use.

graphics for each different print type simultaneously so the designer can be sure that the graphics can be reproduced using all required print types.

DESIGN PERFORMANCE

There are three main elements in developing a design that works:

- psychology,
- aesthetics and
- functional characteristics.

Psychology

Psychologically, the printed design reflects the personality of the product and the philosophy and taste of the firm that made it. With textiles and many paper products, design sets the mood or complements the decorative scheme. With gift wraps and party accessories, it augments the occasion with complementary subject matter to reinforce the event's importance. In packaging and labeling, it provides the visual essence of the product's character and end-use (*Figure* ❻).

Printed designs can evoke feelings of comfort, joy, good taste, excitement, etc. They can be solutions to household or commercial problems. Designs grab attention and provoke interest, and they identify and provide instructions. In all their versatility, designs are geared to spur a response in people by the message that they convey.

Aesthetics

Pleasing aesthetic quality and superior print quality is a winning combination. There is, however, little value to creating a fantastic design that is stunning on the proofs but is economically and mechanically impossible to recreate in print format. The goal is to design within the window of opportunity. This window is continually growing and changing and therefore, so are the designer's challenges and opportunities. The customer wants the designer to push that creativity window and explore. It is also the obligation of the printer to push the limits of production and work with the designer to meet the challenges (requirements) of the consumer product company.

Aesthetically, whether a design is bold or delicate, it should be developed in good taste and with a proper balance of line, mass and color. Each element of design, such as the color scheme, typography or subject matter (in photographic or illustrative form) is part of the layout and should relate to the others in overall theme.

Creating a design has often been compared to writing music for the organ. There are many tonal combinations that can be produced using stops, keys and controls. The composer combines talent and understanding of these components to blend them into a satisfying and effective musical composition. Likewise, the graphic designer does the same with visual elements and design tools to produce an aesthetic composition.

Functional Characteristics

Functionally, the design should meet certain criteria. Whatever form it takes, the design has important objectives – whether in areas of pure decoration or in the precise details of a small printed label. The function

may be to convey comfort, pleasure or some other emotional or environmental state. In packaging, the design, in its broadest sense, must identify the product, the brand and its uses. An instructional tag or label should provide information with accuracy, brevity and clarity. On shipping cases, the graphics should instantly identify a product, along with coded data, to assist warehousemen and handlers from the packing line to the final display areas.

It's important to stress the relationship between design function, and production and manufacturing concerns. Designs prepared with knowledge of electronic prepress, substrates, platemaking, inks, press characterization and press operations will perform with greater efficiency and profitability.

DESIGN PURPOSE

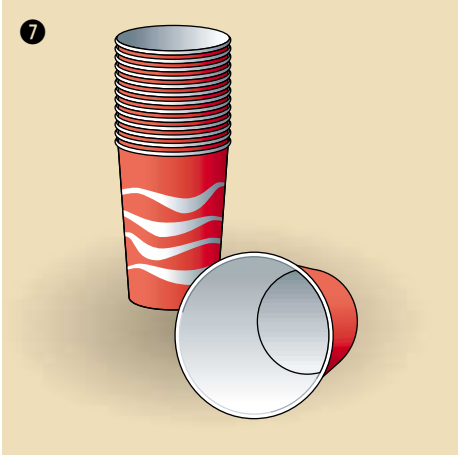
Generally, designs prepared for flexographic printing fall into one or more of these categories:

- decorative,
- visual impact,
- identification and
- information.

Decoration

An important segment of flexo work is the production of decorative products. These include printed textiles, gift wrap papers and foils, party accessories and decorations, paper cups and other household and commercial products. Although some of these designs are customized, our primary concern is with generic designs of different types of subject matter, techniques, color schemes and treatments. Many are continuous patterns with multiple units repeated across and around the substrate (*Figure* ❼).

Subject matter can be taken from nature, geometric shapes, holidays, seasons or other themes such as anniversaries and birthdays. Design approaches to decorative products are endless. There are many challenges, especially since the printing has to conform to the requirements and capabilities of production equipment.



❼ Decorative products are commonly printed with continuous patterns, with multiple units repeated across and around the substrate.

Visual Impact

All graphic design is aimed at triggering a reaction, so visual impact is a major objective. In the decorative products mentioned in the last paragraph, the visual impact of original and consumer-oriented designs plays an important purpose in highly competitive product lines. In addition to attracting attention when bought, the designs serve a purpose in home decoration and furnishings. Similarly, in gift wrap and party products, a winning design contributes greatly to the product's sale and ultimate success.

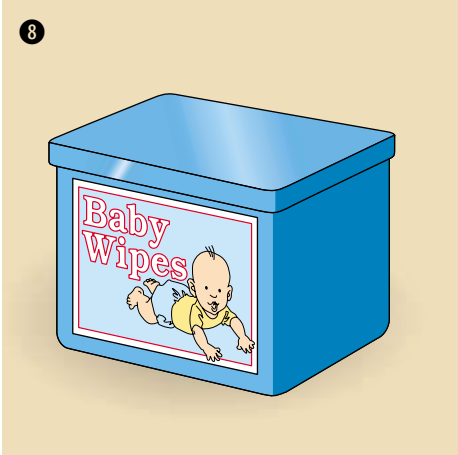
Packaging is the "silent salesperson," the unending advertisement and the product's most conspicuous identifier. Whether the package figuratively shouts from the store shelf or quietly taps the consumer on the shoulder isn't important; there must be impact. Without it, the other design purposes could be seriously impaired or, even worse, never be given the chance to perform.

Identification

What is it? What does it do? Who makes it? How does it relate to advertising and promo-

❽ The illustration or photograph used on a label identifies the product and provides information or characteristics and end-use.

❾ An important part of the design of a package, is it's ability to quickly and clearly convey information relevant to the consumer.



tional programs? If there is an illustration, is it a true representation of the contents? (*Figure* ❽)

Depending on the product and its merchandising slant, the identification emphasizes product name, brand name and manufacturer. How these and less tangible identifying elements are organized depend on the designer's purpose. Established graphically in a visual priority, the viewer's eye should be carried from a particular identifying element and continue around the design in a proper sequence of dwell spots. In doing so, the viewer takes in the information of most interest.

Strong identification of a product, package or label is the basis of advertising programs in which recall is essential. Often, a properly identified package design becomes the best advertisement because the package is as much a part of the product as the product itself. Another sought-after advantage of strong identification is association, in which confidence already established in one product carries over to another with the same brand identification. This can happen readily in a family of products with closely related designs. This is especially helpful when a new item joins an established product line.

Information

An additional design purpose is to provide information about the product. This is especially true of designs whose purpose is not strictly decorative. With correct and helpful information on how the product can be used, the design's purpose is fulfilled. Does the package design show and tell color, style, size and count? Does it indicate if the contents have to be assembled? If so, are assembly instructions clear and complete? Ingredients, weight, size, price and legal data all comprise needed information for the purchaser, while exact instructions help ensure a satisfactory experience. (*Figure* ❾)

Learn all about the customer and his product: What is it? What does it do? How is it made? Where will it sell? What are the marketing plans? If the client is presenting a new line of flexo-printed merchandise, where is it expected to sell? In stores, on the internet or by catalog sales? What is the price range? What are the competitive conditions in the intended market? What promotional and advertising programs are planned? Who is the intended customer?

Before designing a package, data has to be assembled. This includes:

- product information,
- brand identification,
- merchandising considerations, and
- research.

Product Information

To encourage sales, information about

end-use is necessary to direct the design theme and the graphic technique.

For example, subject matter for gift wraps is dictated by the occasion it's intended for – birthdays, anniversaries, holidays or other special events. With the objectives in mind, product information provides input about the market, competitive forces, consumer preferences, design trends and techniques.

Information about the material to be printed (textile, corrugated, paper, foil, film, etc.), its texture, ink coverage, design repeat size and end-use, provide necessary guidelines for the designer (*Figure* ❿). In a speculative market, careful research into consumer acceptance and buying habits is important to the designer and will help predetermine if a product will sell.

In designing labels and packages, product information refers to an actual examination of the product that the label or package must identify. It also includes knowledge of the product source. It helps to know the conditions under which the product evolved; for example, is it grown, manufactured or processed from several ingredients? What are its form, shape, weight and color? What will it be used for? Answers to these questions provide early hints about a package's final appearance, the materials to be used and other important characteristics.

Brand Identification

For textile and gift wrap items, input is seldom provided. But for packaging and labels, data should include examples of registered brand markings, trademarks, logotypes and associated color schemes. When any of this data is included in the graphic design, it is imperative that it does not deviate from the original. The product may be one of a family, and a close match to the other package designs is essential.

It's always possible that a totally new brand-image or mark is called for. If so, the identifying mark should lend itself to advertising and other promotional programs. It should also be easily adaptable to any collateral material that's planned, such as point-of-purchase (POP) displays at the retail level. High recall can only add to the design's effectiveness at every stage and contribute to repeat sales.

❿ Necessary guidelines for the designer to know prior to the package design are the material to be printed, it's texture, ink coverage, repeat size and end-use.

Merchandising Considerations

What will happen to the product and its package once the retailer gets it? The package design is always strengthened by knowing how a retailer plans to merchandise the product. If the package is a printed film bag, it may be displayed differently from a printed carton or an item for a point-of-purchase display. This changes the design's orientation and determines the amount of identification needed for the face, end or side panels.

Positioning factors are helpful in planning the design. Many products have to shout from the bottom shelf, "Hey, look down here at me!", while others advantageously meet the consumer at eye level. Ideal display space is slightly below eye level. The following merchandising considerations should be factored into the package design:

- What kind of store is the product being displayed?
- Where is the product to be displayed, and where in relation to eye-level?

- Can the product, package size and design be produced to compete for this display level?
- How can the graphic design contribute to large-mass displays, to shelf-talkers and other promotional material?
- Is the package designed for mass-merchandising chains, or is it designed for bulk-selling through discount outlets, and if so does it have pallet impact?
- Is it designed and "sized" to fit standard store counter bins and mass-merchandisers' fixtures?
- Will this product only be sold through catalogs or on the internet?
- What type of bar code will the package carry?
- Are shipping cases designed to facilitate use of pallets and other mechanical and marking devices?
- Does the shipping case contain an inventory-related product code?
- Will the product be advertised? If so, will it appear in print, on television or on the internet, or perhaps all three?
- Will color-value contrasts allow the message to come across in the desired medium?

The more information you gather about merchandising considerations, the more effective your designs will be (*Figure* ⓫).

Research

Thorough research can only increase the odds of creating exceptional designs while

⓫ Merchandising considerations play a very important role in how a package is designed. A package's design may be changed significantly based on whether it is to be sold in a store, on television, in a catalog or on the internet.

avoiding costly trial-and-error misjudgments.

Although research methods can be simple or highly sophisticated, a healthy curiosity and an ability to listen are important attributes. Designers with a knack for research can gather relevant statistics to guide their efforts. Visual and psychological testing provide answers from professionals, including focus groups, and is an effective way to obtain good data. Other topics to research: printing equipment and manufacturing methods, merchandising systems and industry and trade customs are vital to the design as well.

In-depth research can result in a more economical package. It can reduce the chances of lowering the value of the merchandise or creating an inflated price because of under- or over-designed packaging. On the other hand, it can also help eliminate exposing quality merchandise to the risk of slack sales because of inferior packaging. It's important for the designer to always remain alert to current techniques designed to hold down per-unit packaging costs.

Beware of artists/designers who rely only on their own talents without tapping other sources for information. Package design is a logical exercise. It's also based on a need and ability to identify problems and provide solutions. Appropriate research into each design project helps bring the challenges into sharper focus. Only then can systematic solutions be worked out to help the product function well through each manufacturing stage and at the point of purchase.

Printing Equipment and Manufacturing Methods. Without the benefit of research into production methods and equipment, an otherwise simple design for gravure or offset would pose many printing problems for flexography. The added cost and delays could be substantial. So far, this chapter has tackled only the basic requirements of a successful design. Now we'll get into the specifics of gearing it for flexographic printing.

The recommended procedure is to list the factors the design must achieve (*Table 1*). In compiling the list, the designer is forced to consider all the production and printing pitfalls while creating the design. In doing so, the designer can proceed with the knowledge that research has paid off.

DESIGN BRIEF MEETING

The purpose of the design brief meeting is to review all aspects of the packaging design objectives and strategies and to exchange ideas on anticipated design directions that should be pursued. All information that is relevant to the listed items must be supplied.

- Project description
- Background
- Product development
- Product positioning
- Project timing
- Target consumer
- Competition
- Copy: package messages, legal copy
- Communication priorties
- Print specifications and film contacts

Table 1

The term "design development" is used because systematic study and hard work create designs. Unlike fine art, design for the graphic arts is mainly a means to an end. For flexography, the design must be a marketable decoration and identification system, whether for a corrugated box, a multiwall bag, film and foil packaging or pressure-sensitive tags and labels.

Merchandising Systems. Research into the proposed merchandising program can only enhance a designer's effectiveness. For packaged and labeled products, the most important design features are perhaps the brand name and image. These should adapt easily to shipping containers for the benefit of anyone handling the package.

Think about the part of the package design that cannot be seen by a purchaser. If a section isn't visible, repositioning certain design

elements or adding display-and-sell copy to the part of the shipping container that remains with the products can help.

If a product does not have promotional helpers, it has only its package to help make the sale. For packaged clothing items that compete at the purchase point with a competitor's brand item, differences in the quality of the package design can influence the position they get on the display counter. Research information about merchandising systems can contribute significantly to the designer's success rate.

Industry and Trade Customs. An ongoing system of research into industry and trade customs requires little explanation. The designer should establish sources from recognized industry groups to become sufficiently knowledgeable about the packages and packing materials used for different products. Legal sources might also be consulted for current information on acceptable type sizes, correct location of bar codes and other legal questions.

THE INTENDED BUYER

Just as a product is created to fill a buyer's need or satisfy a desire, the package and its graphic message must be designed to attract that particular buyer. Because the package helps communicate the product's image and essence, visual communication should be in terms people can understand, and such that the message will prompt a purchase.

It is important for the designer to visualize the assignment from the consumer's point of view and to develop early concepts based on the intended buyer's needs, desires and impressions. Constant research into this area includes a number of considerations:

- needs and preferences;
- buying habits;
- motivations;
- economic situations;
- the act of buying;
- end-use conditions/applications;
- advertising recall; and
- repeat purchases.

Needs and Preferences

In shopping centers, basic products are considered staples: food, beverages, clothing, hardware, condiments and many others. Packaging for such items should stress product identification. But because even potatoes, toys and children's socks compete for store space and consumer attention, the package's graphics should feature prominent brand identification. If the first try results in a satisfying experience, the consumer will probably pick the same brand the next time.

Even more important, a preference has taken root in the buyer's mind. Although sales statistics confirm this, it's still important for a retailer to know which products should be stocked and the amount in the inventory. And don't forget that prominent brand name identity promotes sales to retailers, too.

It is important that the brand identification of staple products look contemporary. A product that has been around for generations must not look out of date in its packaging. In the consumer's mind, antiquated package design can translate as old inventory. This is not to say that a package can't have the look of a particular period: Victorian, Nouveau, 1950s. These periods of graphic design are well established and effective in commercial art and can be a product's single most important identifying feature. Changes in package design of established product lines have been more successful if they are evolutionary rather than revolutionary.

Buying Habits

Studied and recorded, buying habits vary from store to store and from one geographic or economic situation to another. Age, family size, dwelling location and income bracket govern the planned buys of the shopping trip. By studying the range of buying behavior at

certain stores, the rate of selection and collection of products can be registered to provide clues for the design elements that deserve emphasis. Who are the purchasers? What products do they seek? What specific information about the product are they looking for, and do they have a hard time finding or understanding it? Do they ponder or procrastinate? Is the product strictly an impulse item or is it on people's shopping lists (*Figure* ⓫)?

To fill the shopping cart and stay within budget, some people may use coupons and specifically listed brand items. Others may list only items and wait to decide on the brand from available choices.

In time, shopping trends, stores and products can be identified and the data turned into more effective package designs and labels.

Motivations

Most purchases stem from repeat sales of a product that has satisfied the buyer in the past. When a well-planned advertising campaign, samples or in-store promotions help along new or improved products, the consumer can be motivated to try it. Television commercials and print ads greatly motivate consumers to buy another brand or a familiar product in a new form. Often enough, people aren't aware of a need or an additional benefit until an emotional reaction is triggered.

Economic Situations

An overdesigned package, like an overpackaged product, often causes hesitancy or a negative reaction by the consumer on a limited budget. The package and its graphics are generally regulated by the relative margins the manufacturer establishes; however, an effective and hard-working package design does not have to be elaborate.

Whatever the buyer's income bracket, you can bet that he or she will insist on a fair price. At all income levels, a fluctuating economy affects purchasing decisions, and product integrity is important to that decision. The careful designer is alert to differing income levels among consumers.

⓬ Studying the shopping habits of consumers helps the designer know which design elements need the most emphasis on a package.

The Act of Buying

The act of making a purchase is, of course, intertwined with buying habits, but deserves additional explanation. Perhaps the most critical time in the life of a package design is the moment the actual purchase decision is being made. After all the development, testing, advertising and promotional hype, the last few seconds between the product and the consumer are crucial. The design – with its elements of impact, identification and information, along with its controlled image – was meant for this moment, and it had better answer the consumer's questions: Do I need it? Will it help me? How can I apply it? Can I afford it? These and many other thoughts race through a buyer's mind. It's at this point that the designer's talents must shine.

End-use Conditions/Applications

What is the life and mission of the package design after the sale? The longevity of the design depends on the nature of the product – whether it's used up all at once or over time – and on the package itself. Early graphic planning should consider how and where

the package will hold the product before it's used, and the design should continue its mission in its new environment.

The "hard-sell" that's been built into a product's package for displaying in the supermarket often becomes offensive in the home. Consider a giant carton of detergent that dominates the laundry room, or the coffee can on the kitchen counter. Many homemakers invest in careful color-coordination for work areas, but will condone the brash commercialism of a package design there. Most packages are stored in cabinets anyway. But because others are mainly designed for countertops, they are used more often and naturally tend to create higher repeat sales.

Graphic designs that function well after purchase tend to be compromises between hard sell and soft sell. This should be given considerable thought in the early stages of the design process. There's an additional, and quite useful, psychological factor in graphic design: What can be incorporated into the design to make consumers pause during the moment of decision to imagine the benefits of the product? Can they visualize the package and the product helping to make their life easier?

This is where the value of product photography or illustrations comes into play. From color photography or simple illustration techniques that show the product helping someone, the buyer's thoughts can flash from the initial purchase to final use. These images can be exciting visions of any pleasant experience.

Advertising Recall

Research into planning an advertising campaign also provides insight for design planning. Will the graphics be readable when reduced in size or if reproduced in black & white? Is there sufficient image-strength to survive different methods of media reproduction? Scale is also important. Does changing the balance and the elements of a package alter the brand's personality? Does the brand name have enough visual impact to cause the observer to silently repeat it in his or her mind? Or is it too dependent on sound? Because it appeals only visually in the marketplace, brand and product recall are generated through graphic design.

Repeat Purchases

Package design recall helps spur repeat purchases. If the product has been satisfactory, these pleasant experiences are recalled during the next shopping trip. A well-planned package design succeeds in presenting the product or brand. With all the distractions in today's marketplace, identification impact is necessary to generate repeat sales.

THE DESIGNER

To organize and successfully implement these design factors, the designer must be a problem solver as well as a skilled artist. He or she must have a command of graphics, typography and a good sense of form and color. A good designer must also be aware of the client's concerns, in addition to being curious and knowledgeable about potential buyers. Reviewing a designer's qualifications and portfolio of previous projects is the first step toward picking the right designer for the project.

Visual Communications Specialist

The graphic designer is essentially in the visual communications business. The essence of graphic design is the translation of ideas into visual form and the creation of order from unorganized information. The story the designer has to tell cannot be heard; it must be translated into visual elements, which must be seen to be understood. The message should be presented so that it registers quickly and indelibly. At all times, it should be truthful, informative, exciting and interesting. Also, a package's design controls,

or should at least influence, the product's position in the industry.

A Problem Solver

Training and an interest in problem solving are both invaluable qualities. Obviously, the design problem must be identified before it can be solved. It's at this point that curiosity about the product, the marketplace and the consumer generates the necessary input to establish the client's design requirements.

During this process, the designer must thoughtfully sort the information obtained from the client, sales and merchandising personnel, and from research material. Once this is accomplished, and with visual priorities established, the designer begins to translate graphic needs into initial rough concepts.

Graphically Proficient

A designer with sound training in art and education in design principles is well versed in the terms and tools of the trade. The designer must know and use various techniques of artistic rendering, typography, color theory and effective design concepts.

Today's designer has many software programs available as tools to help with the creation of their ideas. There are programs for three-dimensional product design, illustrating, photo retouching, painting and page layout, just to name a few.

As in the past, all work should be produced with color separation, platemaking, ink mixing and press operation in mind, if the production art is to succeed. Familiarity with all these production areas enables the designer to intelligently present and discuss the work with the production artist.

Client Oriented

The more a designer knows about the client, along with product and sales objectives, the easier it will be to organize the design plan. Technical data about packaging and labeling equipment, handling and display methods cut the time needed to arrive at the best design solutions. Knowledge of trade customs and competitive packaging practices is also helpful in developing an effective design concept.

Knowledge about the Consumer

Since the design's goal is to gain the greatest consumer acceptance of, and preference for, the product, an intimate understanding of the targeted consumer category is essential. Information is often supplemented by "in-store" studies of behavior patterns and by the use of focus groups.

DESIGN DEVELOPMENT

It is beneficial to establish ground rules and procedures for creating and separating designs before the actual production begins. These ground rules need to take into account production issues relating to the complexity of potential graphics, prepress requirements, press characteristics and other print methods besides flexography that will be utilized. Thorough planning greatly benefits the efficiency, cost, quality and speed of transforming a product idea into an "on the shelf" product.

Preproduction Meeting

Preproduction meetings should be planned at the beginning stage of each project, with a specific list of topics to be discussed. All of the topics will require decision making at one time or another during production. The most productive and cost effective way to make these decisions is early in the process in the pre-production meeting. All portions of the production process are addressed and planned for during this meeting.

The designer should be thoroughly familiar with the methods used by the production artist and learn exactly how he/she plans to prepare the finished electronic files for the platemaker. Will the artwork be created in an illustration program, or will photographic or

PREPRODUCTION MEETING

The consumer product company's representative usually calls this meeting but the design firm, prepress provider(s), or the printer(s) can also intitiate it. The meeting agenda should include these items for discussion.

- Design consideration
- Design review
- Specifications, dimensions
- Number of colors
- Film assembly
- Trapping
- Print control targets
- Contract proof requirements
- Timetable
- On-press approvals

Table 2

page layout software be used?

If process color is used, ink and color-matching methods should be discussed to avoid problems during the press run. Ask for suggestions from the printer/converter's art and press personnel. Will there be color overprints? If tints and/or halftones are involved, what screen count is the printer able to handle and is his/her equipment outfitted properly? If tight color-to-color registration is involved, can the printing presses hold it? How many print stations and printing plate cylinders are available (*Table 2*).

Press Characterization

Press characterization data encompasses the process capabilities and requirements for a specific press using certain materials and settings. This information usually comes from the printer or separator and varies from press to press. A press characterization target can be used to generate this information.

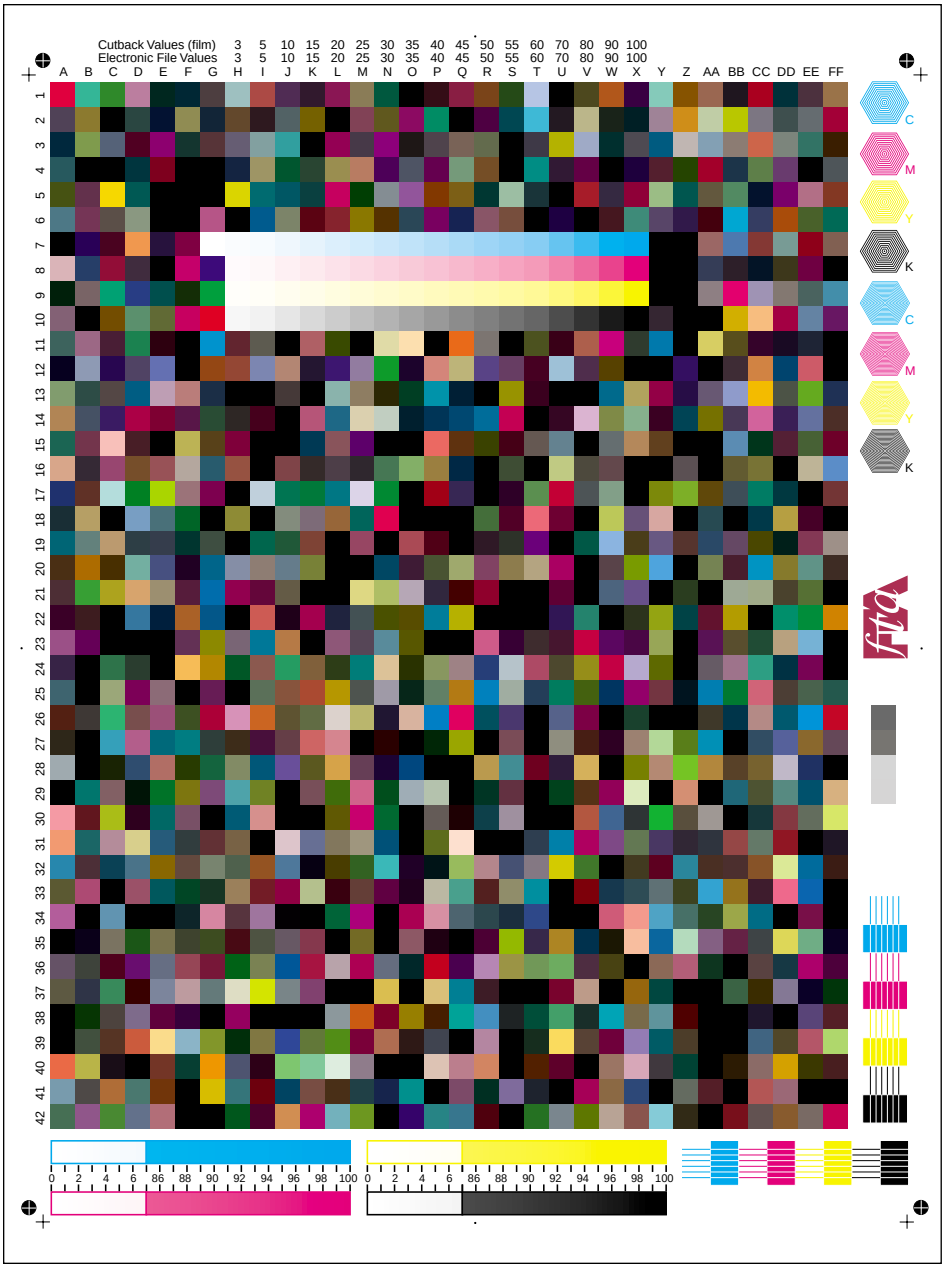
Many times a printer will utilize several different combinations of materials (e.g. different plates, inks or substrates) on one press and new press characterization data is required each time the materials are varied. The data provides a snapshot of the print capabilities of the press utilizing those specific materials (*Figure* ⓭).

Once all the input has been evaluated, and before the first line is drawn, the designer must remember that the extent of the design's creative limits are governed by production and equipment capabilities. Some of these are:

- Print stations available on the flexo press, which dictate the maximum number of colors needed to reproduce the design.
- Effect of special printing procedures such as web-reversal limits printing to three-colors face and three-colors back on a six-color printing press.
- Color sequence, especially when the usual light-to-dark color progression is changed for some reason.
- Hold-to-register tolerances that suit the type of press to be used (CI, stack or inline).
- Placement of large solid areas and fine details such as small type, tints, fine filigree or halftones in the same color which should be avoided.
- Consideration of color-trap tolerances to minimize color-to-color misregistration.
- If tight-registration is unavoidable, it should be confined to a limited print area whenever possible.
- Consideration of ink fill-in and distribution problems inherent in reverse printing (copy reversed in a solid field).
- Use diagonal lines, curves, wavy and irregular leading edges to minimize press vibration and bounce, instead of straight, hard-edged solids placed horizontally across the web.

Packaging Specifications

Given their influence on the final result, some other factors have to be taken into account. These must meet exact specifica-



13 The use of a characterization target can provide a snapshot of the presses printing capabilities. Pictured here is the FIRST characterization target available from the Flexographic Technical Association.

tions, preferably in a flat layout showing the following design details:

- Location and size of package face, back, gussets and/or any other surface to be printed;
- Size and extent of folds, diecuts, slots, perforations, seams and other important features where they exist;
- Exact print areas;
- Product-fill height and/or contours whenever they are essential to form;
- Color-matching names or numbers and/or color swatches related to color preference or standards where they exist;
- Accurate package mock-up or complete prototype; and
- Exact specifications on the size and

location of all design units specified by Federal Packaging and Labeling Acts wherever they apply.

Substrates and Materials

Whether or not the design is to be prepared on the actual substrate to be printed, a sample of the material should be obtained so colors and techniques can be evaluated against the substrate. Since flexo printing is done on paper, board, film, textiles, foil and many other materials, the comprehensive roughs can often be prepared on these surfaces, although they may require different rendering techniques and art materials.

As far as substrates are concerned, the designer must be alert to possible printing problems. Some common substrate concerns are listed in *Table 3*.

The designer familiar with the entire manufacturing cycle will be able to use all of the special features available only with flexographic printing.

The Point of Purchase

Many flexographic applications are for consumer products sold at the retail level. A valuable exercise for a designer, is a trip to a display and sales area, which can provide helpful insights. For example, notice the type of retail outlet, location, the probable shelf position and its height, lighting conditions, store traffic and competitive practices.

In addition, the designer should sense the store's atmosphere, the shoppers' tempo and available time, and the benefit of advertising recall in the area. This is where packaging impact, identification and information are measured.

If the package is meant for an industrial item instead, such as 25- or 50-pound bags to be packaged palletized and stockpiled in a warehouse, the designer will benefit by visiting the premises and personally checking equipment and methods. The designer then can determine whether product identification through the use of names, color or symbol coding should be placed in a conspicuous location on the package so that items can be more easily located. It also allows the designer to visualize his or her proposed design at work and will allow consideration of intangibles that could give the design subtle advantages.

PACKAGING SUBSTRATE CONSIDERATIONS

- Images printed on thermoplastics should usually be kept away from heat-seal areas.
- Packages for certain food items frequently require special inks; consider this in the early stages.
- Most plastics have a nonabsorbent surface and may not readily accept and retain printing ink.
- Foil substrates present ink problems similar to those that occur when printing on plastics.
- Fine details should overprint solids (usually white) rather than on the bare plastic surface. This leads to cleaner and crisper print results and tends to minimize ink problems such as fill-in and webbing.

Table 3

The Consumer

Who will buy this product? What are the buyer's needs and preferences? Clients who have already targeted a product for a particular market can provide some of this information. But sometimes the designer may want to go deeper. A natural curiosity about behavioral patterns, buying habits and case histories from other projects often provides first-hand information. Designers also can add value to the design by projecting motivation to the buyer.

Branded Products

Products are often part of a family of products or brands. If the intended design is supposed to complement other items in the line,

or its package is a private label or national brand, then that design has to be considered in relation to the other products. Does it look like another successful product line? Should the newly designed product establish its own image and value? The designer and client must answer these questions together, based on the overall merchandising program.

Graphic Objectives

After all the research is done, and after reviewing the list of design requirements, it's helpful to think of the design project in terms of some basic graphic objectives. This can help to avoid undue concentration on minor details and allow the designer to focus attention on the more important principles. Some objectives are:

Visual Message. At the outset, the designer should know the primary design objectives.

- What must the design accomplish?
- Does the design motif suggest pleasure, excitement, celebration, good taste, cleanliness, happiness, tradition or other possible objectives?
- If the design is intended for a package or label, will it best serve the product by clearly identifying it?
- Is the design done in a style that will appeal to the buyer? Is it sincere?
- Will the buyer select and use the product with confidence because of the newly designed package?
- If the design is used for packing cases and shipping containers, will it function well and be easy to handle?
- Does the design effectively identify the manufacturer, producer or packer, and does it discretely project the image that this is another quality item from a well-organized company?

Information and/or instructional copy for pharmaceutical labels or packages is usually brief, as is the case with just about any small item. It's imperative to keep the small type legible. The choice of appropriate typefaces, point sizes and layout can help promote readable copy.

Product Personality. Projecting the true characteristics and personality of the product through thoughtful design is closely related to the art of projecting a visual message. Employing suitable graphic design, color schemes, illustration techniques, photography, typography and ink coverage in the right balance and in the proper relationship to the substrate emphasizes the true nature of the product and its uses.

The design that takes advantage of all its different parts can do a lot to help establish, illustrate and describe the product. Carefully selected elements can spell the difference between an ordinary or extraordinary design.

Priority of Elements. Before making a final choice on the design, the designer should check the visual priorities of all the elements. In package, label or carton design, it's especially important that the viewer's eye is attracted to the most important elements. There are many ways to emphasize these, including color, size, space allocation, typography, contrasting color values, shapes, illustrations, brand names and subject matter.

The ultimate design choice should have the assurance that the parts are in proper visual order and relate to each other under a priority system. Elements should not compete with one another for top billing.

A simple test of visual priority is to put yourself in the buyer's position and imagine what information you most want to see. Questions such as: What is it? What can it do? Who makes it? How can I use it? Will it fill my needs? What does it cost? Is it guaranteed or approved? will help establish the right visual priorities. Of course, these priorities will differ with each project.

Mechanics of Design Preparation

Until now, planning for the design has been the main concern. Obviously, the degree and depth of planning is different from one flexo application to another. Some projects may require less, while others may require more intense and varied research before the design concept is decided. The actual steps in the preparation and presentation of the design to the client are discussed below.

THUMBNAIL SKETCHES

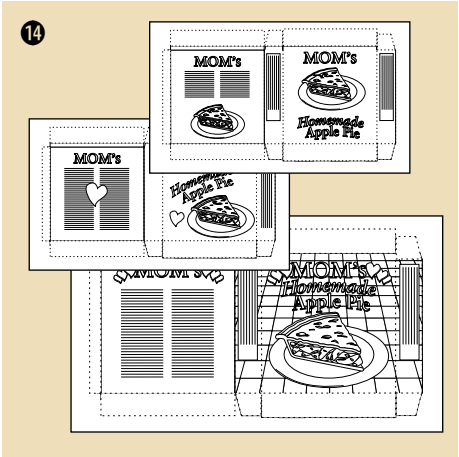
The designer may start with some simple thumbnail sketches, either drawn by hand or done on the computer (*Figure* ⓮). For the first time, the design ideas are in visual form. Revisions and refinements are easily done at this stage to meet any change in design requirements. The designer will choose several of these thumbnail sketches to work up into comprehensive roughs (comps).

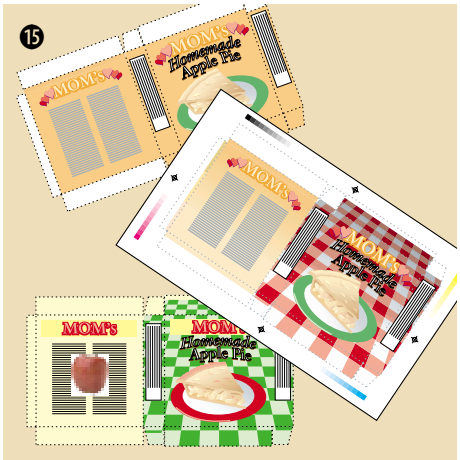
COMPREHENSIVE ROUGHS

Initial graphics can be roughed-in at low resolution on the substrate or some similar material. The roughs are reworked and refined, until one layout plan emerges that can be reviewed against the list of design requirements. As this work continues, many graphic decisions are made along with those regarding colors and techniques. The graphic plan is finally checked against specifications and other technical aspects.

RENDERING (FINISHED COMP)

Designs and comps should be prepared with inks and color separations in mind and a concern for line, tints and/or halftone areas. The converter's equipment limitationsre also has to be considered. If these elements are incorporated early in design planning, valuable time is saved in interpretation.





⓮ The designer's first step after the planning stage is to do a number of thumbnail sketches. The design concept is finally in a visual form.

⓯ A finished comprehensive rendering of the package is presented to the client for approval. It is only after this approval that the production stage can start.

Also, problems are reduced for the platemaker, ink personnel and press people.

The working layout is usually printed on high-quality computer paper. A rendering, or finished comp, is generally done on the actual material to be printed or a reasonable substitute to which the colors can be applied. How the rendering of the design comp is handled depends on the substrate and the proofing equipment to be used (*Figure* ⓯).

PRESENTATION

The wide range of methods of preparing designs for presentation allows the designer many techniques to work with. He or she has the option of using a suitable rendering technique for the design project at hand and, depending on time and cost, can tailor the rendering phase to gain the most effective, efficient and economical result.

To give the design a chance to express itself, a three-dimensional mock-up should be made. This ought to be done with care and concern for ease of printing.

Once accepted, the design is ready for the production artist. The production artist needs to follow guidelines set by the client, art director and printer/converter, in order to create the electronic files with minimal possibility of error.

ELECTRONIC IMAGING AND COMPUTER GRAPHICS

Over the past 20 years, many conceptual and mechanical aspects of design for flexographic printing have changed dramatically. Computer graphics have altered every aspect of production. Design studios, prepress houses, and printers all realize the profit potential and enormous power of computer graphic systems now available. A glance at the computer-oriented environment reveals the many changes. (*Figure* ⓰).

The Work Flow Process

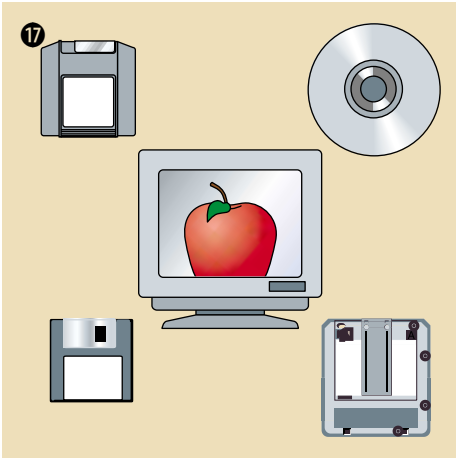
Let's suppose that a designer has the title, copy matter and pertinent legal description of a new wine about to debut. The client wants flowers on the label, and market research agrees. The designer pores over a file full of photos, gleaned from many sources, and chooses some. Then, the designer sends an assistant out for a dozen roses.

With roses and pictures in hand, the flowers are arranged nicely and some colored paper is set up as a contrasting background. The three-dimensional arrangement is photographed using a digital camera, and the scene is captured on the computer screen and the image is backed-up and stored on a hard drive.

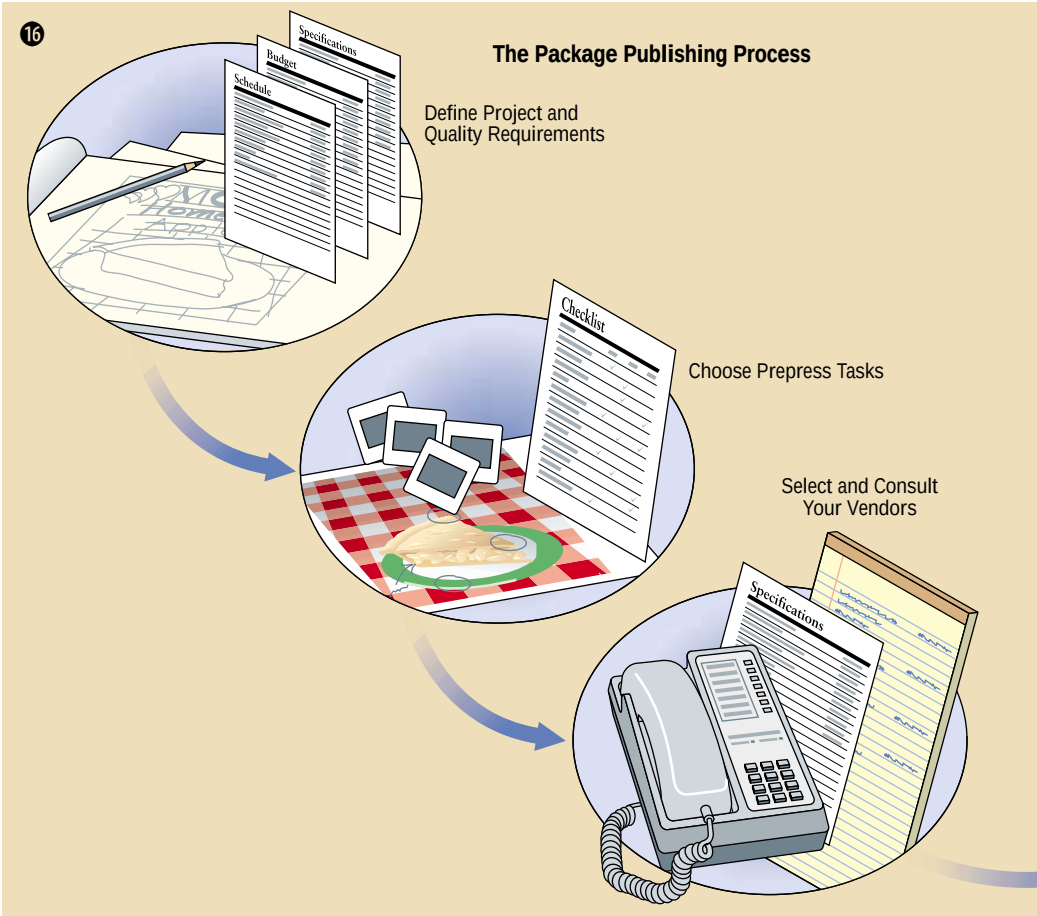
The designer's next step is to put the title and copy into the system. If the copy is somewhere other than in the designer's computer, it can be transferred directly into the designer's workstation by disk, CD-ROM, over a network with other computers or by using a modem (*Figure* ⓱). A modem receives and transmits data over a telephone line to give the designer access anywhere.

Experimentation

After gathering the elements of images and text, the designer is ready to start experimenting. What was once a very costly and



⓱ There are many types of removable storage available today. Be sure to check compatibility with your service bureau.

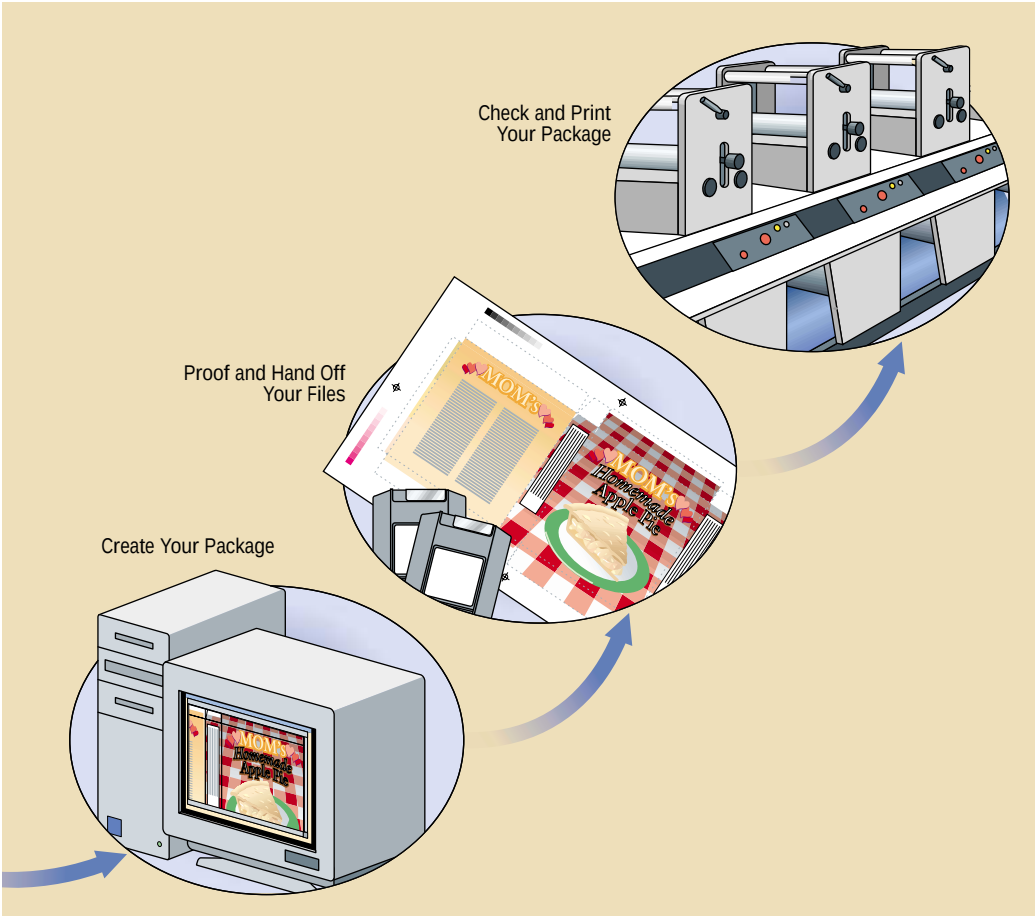


time-consuming ordeal consisting of camera work, typesetting and art is now quick and cost-effective. Computer graphics provide almost immediate and limitless variety. By using the computer monitor as an electronic canvas and the mouse as a paintbrush, the designer can scale, crop or combine the images and backgrounds in any combination. Red roses can be made yellow, a mountain scene can be placed behind them or they can be made to float among the clouds. At every stage, a new view can be saved for comparison. Images and type matter can be twisted, stretched, turned and otherwise modified in minutes, compared with hours, perhaps days, using traditional methods.

With the increased control of the design, the designer's imagination is now allowed to move freely and quickly. Essentially, the designer assumes the role of typesetter, illustrator and cameraperson, but without a disjointed sense of separate elements in the process. Computers enable the designer to maintain and refine the concept without the high cost of yesterday's technology.

Presentation and Approval

When it's time for the presentation, the computer allows the client to see the affect of his/her input quickly and clearly, without sending the artist back to the drawing board. The client can decide then and there that pink roses would add the necessary impact to the label. Since the designer can make on-the-spot changes, there's no need for another meeting.



16 Successful packaging requires several steps including planning and organization, design and production, pre-press, proofing, and printing.

If the client would like to see the new design on the bottle and on the shelf next to competitors, a trip to the local market to shoot slides of the wine section is all that is needed. The slides are scanned into the computer and the new label is electronically wrapped around one of the bottles by using a three-dimensional imaging program.

If the client wants to show the designs to the board of directors for final approval, all the designer has to do is generate 35mm or 4" x 5" transparencies from the computer or full-color paper proofs from either a laser printer or ink-jet printer of each composition. The images can also be transferred to videotape.

In the case of our wine label, the client's approval simply tells the designer to print out a final high-resolution set of negatives from an imagesetter to be delivered to the printer. This branch of the computer system usually is at a printing facility. It does all the color separations, which require only a final review by the art director.

The growth of this technology has been incredible and is sure to continue. It's important to remember that, while these tools spur the creative process and boost productivity, they can't replace the human element. Indeed, people will always be the crucial investment for any design studio that wants to stay competitive.

Production Art

By establishing a dialogue with production artists who turn concepts into electronic art files, the designer can learn about the flexo tolerances within which the design must function during production. This can save time between the initial concept, the final digital file and the film from which printing plates will be made.

Interruptions for clarification or revisions can be costly. To avoid printing problems, the designer should have a reasonable working knowledge of flexography's production art requirements. Communication with the plant or production manager regarding the limitations of the manufacturing equipment will help the designer develop designs specifically geared to the situation.

Guidance from the production artist, the prepress shop and the printer is important. Methods of producing the finished artwork, color separation, prepress proofing devices (digital proofs, color keys, matchprints, etc.), and any other art preparation data must be considered.

The production artist's job is to take the customer's design and turn it into the final art file from which printing plates can be made. The finished artwork must, of course, fit the final package, container or product, with all type and illustrations properly positioned. The copy and other design elements must be capable of clean, crisp reproduction on the substrate being printed. In addition, it must maintain registration.

DESIGN ELEMENTS

There are many similar elements that are included in all designs, including typography, contrasting color values, shapes, illustrations, photographs, brand names and descriptive subject matter. The overall design should have the assurance that the parts are in proper visual order and relate to each other under a priority system. Elements should not compete with one another for top billing. An easy test of visual priority is to put yourself in the buyer's position and imagine what information you most want to see. Of course, these priorities will differ with each project.

Typography

The length of a line of type is measured in pica units and there are 12 points to a pica, and 6 picas to an inch. The type character, or face height, is measured in point units. A point size is equal to the distance from the top of the lower-case ascenders to the bottom of the descenders.

The vertical spacing between lines of type also is measured in points, but is referred to as leading, or a given number of lead points. Multiple lines of copy are expressed as a combination of the actual point size of the type and the lead point height. For many texts, common settings are 9-point type on 11-point leading, or 10-point type on 12-point leading and is said to be "9 on 11" (9/11) or "10 on 12" (10 / 12) . Type set without leading is described as being set "solid." Although type is generally designed to provide minimum vertical line spacing when set solid, there is a chance vertical alignment of lowercase ascenders and descenders may touch. Lateral spacing of type that creates lines of equal length is called justification.

Individual lines of type can be justified.

When using type, the designer should take into account the aesthetics, as well as the press characterization information provided. The designer should consider the size of positive and reverse type, line weights of the type, the number of colors used, registration tolerances and trapping type. Other factors to be considered are the origin of fonts, text wrap, outline or stroked type, attributes or styles and special kerning specifications. Listed below is an explanation of characteristics that should be considered when selecting type.

Size. The minimum size of the type is based on print segment and the press characterization data. Six-point type for positive and 8 pt. type for reverse or knockout copy are the general industry standards for wide web. Four-point type for positive copy and six-point for reverse copy is commonly seen in the narrow-web field. When dealing with small type sizes, try to avoid typefaces with serifs and delicate strokes.

Line Weight. The press characterization data includes the minimum line weight that can be printed and the minimum reverse line that can be held open. Whether utilizing a serif or sans serif font, these minimums cannot be exceeded.

Color. Type should always be created with the fewest possible number of colors. As a rule, you should never use a combination of more than three colors for type. Remember, the looser the registration tolerances, the fewer the colors; and the smaller the type, the fewer the colors. Where colors overlap to maintain register, related colors are preferable to complementary colors because the latter may produce an undesired third color in the overlapping area. Where this can't be avoided, as when printing yellow type matter within a solid blue field, the undesirable discoloration around the lettering may be minimized by printing the yellow under the entire blue field if the color it creates is acceptable.

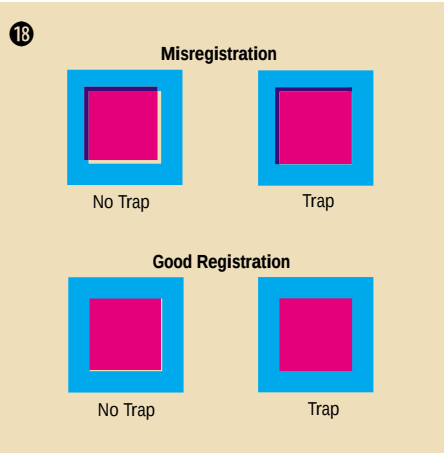
Logo colors are usually made up of spot colors to achieve the customer's color requirements. If this approach is used, the graphic file must have the logo color specified as a spot color and not a process color.

Registration. Although today's sophisticated presses are able to maintain fairly tight register, it is still a good policy to avoid hairline or butt register situations. Registration problems can occur anywhere that two or more colors adjoin. Printing presses are not consistently precise, due to the speed and force with which the substrate is pulled through. Even very small shifts in registration can cause noticeable white gaps if not compensated for (*Figure* ⓲). In wide web, 1/32" is the accepted tolerance if a design is prepared for a CI press. For a stack press, 1/16" is preferred. Corrugated printers look for 1/4" whenever possible, while narrow-web printers frequently work with less than 1/64". If in doubt, the designer should talk to the printer/converter's production staff about their equipment and personnel capabilities (*Table 4*).

Trapping. It is very difficult to read type that is made up of two or more colors and out of register. With larger type sizes, a solid holding line is usually applied to the type to hide any possible registration problems. Many logos contain two words that are in different colors. If these two colors are out of register, the two words will overlap or misalign. A distance that is at least twice the image trap is recommended to separate different color text (*Figure* ⓳). Applying a colored stroke or outline to the type can trap computer-generated fonts. The amount of the trap applied to a font is dependent on the size of the type, the kind of substrate being printed on and other variables. As a rule, the smaller the type, the smaller the trap that is required to prevent distortion of the letterform (*Figure* ⓴). The amount of trap required for proper registration ordinarily depends on

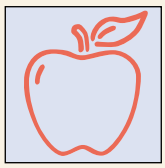
- the type of printing press involved;

⓲ Even if film is prepared correctly, there are often problems with holding exact registration due to the substrate stretching or shifting during printing. Even minute shifts can cause visible problems.



DOES THE ARTWORK REQUIRE TRAPPING

NO:
No colors touch, or colors that do touch have a common color element (C, M, Y or K).



YES:
Colors that do not share a common element (C, M, Y or K) touch each other in this file

QUESTIONS TO ASK:

Which colors should spread and which should choke?

Where do traps go?

How much trap is needed?

DO-IT YOURSELF OPTIONS:

- **Manual trapping:** Common controls within graphic programs provide do-it-yourself trapping, once you've mastered trapping concepts.
- **Automatic trapping:** Some programs include automatic trapping features that will make trapping decisions for you. While such programs are sophisticated, successful use of these automatic features requires some knowledge of trapping concepts and familiarity with the methods used by the program. Also, they cannot create traps in art that has been imported from another application.

PREPRESS OPTIONS:

- **Manual trapping:** For a fee, the prepress provider will prepare the traps using the controls in the graphics software.
- **Automatic trapping software:** Many prepress providers use sophisticted trapping software that can automatically trap artwork, including imported graphics.
- **Automatic trapping during imagesetting:** Some RIPS automatically trap files as they are output, resulting in little extra time or cost.

Table 4

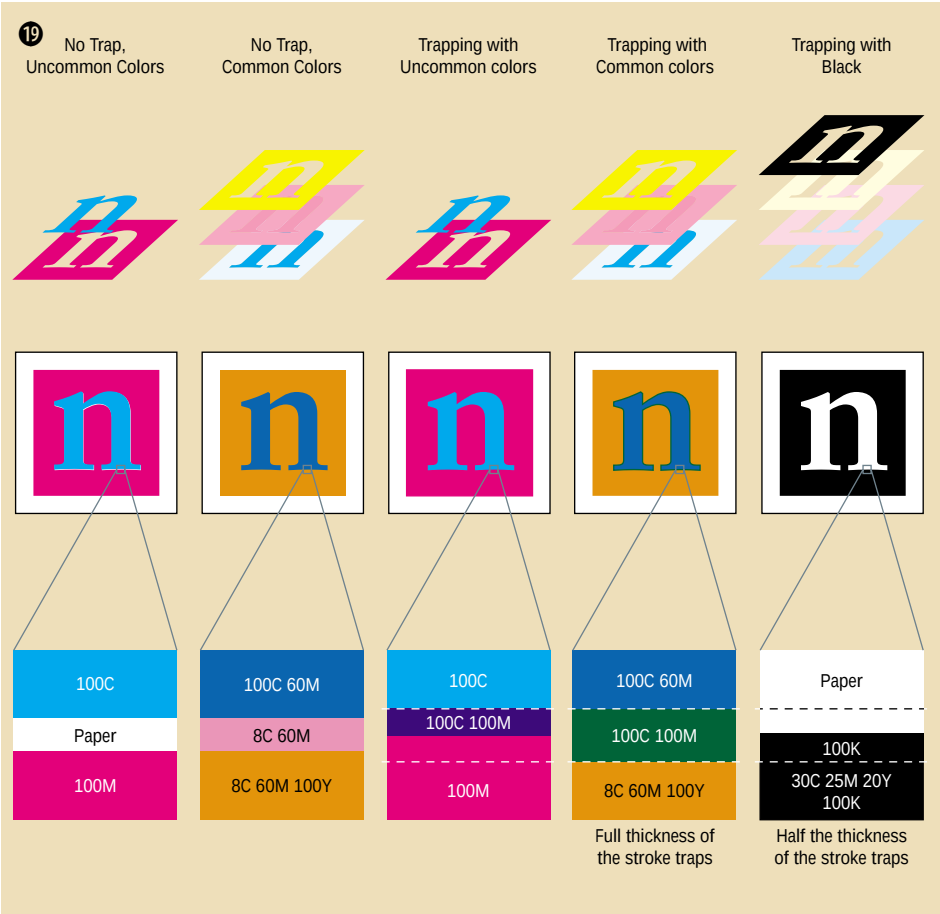
- the design intricacy;
- the substrate;
- the number of colors;
- the printability, flow, colors, and
- the opacity of the inks.

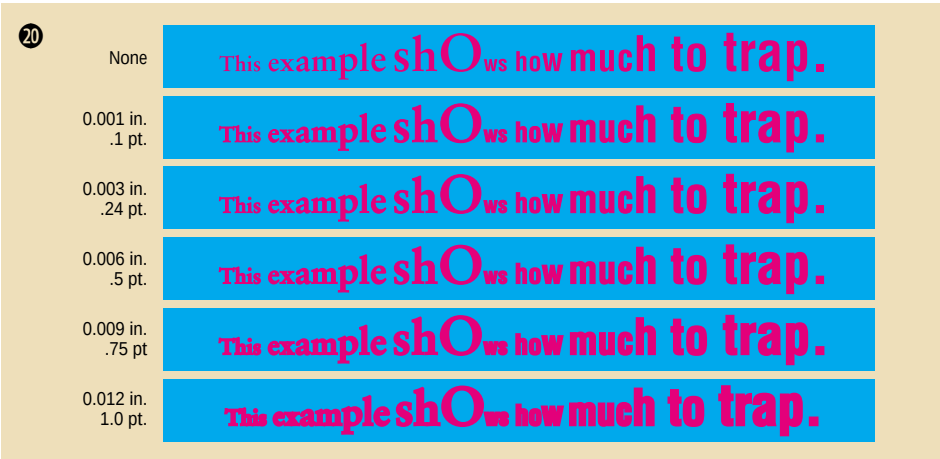
A central impression press may hold register better than an in-line or stack press, especially on flexible webs and may need less trap. A fine-line, six-color illustration on coated stock might take a 0.030" trap, while three or more times as much may be needed in a poster-style illustration printed on kraft stock. When printing related colors, a more generous overlap may be acceptable than when printing complementary colors. Trapping complementary colors is likely to cause an objectionable third color.

When transparent colors are overprinted to produce second and third colors, butt register is often necessary. In such cases, take great care in handling color register. It's often wise to use outlines where the overprinted colors touch to prevent the appearance of misregister.

Origin of Fonts. There are thousands of type fonts available in both TrueType and PostScript formats. Though TrueType fonts are prevalent in the desktop industry, they do not always RIP (raster image process) correctly, so they are generally not supported and should be avoided. Type 1 PostScript fonts are recognized as the industry standard and contain both an outline font (printer font) and screen font (bitmap font). When using PostScript fonts, both files must be installed on the output system. To ensure that the fonts will output correctly, it is necessary to include both the outline and screen font with the file. If a design requires a unique font, the designer should convert the type to an outline. This is only recommended if it is a large type size and a minimal amount of type (*Figure* ㉑).

Text Wrap. When automatic type wrap options are on, text will reflow every time an

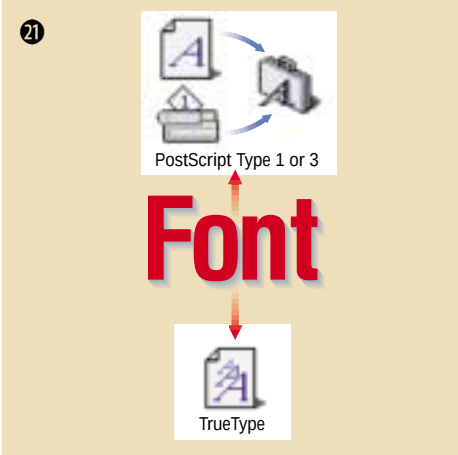




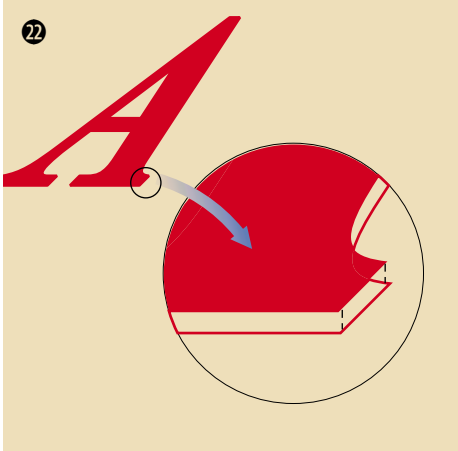
19 There are a variety of ways that trapping type can be handled including top to bottom: No trap, uncommon colors; no trap, common colors; trap, uncommon colors; trap, common colors; trap with black.

20 In the example shown you can see how different trap values affect the serifs as the size of the trap is increased.

image is placed or replaced. If the image is an FPO (for position only) and the separator replaces it with the high-resolution image, the text might reflow differently and the separator must then manually flow the text to match the original design. Most software programs allow the user to create polygons for the text to wrap around instead of the actual image. When polygons are used, the text does not reflow if the image is replaced.



㉑ Font icons identify the type of file (screen or printer), the maker of the font (foundry) and whether it is TrueType or PostScript.



㉒ Outlines around type should be the same color as the body of the text.

Outline or Stroked Type. Thin outlines around a tint should be in the same color as the tint (*Figure* ㉒). If a trap outline is being created, the line weight must be at least twice the specified trap allowance because both the background color and text color have to trap to this outline. After the stroke has been applied, it is important to verify that the "counters" (holes in letters such as a, b, D and R) or serif areas have not closed up. It is best to not stroke large amounts of text as it does make the file larger and slows down the processing time.

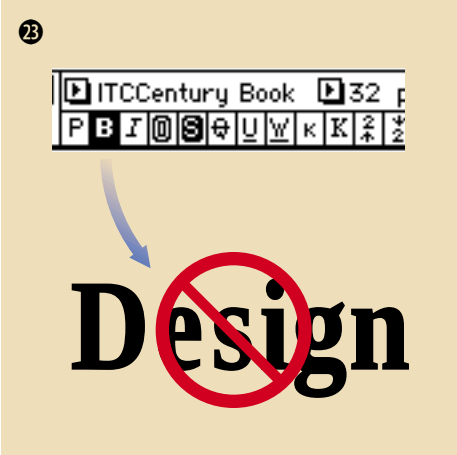
It is recommended that when an artwork file has an embedded EPS file containing type, the text should be converted to paths or outlines to avoid RIP conflicts. But converting type to an outline is not recommended to resolve standard font conflicts. When a typeface is converted to paths, the copy is no longer editable and the conversion process can degrade the quality of the text, especially small type sizes. If possible, it is better to include all fonts (even those that reside in an embedded EPS file) with the artwork file to be output.

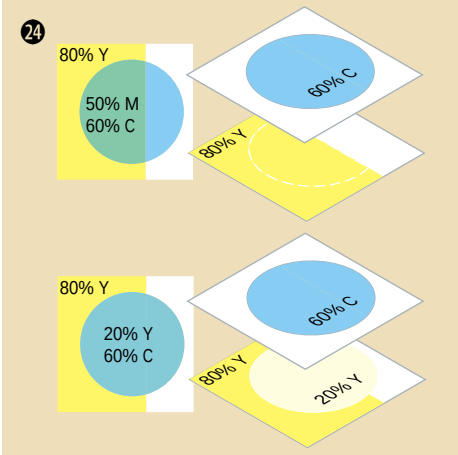
Attributes or Styles. The typefaces in a file should never have an attribute or style applied to them. Attributes and styles are convenient tools available in most desktop applications that can be used to modify typefaces. When attributes are used on a font, it will appear on the screen as a modified face, and may even print to your proofing system correctly, but it is not guaranteed that the selected style will be applied to the typeface upon output. It is always best to use the actual fonts available in the software program (*Figure* ㉓).

Special Kerning Specifications. Any modified kerning, tracking tables or suitcases must be supplied to the separator with the final graphic file. Failure to do so will cause all of the modified information to be ommited from the final separated graphics.

Overprints

An overprint is when one solid color prints on top of another solid color. Overprinting graphic elements might seem like the perfect solution for eliminating undesirable traps. This is especially true when the designer wants to use small graphics that are surrounded by another color. The designer should be aware of some overprint limitations. Dark-colored graphics overprinting a light color can work very well. On the other hand, overprinting light colors on top of darker colors can change the look and color of the overprint to something undesirable – think of a yellow printing on top of a cyan vs. green overprinting cyan (*Figure* ㉔). When





㉓ You should always check to see that typefaces do not have an attribute or style applied to them which will modify the face and could create problems upon output.

㉔ Overprinting objects without common ink colors, combines the ink values where the objects overlap. Overprinting objects that share inks show only the overprinted color where the objects overlap.

you overprint colors with shared inks, common ink values will not combine. Illustrator has a filter called “trap hard” and trap soft”. These filters can be used by the designer to view a simulation of what an overprint will look like when printed.

Trapping

Trapping is a major concern in the flexographic industry because of the unique registration tolerances on a flexographic press. Trapping is used to compensate for any possible registration problems. The trapping requirements used for flexography are often larger than those used for an offset press. Most designers are not required to build traps into an artwork file and therefore are unfamiliar with requirements for trapping. However, it is important to be aware of how much trap will be applied to the graphics so that good design decisions can be made in creating the graphics. Desktop application software has tools or special features that allow a designer to trap the artwork, but it is usually the job of the separator to build trapping into an artwork file.

Trapping is simply enlarging a print element so that the edges that come into contact with other elements overlap (overprint) by a specified amount. The amount of trapping required for an artwork file varies from press to press. Each press has a set of tolerances and operating parameters. The trap radius is one of the tolerances that a flexographic press should be characterized or fingerprinted for and then applied to all artwork that will be printed on that press. Trapping is a necessary stage in the prepress process that compensates for the registration tolerance of a printing press.

Trapping can change the appearance of artwork. Some colors create dark lines where they overprint another color (*Figure* ㉕). This dark line, the trap, then becomes a visible element in the overall design and in some cases can be distracting to the artwork’s overall appearance. Sometimes the trap can be modified to make it less obvious, but it cannot be removed. It is in the basic design of the artwork that trapping problems can be avoided.

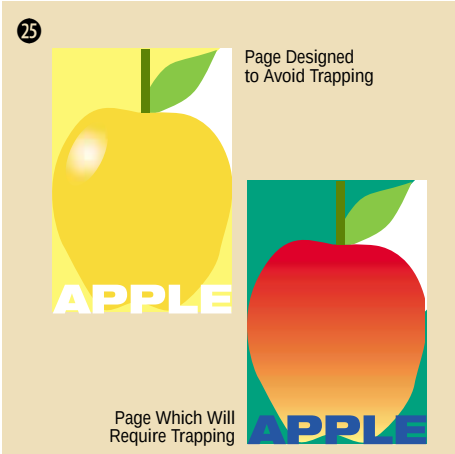
Vignettes and gradient fills can be difficult to trap because of the gradual change of the tint values that occur in a gradient fill. If the vignette is trapping to an element that is a 100% solid color, the trap is easier to hide. But if a design has a vignette abutting a second vignette, the trapping can become much more difficult and visually unappealing. With some prepress systems, trapping vignettes can even be impossible to do.

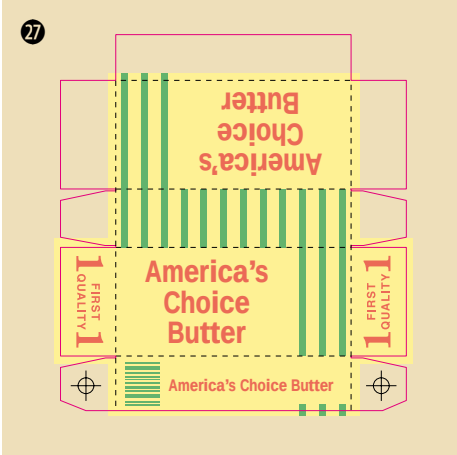
Drop shadows in a design are also difficult

㉕ The trap line must be a wider thickness and overprint the original object.

㉖ Drop shadows are often difficult to trap and can create unusual looking results on the final package.

㉗ Die lines provided by the die maker will ensure accurate positioning of all graphics to the cutting and folding lines.





to trap and tend to create some unusual looking results on the final printed piece. An example of unusual trapping would be a bold typeface, colored in a pale green and sitting on top of a 50% black drop shadow, with the entire image on a background of a pale yellow (*Figure* ㉖). The typeface would be lighter than the drop shadow and would have to spread into the shadow. The background yellow would have to spread into both the shadow and the green type.

Die Lines

Most packaging graphics have to be placed according to die-cut scores, cuts and folds (*Figure* ㉗). Therefore, the final package must incorporate print-to-print and print-to-cut (or fold) registration. Specifications for the positioning of graphics in relation to the location of die-cut scores, folds and cut line, will vary depending on the press width and press type, and must be adhered to by the designer.

Die lines can be requested from the die maker's CAD (computer-aided design) system, usually as an EPS or Adobe Illustrator file. The die lines from a CAD system will accurately show all cuts, perforations and score lines being made on the final project from the die maker's perspective. Die lines require exact dimensional accuracy (for example: 2.000, not 1.998 or 2.003 for a 2" dimension).

Illustrations

Many tools available for a designer to create illustrations. Many formats used to build illustrations prove difficult to separate and then print on press. Some of these difficulties relate to the way the illustration was created and some to the actual makeup of the illustration. Thin lines, strokes, trapping, gradations, pattern fills and other elements can cause difficulty when trying to maintain the integrity of the illustration on the flexo press.

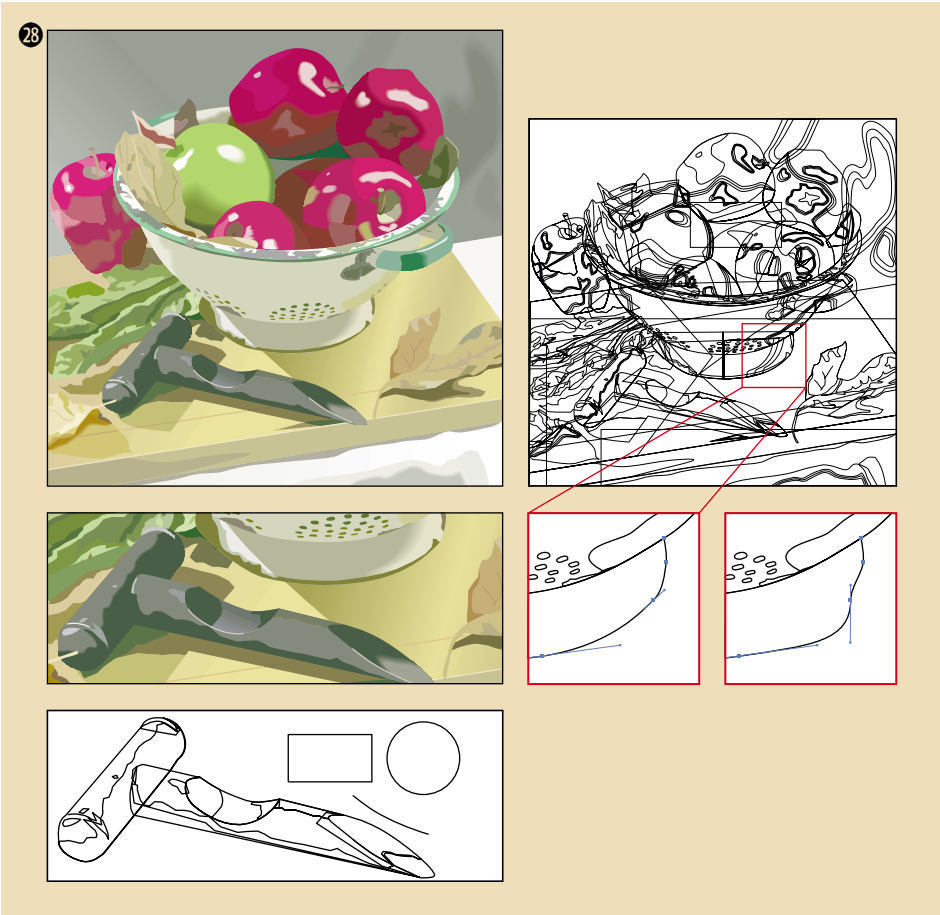
When selecting color for an illustration, there is no limit. But a smart designer will use one plate or a spot color to define the

stroke for the illustration. Two or more plates can successfully define color areas inside an illustration, but areas that are defined in this manner should be chosen carefully. Broad color areas that abut bold strokes are more forgiving with press mis-registration than small color areas that abut thinner strokes. Another problem that can occur when coloring an illustration is "gaps". Gaps can occur when a file is created in such a way that an illustration's strokes are placed on top of color areas that contain separate elements of the illustration. An area that has an abutting or underlying color area should be magnified to see that the elements are flush with one another and that the color areas are under the stroke.

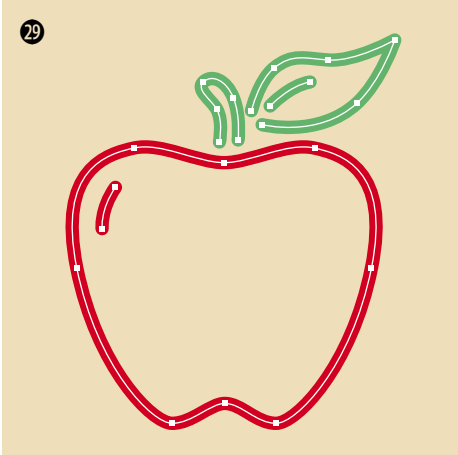
Another culprit of gaps is an open path or strokes with a color fill assigned to them. Strokes should have no color fills assigned to them. If the file is not void of gaps, problems could occur during the trapping phase of the artwork.

Object-oriented Artwork

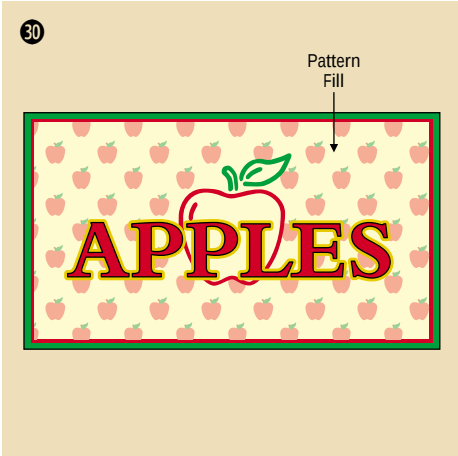
Object-oriented graphics, also known as vector graphics, are shapes such as curves and line segments, mathematically defined across an invisible grid. Simply using the mouse to select and drag individual or groups of control points can reshape object-oriented graphics. Vector graphics are resolution-independent, which means that they can be printed or displayed at any resolution that a printer or monitor is capable of (*Figure* ㉘).



㉘ Object-oriented images are made up of drawn objects such as circles, squares, lines and complex curves called paths. Object-oriented images are defined by points which are used to manipulate the image.



❷❾ To avoid problems during the prepress processing of electronic files, the production artist should simplify paths.



❸⓪ Fills are great looking, fun to use and create impressive results, but they can cause processing problems in interpreting the pattern data at the RIP.

Auto-trace and vector graphics. Should a designer decide to create a design the "old-fashioned" way by hand drawing with a pen and ink or pencil, the illustration must be scanned into the desktop environment. Once scanned, the design is converted to line work using a vector conversion application such as Adobe Streamline or an autotracing feature available in Adobe Illustrator or Macromedia FreeHand. Autotracing and vector conversions are not very accurate in recreating the original image because additional points can be added to a path. These additional points can alter the shape of the original line, add more data than is necessary and slow down processing. It is crucial that settings are correctly used or the traced illustration may be reproduced with an excessive amount of control points along the illustration's paths. Artists should also try to avoid long, continuous paths. Paths that are complex with many points can cause problems during the prepress processing of the electronic file. The cleanest lines are the lines created with the fewest points (*Figure* ❷❾).

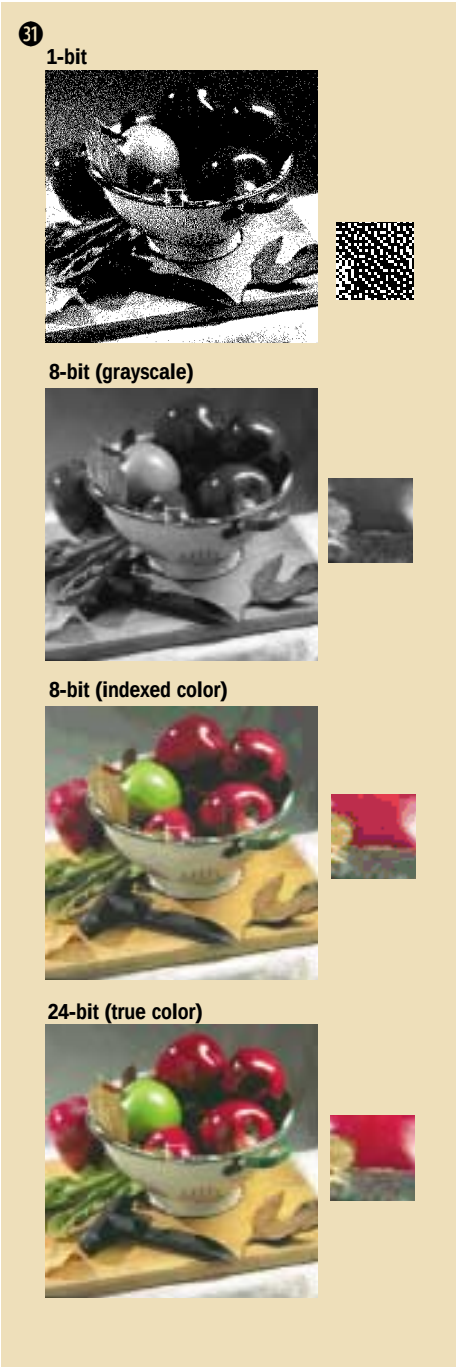
Pattern Fill. A further consideration to be taken into account when coloring an illustration is pattern fill (*Figure* ❸⓪). Fills are great looking, fun to work with, create impressive results and are easy to use – truly a designer's dream come true! But, they can be a production artist's nightmare. Pattern fills modify an electronic file's integrity in ways that are not evident to a designer. Still, pattern fills make electronic files difficult, if not impossible for many prepress systems to process. Pattern fills should be avoided, or before using, test the output of the pattern on the output device. One of the processing problems with pattern fills is that the RIP can have difficulty interpreting the pattern data.

Sizing. At times, an illustration is reduced in size after being created. For instance, an illustration might be reduced to fit onto a side panel of a package. This reduction can cause problems with the printability of the illustration. Line weights, type size and trap areas may become smaller than the minimum specifications.

Complexity. Some illustrations can be very complex, containing many graphic elements like patterns, gradations, colors, varying line weights, text and more. When a separator is working on this type of illustration, the layering of the elements can change, making it very difficult for the separator to get all elements back into the correct layering order. The illustrator should try to group "like" objects together or elements within one object together, to avoid this problem.

Bitmapped Graphics

A bitmapped image is defined pixel-by-pixel and has a fixed resolution. (A pixel,



31 A 24-bit continuous-tone image can be depicted with up to 16.7 million colors, but the size of the file will be much larger than a similar image created with 8 bits per pixel.

short for picture element, is a square of color). Bitmapped artwork can be drawn, painted or scanned onto the computer. The simplest of computer graphics are defined by one bit of data per pixel, which instructs the computer to display a black dot or a white dot. Color graphics utilize four to 24 bits of data per pixel.

Resizing a bitmapped graphic changes the size of the individual pixels. A 2" x 4" image scanned at 72 dpi will look fine on the monitor, but enlarging the image to fill the screen will create an unsatisfying picture.

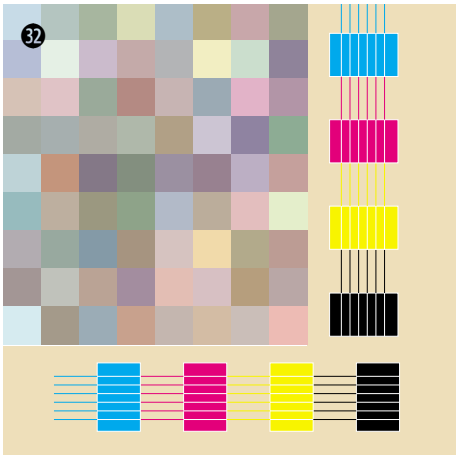
Printing bitmapped graphics can present additional problems, which must be taken into account during the preparation of the file. Continuous-tone color or grayscale images must be converted into halftones for conventional printing. The final printed resolution and method of screening must be known before a bitmapped image is created (*Figure* 31).

Line Drawings and Clip Art

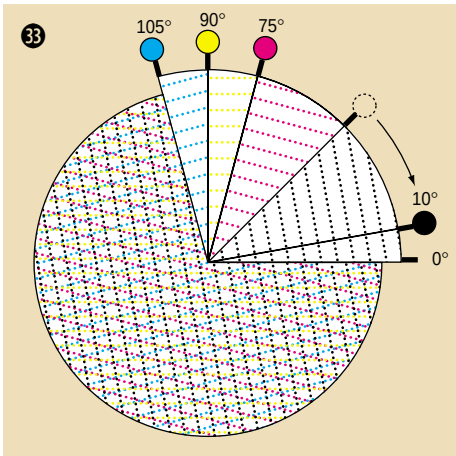
Drawings made up of solid lines are frequently used in packaging design. The designer can create the line drawings, hire an illustrator for the job, or use clip art. Clip art needs to be carefully evaluated and selected if it is going to be used in the design. Some clip art is of very good quality and is saved in usable formats, while other types can cause major problems. Before choosing clip art the following should be checked:

- File format is one that can be easily edited by the designer or separator, such as a vector EPS.
- Pixel artwork saved at the correct resolution, 300 dpi for printing.
- Artwork paths in clip art do not contain an excessive number of points or problems could occur when the file is output.
- Colors used in clip art can be easily combined with the colors available on press. Care must be taken to be certain that all colors are converted to the color palette available for the job.

Line Weight. Expect an increase in line weight of positive lines and a decrease in line weight of negative lines in the finer, nar-



32 Typical line-weight scale from a press characterization target used to determine minimum capabilities.



33 Examples of a moiré pattern which occurs when the angle of the anilox roll is not taken into consideration before choosing screen angles .

rower lines of illustrations, just as with smaller type sizes. Compensate for this by drawing positive fine lines slightly thinner and reverse lines slightly heavier than the line value desired in the final print. Line thickness tolerances vary from press to press, so it is necessary to refer to the press characterization data for the line-weight minimums (*Figure* 32). If you supply art with a line weight less than the printers' specifications, the separator will need to make the line weights heavier to meet the printers' capabilities.

Dots. The same thing happens to dot sizes in tints and screen values. According to your own printing circumstances, compensate about 10% to 20% for dot growth when selecting screen values.

Be sure to consider the web direction and linear direction of dots in tints, monotones and duotones as they are applied to the art. The cells of the anilox ink metering roll usually run 45° to the web direction. Therefore, the direction of the dots in the screen should be angled off those of the anilox roll to avoid possible moiré patterns. A moiré pattern can occur when two or more screen angles that are too close to each other are used. When screen angles conflict, they create a variety of objectionable patterns instead of the tone values you want (*Figure* 33).

PHOTOGRAPHY

When the designer takes part in planning photography for the design, he/she can provide parameters that will ensure the successful printing of any photograph.

Highlights. Offset photographers might try to accentuate the highlight area of a product or make the highlight a focal point of the image. The same approach can be used with some photos that will be printed flexo, but must be carefully addressed. Remember that generally, the smallest flexo dot that will print is 3% and the 3% dot, with dot gain, will actually print at around a 12% dot.

Shadow. The shadow area requires the same considerations as the highlight area. Large shadow areas could fill in. As a result, the detail will be lost and the shadow area will just appear dark.

Amount of detail. The clarity of the photograph is directly related to the line screen at which the photo will be printed. Clarity is dependent upon the number and size of objects and the amount of detail. For instance, if an image is going to be printed at 175 lpi, the detail and small objects will have clarity and look good. If the same image is going to be printed at 100 lpi or 85 lpi, the detail and small objects may not print as well.

Digital Photography. With digital photography, the photographer can play the role of

separator and photographer. Most digital camera software offers the option to convert from RGB to CMYK on the fly, but unless the photographer is a trained separator, the CMYK conversion should not be done. The separator has the print characterization data and experience and should do the conversion. However, the photographer does need to control and properly set the following:

- Make certain that the highlight and shadow input/output values are set to the tonal range of the actual flexo curve. Setting tonal values in this way limits the amount of detail and contrast in the photo. The full 0–256 gray scale range should be used. By using software like Adobe PhotoShop, the flexo tonal range can then be applied to the photo data file.
- Ensure that the lighting and exposure of the actual photo area is controlled so there is plenty of detail in the shadow areas.
- Be sure the camera is capturing true neutrals. A gray reference should be used in each photo. Camera software should be properly neutralized to the gray reference.

Halftone Images

Halftone, process, grayscale, monotone and continuous-tone images all refer to artwork that has been scanned or created in a pixel-based application such as Adobe PhotoShop (*Figure* ❸❹). Working with such images opens an entirely different arena of situations that need consideration during the design process.

Content of image. Applications such as Adobe Illustrator, Macromedia's FreeHand or QuarkXpress allow a designer to crop, rotate, resize and mask graphics, but it is far better to manipulate raster images directly in PhotoShop.

Unfortunately, many artists do not use PhotoShop to perform these tasks. If an image is cropped or masked in PhotoShop before it is placed in an illustration program, the image file is easier to manage in the secondary application. Modifications in PhotoShop also make the overall size of the completed artwork file smaller, which then makes transfer easier across a network or process through a prepress system or RIP.

❸❹ Halftone, process, grayscale, monotone and continuous tone images all refer to artwork that has been scanned or created in a pixel-based application.

Screen resolution. It is important to use the specified line screen resolution when viewing illustrations for approval. Viewing at the correct line screen can be done with the color printer, but cannot be seen on the monitor. Line screens can look very different at a high resolution, such as 175 line screen, compared to low resolution (45 line screen). Typically, color proofs and monitors use a viewing resolution comparable to a 175 line screen.

Color. Another area of consideration is the color mode of the image that the designer is working on. If a full-color photograph has been scanned in, chances are that the photograph was scanned into RGB channels. Initially, when working during the design phase of the artwork, using RGB channels can be helpful in expediting the creative process. Files saved with three channels makes for a smaller file, which allows for faster manipulation of the image in desktop application programs. A problem occurs

when the designer does not preview the image in CMYK. The file should be sent to the separator in the original RGB format. The separator will then convert to CMYK using the correct dot-gain compensation. RGB channels are a color mode used for projecting color onto the monitor. It is also the color mode that many desktop scanners support. But presses do not print in RGB and if a press will not support a color mode, chances are excellent that a prepress system or RIP will not support it either. Some prepress systems will not process an artwork file if an RGB image is detected. Converting files into printable color modes is done very simply inside an application such as Adobe PhotoShop. It can be very useful for the designer to know what file formats and color modes are supported by the prepress system or RIP that will process the artwork files.

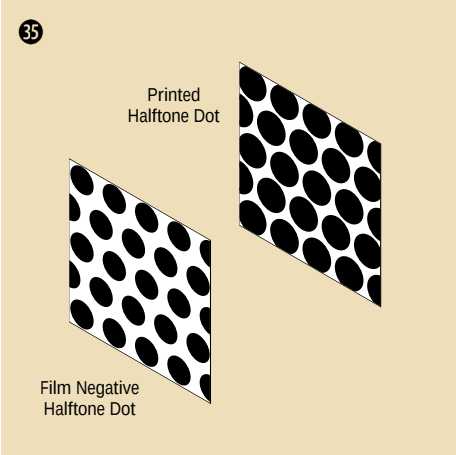
Trap. Trapping a halftone to another halftone can be tricky because different halftones contain common colors. The designer may not want a trap to occur, while the prepress software may automatically apply a trap. It is best to consult with the prepress provider to find out what will happen when these files are sent to the RIP. It is up to the designer and separator to decide whether or not the halftones should be trapped to each other. Trapping a halftone to a solid color or outline is fairly simple. If the halftone is trapping to a dark color, the trap probably will not show. But if part of the halftone is dark and part light, a dark line color will show in the light area of the halftone.

Shadow, Highlight. Shadow and highlight areas (the darkest and lightest areas of an image) can have a positive or negative impact on the overall design appearance, depending on these areas print. When an image has a highlight area that graduates from 15% black to 0%, it may look good on the computer screen and may even print out beautifully on the laser proof. There is no guarantee, however, that what is seen prior to printing is what is going to come off the press. To avoid this type of problem, a designer should be aware that all presses are different and refer to the specific press characterization data from the printer or separator.

Each press has a set of tolerances or limits. For example, some presses are unable to print very small dots. These limits occur for a variety of reasons. T he substrate that a job is being printed on, the plate material or the ink being used can cause limitations. Even the pressman running the press can have an effect on the print appearance of a particular project. Looking back to the example of a graduated highlight area consisting of 15% black through 0%, imagine that the press running this particular project is unable to print any dots that are 5% or lower. The result will be graduated areas of the image that fall within the 0% to 5% range will not be printed. When this occurs in a highlight area, what will appear on the printed copy is a gradual reduction of the black area and then an abrupt stop at 5%. This abrupt stop leaves what is known as a “break”, or if we compare it to printing with a rubber stamp, a bald spot where the ink didn’t print.

A designer can modify the highlight areas so this “break” will not occur if he/she knows which press the project will run on. Using the example of a highlight area that graduates from 15% to 0% with a break at the 5% area, a designer can modify the highlight area so that it graduates from 15% to 6%. This modified gradient will provide enough dot coverage to prevent a break or bald spot from occurring.

A similar phenomenon can occur at the opposite end of the tonal range. Shadow areas in an image may “close up”, become “muddy” or “disappear”. The primary cause of shadow areas “closing up” is a problem known as dot gain. Dot gain on a press is created when the surface of the plate (which is loaded with ink) comes into contact with the substrate and impresses (prints) the image



35 Halftone dots typically increase in size as the wet ink spreads when it reaches the surface of the substrate.

36 To achieve good solid coverage on the solid black, without causing the process black to fill in, two black print stations are used.

onto the substrate. A variety of reasons may cause the image to become slightly enlarged. When an area of the artwork is tinted or screened, the dots that create this screen can become enlarged during the printing process (*Figure* 35).

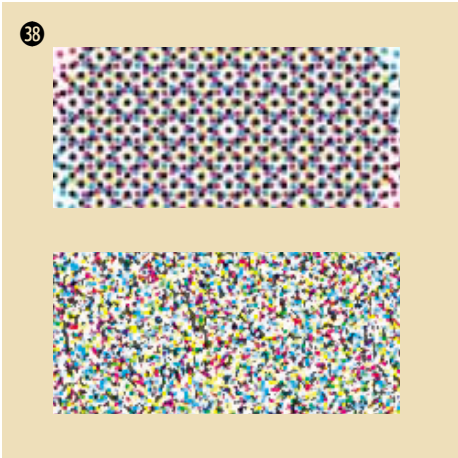
There are ways of applying creative solutions to manipulate halftones and accentuate the look of the graphics while hiding possible print defects. In *Figure* 36, the black in the text is the same process black that is in the image of the apple. Many times black requires more impression or a higher volume anilox to get good, solid coverage. This approach, however, will make the process black in the apple print heavier and therefore, they will look dirty. If there are enough print units, the black in the text can print on a separate unit from the one used for the black in the halftone image. Impression on the black in the apples can remain light, giving it a crisp, clean look.

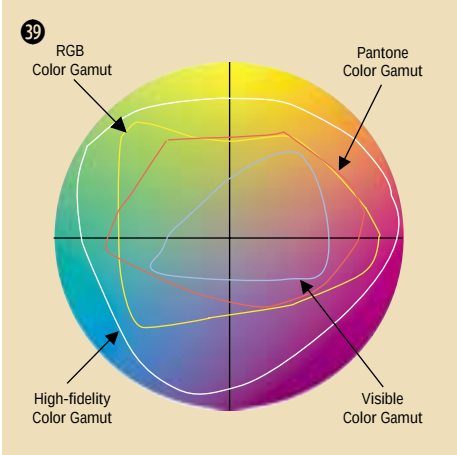
Duotones

A duotone is a halftone consisting of two colors (*Figure* 37). One color is usually used for the highlight and shadow areas and the other color for the midtone areas. Not only do duotones offer a fresh look for conventional halftones, they also offer print advantages over some halftones. Duotones can be used for particular print situations. For example, when the registration tolerances are not very tight a halftone made up of four colors instead of two could look quiet blurry. Duotones can also be used just for the interesting graphic effect of a two-color halftone. Duotones are handled by both the designer and separator the same way halftones are handled, except for color breaks. It is important to proof a duotone so everyone can see and approve or reject the two-color look. The settings and color separations need to be adjusted and proofed until a desirable outcome is achieved. Duotones can be fun to work with and look better than halftones in many cases.

Alternative Screens

Traditional halftone screening uses the size of the dot to convey shading. The larger the dot the darker the shading, while smaller dots provides lighter shades. Alternative screens can be visually appealing options for the designer. These screens look different than conventional halftone screens and can be more forgiving to print than conventional screens. Alternative screens come in the form of mezzotints, random or FM (*Figure* 38), pixelization, noise and others. Much attention has been given to FM (Frequency Modulated), also known as stochastic,





37 Duotones are usually printed in black and a custom color. In an image-processing program it is very easy to see how a duotone will look on-screen before the image is finalized.

38 Conventional (AM) and FM Screening. Because there is no regular dot pattern in FM screening, moiré patterns cannot occur and the smaller dots display more detail.

39 The color gamut shows the enlarged palette of colors available with high-fidelity printing techniques.

screens in the past few years, although usage in final production is still limited. FM screening renders the different shades of an image by controlling the number of dots in each area. More dots produce darker areas and fewer dots produce lighter areas. FM and conventional screening can be combined effectively in what is called combination screening, which is covered in more detail in the prepress chapter.

Before using any screen other than a conventional screen, the separator and printer should be consulted. The characterization data for new screen styles is not the same as that for conventional screens. Dark print or low contrast images could result if the new screen is not characterized on press before being used in a design. These screens could have very small dots – smaller than 1% conventional dots, which might not print or be on the plate at all. There could be RIP problems as well, because the RIP may not correctly interpret the data. Once the characterization and RIP tests are successfully completed, alternative screens can be handled in the same manner as conventional screens.

High-fidelity Color Printing

High-fidelity color printing uses additional process inks in order to reproduce more of the color spectrum. A package printed with high-fidelity color may use orange and green inks in addition to the cyan, magenta, yellow and black process inks. This would increase the color gamut by approximately 20% (*Figure* 39). High-fidelity color is relatively new and is not widely used at this time, but produces some very striking results.

Scanning

The rule of thumb for scanning in photographs is to scan an image at a resolution that is double the line screen used to print the image. Hence, an image that is to be printed at a 100 line screen should be scanned in at 200 dpi (dots per inch). If an image is scanned at too low a resolution, there is little that can be done to improve the quality of the image for printing. If any devi-

ation from the rule of thumb is made, it is better to scan an image at a higher resolution than is needed. Reducing a file's resolution is a much more pardonable offense than trying to add resolution to an already scanned image (*Table 6*).

The image should not be scanned using offset settings. The settings must be adjusted for flexo. The information needed to scan includes the minimum highlight, maximum shadow and the dot-gain curve. The dot-gain curve can be used as the density curve. The scanner operator will convert this dot gain curve into the correct density curve. GCR and UCR are widely used in flexo printing and the scanner operator can adjust the scan for the correct amount of each of these variables if this information is provided. GCR and UCR are applications used to make the black longer in the shadow areas. In other words, instead of trying to create shadows or neutrals with a combination of C, M and Y, black is used. Using these applications makes register, color control and trapping much simplier during the printing process. Since more black is being printed, the printer will separate the process black and the line black onto different print decks. This separation allows the printer to set the press for enough density and coverage to print bar codes and fine type, but limit dot gain in the process image.

The artist should also consider the size at which the image is to be scanned. If any enlargements to the original image are to occur, it is best to scan the image at the enlarged size. The scaling of images can have a direct impact on the time it takes to process the completed artwork. Also, the scanned image should not be much larger than the size at which it will be printed. A label image might be scanned from an 8" x 10" transparency, creating a 21.6 mb file. Yet the label might only print at 2" x 2.5", which is only a 1.35 mb file. When the image is scanned in at a much larger size, the designer or separator will have to reduce this image to the print size to make the file small enough so that it is manageable. If the orientation of the print is known, it should be scanned at the same orientation, if possible. Correct orientation saves output time and also makes the files somewhat smaller.

FILE SIZES OF SCANNED IMAGES

	1	2	3	4	5	6	7	8
1	277	553	830	1080	1350	1620	1890	2160
	352	704	1030	1370	1720	2060	2400	2750
2	553	1080	1620	2160	2700	3240	3780	4320
	704	1370	2060	2750	3430	4120	4810	5490
3	830	1620	2430	3420	4050	4860	5670	6480
	1030	2060	3090	4120	5150	6180	7210	8240
4	1080	2160	3240	4320	5400	6840	7560	8640
	1370	2750	4120	5490	6870	8240	9610	11000
5	1350	2700	4050	5400	6750	8100	9450	10800
	1720	3430	5150	6870	8580	10300	12000	13700
6	1620	3240	4860	6480	8100	9720	11300	13000
	2060	4120	6180	8240	10300	12400	14400	16500
7	1890	3780	5670	7560	9450	11300	13200	15100
	2400	4810	7210	9610	12000	14400	16800	19200
8	2160	4320	6480	8640	10800	1300	15100	17300
	2750	5490	8240	11000	13700	16500	19200	22000
9	2430	4860	7290	9720	12200	14600	17000	19400
	3090	6180	8270	12400	15500	18500	21600	24700
10	2700	5400	8100	10800	13500	16200	18900	21600
	3430	6870	10300	13700	17200	20600	24000	27500

2700 Digital file size image scanned at 266 ppi/133 lpi
3430 Digital file size image scanned at 300 ppi/150 lpi

Table 6

Bar Codes

Almost all packages require either a bar code or UPC symbol for pricing, identification and inventory information. FIRST (Flexographic Image Reproduction Standards and Tolerances) and ANSI (American National Standards Institute) have specifications that should be followed. The difficulty for a designer who has to use the UPC code in a package design is that the specifications for creating these symbols are very strict and UPC codes rarely, if ever, add to the appeal of an overall design. Not only have bar codes

40 An FPO label denotes that the bar code shown is only intended to indicate orientation, size, color, etc.; it is not to be printed.

become a necessary evil, they also have a very strict set of tolerances that must be followed by the designer and separator.

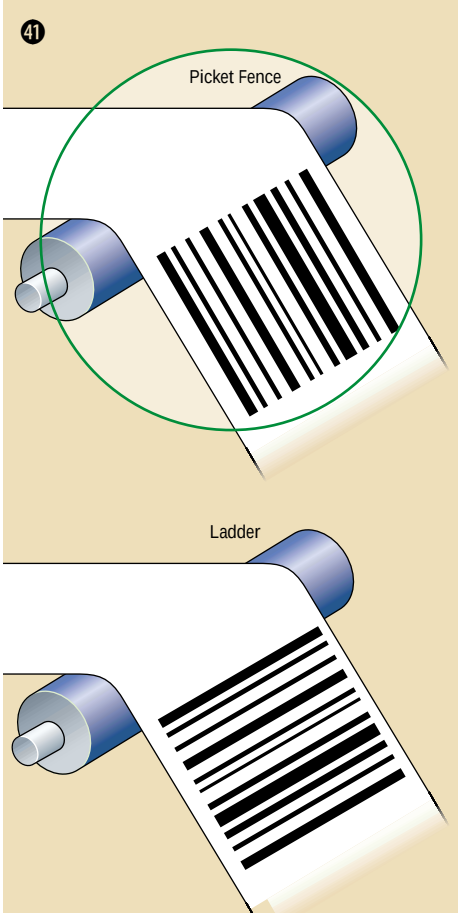
If designers decide to generate the bar code themselves, there are many utilities and applications available in the desktop environment that will create bar codes and UPC symbols. A word of caution: if a designer chooses to generate the bar codes to be used in the final printed piece, then he/she also accepts all of the legal responsibility for guaranteeing that the bar code will print accurately. Should the designer decide that this is a responsibility he/she does not wish to incur, he/she can provide an FPO. The FPO (*Figure* 40) represents where the bar code is to be placed in the design and the separator creates a correct, final bar code. When providing an FPO for the final placement of a bar code, the designer should be aware of the tolerances necessary for accurately printing a bar code, so that the placement, dimensions, quiet zone and color of the FPO are correct for the final printed symbol. The ultimate goal by everyone involved is to create a symbol that, when scanned, is within ANSI standards of acceptance.

Compensation. Compensation is achieved by undercutting the bar width, so that when printed with the expected amount of gain, the bar code grows back to the original size.

Color and Symbol Contrast. When selecting a color for the UPC symbol or bar code, it is imperative to choose a color combination that will provide sufficient contrast between the scan bars and spaces. Black bars with white spaces provide the highest symbol contrast (SC) for accurate scan reading. The amount of required SC varies based on the symbol and where it will be used. The light sources used in bar code scanners generally use red light. Therefore bar codes should not be colored in reds or oranges, as they will not read when scanned. These colors can be used for background colors. If the bars are printed with a color other than black, dark colors such as brown, blue and green; with backgrounds in yellow, orange, pink, peach and red generally scan successfully. Bar codes should be created with one color to create sharp edges and avoid any register issues.

Placement. Certain types of packaging may require specific symbol placement. The positioning depends on the symbol used and the packaging of the product. It is strongly recommended that the symbols be printed in the web direction, also known as through the press or picket fence (*Figure* 41). The widths of each bar and background space are what the scanner detects and must be printed as accurately as possible. When the symbol prints through the press, the bars might be longer because of press slur, but the width will not be affected. If there is no other choice but to print in the across the press direction (Ladder) the printer must provide specifications.

Size. Symbol sizes are specified according to the symbol and the use. UPC codes that are scanned by point-of-sale scanners have a fixed relationship between height and width. The specified magnification range is 80 - 200% of nominal size. Most symbols have minimum requirements for the quiet zone, the background area free of printing on the left and right side of the bars. As symbols are reduced in size, so are the bars and back-



41 Bar code symbols should be printed in the web direction, also known as through the press or picket fence. When the symbol prints through the press, the bars might be longer because of press slur, but the width will not be affected.

ground areas. Tighter tolerances are required for bar-width reduction. Most symbols have a height/width relationship that must be maintained, which makes truncation unacceptable.

Color Reproduction and Line Count

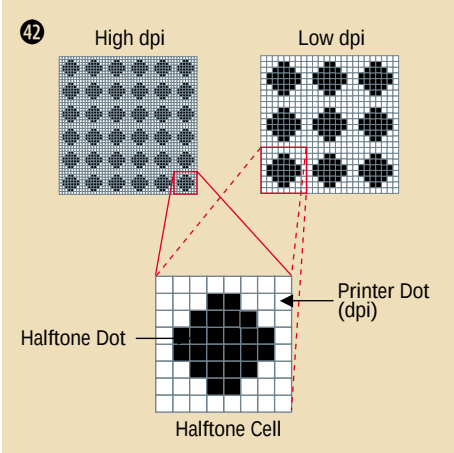
When continuous-tone, full-color reproduction from original copy is required – as with color photographs and transparencies, oil paintings, reflective art, watercolors and illustrations – a full understanding of three- and four-color process printing is mandatory If single-color reproduction of continuous-tone copy is required – as with photographs or vignettes – halftone reproduction must be fully understood and an appropriate halftone screen count specified. The original artwork must be digitally captured to be usable in the computer by using a flatbed or drum scanner or a digital camera.

For printing either tints or halftones on corrugated board, 45- to 65-line screens are suitable. Screens for wide-web package printing on film range anywhere from 65- to 133-line, while narrow-web printers typically range from 120 to 150. 200-line screen printing and higher is being achieved with the use of newer technology in plates and anilox rolls. The preprinted linerboard industry initially attempted 150-line screens, but dropped back to 100- to 133-line screens with far better results.

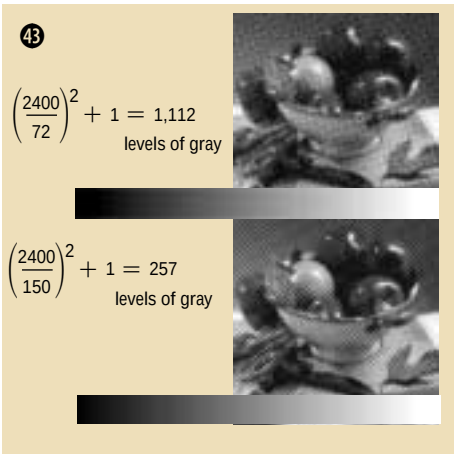
When halftones, duotones, three- and four-color process halftones are used in a design, they can either be handled separately in photography, photoengraving and printing or they can be combined with line work. The method depends on the number of printing stations available, whether line copy is fine enough to print on the plate with halftones, or whether the presence of large solids in the line plate makes it preferable to run the halftones separately. Running halftones separately minimizes ink distribution problems and allows finer impression control.

Many times, a low-resolution file is placed in position by the designer as a FPO. It is the separator's job to replace FPOs with high-resolution images. All FPOs must be clearly marked.

Screen Ruling. When referring to illustrations, halftones, screen tints and duotones, screen ruling refers to the number of rows or lines of dots used to render an image. Screen ruling is measured in lines per inch (lpi). The relationship between the output resolution (dpi) and the screen ruling (lpi) determines how fine or coarse an image will appear in print. To determine screen ruling, fill a 1" square area with an imaginary grid that contains 100 lines running vertically. Next fill the square with 100 imaginary horizontal



42 The lower the screen ruling, the larger the halftone cells; the higher the screen ruling, the smaller the halftone cells.



43 Increasing the line screen ruling creates smaller halftone dots which adds detail to the image, but it reduces the number of grays available.

lines. The intersection of each line has a dot on it; the number of lines of dots in this arrangement is referred to as the line screen. In this example, the line screen is 100 lpi. If the square has 133 lines vertically and horizontally, it is 133 lpi.

Screen ruling also determines the size of a halftone cell, which in turn determines the maximum size of a halftone dot. The relationship between screen ruling and printer resolution determines the tonal range that can be printed. The halftone dot is made up of printer dots, with the printer resolution determining the number of dots available to create the halftone dot. When the screen ruling is increased, the size of the halftone cell is decreased and fewer printer dots are used to create the halftone dot, so fewer shades are represented (*Figure* 42).

Printable Line Screen (lpi). Line screen printability varies greatly depending on the print variables. These variables could be substrate, ink-metering system, ink formulation and anilox configuration. The same graphic can look very different depending on the particular line screen (*Figure* 43) used, and successful designs must look good in the line screen actually printed. Line screens can vary from 45 to 175 lpi.

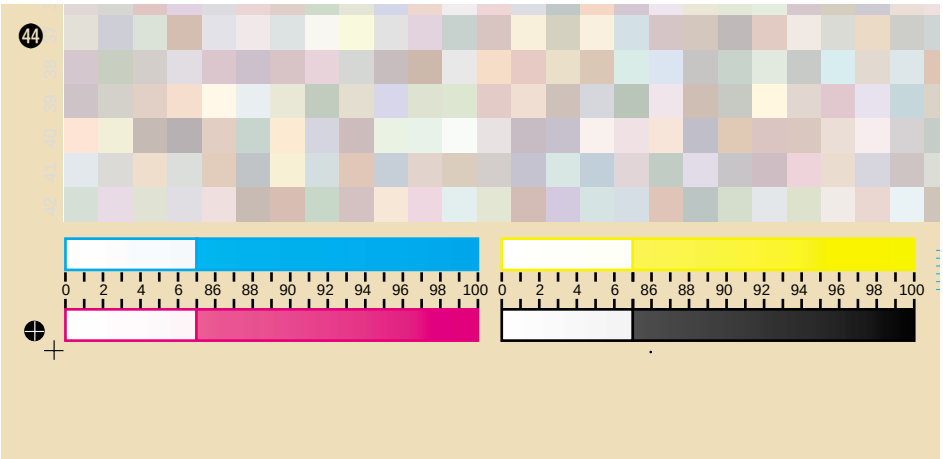
To calculate the levels of gray available at a given screen ruling and output device, use the following formula:

$$\left(\frac{\textbf{output resolution}}{\textbf{screen ruling}}\right)^2 + \mathbf{1} = \textbf{shades of gray}$$

The maximum number of grays available on most output devices is 256. The levels of gray available also determine the smoothness of blends and vignettes.

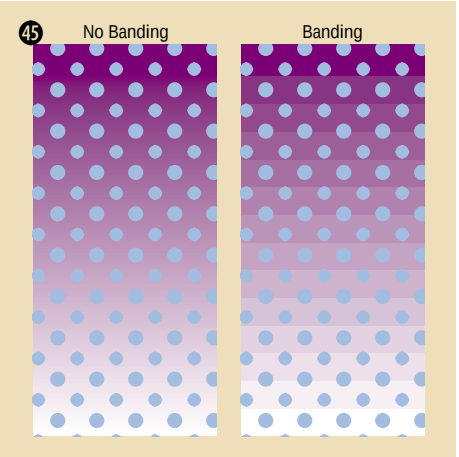
Blends, Vignettes and Gradation Fills. Vignettes, gradients and blends all describe a color filling in an area of artwork where one or more colors progress from one percentage of the color or colors to a different percentage. When used correctly, gradients can add spectacular results to a design. When created incorrectly, they can be extremely difficult to print accurately or can ruin the overall impact of the final printed piece. The tools available in desktop software applications make it very easy to add gradients to every element of a design. Unfortunately, it is also easy to create them incorrectly. Because gradations can be complicated, it is recommended that the designer create the gradations as an FPO with the design specifications noted, and let the separator create the final, ready-for-film gradation. When working with blends and vignettes, the following characteristics of the gradations should be considered: tonal range, banding, and color mixtures.

Tonal range. Most artists will create a tonal



44 Tonal range in the press characterization.

45 Banding in a vignette occurs when the length of the area to be filled exceeds the capability of the number of tint levels available.



range of 0% to 100% for all gradients or blends. This range presents problems in flexo. Because some flexo plates cannot hold a dot below 3%, the tonal range in the graphics should typically not be below 3%. Some plates can hold a 2% or even 1% dot, but because of substrates, anilox or ink choices, the dot is often not printed. Therefore, when creating the flexo gradient, the minimum dot percent should be what is specified in the characterization data. On the shadow end, dot percentages above 85% have a tendency to "fill in" which can result in an excessive ink laydown. Again the maximum shadow dot should be in the characterization data (*Figure* 44). If this data is not available, use the standard flexo gradient of 5% to 85% .

Banding. A problem that can occur when using a gradient fill is banding (*Figure* 45). When tints do not blend smoothly, there is a distinct "stepped" appearance as opposed to a nice, smooth gradation of tints blending from one percentage to another. Banding in a gradient is usually created when the length of the area to be filled exceeds the capability of the number of gray levels available for a particular gradient range to fill the area.

Banding can be avoided by remembering a few, basic rules:

1. Keep gradient fills small. Banding is more likely to occur in gradients that cover a large area.
2. Use larger gradient ranges. A blend from 5% through 25% covering a relatively large area will most likely band because there will most likely not be enough gray levels to create a smooth transition from tint value to tint value. A larger range, such as 5% through 75% will be more successful.

Another way to create gradients is to manually create a blend by selecting two elements in a file and using the blend tool in the application's toolbox. When creating gradient blends in this manner, the operator has the ability to set the number of steps that will complete the blend. If gradients are created in this manner, 256 steps should be used

to create a blend that varies from 1% to 100%. A gradient that blends from 1% through 50% requires a minimum of 128 steps to blend without banding. Simply put, more steps equal better blends.

Another cause of banding in vignettes occurs when blends run at a variety of different angles on a design. Electronic artwork files must be converted to binary coding when set to the RIP to be output on a film imagesetter or platesetter. Binary coding uses a coordinate system that is comparable to a grid. Under the line screen grid is a secondary grid that is determined by the resolution of the artwork file. The line screen grid can be rotated on top of the underlying resolution grid. Because the line-screen grid can be rotated, but the resolution grid (which contains the dots) cannot, banding can occur when lines in the line-screen grid run in different directions than those on the resolution grid. This phenomenon can be compared to painting a wooden fence. The paint lies more evenly and fills in all of the cracks with a stroke that follows the grain of the wood, versus a stroke that runs across the wood. Paint strokes that run cross-grain can leave cracks that are completely untouched by the paint.

A good way to avoid banding in a vignette is to create the gradient in Adobe PhotoShop and use the "Add Noise" filter. The "Add Noise" filter will shift the pixels in the gradient blend so that different tint values will not align along a straight edge. This shift creates a feathered effect that softens any hard breaks where different tint values meet. The difficulty in using this method to create vignettes is that files generated from Adobe PhotoShop are much larger than files created in Adobe Illustrator or Macromedia's FreeHand. The PhotoShop files must be placed in a drawing application and can be difficult to manipulate inside the drawing program. These files can also greatly increase the amount of disk space the artwork file requires for storage.

Blends which might appear banded on the computer screen, or even on a laser proof, may have been correctly created and may not band in the final film. Computer screens generally display at a resolution of 72 dpi. The artwork will probably be output to film at a resolution of 1,200 dpi, or even higher. These higher resolutions of film imagesetters will help in decreasing the possibility of banding in a gradient fill.

Color Mixtures. When two elements are made of two different spot colors and then blended manually, the resultant blend might not actually consist of the two spot colors. Usually drawing programs will convert this type of blend automatically into a process-color breakdown. The blend function is unable to separate the different percentages of both spot colors and hold the integrity of those colors at all tint values. It is easier for the application to convert the entire blend to process colors. For example, if a blend needs to be created with a blue-spot gradient to a red-spot gradient, the designer will have to create two separate gradient blends. The blue should be placed on top of the red, with the blue gradient set to overprint. This procedure is the only way to ensure the gradient will separate into the two spot colors upon film output. It is also important to consult the separator or printer because some colors, yellow or beige for example, can grade to 2% but look like a fade to 0%.

Color

Creating a custom color palette before beginning the actual design is a good practice for designers. At this time, they should refer to the print color criteria of the project. The print color refers to how many and what colors will be printed. The designer should not use colors that the printer will not be using. Usually the palette includes cyan, magenta ,yellow, black and any spot or special colors specified for the project (*Figure* 46). Unfortunately, it is common for the designer

to not specifically create the palette using the designated printing colors. If the graphics are created without a prepared palette, colors not intended to print are unintentionally added to the palette. Actions that can unintentionally add colors to the palette are:

- Creating a blend from one spot color to another.
- Adding or pasting in clip art that has additional colors in it.
- Naming one color (such as Pantone 259 purple) two or three different names.
- Creating graphics using colors that look good but are not one of the specified print colors.

When deciding on the number of colors in one item, the designer should consider what the item would look like when it is out of register. Misregistration of two or more inks can ruin a beautiful design faster than anything else in the printing process. There is a way for the designer to evaluate the out-of-register look. Each color used must be on its own layer, then select all items on one layer and move in one direction — the amount of the trap. The result simulates the worst-case look of the graphics when printed.

If the designer chooses to create a custom color, the color should be designated in the drawing program as a spot color. Custom colors are not always designated in a drawing program as a spot color, but instead default to a process color "breakdown". When this default happens, the spot color separates into the process color match instead of being one spot color on the final film. It is recommended that a designer use the Pantone library provided with all drawing applications.

When choosing a color palette for a project, it is necessary to know the number and color of inks that will print. It can be expensive and difficult for a production artist to "clean-up" an electronic artwork file that should print with five colors, but ends up with 22 colors as a result of how the colors were created in the artwork. An artist should use only the specified printing ink colors. In addition, colors should not be duplicated and renamed. Extra, unwanted colors can be inadvertently added to a graphics file when artwork from one application is cut and pasted or imported into a file in a different application. Even when precautions are taken, unwanted spot colors can appear in the file. For example, if the file is in Adobe Illustrator, one way to eliminate these colors is to select objects from the menu, then select custom colors and delete all unused colors.

46 When choosing a color palette for a project, it is necessary to know the number and color of inks that will print. It can be expensive and difficult for a production artist to "clean-up" an electronic artwork file that should print with five colors, but instead has 22 colors as a result from how the colors were created in the artwork.

Tints. Extra colors or inks can also be inadvertently added to an artwork file when spot-color tints are incorrectly created. To create a spot tint correctly, select the spot color and define a percentage of that color. Spot tints should not be created by selecting a new color to create the tint. If a new color is selected to create the tint, it will create an additional color that will separate onto its own film, rather than appear on the original spot-color film. During the final design review, any colors that are not one of the specified printing colors and are existing in the graphic file should be eliminated.

Of course, many times the designer and separator work together to decide how cer-

tain effects and colors can be achieved using available process and spot colors. When a special color is needed, the designer leaves an extra color in the design, so the separator can determine how it should be created. This is only done when the designer and separator have communicated and agreed upon this action plan. The designer must specify the special color as “match color PMS 259” for example, or whatever the match is supposed to be.

Final Approval

With the production art completed, it's ready for the platemaker. Now is the time, before the expense of platemaking, to get final approval of all copy, positioning and color. Depending on the specific printer, interdepartmental as well as customer approval may be required. Usually, you can save time if the original production art is retained in-house and copies forwarded for customer approval. For purposes of approving the copy and positioning of line work, ink jet or laser copies are often sufficient.

COLOR PROOFING

Color proofs, better known as contract proofs, are used for customer approval throughout the entire design, prepress and print process. The proof is used to represent what the graphics will look like when printed. A proof is a very useful and inexpensive way to determine if any changes should be made to graphic color, placement, text, trap, dot-gain compensation and much more. Unfortunately, many contract proofs are produced on devices that are not calibrated or even capable of reproducing a proof that will match the press result. Consumer product companies and designers are approving and expecting the final print to match this proof, which doesn't happen in many cases. The most common issue with contract proofs is that they are made to offset and not flexo specifications. The proofing stage needs to be set up for flexo specifications. Although the designer does not usually produce the proof that is used in the approval stages, he/she can take charge of providing the correct flexo information to those making the proof. The designer should work closely with the flexo separator when determining how the contract proof should be made. Some guidelines to follow when using an analog or digital proofing system are:

- Use flexo target densities.
- Make sure the correct color of the substrate is compensated for or simulated.
- Use the correct flexo tonal values for minimum highlight and maximum shadow dots.
- Do whatever else the separator or printer suggests.

Programs and Applications

The designer needs to focus on the printability of the design, and at the same time, create files that can be edited. With all of the software bells and whistles available today, it is very easy to create graphics that are difficult for the separator to pull apart and separate, and to make compensations for dot gain and trap.

Computer programs or applications are the tools that designers use to create electronic artwork, the way a carpenter uses saws, hammers and awls to create furniture or cabinetry. And like a good carpenter, a good designer will be familiar with many of the tools available for creating artwork in the desktop environment. He/she will be aware what each application offers in features and options to accomplish a specific project. A carpenter can't create every piece of woodwork with just a hammer and a designer shouldn't try to create every design with just one application. While many programs available today are similar, all offer unique features or options that set them apart from other programs. Some programs are specifically developed to handle page layout with graphics. Some are more applicable for packaging graphics and some are ideal for working on scanned graphics. Packaging graphics are usually created and completed in a drawing program.

The designer must use software programs that allow for easy and efficient graphics creation. These programs also must allow the separator to easily separate and compensate for flexo variables. Choosing software that works for both processes should not be an issue if the designer and separator have good communication procedures in place.

Regardless of which application the designer chooses to create artwork, the application is a tool that the designer must skillfully use so that the completed project can be effectively separated. Artwork files that are successfully separated are usually very simple files. That is not to say that the artwork design is simplistic or unsophisticated. Simple files are files that are built or created in an uncomplicated manner.

LAYERS

The layer function is available in most desktop applications. Layers are a useful tool for organizing elements in an artwork file (*Figure* 47). Some graphics are simple with very few elements and do not justify the time it takes to create layers for varying elements. Other graphics can be quite complex by incorporating many different graphic elements, such as a variety of flavors or special banner information. These graphics can easily cause confusion, and if not organized accurately, they can result in the wrong graphic elements appearing on the separator's proof. With complex graphics, layering can be very useful. Layers used in creating an artwork file can make editing or outputting the correct color separations or flavor separations very efficient.

Separate layers can be created to organize an artwork file in the following manner:

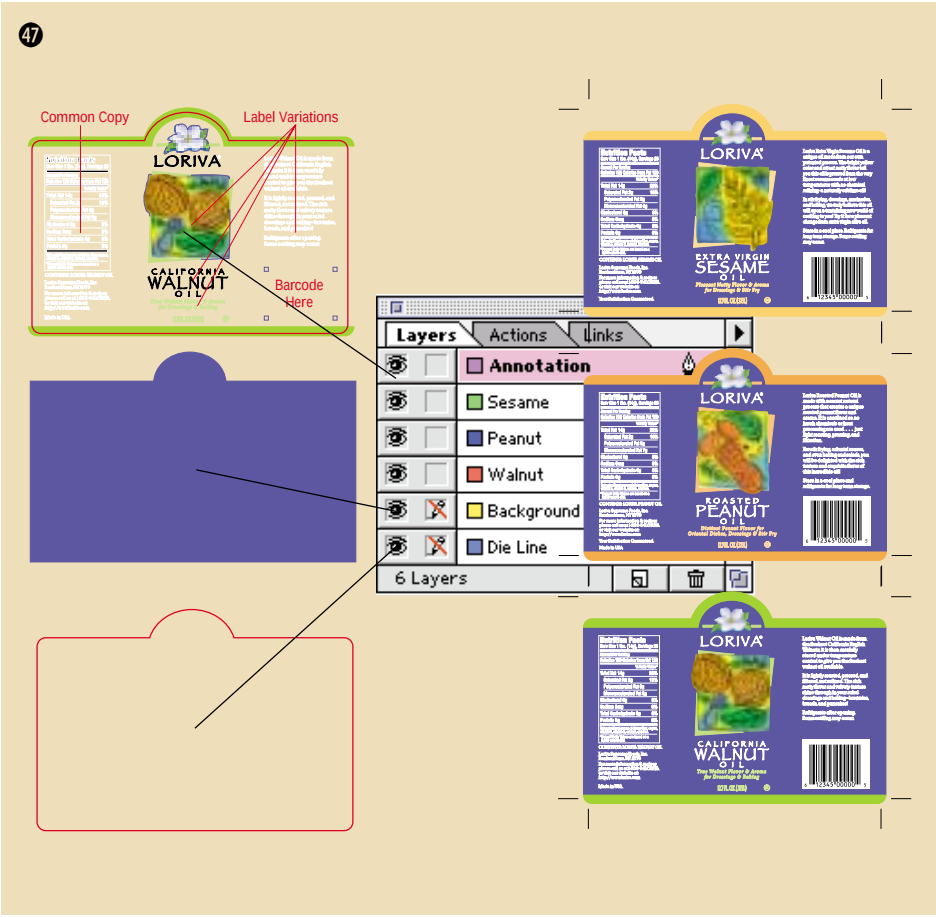
- **Die line.** This layer indicates the overall shape and layout of the packaging design, and should be created in a color called "die line".
- **Graphics.** This layer contains the main

portion of the overall design and any common artwork. It is not unusual for a packaging project to have different versions of the same package. If all elements that are common to the different versions are on one layer, modifying the file to output a specific version of the package becomes easy.

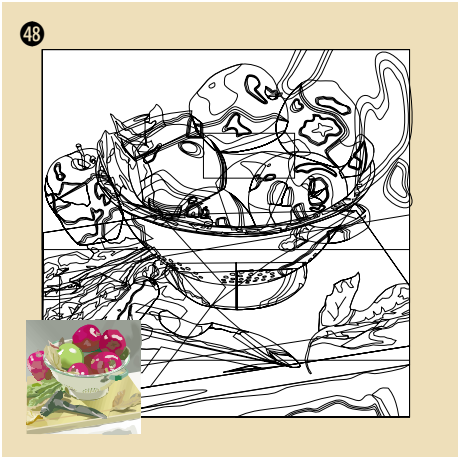
- **Additional versions.** This is where artwork unique to a specific version of the package should be placed.
- **Annotation.** This layer is used for any comments or remarks relevant to the project, as well as for the graphic layering information.

When designing a project consisting of layers, a designer should be aware of what element(s) are being placed on which layer(s). To check the contents of the layers, the designer should deactivate the display of all layers and then display each layer, one at a time. This procedure is a good way to avoid a print rerun caused by misplacing an important element on the unintended layer.

A designer should also try to organize the file so that it doesn't contain excessive layers or layers with confusing names. Remember that a production artist is going to have to output this file after the designer is finished with it. It is not unusual to have a last-minute change to the project that a production artist will have to make in the file. Layers that have confusing names or that are excessive in numbers can make editing the file very difficult and time consuming.



47 Layers are created to organize an artwork file in the following manner: die, annotation, image, harvest, strawberry.



㊽ Drawing programs utilize vectors, i.e., points that define how the lines between them should act – as straight lines, arcs or Bezier curves.

DRAWING PROGRAMS

Drawing programs utilize vectors (mathematical information of a point and line in space, defined by its magnitude and direction). Vector-based or object-oriented artwork consists of points that defines how the lines between them should act – as straight lines, arcs or Bezier curves. The shapes defined by the lines can then be filled with or without color (*Figure* ㊽).

Several drawing programs are available for the desktop publisher – the two most popular applications are Adobe Illustrator and Macromedia FreeHand. Vector-based programs create object-oriented art with the following qualities:

- Objects are perpetually editable.
- Objects print at the highest possible resolution.
- Objects maintain their quality and don't degrade like bitmapped images.
- Objects are infinitely scaleable.
- Graphics are very small compared to bitmapped graphics.
- Die lines can be created in vector-based software that can then be forwarded to the diemaker.

Other features of these drawing programs include the ability to create blends or vignettes and edit raster images.

The designer should find out what format the separator prefers for placing or importing graphics into a drawing program. If using Adobe Illustrator, for example, it is recommended to use only placed EPSs, especially when working with process color graphics. When a file has an embedded TIFF file, instead of a placed EPS, the separator may have to re-raster the image in PhotoShop to color correct it. The edited file is then placed back into Illustrator as an EPS. This lengthy procedure increases time expended on correcting the file and increases prepress costs.

When designing with a placed EPS, verify that the clipping path is included in the Illustrator document, especially if the image has to trap to a background or gradient. This procedure enables the separator to quickly trap the Illustrator file and can be done as follows :

1. Export the clipping path to Illustrator from within PhotoShop.
2. Save the graphic as an EPS.
3. Open the Illustrator file with the exported path, which opens it with crop marks and indicates the document boundary.
4. View the image in the artwork mode showing the rulers and choose any corner.
5. Line up two guides – one vertical and one horizontal. Make sure the general preference is set to "snap to point".
6. Place the EPS by selecting and dragging from one corner; the graphic will snap and line up exactly with the path.

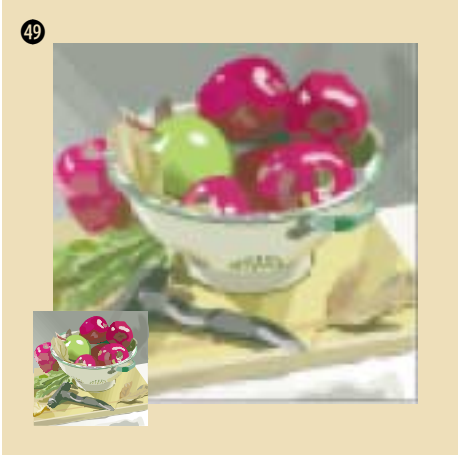
PAGE LAYOUT PROGRAMS

As with the drawing programs, there are several applications available in the desktop environment designated as page layout programs. Two major applications for page layout are QuarkXpress and Adobe Pagemaker.

As the title suggests, page layout programs are designed for laying out documents that

can be of a single page or of multiple pages. The primary function of the page layout program is to create a layout that has text with placed graphics to complete the file. The tools available for assembly and manipulation are very extensive for handling large bodies of text. While the functionality of these page layout programs may be very impressive when producing files for the publishing industry, they have few tools to address packaging graphics. These applications were designed to create layouts by flowing text from page to page and dropping in graphics as necessary. Most packaging projects are graphic intensive, contain bar codes, have very little text and must be applied to diecut structures of unusual shapes. Page layout programs are not usually designed to handle all of the various items that are required of packaging.

The focus of page layout applications is to effectively handle type, not graphics. Some simple graphic elements can be created in page layout programs, but the applications were not originally designed to create graphics. Additional bodies of text can be created and modified in a page layout program and then imported into the drawing program. Importing text from the page layout program to the drawing program is especially recommended if 80% of the artwork is graphics and the remainder is text, some of which may be created in the drawing program. It is an unnecessary, time-consuming step to import the bulk of artwork into a page layout program in order to add a few lines of text. Some designers import the bulk of artwork into a page layout program because of the misconception that the page layout program is needed to output to a digital color proofer. Actually, all desktop applications have the ability to output to a digital color proofer. If TIFF images are used in a page layout program, it is recommended that the image is to cropped or rotated in the native application, such as PhotoShop or Illustrator, thus decreasing the file size. Be sure to includea bleed area of 0.125" for the separator to work with.



49 Raster programs use pixels to define the image.

Recent releases of page layout programs, has added the ability to create graphics within the program. Though this may seem like an excellent addition, in reality these new features can cause a prepress processing problem. Many of the new features are automated; therefore the level of control for editing is severely restricted or impossible.

RASTER IMAGE PROGRAMS

Raster image applications such as Adobe PhotoShop provide a means to manipulate scanned photographs in the desktop environment. Raster image programs are excellent tools for cleaning scanned images, utilizing GCR/UCR, compensating for press characteristics, adjusting color to match the original and even converting the file formats of digital artwork. When using a raster image program to modify scanned artwork, it is best if all modifications and manipulations of the image are handled in the raster program. Scaling, cropping, clipping paths, color application and rotations are best dealt with in the raster program, rather than placing and manipulating the scanned artwork in a drawing or page layout program.

50 Image manipulation progams offer a variety of filters to achieve interesting effects in addition to photo retouching and color correction.

Original Image

Crosshatch

Cutout

Dry Brush

Glowing Edges

Halftone

Lighting

Mosaic

Pointillism

Posturize

Ripple

Spatter

Texture

Twirl

Watercolor

Raster programs use pixels to define images (*Figure* ㊾). These pixels or squares define all data in a bitmapped graphic. Every pixel can have different colors in a bitmapped graphic. In a high-resolution graphic with hundreds of pixels per inch, this capability allows for the reproduction of subtle shading and tonal changes.

A raster program can provide the designer with many creative avenues for the look of the type. But, this type cannot be edited and makes the type file large compared to type files created from a font in a drawing program. Therefore, a raster program should only be used for small amounts of text and effects that cannot be created in other programs. There are several capable and creative special effects that can be used in a raster program. When utilizing these effects, keep in mind the flexo criteria (parameters) within which the design must be created.

SPECIAL EFFECTS

In addition to photo-retouching and color-correcting tools, image-manipulation programs such as Adobe PhotoShop offer a large variety of visual effects. These built-in features have been enhanced and supplemented over time by third-party software plug-ins. *Figure* ㊿ shows the variations created using various filters. These special effects may take an image so far from its original form, that the final result is an image that itself appears entirely original.

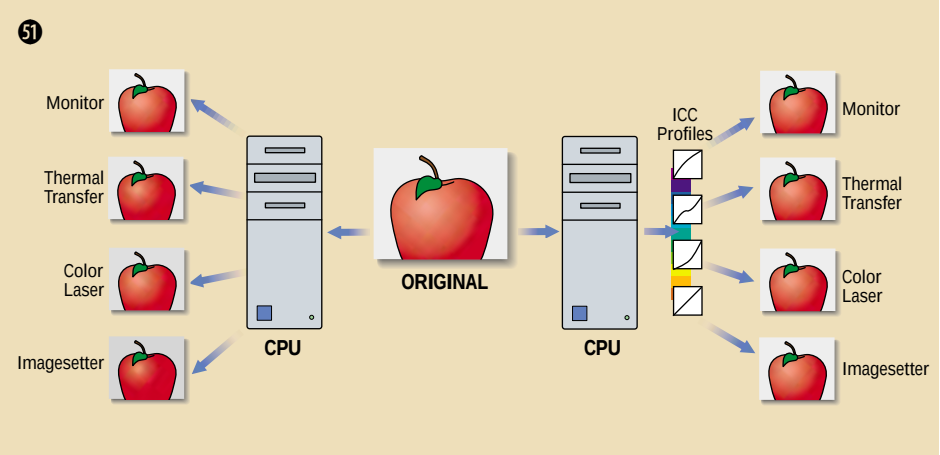
INTEGRATING PROGRAMS

A designer should always remember that after the artwork is created, the electronic file has to go through a RIPping or translation process in order to output to film. During this process, the electronic artwork file is essentially pulled apart, converted into binary language and then put back together in a manner such that the imagesetter can receive the data. It is during the RIP that many problems occur from the electronic artwork. Files that are built cleanly and simply are the most successful files to translate during the RIP stage.

Receiving a package and opening the package is comparable to the first stage of the RIP – the electronic file is received and opened. But before a file can be translated, the RIP must know what is in the file; data such as bar codes, scanned images, text, die lines, gradations, illustrations, placed graphics and more. All of this electronic data can confuse the RIP. This first stage of the process is referred to as file nesting. When building an electronic artwork file, a designer should try to create the design in as few desktop applications as possible.

If the bulk of the design is built with graphics, the final electronic file should remain in the drawing program in which the artwork was created. Files that are imported into the main artwork from raster image applications should be imported as EPS files and should not require further manipulation in the drawing program. Any resizing, rotation or color adjustments should be applied to the imported artwork in the application originating the artwork. This guideline is also true of any text that is imported from page layout applications.

Another step to avoid is to create artwork in a drawing program, save it as an EPS file and then re-import it into the same drawing program. The EPS file from a drawing program can be opened and cut and pasted into the design layout. Placing an EPS file into the file's native application creates unnecessary steps and data for the RIP. The designer who copies and pastes the EPS file in the native program creates a stable electronic artwork file that will RIP successfully. Files that don't RIP successfully sometimes require an entire rebuild of the artwork file, which can add significant time and cost to the entire project's progress. The cleaner



51 Applications of color management technology can range from CMYK-to-CMYK conversions which match four output devices, such as a proofer to a press, all the way to the full-scale integration of the technology to implement what is known as device-independent color.

and more simple a file is built, the fewer problems it will have during the prepress processing and the more likely it is to successfully print.

COLOR MANAGEMENT PROGRAMS

With the advent of reasonably priced instrumentation, it has become possible to measure and control color using CIELab color space. Basically this means measuring color in the same way that people perceive color. Instead of a set of CMYK values, a color is described in terms of the three characteristics that people distinguish in color: hue (red, green, blue, etc), chroma (the saturation or purity of the color, where gray has zero or no chroma), and lightness (the brightness of a color, where black is at one end of the scale and white at the other).

Color management programs are tools that apply this technology to the workflow (*Figure* 51). Applications can range from CMYK-to-CMYK conversions which match two output devices, such as a proofer to a press, all the way to the full-scale integration of the technology to implement what is known as device-independent color. The latter term refers to color that is measured and managed from an absolute measurement point of view. In the CIELab color space or color description, any color has a unique value given by three numbers. If that particular color is to be reproduced, the characteristics of the output device must be known. These characteristics are called the profile, or more specifically, the ICC profile of that device. If all input and output devices are characterized in this way, color can be specified and reproduced in terms of these "absolute" values.

By the late 1990's, color management has received a lot of attention and is becoming more widely used. It is by no means as prevalent as some of the more mature technologies, such as Postscript, for example. Many different "workflows" still exist and will likely continue to exist as the technology matures and becomes the accepted way of working with color from creation to ink on substrate.

File Formats of Imported or Placed Graphics

A variety of applications can be used by a designer to create artwork. It is common to create different elements of the completed design in a variety of applications and then make a composite file of these elements in one program. The secret to creating an artwork file that will successfully process during the prepress stage is knowing which file types can be combined to create the final composite artwork file. There are as many file types as there are applications to create them and each one has its own unique features to offer (*Table 7*). A description of some of the more commonly used file types follows:

PICT file format is a common file type used most frequently for graphics that are only used for monitor display. PICT file support RGB channels, which make it a poor choice for saving images. RGB channels are generally not supported by RIPs and can cause the artwork file to fail or crash during the RIPping process. PICT files should not be used in finished artwork files that are ready to be processed for film or plate output.

TIFF (Tagged-Image File Format) files are the most commonly used and most widely supported file formats available in the desktop environment. TIFF files support RGB, CMYK and grayscale channels, which make this file format an excellent choice for saving scanned images. Some prepress systems may have difficulty processing TIFF files. A designer should check with the output provider's ability to support this format.

JPEG (Joint Photographic Experts Group) images are commonly used for transporting or displaying scanned images across the World Wide Web. CMYK, RGB and grayscale channels are supported by the JPEG format, but JPEG files are automatically compressed when saved to create smaller file sizes. To accomplish this compression, image data is discarded resulting in a lower quality image. JPEG files are excellent for displaying on a computer screen, but are a poor choice for printing artwork files.

GIF (Graphics Interchange Format) is another commonly used file format for transporting or displaying scanned images across the World Wide Web. This format supports bitmap, grayscale or indexed color channels. Index color is a limited color palette using up to 256 colors. These limitations on the supported color channels result in a much smaller and more compressed file. The smaller file size transfers quickly across Internet lines, which makes it an excellent choice for use on the World Wide Web. These same color limitations make GIF files a poor choice for artwork that will print on a press; therefore, GIF files should never be used in composite artwork files designed for printing.

PDF (Portable Document Format) files are self-contained files that can be created by most desktop applications. These files contain both line work and raster images and are an excellent choice to send graphics to a customer to soft proof. The customer cannot edit the file but he/she can view it on a com-

FILE FORMATS SUPPORTED BY COMMON DESKTOP APPLICATIONS

APPLICATION	FILE FORMAT SUPPORTED											
	EPS (vector)		EPS (bitmap)		PDF		PICT[1]		TIFF		TXT	
ILLUSTRATION	Import	Export	Import	Export	Import	Export	Import	Export	Import	Export	Import	Export
Adobe Illustrator	Vector	Vector	Bitmap[2]	Bitmap	Bitmap	Bitmap	Bitmap	Bitmap	Bitmap	Bitmap	☑	☑
Canvas	Vector	Vector	Bitmap[2]	Bitmap	Bitmap	Bitmap	Bitmap	Bitmap	Bitmap	Bitmap	☑	
CorelDraw	Vector	Vector	Bitmap[2]	Bitmap	Bitmap	Bitmap	Bitmap	Bitmap	Bitmap	Bitmap		
Macromedia FreeHand	Vector	Vector	Bitmap[2]	Bitmap	Bitmap	Bitmap	Bitmap	Bitmap	Bitmap	Bitmap		
	EPS (vector)		EPS (bitmap)		PDF		PICT[1]		TIFF		TXT	
IMAGE PROCESSING	Import	Export	Import	Export	Import	Export	Import	Export	Import	Export	Import	Export
Adobe Photoshop	Editable bitmap, Vector	Vector	Editable bitmap, Bitmap[2]	Editable bitmap	Bitmap	Bitmap	Bitmap	Bitmap	Bitmap	Bitmap		
Painter	Vector	Vector	Editable bitmap	Editable bitmap			Bitmap	Bitmap	Bitmap, Editable bitmap	Bitmap, Editable bitmap		
	EPS (vector)		EPS (bitmap)		PDF		PICT[1]		TIFF		TXT	
IMAGE PROCESSING	Import	Export	Import	Export	Import	Export	Import	Export	Import	Export	Import	Export
Adobe InDesign	Editable bitmap, Editable bitmap, Vector	Editable bitmap, Editable bitmap, Vector	Editable bitmap, Bitmap[2]	Editable bitmap, Editable bitmap	☑	☑	Bitmap	Bitmap	Editable bitmap, Editable bitmap	Editable bitmap, Editable bitmap	☑	
Adobe PageMaker	Bitmap, Bitmap	Bitmap, Bitmap	Bitmap, Bitmap[2]		☑	☑[3]	Bitmap		Bitmap, Bitmap		☑	☑
QuarkXpress	Bitmap, Bitmap	Bitmap, Bitmap	Bitmap, Bitmap[2]	Bitmap, Bitmap	☑	☑[3]	Bitmap		Bitmap, Bitmap		☑	☑

Notes:

1 PICT = Macintosh format; BMP = PC equivalent

2 Supports DCS format

3 Through Acrobat Distiller

Legend:

Vector-based art

Scalable/rotable bitmap

Editable bitmap

Allowable

puter or download it to a color proofer. The customer should know that the color proof is not what the printed piece will look like, unless that proofer has been adjusted to flexo press specifications. PDF files are compressed to reduce file size and they contain all pertinent file elements, including fonts and placed images. This file format is relatively new to the desktop arena and is not yet fully supported by all prepress systems or fully tested in the flexo packaging industry. In addition, PDF files currently have difficulty supporting spot colors. Flexo compensations cannot be applied to a PDF file, so don't send this format to the separator unless it is to be output to film with absolutely no adjustments.

Updates to the format can be obtained from the following two websites:

www.npes.org
www.seyboldpublications.com

TXT (text) files are files generated by any computer and saved as an ASCII format. TXT files are very easy to create and very useful as a form of communication with other suppliers. These files can be used to communicate special instructions pertaining to any portion of the graphics, colors, or the project itself.

DCS (Desktop Color Separations) files are "preseparated" EPS files containing the C, M, Y and K channels and a low-resolution placement file. DCS files make it very efficient for designers to work with large scanned images because the low-resolution file is placed in the working file and the high-resolution separations are not used until the file is sent to the RIP for output. During the RIP stage the low-resolution file "tags" the high-resolution data and downloads the high-resolution images when needed. If a designer uses DCS files, he/she must remember to send all of the high-resolution files to the output provider when releasing artwork files for separation and output

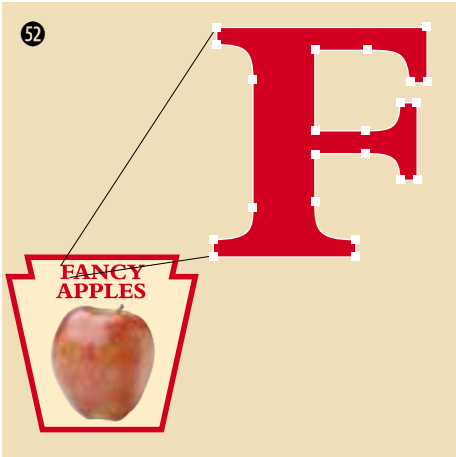
Adobe PhotoShop has released DCS 2.0. This latest version allows operators to create halftone images that will reproduce CMYK colors combined with spot color channels. It also allows designers to create high-fidelity color images. DCS 2.0 format may not be supported by all prepress systems, and the designer should verify with the output provider if this format is acceptable.

EPS (Encapsulated PostScript) file format is the most commonly used and supported file format available in the desktop environment. EPS stores files as a series of bezier curves (vectors) and also includes a low-resolution bitmap representation of the file for quick on-screen viewing. It supports all color modes, excluding alpha channels. (Alpha channels are channels or layers in raster image programs that allow an artist to create elements on a separate channel or layer and activate or deactivate it for viewing and editing purposes. Alpha channels are supported in some of the file formats mentioned here, but not all. Data that resides on an alpha channel usually has to be merged into a supported channel, i.e., CMYK, RGB). When saving a file as an EPS format, information in the alpha channel may be discarded. EPS files contain almost all data for processing an artwork file, excluding fonts and DCS color information. The EPS file format is a very stable format and is an excellent choice to use when a file needs to be placed into a document.

Embedded. In addition to using workable file types, it is important to make sure embedded files do not have any of their own hidden problems. Text that is embedded in a file can easily be overlooked when opening all fonts in the composite file. It is best to convert the embedded text into an outline so the font is not required (*Figure* 52). Other potential problems to be aware of are patterns that are embedded, colors that are not in the custom-ink color palette and an embedded blend that has banding or a 0% to100% tonal

52 Convert the embedded text into an outline so the font is not required for RIPping.

range. The artist should very carefully review the items being used in an embedded file to avoid hidden problems that usually are not found until after film has been output or sent to the RIP. Simply put, it is best to avoid using embedded files or graphics for trouble-free prepress and separation applications.



Completed Design Guidelines

When certain issues are taken into consideration prior to the artwork file being handed to a service bureau or prepress department, the final file has a much better chance of successfully navigating through production and processing accurately and efficiently. All graphic elements must be within FIRST compliance and in accordance with press-characterization data.

The final design may seem very simple to the designer, but it can be difficult to decipher by another user at a different stage of the production process. Fortunately, most programs have the option of creating comment layers or report features that can be used to provide detailed information about the file and design elements. These report features can be used to provide much of the documentation required by FIRST and the separator.

Preflight Guidelines. All files should be preflighted before they are given to any other user. Preflighting can be done manually or using automated preflight software. A disk should be preflighted on a different computer than the one that the graphics were created on. In the Mac system, all fonts must be turned off except the standard 35. The designer should take the following steps for a manual preflight or simply follow the directions on the preflight software. Any errors or problems encountered during this process should be documented and then corrected. After corrections, the entire preflight is performed a second time.

1. Open the final graphic file to identify any renamed or missing placed images and list the name of fonts used.
2. Load the fonts to make sure all correct fonts are present.
3. Print the file to a laser printer at 100%, using tiling if necessary. This type of proof has limitations but is usually the best available at this stage.
4. Compare these laser proofs to approved comps or anything that indicates the graphics, text and other elements required on the packaging.
5. Make a PostScript file of the document and output this to any laser printer. This precaution gives the designer the opportunity to work on correcting the graphic file before sending it to the separator.

Media. The software, hardware and media used for the final graphics must be compatible with the separator's hardware and software. The designer does not have to alter his hardware or software but the designer and separator must communicate in advance and devise a plan for compatibility.

Many final graphic files are very large and are more easily handled when they are compressed. The major consideration with compressed graphics is verifying the receiver has the ability to decompress files. In case the receiver does not have the same utility software that the designer is using, create the files with a .sea extension (self extracting archives). Some software allows a file to be segmented onto different disks instead of being compressed. But again, it is necessary to make sure the receiver can open these types of files.

Proprietary Settings. Some programs like QuarkXpress offer the option for a user to create custom settings, such as kerning. When the graphic file is sent to the separator, the designer must send any of these proprietary settings as well.

Documentation. The required documentation must be in hard-copy format. If any report files or comment layers are used, they must be listed on the hard-copy documentation. It may be more efficient to create a form that is filled out for the required documentation. The checklist (*Table 8*) should be used and can be modified.

After the documentation is complete, all of the items going to the separator should be pulled together and compared to the checklist to ensure that nothing is missed.

DOCUMENTATION CHECKLIST

TASK
List and include key files and FPO files within the key files.
List fonts used and correct names (include if necessary).
List software used and version number.
List names of nested files.
Identify final graphic file name(s). It is recommended to put all other support files in a separate folder.[1]
List all layers that are common.
List layers to be used with base design.
List the disk directory – make a hard-copy printout of the disk directory and directory for each folder.
List all colors: process, spot and mixture colors.
Write instructions for blends.
Write instructions for special effects.
List items provided, including the disk (transparency, color proof, etc.).
Write specifications on data compression, if used.
Create a hard copy of final graphic file(s) at 100% size.

NOTE:

1 When more than one design file is sent, a folder should be created with the design file in it and another folder in it that contains all of the support files.

Table 8

CHAPTER 2

Prepress

ACKNOWLEDGEMENTS

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Introduction

In the current age of specialization, prepress has become an industry unto itself. This is especially true in the flexographic reproduction process. While there are many designers and printers/converters with prepress capabilities, this chapter will center on prepress as a separate entity. Prepress facilities in all converting operations will generally follow the same workflows and procedures.

Prepress involves several job functions, each requiring its own skill set, software and hardware:

Image Capture. The process of converting reflective or transparent artwork into a digital image. With today's digital cameras, it can also mean the direct capture of the real-world image.

Preflight Quality Control. This function is similar to the preflight function in that all incoming materials are reviewed to ensure a smooth workflow in production. The difference is that at this point, the customer-supplied low resolution proofs are used to check various aspects of the job. This function is done before viewing the electronic files themselves.

Desktop/Preflight. This function involves reviewing incoming electronic files, checking the elements of the file in order to process those files before creating some type of postscript output which adheres to flexographic printing specifications. Preflight, in conjunction with preflight quality control seeks to screen out potential production problems before the actual production process is started.

Job Assembly/Layout. This process, when done manually, is known as stripping. In today's environment, it is where the electronic files are assembled and trapped for output of plate-ready films or direct-to-plate systems. This is the start of the actual production process.

Film Output/Imagesetting. This normally entails the addition of distortions or compensations and generation of plate-ready films required for flexographic reproduction. These films are output on high-resolution imagesetters. Plate output would fall into this category when a direct-to-plate system is being utilized.

Proofing. This process involves creating a representation of the assembled file prior to plate-ready film output or digital platemaking.

Back-end Quality Control. In this process, materials (usually proofs and films) are inspected before release to the platemaker, converter or customer.

Customer Service. This function acts as the liaison between the designer or generator of the job and the printer/converter.

Image Capture

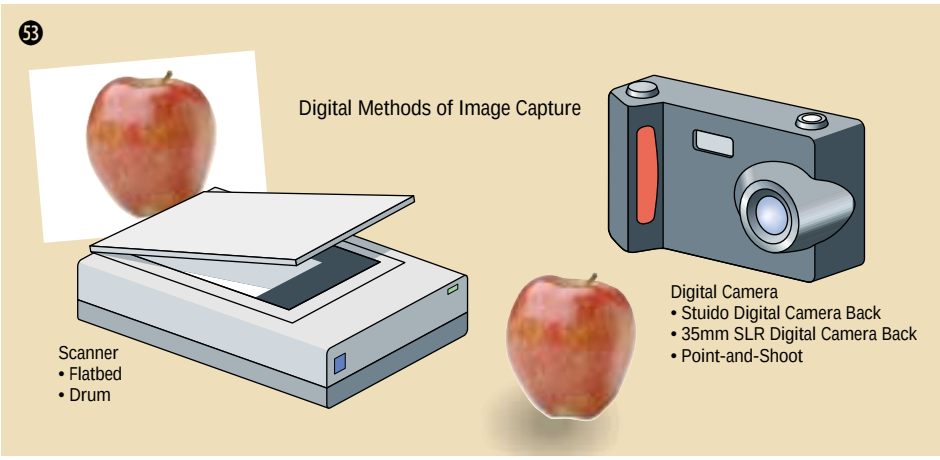
Image capture is the process of converting original photographic artwork into a digital file. This process takes the continuous-tone reflective or transparent artwork and "separates" it into its RGB (red, green and blue) or CMYK (cyan, magenta, yellow and black) components. "Real world" images can be captured digitally. By using a digital camera, the live image is captured without first going through the stage of a photograph or other artwork.

SCANNERS

Scanners record the data in red, green, blue channels by measuring or sampling the image and assigning the information in the form of a single picture element or "pixel." Each pixel has either a red, green or blue-color value associated to it. Some scanners may also convert the original RGB image and preset that as CMYK data.

The quality of a scanner is affected by its optical mechanism, which controls the scanner's ability to capture a broad dynamic range (variations in light and shadow), as well as the resolution (number of samples per inch) of the scan and the scanner's pixel depth, which controls the number of colors it can capture. The scanner's optical mechanics or "optics" dictate the resolution, the light-detection device and electronics and color information.

Scanners come in two primary configurations: drum and flatbed (*Figure* 53). Drum scanners require that the original artwork be wrapped or mounted onto a clear acrylic cylinder. The cylinder is rotated at high speeds as the light source exposes and the optics and electronics of the scanner record the color information for each pixel. Flatbed scanners have the same function, except that the artwork is laid flat and the light source passes over the image and records the pixel information. With transparent artwork, a scanning light passes through the transparency, while with reflective art, the light reflects off the artwork.



53 Typical flatbed and drum scanners. These are used to capture original artwork and convert it into digital form.

Drum as well as flatbed scanners filter the light through red, green and blue filters and then use an electronic detector to convert the light into the separate electronic RGB channels. Drum scanners use a photomultiplier tube (PMT) to convert the light. This technique allows for capturing a wide range of color. It also makes the equipment more expensive when compared to flatbed scanners. Flatbed scanner optics utilize CCDs (charged coupled devices) to detect the light, one scan line at a time. CCD technology is less expensive, but it generally provides a lower range of reproduction. Recent advances in CCD technology have greatly leveled the playing field.

Another difference between the two types of high-end scanners is the ability to provide an image compatible with high-resolution output devices. Resolution outputs of most high-end devices range from 2,400 to 4,000 dpi (dots per inch) for commercial work. Both drum and desktop high-end devices easily meet these requirements. However, for especially high-resolution output, the drum scanner far surpasses the desktop models. Drum scanners can go up to 10,000 dpi, while desktop models max out at 5,000 dpi.

SCANNING IMAGES

A good scan is as important as a good original to successful reproduction of an image. Digital retouching, either by resampling or interpolation, or high-quality output can not make up for an inadequate scan. The quality of a scan is highly dependent on the number of pixels per inch (ppi) a scanner can capture. This is called its resolution.

Before scanning an image, it is important to know how that bitmap image will be reproduced, its printed size and which screening technology – either stochastic (FM) or conventional (AM) – will be used. The resolution to use when reproducing images via FM screening depends on the FM screen used. An image with a FM dot that is close to the minimum size the printing press can print consistently is considered ideal.

If traditional halftone screening for color and grayscale bitmap images is used, the resolution required is usually dependent upon the screen ruling and the final printed size. At actual reproduction size, it is recommended that the resolution be at least 1.5 times the screen ruling. For instance, an image printing at 120-line screen should have at least 180 (120 x 1.5) ppi for high quality reproduction.

During the process of enlarging or reducing the size of an image, the “effective” resolution is changed. Resolution is changed in direct proportion to the percentage of enlargement or reduction. If, for example, the 180 ppi scan were enlarged to 200%, the effective resolution is reduced in half to 90 ppi. This scan would now only support quality reproduction at 60-line screen. This is why scanning should always be done with the final printed size in mind. If a scan will be used for more than one size, or the size is not known precisely at the time of scan, it is best to scan at the highest resolution. A scan with too much resolution can be safely downsized, but a scan with too little resolution can not be upsized (resampled). The missing data simply can’t be created (interpolated) to still maintain the quality for printing. With a resolution of more than twice the line screen, however, there is no appreciable improvement in the quality. The following is the formula to calculate the scanning resolution required:

$$\textbf{Scan Resolution} = \textbf{Quality Factor} \times \textbf{Screen Ruling} \times \textbf{Magnification}$$

Where

Quality Factor = 2.0 is the rule of thumb; 1.5 minimum recommended.

Screen Ruling = Screen ruling which will be used to print the image, such as 120 lpi.

Magnification = Magnification of original image to the printed image.

Example: The image from a 35mm slide transparency will be printed at 300% enlargement (magnification of 3) at 120 lpi. Using a quality factor of 2, the required scanning resolution would be 2 x 120 x 3 or 720 ppi.

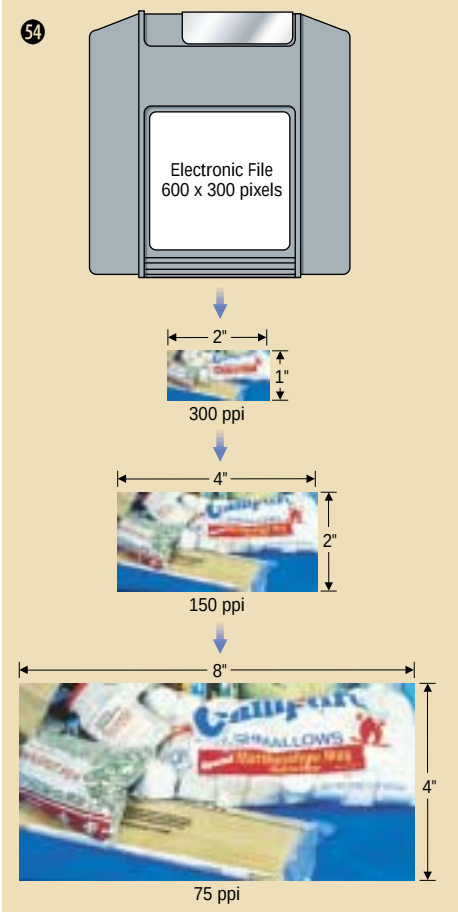
Note: *For a given scan resolution and quality factor, screen ruling and magnification can be traded. That is, a file of a given size in total number of pixels can be printed with the same quality level at different combinations of the two.*

In the above example, if instead of a magnification of 3, a magnification of 2 is used, the screen ruling now becomes 360/2 or 180 lpi. That is, the same file could be printed at the 200% magnification at a screen ruling of 180 lpi with the same quality level as before at a 300% magnification and 120 lpi.

This calculation can easily be seen in a program such as Adobe® Photoshop. Suppose an image has a width of 8" and height of 4" at a resolution of 75 ppi. This means, the file has a total of 600 by 300 pixels. In the Image Size menu, if the resolution is changed to 150 ppi and the resample image box is not checked, the new width and height will be 4" by 2". Similarly, changing to 300 ppi decreases the size to 2" by 1" (*Figure* ❺❹). These examples demonstrate how the originally available pixels have simply been redistributed.

Note: *If the resample image box is checked, the program will interpolate data to give the same size image at the higher resolution. Quality will not be maintained in that case. Taking the original image and forcing the resolution up by a factor of 4 (from 75 to 300) and then outputting at the original 8" by 4" size will result in a totally unacceptable image.*

For line art, scanning is not dependent on the screening method. Instead, line art should be scanned at the output device resolution, if the output device is less than 1,200 dpi. Scanning at a higher resolution than 1,200 pixels per inch will not yield a better looking image.



❺❹ The same electronic file of 600 by 300 pixels results in different size images at different pixels per inch. If the resample dialog box is not selected in an image-editing program, as pixels per inch goes up, the image size goes down, keeping the total number of pixels available for output constant.

PRODUCING A COLOR SEPARATION FOR FLEXO

It is important to point out that traditional methods of producing color separations are geared toward offset reproduction. The uniquely different characteristics of flexographic printing dictate that offset separations should not be used for flexo printing. The following describes the differences between flexo and offset separations.

Highlight/Shadow Treatments

Highlights and shadows are treated differently in flexo than in offset. The smallest reproducible dot on a flexo printing plate is about a 2% dot. Dots that are 1% do not carry the same amount of support on the plate, and in some cases, do not print at all. In other cases, ink builds up on the dots and is released onto the substrate in blobs. This is known as "dirty print." A scan, then, should not have anything less than a 2% dot.

A current technique addressing minimum dot size is frequency modulated (FM) dots in the highlights. Printed samples have shown that it is possible to fade to a 0% dot. This technique not only allows for the reproduction of cleaner, brighter highlights, but also results in cleaner or more saturated colors.

Shadows also require a different printing approach. Flexographic presses generally record the highest density value at 93% to 98% screens, not on a solid. Solids, especially when printing in combination with screens, tend to produce picking. This is when the ink does not fully adhere to the substrate, leaving tiny holes. Screen values of 93% to 98% not only adhere better to the substrate, but also gain on press to a solid. Due to these factors, separations for flexo should not be made where the shadows go to 100%.

Separation Techniques: GCR/UCR/TAC

GCR (Gray Component Replacement), UCR (Under Color Removal) and TAC (Total Area Coverage) are separation techniques which are used differently in flexo than they are used in offset.

UCR is the balanced reduction of cyan, magenta and yellow in shadow areas, with an increase of the black to maintain the dark and near neutral shadows. This technique is not always best suited for flexographic printing. The ideal use of this technique will be where one can reduce the amount of color in yellow, magenta and cyan while maintaining the shape and shadow detail in those three colors.

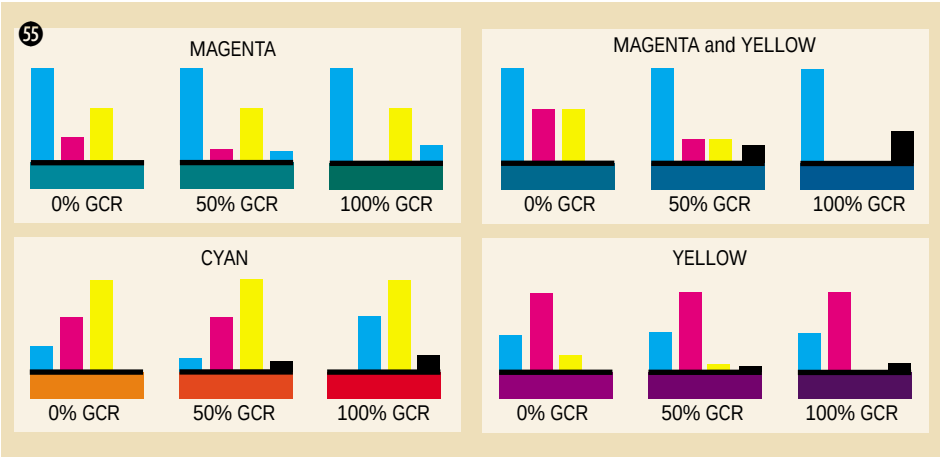
TAC is the total of the dot percentages of the four process colors on the final film in the darkest shadows. Knowing and compensating for the TAC is important during the conversion stage. Typical maximum TAC for flexo runs from 280% to 320%.

GCR is more easily defined by saying that an unwanted color (cyan in reds or magenta in greens) can be replaced entirely or partially with black. Under normal conditions in the flexo process, it is recommended that GCR be restricted to a single unwanted color. The use of GCR in flexo separations allows printers more latitude on press and prevents printed images from looking gray and dirty.

GCR should not be used when the printer is forced to print line black on the same station as the process black. It is better to have a short (skeleton) black for the separation, so there is more latitude in setting the impression. The use of GCR also allows items of significant color variations to be printed side by side (*Figure* 55). For example, printers traditionally stay away from printing an item like carrots next to a bowl of peas. The results are usually poor because in an effort to get more red into the carrots, the increased magenta makes the peas dirty. The use of GCR removes the magenta from the peas (and cyan from the carrots). This allows the printer to increase the magenta as needed without the peas being affected. In conjunction, the cyan in the peas can be manipulated without affecting the color of the carrots. *Figure* 56 shows a separation with and without GCR.

Cutback Curves/ICC Profiles

Cutback curves and ICC profiles are two methods of compensating for the particular print characteristics, mostly the dot gain, on a flexo press. The methods will be discussed elsewhere in detail, but depending on the particular workflow, some, or all of these



55 Colors respond differently to the GCR process. When yellow is swapped out for black the resulting color changes are most noticeable. Replacing black with cyan or magenta exerts a significant, but less obvious, impact on the color palette.

56 The apple image is compared with and without GCR. When GCR is used, there is an increase in the black separation.

measures, can be built in right at the scanning stage. When working with ICC profiles, for example, the profile of the scanning device can be generated and used with the scan. Ultimately, using ICC profiles, each input and output device is characterized and the desired color is specified in device independent CIELab color space. With current practice and technology, this workflow has not been implemented to any large extent.

DIGITAL PHOTOGRAPHY

Digital photography is still in its infancy when it comes to the flexographic print process. It is important to recognize the current uses and workflows in which digital photography is utilized and then compare them to how things should work in today's flexo prepress environment.

Digital photography has been an enormous benefit to the offset-print market. This process captures and saves the image as digital data during the actual photography stage. Where traditionally an image is photographed, a color negative developed and then a color transparency or print is generated that can then be scanned; a digital photo bypasses almost all of those steps. Once the image is photographed it is transferred to computers for immediate editing and output. Generally, the images do not require separation from an RGB color space to the CMYK printing color space. The cost of separating the image is eliminated as is the time to do so.

The RGB digital capture is easily converted

by the photograhper to CMYK through color conversion tables. Digital proofing devices, available to the photographer, allow the image to be proofed and submitted to the customer for review. If any color changes are needed, the photography studio can easily execute the changes and resubmit the image.

This process works well for offset printing because the conversion tables and proofing systems have been optimized for that process. It does not, however, meet the needs associated with flexographic reproduction for the same reasons that a scan specifically created for offset will not print well in flexo. The following are some of the reasons.

Minimum/Maximum Dot Requirements

As mentioned previously in the scanning section, flexo requires a minimum of a 2% dot and a maximum of 95% to 98% dot. The RGB-to-CMYK color conversion tables available to the photographer do not traditionally allow for these settings. However, new software and more sophisticated color conversion programs are quickly closing the gap.

Use of 100% GCR

Today's flexo separators are using a full GCR (gray component reduction) approach more than ever before. This means that separations are done predominately with full range (0% to 100%) in yellow, magenta and black and a short range (60% or greater) for cyan. This "short" cyan is used when a green color is reproduced and to add weight to very dark shadows. Color conversion tables that go from RGB to CMYK have been set up to produce an opposite separation. Those separations are done with a long yellow, magenta and cyan, and a short black. This requires extensive retouching to make the adjustment from long cyan to short cyan. New software entering the market will address this issue and offer acceptable alternatives.

CMYK vs. RGB Proofing

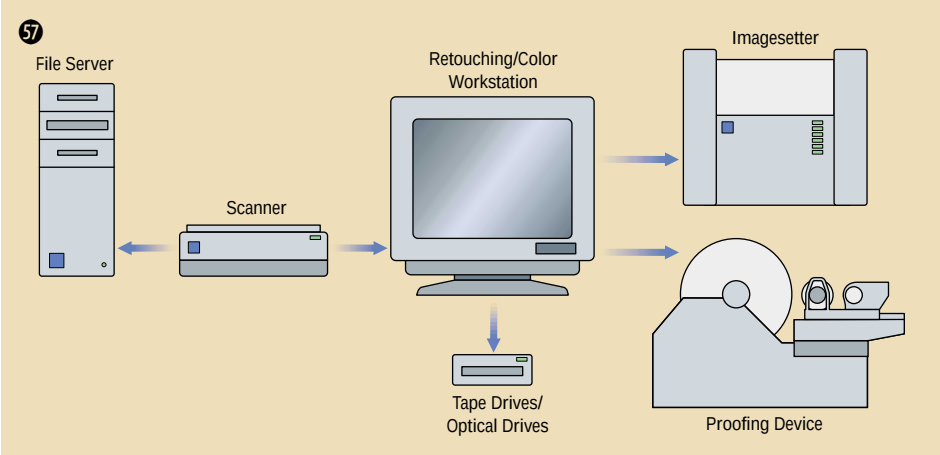
One of the biggest reasons why digital photography has not benefited flexo the way it has the offset market is because of the digital proofing dilemma. The proofing devices use an RGB-to-CMYK color conversion table that is completely different than the one used to create the color separation for printing. This is an important fact to consider. The digital file output by the separator is completely different from the proof supplied by the customer as a color target. The separator, then, has to manipulate the file to match the customer's or the photographer's proof.

These issues can effectively eliminate the cost and time savings associated with digital photography. In short, the file received by the flexo separator can not be used as is. It must still require minimum and maximum dot percentages and GCR applied, and must be color corrected to match the customer-supplied proof. Digital photography is a valid means of capturing an image, but the customer has to realize that, because of the unique properties of the flexo print process, the digital file must be treated as if it were an original transparency or reflective art.

SCANNING DEPARTMENT SETUP

The quality and variety of equipment found in a scanning department in a prepress house varies from supplier to supplier (*Figure* 57). Generally, components include:

- **Scanners** – drum, flatbed, transparency, for translating hard-copy originals into electronic files that can be manipulated by electronic prepress systems. Software bundled with some high-end scanners allow sophisticated image manipulation, or produce separated files in PostScript, or proprietary formats, which can be output on an imagesetter. As high-resolution images tend to be large and difficult to work with on a desktop computer (see *Table 9* for file sizes of CMYK scans),



57 A typical scanning department includes a file server, scanner, retouching color workstation, imagesetter and proofing device. These pieces of electronic equipment control the flow of data.

many prepress services provide a low-resolution of the image to the customer for use during layout and design, storing the high-resolution version until the pages are output. (See the section on low-resolution placed images for more detail)

FILE SIZES OF SCANNED IMAGES

	1	2	3	4	5	6	7	8
1	277	553	830	1080	1350	1620	1890	2160
	352	704	1030	1370	1720	2060	2400	2750
2	553	1080	1620	2160	2700	3240	3780	4320
	704	1370	2060	2750	3430	4120	4810	5490
3	830	1620	2430	3420	4050	4860	5670	6480
	1030	2060	3090	4120	5150	6180	7210	8240
4	1080	2160	3240	4320	5400	6840	7560	8640
	1370	2750	4120	5490	6870	8240	9610	11000
5	1350	2700	4050	5400	6750	8100	9450	10800
	1720	3430	5150	6870	8580	10300	12000	13700
6	1620	3240	4860	6480	8100	9720	11300	13000
	2060	4120	6180	8240	10300	12400	14400	16500
7	1890	3780	5670	7560	9450	11300	13200	15100
	2400	4810	7210	9610	12000	14400	16800	19200
8	2160	4320	6480	8640	10800	1300	15100	17300
	2750	5490	8240	11000	13700	16500	19200	22000
9	2430	4860	7290	9720	12200	14600	17000	19400
	3090	6180	8270	12400	15500	18500	21600	24700
10	2700	5400	8100	10800	13500	16200	18900	21600
	3430	6870	10300	13700	17200	20600	24000	27500

2700 Digital file size image scanned at 266 ppi/133 lpi
3430 Digital file size image scanned at 300 ppi/150 lpi

Table9

- **Monitors.** High-resolution models are capable of 24-bit color display. Larger screens usually require a video card to accelerate the display.
- **Software**. Programs include those to operate the scanner, color management software, and image processing/color correction/retouching applications.
- **Short-term Storage Devices**. Transportable or removeable media include Zip, Jaz or optical disks and CD-ROM.
- **Long-term Storage Devices.** Hard disks, or an array of hard disks, CD-ROMs and/or magnetic tape are needed to handle and archive the many gigabytes images require.
- **Computers.** Workstations with a fast CPU and sufficient RAM are required to run the software and handle the large files.
- **Proofing Devices.** Contract-quality and digital proofing systems are essential to proof the image prior to the output of film. These proofing devices, when set up to conform to actual press characteristics, are extremely useful tools to the prepress company as well as the end-user.

Preflight Quality Control

Quality Control (QC) reviews are conducted prior to manufacturing and the release of materials to a converter, printer or customer. In the prepress environment, the job engineer is responsible for reviewing each project for manufacturing issues prior to actual execution. This is done soon after the arrival of the desk-top mechanical or laser proof.

The job engineer looks for issues that could cause printing problems if not handled properly, and plans each job in order to maintain consistency between operators. All of this is done with the customer-supplied laser proof as a reference point. This is what separates the function of the job engineer from the preflighter. Where preflight reviews the actual electronic file, the job engineer only reviews the laser proof supplied by the customer.

In actuality, the preflighter and the job engineer work very closely together. The job engineer identifies potential issues based on the laser proof and the preflighter confirms how the electronic file is set up. The following section describe what the job engineer checks for on the incoming laser proof to confirm that the information for the job is accurate. *Table 10* summarizes that process.

SIZE/DIMENSIONS

One of the initial checkpoints is the actual size of the job. A low-resolution or laser proof supplied to the prepress provider should either be at full (100%) size or, if at a reduced or enlarged size, it should be clearly indicated. The dimensions can be checked with a ruler to confirm their accuracy.

A JOB ENGINEER'S CHECKLIST

- Size and dimension
- Scan techniques required
- Inks requested vs. inks required
- Spot colors or process match
- Ink rotation and trapping
- Tint builds
- Screening requirements
- Vignettes, gradations and blends
- UPC positioning

Table 10

SCANNING TECHNIQUES

Both the job engineer and scanner operator should review the actual scanning techniques required for an image. Sometimes it is possible to eliminate one of the process colors through the use of GCR. This information, if realized up front, can help in deciding how many colors the job actually needs. For instance, when separating a field of peas, magenta may be eliminated altogether, since it is a contaminating color. If there is no other magenta required on the package, the customer and printer have freed up an additional deck, which they can decide to use for another color.

INKS REQUESTED VS. INKS REQUIRED

The inks requested by the customer could be different than the inks actually required for optimum flexographic reproduction. The job engineer has to take into consideration many factors when trying to decide what

colors will produce the best looking package. More often than not, this discussion is done with full cooperation of the printer. Some of the issues to consider are:

- **The existence of corporate or logo colors.** Colors signifying a brand name or corporate entity are almost always specified as line color to ensure print consistency from press run to press run.
- **Repeating colors in a product line.** When dealing with multiple items in a product line, it is important to consider colors that repeat on each of the different packages. When the products share a common printing color, the usual approach is to print that color as a line color. This is to ensure consistency between all the packages.
- **Utilization of a "code color".** When a customer has products in a line that are very similar, a "code color" may be used to differentiate between items. For instance, a line of three packages could have identical separations and layouts, but the customer chooses to print the flavor description copy in a PMS 287 blue on package "A", a PMS 327 green on package "B" and a PMS 872 gold on Package "C". In order to save films and plates, the job engineer would not want to print those flavor colors in process matches. Instead of having to make four process-color films for each package, a common set of process films would be used and a new line color made for the flavor description.
- **The color's ability to be reproduced in screens versus a line color.** An example would be when a customer has seven of eight decks chosen and has to decide between a logo color of PMS 327 green or some other "sell copy" that prints in PMS 287 blue. While, the initial reaction would be to put the corporate PMS 327 green on the line deck, this might not produce the optimum results. In this scenario, the job engineer might opt to print the PMS 287 blue as the line color. The reason: a PMS 287 is a much more difficult color to match in process than a PMS 327. Some customers have gone as far as assigning a delta (Δ) E[2] to help make the decision. Whichever process-match-to-line-color value has the lowest ΔE-value is put in process.
- **Text size** This issue is closely related to the previous one. If, in the previous example, the "sell copy" to be printed in the PMS 287 blue is small text, this would by itself dictate the use of a line color. With larger type, it might be feasible to use a color matched with process.
- **The amount of ink coverage.** Colors that have heavy ink coverage are better served by being printed on a line deck. Also lighter process match colors, like yellows, light oranges, pinks, pale blues, pale greens and light grays, are better put on line decks because they tend to be a little more difficult to control on press. This is especially true for near-neutrals, where a small shift in one of the constituent colors makes a large visible color difference.

SPECIAL COLORS: SPOT OR PROCESS MATCH

The job engineer should confirm how all colors are to be reproduced, especially whether they are spot or process match. A simpler case is when the designer specifies all the colors used as PMS colors and indicates if they print as a "line" color or a process match. In this case, the task is to assign the proper tint values for those colors that will be matched with process.

A more difficult case and potential problem comes about when the file has a color assigned as a tint-build only. This may seem to be clear, but the problem lies in knowing the real intent of the designer. Most likely, the tint values were copied from the process

1 ΔE is a numerical measure of color difference in CIELab color space. Refer to the chapter on process color for more information.

swatch book and the real desire is to match that particular color in the swatch book. The problem is that the tint values given in the swatch book for that particular swatch are not guaranteed to produce the given color when printed flexographically. As a matter of fact, it is almost certain that the printed color will be a poor match to the swatch.

Swatch books that show process-match builds are printed using offset specifications. For example, the specifications for PMS 485 red is 100% yellow and 100% magenta. For offset, this means that a process match of PMS 485 red is printed with a solid ink density of approximately 1.40 for magenta and 1.00 for yellow. When the same 100% magenta and 100% yellow is printed in flexo, the solid ink density for yellow is typically also 1.00, but the magenta is less – around 1.20. Because of this, the resulting color is significantly more orange; the magenta content has been reduced when compared to original yellow content. The knowledgeable prepress facility will reduce the percent of yellow to regain the balance between the yellow and the magenta found in the original offset PMS swatch. It is worth pointing out that typical flexo solid-ink densities will usually result in a color that is a little "weak" when compared to an offset swatch of the same process build. Of course, only the density has been considered thus far. Besides the density, there is the issue of the hue of the inks used.

In general, the hues of flexo inks are not identical to offset inks, leading to yet another cause of color difference.

Note: *It might be pointed out that even in offset printing, the process-match builds specified in the swatch books often produce unacceptable results and the builds need to be modified. One solution to the problem, which can be applied to flexo as well, is to use a spectrophotometer and special software to calculate the required process-tint values. The spectrophotometer measures the desired color. Then the software, using data stored for the particular printing process, calculates the closest match possible using process tints. Using this technique, any color can be specified with process colors. The software program gives the degree of match possible in terms of the above mentioned* ΔE *value.*

INK ROTATION AND TRAPPING

Ink rotation can determine how a job is eventually constructed or trapped. For instance, when a customer uses a very opaque ink, such as a PMS 872 metallic gold, the job engineer must know what the exact rotation will be. The ink rotation will be determined by the printer, taking into account the particular press and complexity of the job. In the case of the metallic gold, if there is solid-black type printing over the gold, the black can be set to overprint, if it prints after the gold. If the black prints before the gold, then a knockout must be applied to the gold to allow the black type to show through (*Figure* 58). This is because the opacity of the metallic gold is such that it will hide any color that it prints over. In all cases, and with all colors, the relative opacity is one of the determining factors when deciding how a job is to be trapped.

The other key factor is the actual colors involved. With transparent inks, no matter what the rotation, proper trapping must be applied or unwanted results can occur. In general, dark colors can be successfully overprinted onto light colors, but the decision of whether to overprint or knockout needs to be made by considering the particular colors involved. *Figure* 59 shows an example where the green type in the yellow circle can overprint the yellow. However, in the red square, the green type must be knocked out. Any potential issues that may arise when two colors require that they be trapped to each other should be reviewed

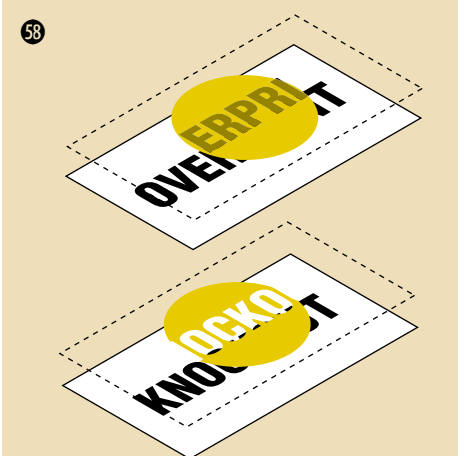
and decided on before film assembly or stripping takes place. Objectionable traps can be discussed with the designer or customer up front and suggestions can be made to alter the design if necessary.

TINT BUILDS – THREE-COLOR TYPE OR TINTS

Any tint builds in a package should have no more than three colors. Print reproduction is better controlled using two colors; however, this is not always practical. The job engineer has to work with the desktop person to determine if any colors that need four-color tints exist or if a three-color tint can be reduced to two colors. For example, sometimes a three-color tint calls for a very small dot percentage for one of the colors. In this case, the customer might approve the slightly cleaner color that results when that small component is removed.

SCREENING REQUIREMENTS

It is common in flexo to print process work (screens) separate from solid line copy. This is due to the cell counts of anilox rolls being used on press. Process printing, which is often at 100- to 133-line screen, requires anilox rolls with a higher cell count. Typically these rolls have cell counts of 600–800. Line decks usually carry solid-line copy – done with rolls that have a cell count of 400–550. The job engineer must be aware of the particular screening requirements when a customer requests that a screen be printed on a line deck. When this request is made, the job engineer must inform the customer, that to get an optimum reproduction, it is best to print that screen in a coarse line screen. The line screen that is generally used to print screens on a line anilox roll is 65 to 85. The customer must be aware of this, because depending on the screen used, there may be a dot pattern that the customer will find objectionable. If the customer is notified up front, it is possible to come up with an alternative before the expense of films and proofs are made. The customer will usually opt to convert the screened color of the line deck to process printing, or use the coarse line screen on the line deck.

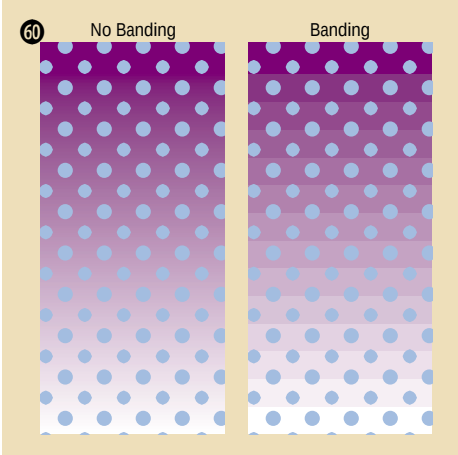


58 An example of ink rotation where the black prints before the opaque gold. With a knockout, the black type is visible. However, if the gold overprints, the black type will not be visible through the opaque gold.

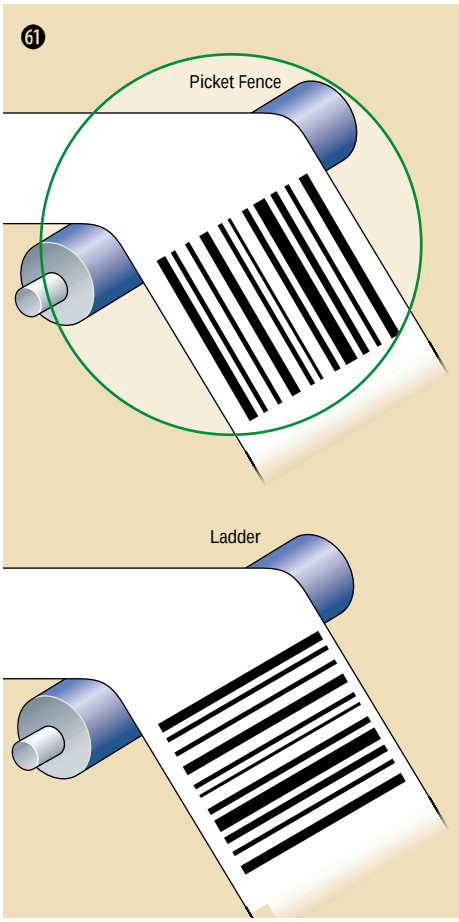
59 Darker green type is set to overprint in the yellow circle, but is knocked out in the darker color of the square.

VIGNETTES/GRADATION/BLENDS

The execution and handling of vignettes (also called gradations or blends) warrant detailed discussions during the job engineering stage. The way the vignette is created in the electronic file is not necessarily how the customer expects it to print. Engineering of vignettes requires that the values of the vignette meet the minimum/maximum dot



60 A side-by-side comparison of an acceptable and unaceptable vignette. Acceptable vignettes contain no banding, while unacceptable vignettes contain banding.



61 UPC codes should be placed in the picket fence position, in which the bars run in the machine direction.

requirements of the printer. It is important for the job engineer to understand what the customer expects and translate that expectation into a vignette that is visually appealing and technically printable. The job engineer must work with the desktop publisher to determine how the vignette is created. With this information, the job engineer will, in most shops with high-end proprietary stations, recreate the vignette to the customer's requirements.

In instances where the vignette will be stripped on a desktop PC/Mac workstation, the vignette may still be recreated to produce the desired effect if the original vignette is not satisfactory. A vignette is deemed unsatisfactory if it either produces a "banding" effect (*Figure* 60) or is specified below the minimum dot requirements for flexo printing. Whether vignettes are created on a desktop or a high-end station, it is a good practice to output the vignette before the final film. To output the vignette at the same time the entire job is output, and to find the vignette needs adjustments, is a tremendous waste of resources. Also, when vignettes will be compensated or cut back during output, it is advisable to apply that compensation to the vignette when it is output during the test.

UPC POSITIONING

For optimum reproduction, UPC codes should run in the direction of the printing unit. (*Figure* 61). The job engineer should question a UPC running in the transverse or ladder direction, in the event that the customer overlooked it.

Desktop/Preflight

Desktop departments in a prepress environment are commonly called the Mac department. These Mac departments grew as an extension of the Mac departments of the designers. When designers created art board mechanicals, there was a need to convert that mechanical to a format that could be stripped. That meant making a line shot or negative of the mechanical's type elements and, through the use of goldenrod mask and manually cutting/stripping in tints, creating plate-ready negatives. Stripping was done on a light table and the various flat negatives and masks were composed together to make a negative for each printing color.

In the 1980s, designing and stripping package art shifted from being done by hand to being done almost exclusively on computers. Designers began utilizing the Macintosh computer for designing while the prepress houses began using various expensive proprietary electronic stripping stations. For the first time a gap was created between the designer and the prepress shop. The prepress shop had no way of taking the designer's file from the disk and getting that digital information into its system. The solution was that prepress companies went out and purchased the same type of computers used by the designers, then used the customer's disk to create a file that could be recognized.

As the computing power available for desktop publishing systems increases, the job assembly and output functions, formerly done by the proprietary systems, can now also be performed with Macs or PCs, albeit with less efficiency.

It is important to note, that while the Macintosh computer still is the dominant operating system for graphics reproduction, IBMs and IBM-compatibles (collectively called PCs) also have the ability to do the same job that the Mac can. Software programs that were once only available on the Mac, are now available for the PC. In fact, the cross-platform capabilities on today's computers have resulted in the desktop departments consisting of both PCs and Macs.

"READING" FILES

To make an electronic stripping workflow possible, a common digital format was required. PostScript became that standard, universal computer language all computer makers adopted to allow for the exchange of electronic documents between varied computers. PostScript files support composite and separated workflows for vector and bitmap images, but require that all fonts be embedded. The prepress shop can easily convert the electronic file created in any software program such as QuarkXpress or Adobe Illustrator to a PostScript file and "read" that PostScript file on the stripping station.

The latest development, spurred by the growth of the Internet, is the Portable Document Format (PDF), developed by Adobe Systems Incorporated. This format is designed as a solution to easily exchange electronic documents between Mac and other platforms. This is possible because PDFs are independent of the original application software, hardware, and operating system used to create those documents.

PDFs have found a niche in desktop publishing, with its positive ability to preserve the original graphic appearance. This file format embeds all fonts, as well as information about whether the PDF is trapped or not it also has the ability to represent bleed and trim, lossless compression and can insert ICC profiles about the intended printing condition. Using special software, such as Adobe Distiller, PostScript level 2 and 3 files can be converted to PDF files. A new format, PDF/X – the X stands for eXchange – is a proposed American National Standard Institute (ANSI) standard being developed by the Committee for Graphic Arts Technologies Standards (CGATS), and most likely to become an International Standards Organization (ISO) standard. It is a variant of the PDF, intended for prepress production and high-end printing, and can handle composite files containing both vector and raster objects. Two PDF/X specifications are being developed. PDF/X1allows files to be output directly; and PDF/X2, which allows modification required by the file, such as OPI image replacement prior to output.

PREFLIGHT RESPONSIBILITIES

Today's desktop department has two primary responsibilities: creating files that can be recognized by the stripping station and preflighting of those incoming files. The ever-increasing power of today's desktop computers has caused, in some cases, the desktop department to be responsible for the film assembly (stripping) of the package.

Preflight is the process of reviewing all materials for adherence to known specifications. In the flexo print process, those specifications are entitled FIRST (Flexographic Image Reproduction Specifications and Tolerances). The desktop publisher is responsible for making sure that the elements of the electronic file comply with either FIRST specs or the printer's custom specifications. Checking the files in the desktop department, also allows the prepress company to notify the customer of required changes before costly film output and proofs are made. The following elements should be reviewed during the preflight process:

- software versions;
- low resolution placed images (FPOs);
- live images;
- imported EPS files;
- fonts;
- line weights;
- font sizes;
- tints and screen builds;
- vignettes and gradations; and
- layers.

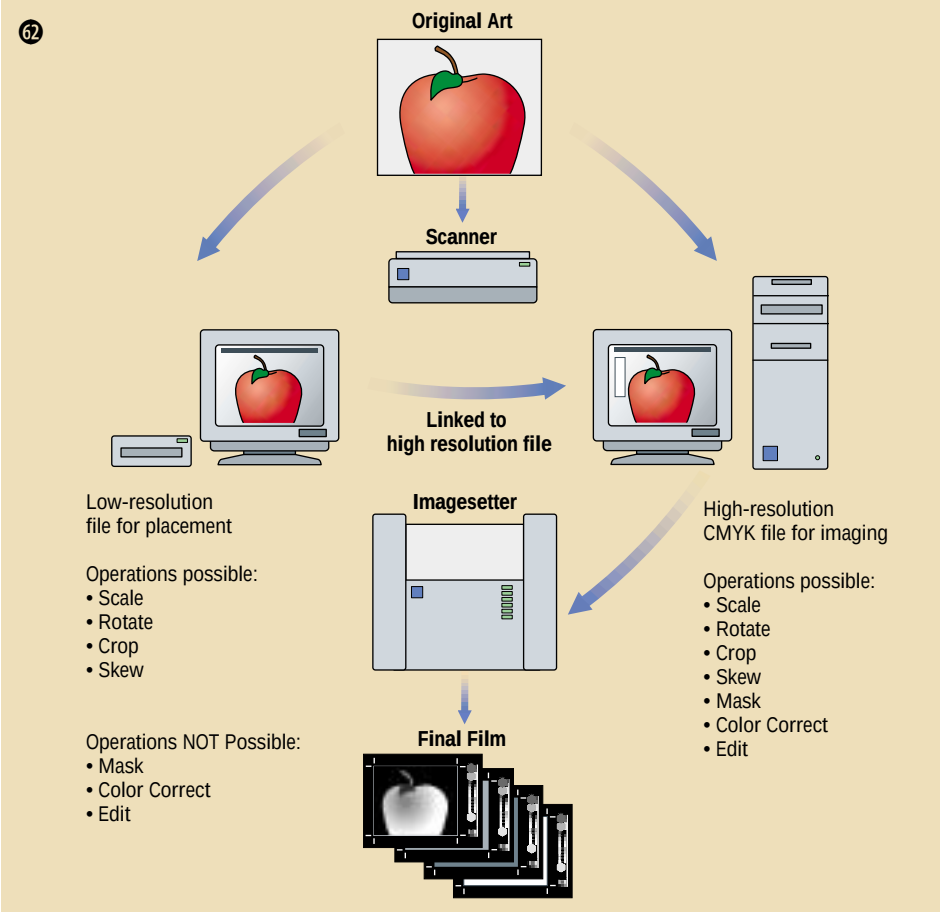
The elements listed above and described below also appear in *Appendices A and B* in a checklist format that can be used as a guide for preflighters.

Software Versions

It is important for the prepress house to have the correct software and version to view and output the file. New versions and updates of software are released, and the prepress house may not have upgraded to the latest version. Software versions should be verified early in the process, allowing sufficient time to either have the customer resend the job, saved in a compatible version, or for the prepress house to purchase and install the new version without delaying the project. Even in an environment where design and prepress, or prepress and printing, are done under one roof, control of software versions is important.

Low-resolution Placed Images

Low-resolution images placed in the layout as a place holder for high-resolution images are for position only, called FPO's. The purpose is to make the layout easier to work with since FPO files are much smaller



62 Systems for automatic image replacement, such as OPI or DCS, are sset up so desingers cn work with smaller low-resolution versions of the images, while the high-resolution images are stored remotely. During output, the low-resolution files are automatically replaced withthe high resolution versions.

and therefore easier to handle. All FPOs should be sent to the prepress provider. It is not uncommon for a designer to forget to copy FPOs to the transfer disk going to the prepress house. Without these items, the job assembler will be unable to accurately duplicate the size and placement required for any high-resolution images to be used for film output.

OPI and DCS are methods of working with low-resolution placed images.

*A*n OPI (Open Prepress Interface) workflow (*Figure* 62), the design utilizes low-resolution placeholder images. The high-resolution image is stored on a file server and the FPO is automatically replaced with the high-resolution image when the file is output to film. Typically, the prepress provider scans the artwork, keeps the high-resolution image on file, and gives the designer a low-resolution image to use in the design.

DCS, desktop color separation, files are five-part EPS files. They utilize a low-resolution display image for placement and high-resolution separation files for cyan, magenta, yellow and black.

Live Images

Any “live” images placed should be clearly indicated. They should also be checked for proper resolution, color space – RGB or CMYK – and size before starting the assembly of the job. It is also important to check that the image is flexo-ready. Often, supplied images are prepared for offset printing and if they are not converted for the flexographic

process, they will not produce a quality result. The preflight person should check for minimum and maximum dot values, as well as the use of GCR. If it is found that the "live" image does not meet flexography specs, the image must be sent to the color department to be adjusted. It is also best to notify and alert the customer of any additional time and cost that will be incurred.

Imported EPS Files

Imported EPS files should be checked for missing fonts as well as flexo readiness. Most software programs only alert the operator to missing fonts in an imported or placed EPS file when it attempts to print it. The desktop publisher should open up each placed image in its native program and check that the appropriate fonts are available, that the resolution is sufficient for the line screen at which it must be output and that the file is prepared for flexographic reproduction.

Fonts

The file must be checked to make sure all fonts are available. Fonts come in two different types: TrueType and PostScript Type 1 or 3. TrueType fonts utilize an outline font file for both screen viewing and printing. Type 1 and Type 3 are PostScript fonts created by foundaries such as Adobe or Bitstream. They consist of a separate screen and printer font. A screen font is needed to correctly view the font on a monitor, while the printer font is required to be resident on the computer to print the document properly.

TrueType fonts used in the electronic document should be replaced with the appropriate Type 1 or 3 font. TrueType fonts have been found to be unstable and problematic when used in a PostScript environment.

Line Weights/Font Sizes

The nature of the flexographic printing plate prevents very thin type or rules from being reproduced during the platemaking process. In addition, the relatively large traps required in flexo printing dictate that rules need to be of a certain weight to allow them to be trapped. FIRST and/or the printer specifies minimum type sizes and rule weights that the desktop person should verify on the incoming electronic file. Any type or rules falling below the specification should be brought to the attention of the customer with the recommendation that they be increased.

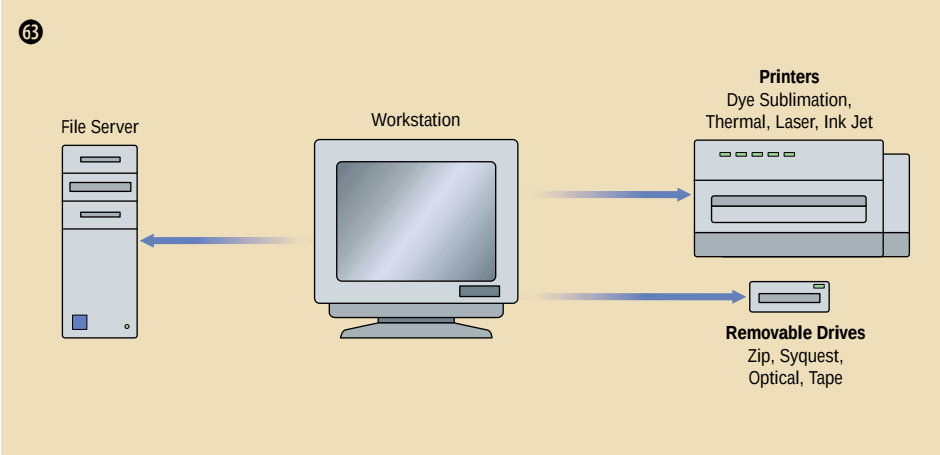
Tints and Screen Builds

The electronic file should be checked to make sure that any screen tints adhere to the minimum or maximum dot values required by either FIRST or the printer. Any screen builds assigned by the design firm should also be checked for use of GCR. If a color is created with a "contaminating color" it should be changed. The customer usually is not notified or required to authorize this change because the resulting color is virtually identical to what the designer originally specified. It is also recommended that there be no color created with more than three process colors, and two-color tints are highly recommended when possible.

Vignettes and Gradations

The desktop production artist should indicate how vignettes are created in the electronic file and check that they are done properly. Vignettes have to adhere to the same minimum and maximum dot requirements specified by the printer. Since it is common to specify vignettes as going from 0% to 100%, it is not uncommon that there will have to be adjustments made to the electronic file. The desktop production artist will usually have to work with the design firm and the printer to make the proper adjustments.

In most prepress shops, it is actually customary to replace the vignettes at the stripping stations. This is done because the strip-



63 A typical desktop department is comprised of basic equipment: a file server, workstation with monitor, and printer.

ping workstations have more control over the vignette and more often than not are able to eliminate any banding that may exist in the electronic file. This is why it is important that the desktop production artist is able to determine exactly how the vignette was prepared so that he/she can accurately communicate those instructions to a stripper.

EQUIPMENT AND SOFTWARE

In addition to the equipment found in the scanning department – scanners, long-term and short-term storage devices and work stations – the desktop department in today's prepress facility also consists of telecommunication devices, server(s) and some type of printer for proofing purposes (*Figure* 63)

Prepress providers that handle a large volume of electronic files often have an electronic bulletin board or mailboxes where customers can dial up to post their files by modem. Such services enable clients to deliver files in a relatively quick amount of time and at a minimal cost.

Individual workstations, either Macintosh or PC systems, consisting of a hard drive, keyboard, mouse and monitor are networked to a server and printer. Software programs for package design, page layout, drawing, image manipulation and word processing are common additions, while more specialized products, specifically created for the flexo packaging market, may reside on the workstations as well.

The workstations are normally connected to a host of removable drives. The media for these drives – Zip, Jaz, CD, DAT, floppy – allows files to be copied to them from the hard drive, and then removed for transport from one workstation to another. Each type of removable drive has its own unique advantages in speed, durability or the number of megabytes it can hold. Those used by the prepress company is usually dictated by the drive used by its customers. For this reason, most prepress companies need to have several different removable drives available.

Printers used in the desktop department are usually color. They do not have to be accurate for color, but the most popular devices can provide an excellent representation of color and be calibrated to reflect different print processes and substrates. Large format ink jet, color laser, and thermal wax transfer are among the different types of printers, all varying in size, color accuracy, cost and method of reproduction as well as resolutions. The right printer should fit with the type of work to be reproduced.

Job Assembly/Layout

Some prepress shops utilize the desktop department as the film-assembly department. Due to the nature of the work produced and the sophistication of today's desktop systems, it is possible to produce jobs that were once possible only on expensive "high-end" systems.

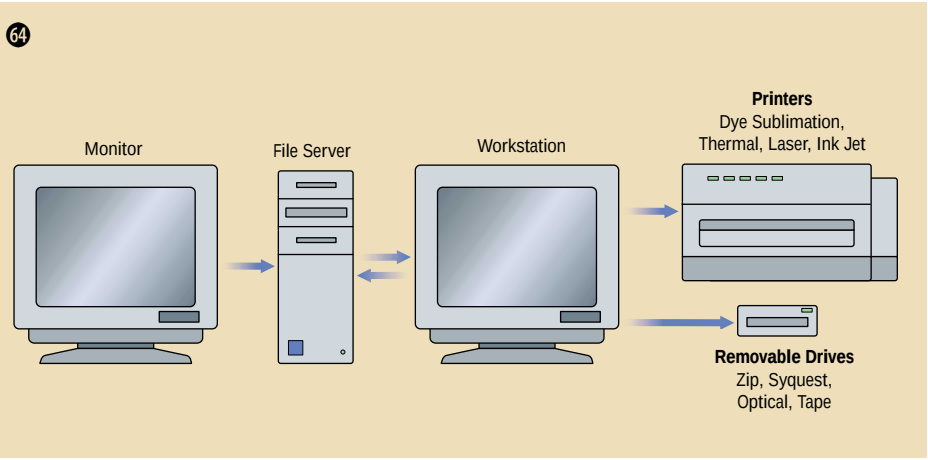
Job (or film) assembly or layout (also known as stripping) is the process of assembling various elements into a file that can be used to generate plate-ready films or photopolymer plates. The "electronic stripper" or job assembly person generally requires the most technical set of skills in all departments within a prepress environment.

The primary responsibility of the film assembler is to combine all elements in such a way that it is consistent with the customer's expectations. He or she must do this within the capabilities of the print segment in which the job will be printed.

Familiarity with the flexographic process allows the stripper to take advantage of flexo's unique strengths while minimizing its limitations. One method to ensure that the job is optimized for flexo is throgh the application of FIRST. By following these specifications, and making a commitment to quality, the job assembler can produce a consistent product. This commitment to consistent print quality applies to the way graphic elements are trapped, separations are handled, logos appear; in short, every element on the package. If the graphics on the outside of the package always looks the same, the consumer can feel comfortable that the product inside the package will always be the same.

HARDWARE AND SOFTWARE

Just a few years ago, stripping was exclusively completed on a light table with rubylith and goldenrod and composed on a vacuum frame to produce plate-ready negatives. Today most, if not all, stripping for flexo packages is done on a computer workstation *Figure* 64. These workstations can



64 Typical equipment found in a job-assembly work area.

be either open architecture or proprietary systems.

Open architecture refers to software solutions that can be purchased and loaded onto the computer of your choice, with the limitation that the software must be written for the particular operting system of the computer (such as Mac or PC). The biggest issue with open architecture software is choosing the right software to produce packages for flexo. This is an area of rapid change, with new programs being offered and existing programs being continually upgraded.

Proprietary systems require the purchase of specific hardware as well as software. For years, these systems were the only way to produce quality graphics for print reproduction. High-end systems dominated the prepress markets with their super-fast processors and enormous hard drives. The emergence of the desktop systems has eroded that dominance and, in several cases, has caused a shift in how these systems are marketed. These systems have shifted to more of an open architecture format with an unbundled software component, allowing prepress companies to purchase less expensive hardware.

Whichever system, the workstations generally utilize some type of hard drive for temporary storage as well as a removable media drive for archival and retrieval of completed packages. The equipment used and process of archiving and retrieving vary, but tapes, CDs and optical media are the most popular formats used and offer excellent stability and relatively long shelf life. In addition, the job assembly department has some type of digital proofing device to check the accuracy of the stripped file before the output of films.

TECHNICAL RESPONSIBILITIES

Whether working on an open or proprietary system, the job assembler must be able to perform the following functions.

Using Layers

Layers are an important tool to streamline the production process. The main responsibility of proper layer use rests with the designer (see Design chapter). The layering should be reviewed to make sure the proper layers are turned on and that the design follows good practice in the use of layers.

Placing High-resolution Images

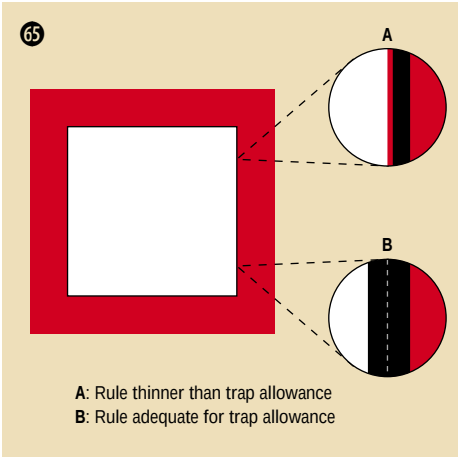
When digital photos or images are required on a package, the job assembler must take care to duplicate the placement of the image per customer instructions, as shown on the FPO. Responsibilities include rotating, cropping or scaling – either enlarging or reducing – the image. The job assembler may also be required to “warp” or anamorphically scale an image to fit. For instance, the height can be enlarged at 120%, while the width is enlarged at 105%.

Silhouetting of Images

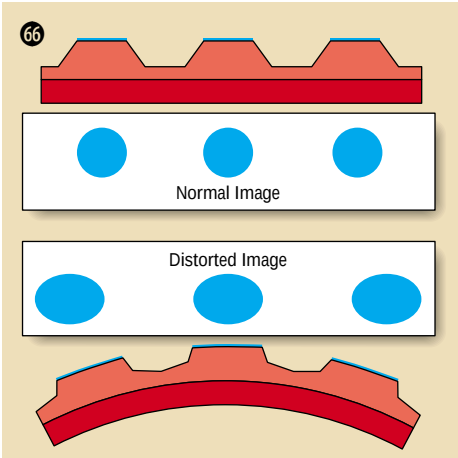
Silhouetting involves the creation of a mask to eliminate unwanted parts of an image. Using an image-editing program, it creates a clipping path. The stripper will, for instance, mask out the scenery or background behind a person, so that only the image of the person is used on the package. Thin objects are especially difficult to capture. Instead of appearing as intended, the thin objects resemble strands of color, and when they are trapped, they all but disappear. Hair, flora and certain foods not silhouetted properly may contain spots of unwanted background image, or have an unnatural outline or shape about them.

Assignment of Screen/Tint Values And Color Information

Print requirements or the number of print stations available for a project dictate the assignment of screen/tints values and color information. The color assignments are either 100% (solid) of a color, a screen mix or



65 The drawing in circle A demonstrates the case where the rule is thinner than the trap allowance. Consequently, the dark red shows through on the inside of the rule. The image in circle B shows proper trapping with the rule wide enough for the trap allowance.



66 Photopolymer plates stretch in the machine in the repeat direction, producing a distorted image. This distortion must be compensated for in prepress.

combination of multiple colors, or a "knock-out" from actual printing colors. The knock-out (KO) copy appears punched out of a color to allow the substrate beneath it to show through.

Trapping (Spreads and Chokes)

Trapping is accomplished through the use of chokes and spreads. This technique is used when two colors are adjacent to each other and prevents a gap of non-color between the two colors. The need for trapping arises from the inevitable misregistration on press. In general, light colors are spread into dark colors. Because trapping requires the operator to make colors that are meant to touch, or actually overlap each other, an objectionable edge can result. For instance, a green box trapping to a red one will result in a thin, dark line equal to the size of the trap where the two boxes meet. This is because the yellow and cyan of the green combine with the magenta of the red to make a three-color (black) rule. Sometimes this is unavoidable, depending on the colors requested by the customer. In some cases, the printer may be willing to accept less of a trap in that particular area, or the customer may allow a rule to be placed around the boxes to "hide" the trap. Sometimes a designer will use a rule that will not support the trap that the printer requires.

For example, a printer requires a 0.004" trap allowance and a designer has a 0.003" rule butting to a colored panel. To satisfy the trap requirement, the assembler needs to spread the colored panel into the rule by 0.004". Of course, once this is done, the colored panel will actually print inside the rule (*Figure* 65). The best solution in this case is to have a rule that measures 0.008" and trap to the center of the rule. This allows for misregistration in both directions.

Bar Code Creation/Placement

The job assembler may also be responsible for the creation and placement of UPC bar codes. He/she will need to know the type of bar code (EAN or UPC-A), the size (100%, 125%, etc), the bar-width adjustment (usually dictated by the printer) and the actual bar code digits.

Application of Distortions

Photopolymer plates stretch or distort in the repeat- or machine-direction (*Figure* 66). This occurs when they are mounted on the plate cylinder. As such, film used for photopolymer platemaking must be scaled in the repeat direction to compensate for this stretch of the photopolymer plates. The distortion is a reduction of the original file size. If, for example, a photopolymer plate stretches by 1%, the original file size needs to

K FACTORS

INCHES			CENTIMETERS		
PLATE THICKNESS	K FACTOR 0.004 BACKING	K FACTOR 0.007 BACKING	PLATE THICKNESS	K FACTOR 0.004 BACKING	K FACTOR 0.007 BACKING
0.030	0.163	0.145	0.076	0.415	0.367
0.045	0.258	0.239	0.114	0.654	0.606
0.067	0.396	0.377	0.170	1.005	0.958
0.080	0.478	0.459	0.203	1.213	1.165
0.090	0.540	0.522	0.229	1.372	1.325
0.100	0.603	0.584	0.254	1.532	1.484
0.107	0.647	0.628	0.272	1.644	1.596
0.112	0.679	0.660	0.284	1.724	1.676
0.125	0.760	0.741	0.318	1.931	1.883
0.155	0.949	0.930	0.394	2.410	2.362
0.187	1.150	1.131	0.475	2.921	2.873
0.250	1.546	1.527	0.635	3.926	3.878

Table 11

be set to 99%, so that it stretches back to the original 100% size.

The distortion can be computed mathematically from the repeat length and plate thickness, using the formula:

$$\textbf{\% reduction} = \frac{\mathbf{K} \times \mathbf{100}}{\mathbf{R}}$$

Where:

K = a constant supplied by the plate material manufacturer

R = the printing circumference (repeat length) of a cylinder (in inches)

Table 11 lists K factors for some common plate thicknesses. The values are given in inches and centimeters because the K factor changes with units of measurement. As an example:

What is the distortion needed in the film negatives for a 0.067" plate with 0.004" backing and a repeat length of 8"?

From *Table 11*, the K factor for this example is 0.396. Putting this value and the repeat length into the formula gives a percent-reduction of (0.396 ÷ 8) × 100 or 4.95%. This means the film used to make the plate must be output at 95.05% of original size to print at full size.

This formula is not used on a daily basis because distortion factors have been determined for most common repeat, pitch and plate sizes.

In the case of rubber plates, two distortions are required. Rubber plates shrink in both directions during their manufacture. In addition to this shrinkage, there is also the same wrap distortion as occurs for photopolymer plates when they are mounted on the plate cylinder. In principle, distortion factors could be calculated for rubber plates also. In practice, the distortions are usually determined empirically.

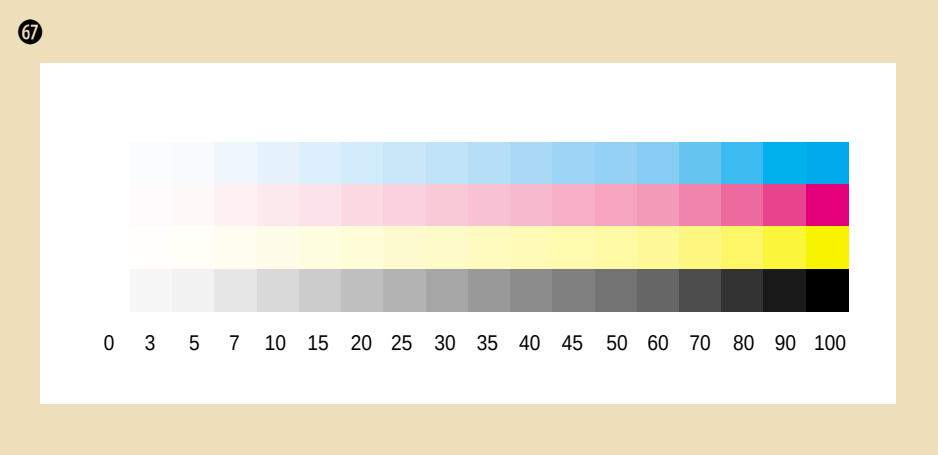
Dot-gain Compensation

Flexo-printed jobs require that they be compensated for flexo-specific dot gains on press. Dot-gain compensation is done in order to match the press and the contract proof. There are generally two ways to accomplish this, depending on the particular workflow a prepress company is using.

The traditional method is to apply a "cut-

67 This typical single-color step scale is used to measure dot gain and calculate cutback curves.

68 A small section of overprint patches in a typical target is used to create ICC profiles.



back" curve to the file, which is to be output to film for plate making. This basically changes the values of the dot percentages so that the dot percentage on the printed sheet matches the dot percentage on the proof. Cutback curves are calculated for each process color from single-color step scales (*Figure* 67).

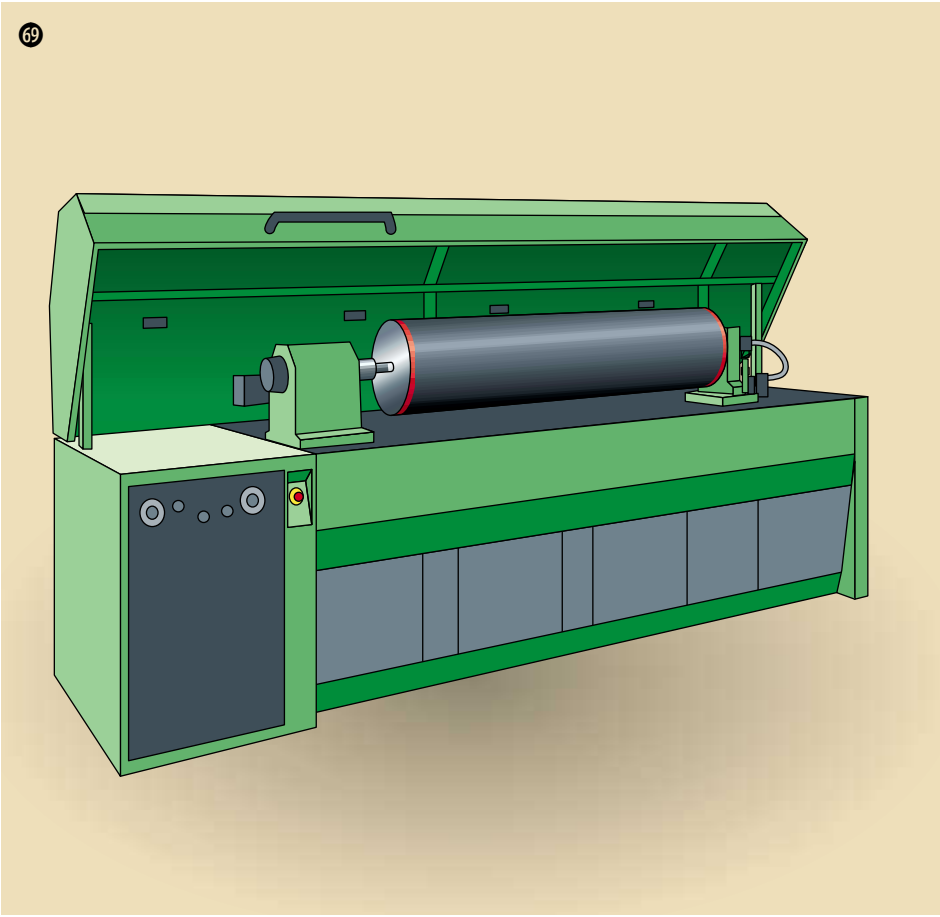
Cutback curves can also be calculated for special colors, particularly those used often and those used in screens opposed to only line work. It is usually not practical to generate a cutback curve for each special color, in which case one of the process-color curves can be used instead. Also, many times a special color is used on a line station at a lower screen ruling. In this case, the cutback required is less than that used for high-screen rulings. Details on how to evaluate the correct cutback curve can be found in the section on process color.

The second method used to compensate for press gain is to use color management techniques, such as the creation and use of ICC profiles. Rather than using only single-color step scales, as in the case of cutback curves, a large number of overprints are used (*Figure* 68). Different color profiling software packages use different numbers of patches, but using over 1,000 patches is common. The goal is still to modify the dot percentages in the output file for the plates, but this time the modification is generated from color measurements of all the overprint patches. Color management techniques can go one step further than simply matching a particular press and proof. Because it is based on spectrophotometric measurement of color, it is possible to specify a color by the numbers and match to that. This latter method, known as device-independent color, is receiving much attention but is not yet a mature production method.

Film Output/Imagesetting

Traditionally, film output represents the actual end product produced by the prepress company. While prepress charges for all items that go into producing the film, the film is what the customer is purchasing. A new type of plotting device, known as the platesetter, entered the market a few years ago. This device exposes a specially treated photopolymer plate, instead of film, thus eliminating the need for plate-ready film negatives.

The film output department consists of a film-plotting device or imagesetter and some type of processor to develop the films or plates that come off the imagesetter. Film plotters are either flatbed or drum models which vary by size, configuration and type of film supported (*Figure* 69). A film plotter's size is measured by the size of the film that the film plotter can expose. Plotters range in film size from 9"x 12", up to 47" x 96". Flatbed



69 A typical imagesetter. Drum plotters are known for their speed and are more effective with larger sheets of film.

plotters are usually better for registration of one color to another. Drum plotters are known for their speed and are more effective with larger sheets of film.

FILM PROPERTIES

Plate-ready film has several important properties:

- emulsion;
- orientation;
- film thickness;
- image properties;
- screen ruling and screen angles;
- dot shape;
- stochastic screening; and
- registration and mounting marks.

Emulsion

Film is made of a clear plastic sheet coated with a light-sensitive silver-halide layer. The side of the sheet with the silver halide is called the emulsion side. The other side is referred to as the base. The emulsion side can be visually detected on an exposed and processed sheet of film by its distinctive dull look when compared to the base's high-gloss or shiny appearance. Another method to identify the emulsion side from the base side is to scratch an area of exposed film (black areas as opposed to clear). The emulsion side will scratch, exposing clear film. It goes without saying that this destructive test should be performed on nonimage areas.

Orientation

The film can be exposed as either a positive or a negative. Positive film has all nonprinting areas in clear or no emulsion, while negative film is the exact opposite. Nonprint elements are black (the color of exposed emulsion) with all printing elements as clear. Film also has an orientation which is determined by how copy appears in conjunction with the emulsion of the film. The film orientation can be either right-reading copy when the emulsion of the film is up (RREU) or facing the viewer, or right-reading copy when the emulsion of the film is down (RRED).

Film Thickness

Film thickness is measured by the clear plastic base of the film in mils or thousandths of an inch (1 mil is 0.001"). Film comes in 4 and 7 mil thickness. Film that is 4 mil is used on smaller imagesetters, while 7 mil is the dominant choice for both large format imagesetters and photopolymer platemakers.

Finish

Film comes in either gloss, smooth, or matte finish. Different platemaking processes call for different film finishes. For sheet photopolymer platemaking, matte finish is usually required. For liquid photopolymer plates, clear is recommended. The particular finish required should be determined by consultation with the plate supplier.

IMAGE PROPERTIES

Aside from the film itself, there are properties of the image on the film: the screen ruling and screen angles, dot shape, image distortion, registration and mounting marks.

Screen Ruling and Screen Angles

Films that contain halftones are composed of dots of varying sizes, based on a particular screen ruling. The screen is determined by the number of dots or lines per (linear) inch. Coarse screen rulings measure below 100 lpi, while fine screen rulings are 150-lpi and above. Line screens from 100 to 150 are the most common screen rulings used in flexo printing. These same dots are also laid out in varying degrees or angles, which allow for multiple colors. When printed on top of each other the screens should create a rosette pattern, not a moiré pattern. Moiré patterns look like crosshatches, or in some cases, rings or

swirls when screens print on top of each other. Conventional color angles are 45°, 75°, 105° and 90°. That is, the four process colors are printed with the dots running at these angles. To minimize moiré, it is common practice to separate the four process colors by 30°. Since only 90° are available, this is not possible and only three colors can be separated by 30°, with one separated by 15°. In flexo, there is an additional consideration – the angle of the anilox roll. The screen angle and engraving angle of the anilox roll can interact and cause moiré patterns. In order to minimize this problem for all anilox engraving angles (30°, 45° and 60°), screen angles offset by 7.5° are used. *Table 12* shows the conventional angles and the angles offset by ±7.5°. It also shows a common assignment of the process colors to specific angles.

SCREEN ANGLES

	MAGENTA	BLACK	CYAN	YELLOW
Conventional	45	75	105	90
Conventional minus 7.5°	37.5	67.5	97.5	82.5
Conventional plus 7.5°	52.5	82.5	112.5	97.5

Table 12

Dot Shape

The dots in the film also come in varying shapes – either square, round, circular, elliptical or star. Each dot shape has its own characteristics regarding dot gain and the ability to be reproduced on a printing plate. A round dot has been found to give the best reproduction in flexographic printing.

Combination Screening

This method of half-tone screening combines conventional and stochastic screening and is used specifically in flexography to address the highlight break problem. Conventional screening varies the size of the dots to increase or decrease the amount of color in an area. That is, the dot density and hence the dot percentage is determined by the size of the dot. Conventional screening is also called AM for amplitude modulation.

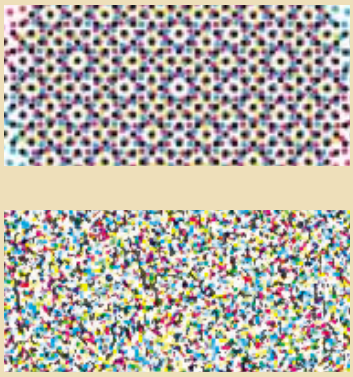
In stochastic screening, the size of the dots remains constant and the density, or dot percentage, is determined by the spacing of the dots (*Figure* 70). Low density has widely spaced dots, while high density has more closely spaced dots. Stochastic screening is also called FM for frequency modulation.

The entire image can be printed using stochastic screening. However, it has been found that stochastic screening only benefits the highlight end of the tone scale and conventional screening does a better job at the midtone and shadow end of the tone scale. This has led to the combination of conventional and stochastic screening. Stochastic screening is used in the highlights and then gradually changes over to conventional screening for the rest of the tonal range (*Figure* 71).

Registration and Mounting Marks

Platemaking films should contain registration marks. Generally a cross-hair, they allow the job assembler to place multiple pieces of film on top of each other for exact

70



70 Conventional (AM) screening varies the dot size but keeps the dot spacing (dots per inch) the same. On the other hand, stochastic (FM) screening keeps the dot size constant (small) but varies the dot spacing.

71 Combination screening uses FM screening in the highlight area and then transitions to AM screening for the balance of the tonal range.

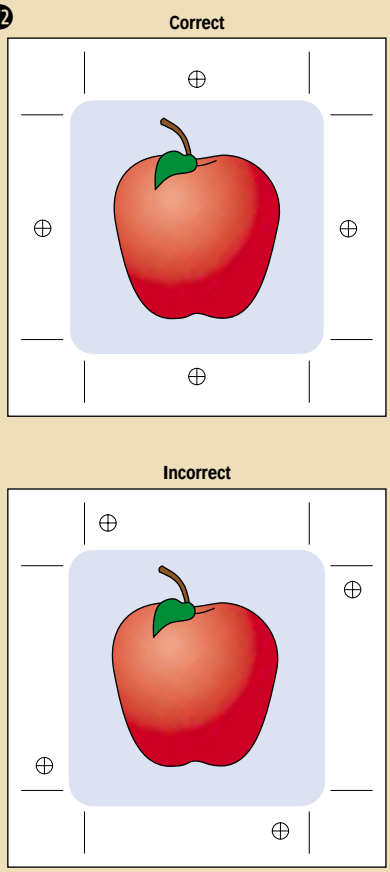
72 Proper placement of registration marks in a one-up and step-and-repeat application are in the center of the overall dimension of the film. The detail shows a slight misregistration of the cyan printer.

73 In a video mounting system, microdots are used. This illustration details the slight misalignment of the four process colors.

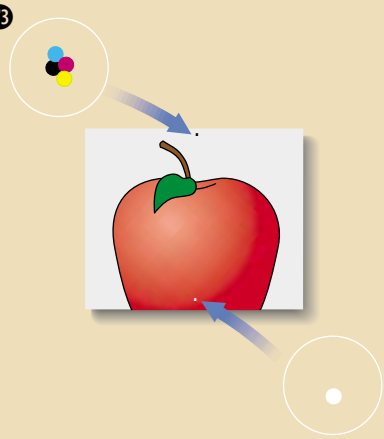
71

alignment. Proper placement of register marks is in the center of the overall dimension of the film. *Figure* 72 shows the proper positioning for a one-up and step-and-repeat application. Many printers utilize video mounting and registration systems. These systems require small microdots (0.010" in diameter) on the films in each of the printing colors (*Figure* 73). The dots are imaged with a video camera and serve as positive alignment locations when mounting the plates.

72



73



Proofing

The proofing department in a prepress company is often the most overlooked. It is assumed that all of the "real work" is in stripping and film output. Proofing should be viewed as one of the most important departments because the proofs have two very important functions:

- to represent the printed product as closely as possible and
- to be the last opportunity for the customer to make any corrections before final films, plates and printed samples are made.

Different types of proofs are made on many different proofing systems. Even with the use of good process control and optimal systems, an exact match to the press will likely not be achieved.

The degree of color difference can be quantified but for the last analysis, it is visual judgement that is commercially acceptable. With conventional techniques, such as dot-gain control, achieved through cutback curves, several issues prevent an "exact" color match. First, the pigments and colorants used in proofing systems are different from the actual printing inks. Second, overprinting of multiple inks or colorant layers, creates a different reaction on the proof than the printed package. Finally, the substrate of the printed piece can be of a significantly different material and color from the proof. The use of CIELab color management techniques can overcome these issues. It will enable better matches to be made because the colors are matched by measuring them in the same manner as the human eye perceives them. While CIELab methods can be used with any proofing system, they are particularly suited for use with digital systems.

TYPES OF PROOFS

There are different types of proofs to satisfy different needs. The types fall into three categories: concept proof, color target proof and contract proof. These types of proofs have been formally defined in the second edition of FIRST and are summarized below and in *Table 13*.

Concept Proof

This proof is used to show the graphic layout of the product, including the type and sell copy. Images and bar codes can be represented by FPOs.

Concept proofs are used to communicate design concepts and layout to others. Color may be used, but it is not necessary to show colors that will accurately match to the final printed job. Low-cost color copies, laser proofs, ink jets and small dye sublimation proofs are common examples.

Color Target Proof

This proof has not necessarily been matched to the particular printing process, nor the particular press. The color target proof does, however, represent the customer's desire or expectation for color. The "proof" may be a previous job printed on an unspecified press and even a different printing method. It may be the final version of a concept proof, output on a low-end proofing device. It may be a proof from a high-end proofing device, optimized for another print-

PROOFING OPTIONS

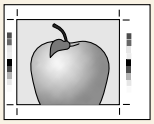
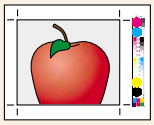
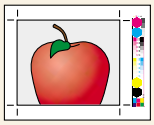
			COLOR ACCURACY	PRICE	PAPER TYPE	RESOLUTION
	**BLACK-AND-WHITE LASER PROOF** PostScript laser printouts should provide the same results as an imagesetter output, but at a lower resolution. Printing colors as grays or printing separations can show color breaks for color jobs.	**WHAT TO CHECK FOR:** All elements as expected from imagesetter output: • copy correct • fonts correct • all elements present • trim and registration marks present	✓	$		✓
	**HIGH-END DIGITAL PROOFS** Made directly from an electronic file, these composite CMYK color proofs meet industry color standards for prepress proofing systems, but cannot proof actual film.	**WHAT TO CHECK FOR:** Color images correct • image colors correct • copy correct • fonts correct • all elements present • trim and registration marks present	✓	$$	✓	✓
	**DESKTOP DIGITAL PROOFS** Made directly from an electronic file, proofs generated from desktop digital printers usually use ink-jet or thermal-wax technology to give all the information available in black-and-white PostScript output, plus an approximation of the specified colors. When used with color management systems, they may provide a fairly close match to press color, but differences in the dyes and pigments and in the the PostScript interpreters, can cause differences between the proof and the film output.	**WHAT TO CHECK FOR:** File preparation correct • color breaks correct • copy correct • fonts correct • all elements present • trim and registration marks present	✓	$		✓

Table 13. *Adapted from Agfa Educational Publications 1999.*

LEGEND

COLOR ACCURACY

- ✓ **Excellent**
- ✓ **Good**
- ✓ **Fair**

COST

- $ **Inexpensive**
- $$ **Moderate**
- $$$ **Expensive**

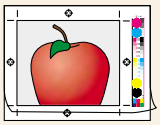
ing process, like offset. In these cases, the color in the proof may, or may not, be achievable on press.

Contract Proof

The most critical proof is called a contract proof. This proof is output in accordance to FIRST specifications using a press profile. It does not have to be a dot-for-dot reproduction, but it must be an overall visual simulation of the expected print results. A contract proof is produced at the end of the prepress process and is what the customer signs off on. It has all high-resolution images in place and should accurately predict what the final printed piece will look like. Remember, some spot colors, varnishes and metallic inks can not be represented by color proofs. Within the FIRST specification, further technical distinctions are made between different types of contract proofs. These distinctions address how the contract proof is made, but do not change the basic definition of what a contract proof is. The three types of contract proofs

PROOFING OPTIONS

COLOR ACCURACY
PRICE
PAPER TYPE
RESOLUTION



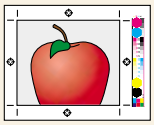
OVERLAY PROOFS

Proofs are made up of layers of acetate attached in register to a backing substrate. Each piece of film carries the image from one piece of separated film. Distortion caused by loose registration and by refraction through the proofing film makes color inaccurate. Can show color breaks.

WHAT TO CHECK FOR:

Separations correct:
- color breaks correct
- all elements present
- traps and overprints correct

$$



LAMINATE PROOFS

Also called single-sheet proofs or composite proofs, these are created by exposing the film separations for a job in contact with C, M, Y and K proofing film and laminating the resulting color sheets onto a single sheet of substrate.

WHAT TO CHECK FOR:

Color images correct:
- color match correct
- color balance correct
- registration correct
- no moiré problem
- traps and overprints correct

$$

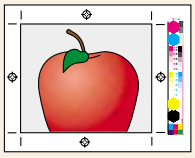
BLUELINE PROOFS

Blueline proofs are made by exposing final fim to a thin-gauge, light-sensitive paper. Bluelines show only a single-color image, but a second color can be shown by varying the exposure time for the second-color film.

WHAT TO CHECK FOR:

Film correctly assembled:
- color breaks correct (2- and 3-color)
- all elements present
- imposition correct

$$$



PRESS PROOFS

As the name implies, press proofs are run on a printing press, using the same inks and substrate that will be used in the final print job.

WHAT TO CHECK FOR:

All elements correct:
- copy correct
- fonts correct
- all elements present
- trim and registration marks present

$$$

Table 13. *Adapted from Agfa Educational Publications 1999.*

LEGEND
SUBSTRATE
- Custom
- Diverse

RESOLUTION
- Low 300 dpi to 600 dpi
- Medium 600 dpi to 1200 dpi
- High based on halftone

defined are: contract analog proof, contract digital proof and profiled contract proof.

Contract Analog Proof. This proof is made by using an analog proofing system. Exposing and processing the proof, as per the manufacturer's recommendations for that analog proofing system, is profiled according to FIRST specifications. The color match, whether using dot-gain compensation or ICC profiles, is to target values for the particular flexo process, but not to the specific press.

Contract Digital Proof. This proof is made by using a digital proofing system. Exposing and processing, as per the manufacturer's recommendations for that digital proofing system, is profiled according to FIRST specifications. The color match, whether using dot-gain compensation or ICC profiles, is to target values for the particular flexo process, but not to the particular press.

Profiled Contract Proof. This proof is profiled on a specific date, using a specific color management system, to match a particular press. Ideally, the press should be running in accor-

dance to FIRST specifications. This type of proof represents a final tweak or correction to the contract digital proof because it is press specific. This type of proof could be done using an analog proofing system but, in most cases, a digital proofing system is used.

PROOFING SYSTEMS

To produce a proof, whether a concept or a contract proof, different proofing systems are available. They fall into three categories: analog, press and digital. Proofing systems that make contract proofs must meet two broad requirements: repeatability and quality. Repeatability means that the proofing system must produce the exact same proof with each print – proof after proof, day after day, month after month. This applies particularly to the color output of the proof. Given consistent color output, there is potential for a color matching system to match the proofer characteristics to a printing press. If color output varies randomly, no color-matching system can match the proof to the press.

Analog Proofs

Analog proofs, the dominant format, can be either:

- "overlay" proofs, such as Color Keys or Cromacheck;
- "laminate" proofs, which include Cromalin, Matchprint and Fuji Color Art; or
- "single-color exposure" types, such as Dylux or Bromides.

All of the above proofs are made from actual film negatives (or positives) through some type of exposing, registration and/or lamination process. Another type of analog proof is often made when the plates are mounted on the plate cylinder. These proofs are discussed in the mounting and proofing section and are part of the production process after prepress.

Overlay Proofs. This process involves using the film and exposing a photosensitive material, which will hold the cyan, magenta, yellow or black colorant. These colorants are then processed to remove the noncolored areas and overlayed on top of each other. These proofs are accurate for content, trapping and to check the integrity of the film. They are not accurate for color approval and they are relatively inexpensive.

Laminate Proofs. This process involves taking the film and exposing a photosensitive material, which creates a carrier or "latent image" to which a liquid ink or toner powder can adhere. This system allows toners to be mixed, thus producing a proof showing spot colors. The color image created can then be laminated to some type of substrate. Some systems allow freedom of choice for substrates, others require that specific ones be used. Traditionally, these proofs are extremely accurate for color, trapping and verifying the integrity of the negatives involved. The systems are not very expensive, as the hardware is often "given away" in exchange for a guaranteed purchase of consumables, such as toners, inks, colorant sheets or substrates.

Single-Color Exposure Proofs. These proofs are also made by exposing a photosensitive sheet. However, these proofs can produce only a single color. Dyluxes are bluish, hence the term "blueline", while bromides are black and white. Exposure of a Dylux produces an image immediately, while bromides must be processed to reveal its latent image.

Press Proofs

Press proofs are made on an actual printing press from the final plate-ready films. These proofs provide almost an exact duplication of the actual production run. They are, however, the most expensive proof to make because they require a great deal of time and materials, including photopolymer plates and press time.

Digital Proofs

There are different types of digital proofing devices available to serve various needs. The key feature of all of them is that the proof is produced directly from an electronic file, without the use of film. This feature makes digital proofing devices less expensive to use than their analog counterparts and is a strong driving force in the adoption of digital proofing. There are basically five print-engine technologies used for digital color output:

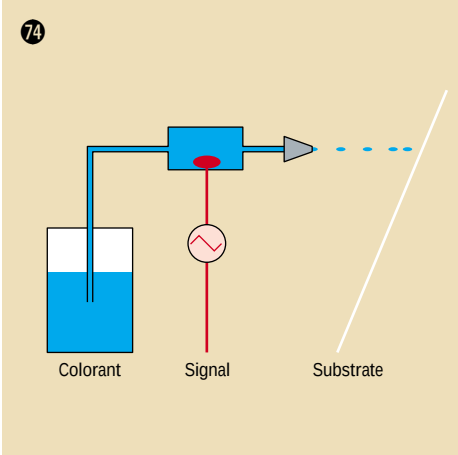
- drop-on-demand ink jet;
- electrophotography;
- wax transfer;
- dye sublimation (heat); and
- continuous ink jet.

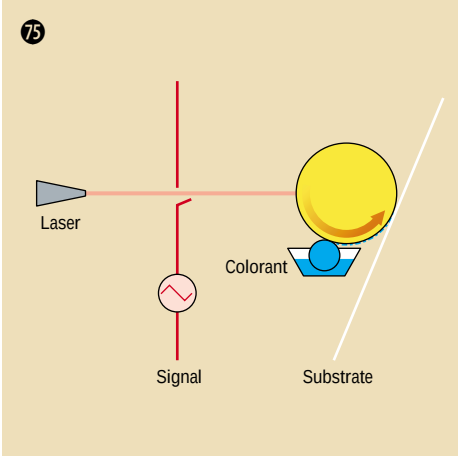
Print-engine technologies can be categorized according to the colorant (the equivalent of the ink in printing), the signal, and how the colorant is applied to the substrate.

Drop-on-Demand Ink Jet. Ink jet is a process where ink is sprayed onto the substrate (*Figure* ❼❹). The colorant is a water-based ink and the substrate is theoretically anything which is water receptive. With drop-on-demand ink jet, the image signal tells the drop when to spray. To accomplish this, the signal in some way causes a change in pressure. When the pressure hits a certain point, a drop flies out of the ink-jet nozzle and onto the substrate. One way to create the pressure change is for the signal to create a bubble in an ink chamber. Blowing up the bubble forces ink to fly from the nozzle.

The advantage of drop-on-demand ink jet is its low cost. Relatively inexpensive print engines can be assembled, making the price suitable for the desktop office market. The relatively low-cost color ink-jet printers, which are so ubiquitous in the office and home, are of this type, as are the wide-format poster printers. The disadvantage is quality and consistency. By nature, this start/stop approach produces fairly large drops of ink, limiting effective resolution. Also, color consistency and repeatability are not suitable for color proofing – tint values will be different in areas of large ink coverage compared to areas of little ink coverage.

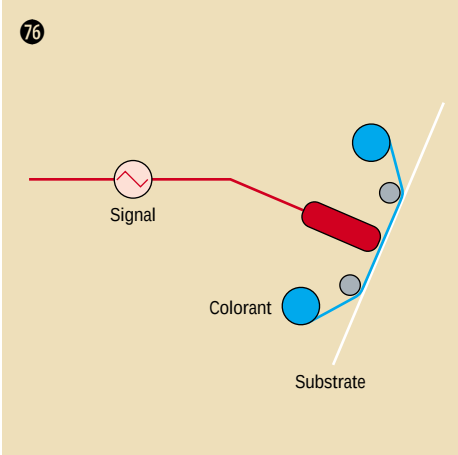
Electrophotography. Electrophotography is more commonly known as xerography (*Figure* ❼❺), which in its conventional form, involves a metal, selenium drum being given an electric charge. Light reflecting from an original through a lens, discharges the drum in non-image areas. The colorant is given the opposite charge to the drum, and when applied, sticks to the drum in image areas. The colorant from the drum is transferred to the substrate, where it is heated to fuse into the paper.



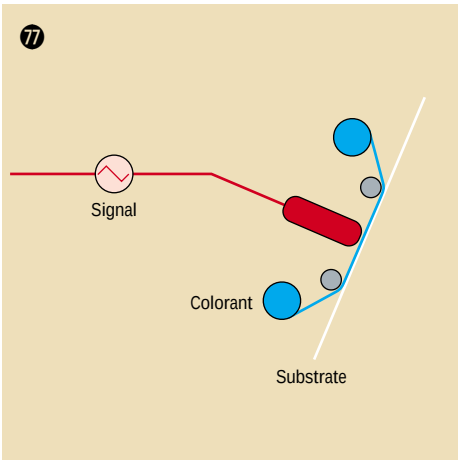


❼❹ In a drop-on-demand ink jet proofing system, ink drops are metered only as needed for the image area.

❼❺ Electrophotography, commonly called xerography, uses a laser to write the image information onto the drum. The drum picks up the powdered toner of the image areas and deposits it onto the substrate. The toner is fused to the substrate by heat.



76 A wax transfer proofing system uses heated elements to melt the wax containing the colorant onto the substrate in the image area.



77 Dye sublimation works by evaporation (sublimation) of the colorant onto the substrate. These proofs are capable of producing higher resolutions than the wax-transfer method.

As a digital printing application, xerography works much the same way. The difference is that a laser is used to write onto the selenium drum, instead of light reflected through a lens. An office laser writer is an example of digital xerography.

Numerous attempts have been made to use xerography for color proofing. To date, success has been limited. Xerography is available in a wide range of price and quality levels. Low-cost technologies work well in black and white and quick color applications, such as color laser copiers, but are not suitable for digital color proofing applications where color judgments are made from the reproduction. Higher-end applications have been demonstrated, but none have taken to market – presumably because of the cost to bring the technologies into final product form.

Xerography also suffers from that "it just doesn't look right" issue. This may be because of the powdered toners and the fusing process used to adhere the toner to the paper. For whatever reason, many viewers aren't satisfied with the look of xerographic output compared to ink on paper. Emerging liquid toner technologies change this objection. Today, however, these technologies have not been refined and are far too expensive for digital proofing.

Wax Transfer. Wax transfer is a technology in which colorant is transferred from precoated wax ribbons onto a substrate through the use of heat (*Figure* 76). The print head consists of an array of tiny heat elements. The image signal is used to instruct the print head elements to heat. These elements melt the wax on the ribbon, which then transfers to the substrate. For process printing, four-colored ribbons are used: cyan, magenta, yellow and black (CMYK). Imaging is processed one color at a time.

Wax transfer is fairly economical for quick one-out color applications. Its low resolution and appearance make it unsuitable for color proofing applications where color judgment is required. Put simply, melted wax on a special substrate doesn't come close to simulating ink on press

Dye Sublimation. Dye sublimation is similar to wax transfer in concept (*Figure* 77). The difference is that the colorant is coated on the ribbon. A more expensive compound, which does not melt, is used. It sublimes (evaporates) into the substrate. This can be done at higher resolutions than wax, and more closely simulates ink on paper.

Dye sublimation has been used increasingly in graphics applications, particularly at design stage of the process. Its main advantage is fairly high quality at a reasonable price. An emerging workflow beginning to gain wide acceptance is to use dye sublimation up front for proofing design and

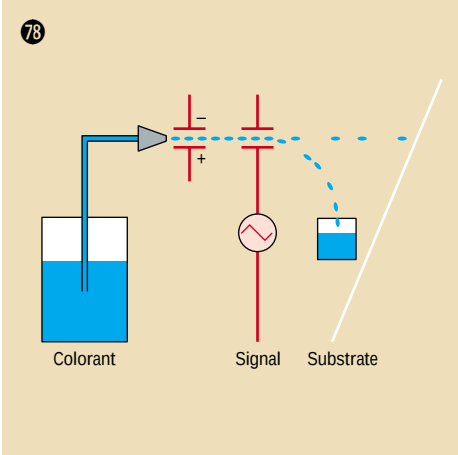
composition-related attributes, and to use continuous ink jet for proofing color-critical attributes.

The resolution available with dye sublimation can be increased by using a laser instead of a mechanically heated print head. Laser thermal dye-sublimation printers are the high-end of this category. They use lasers to burn dots onto a carrier sheet, which is covered by laser-sensitive color-donor material. The donor sheets are C, M, Y and K, and are burned individually and automatically registered. The registration of these devices is very precise.

Many recent advances in dye sublimation have made it a more attractive technology than it was in the past. One manufacturer has opened up its device to be driven by several different RIP manufacturers. With the systems currently on the market, it is now possible to get the same halftone-dot shape and screen angle that will appear on final plate or film. This means one can see moirés, rastering of logos, break-up or banding in blends, etc. At this time, the machines do not have the ability to produce custom colors, but that capability is coming in the future. They offer very high resolutions, up to 4,000 DPI and can produce proofs up to about 21" x 30". The cost of the consumables for these devices is about the same as conventional proofing material. The cost of the devices is in the hundreds of thousands of dollars.

Continuous Ink Jet. As with drop-on-demand ink jet, continuous ink jet is based on the principle of spraying ink through a nozzle onto a substrate (*Figure* 78). Hence, continuous ink jet produces actual ink on paper. To overcome the predictability and resolution limitations associated with the stop-and-start characteristic of drop-on-demand, an ink jet sprays a continuous ink stream onto the substrate. Great precision is taken in nozzle design and pump pressure to ensure that the finest and most uniform stream of drops are continuously sprayed through the nozzle. Each drop is given a charge upon exiting the nozzle. The image signal instructs which drops are to hit the paper by charging deflection plates through which the drops travel. Unwanted drops are deflected to a recycling or waste container. Continuous ink jet is the best print-engine technology for color proofing of color-critical applications. In comparison with drop-on-demand ink jet and other quick-color technologies, its disadvantage is price. However, in comparison to conventional proofing technologies, it is actually less expensive. Materials and labor costs for a continuous ink-jet proof are significantly less than those for a conventional proof. An additional advantage is the faster turnaround times associated with digital proofing.

As more and more of these devices are used, the technology will undoubtedly mature and become more reliable and trouble-free. Another disadvantage of the technology is that the final proof does not have the same halftone dots as an analog proof or the printed sheet. While the color can be very accurately matched using color management software, many people still object to the lack of the familiar dot structure in the proof.



78 A continuous ink-jet system utilizes a steady stream of charged ink drops that come in contact with the substrate in image areas. Unwanted dots of ink are diverted to the recycling or waste container.

Back-End Quality Control

The quality control check is traditionally where "the rubber meets the road." Digital technology, has made prepress more of a science and less of a craft. Almost every step of the process can be measured, recorded and repeated and verifying accuracy is as simple as utilizing a checklist showing all of the in- or out-of-tolerance specifications. The quality-control check should be done on all films, proofs or plates produced by the prepress facility.

Densitometers and spectrophotometers, are used to inspect proofs and printed sheets while a transmission densitometer is best suited to inspect film specifications. Additional tools for inspection may also include:

- machinist's hundred scale;
- metal t-square;
- metal triangle;
- 7-mil film-positive grid;
- 10x magnifying glass (loupe);
- transparent yellow overlay; and
- light table.

It is also essential to examine films and proofs, using both a magnifier and the naked eye. Color comparisons and evaluations should be done in the proper environment. It is highly recommended that color proofs be examined in a viewing booth equipped with a neutral gray surround – Munsell N8 or equivalent – and a standard 5,000° K light with a color rendering index (CRI) of 90 or higher.

CHECKING PROOFS

Once the proof is produced, the following should be checked:

- dot gain;
- solid-ink density;
- ink hue/spectral data; and
- substrate.

Dot Gain

Proofs should be proofed to manufacturer's requirements for dot gain. Most analog proofs are set up to reproduce a 50% dot as a 72% for a 22% gain. This is only to assure consistency of the proof. Matching a proof to a press by manipulating dot gain changes the size of the dot sent to the proofing engine. The inherent dot gain of the proofing system is not changed. The key to quality control is to assure a consistent proof.

Solid-ink Density

The solid-ink density of the contract proof should be the same as the density that will be reproduced on press. Proofs done at densities that are not achievable on press will result in a poor press match. Unfortunately, the printer is usually blamed for not matching the proof. In reality, the proofs should be made to match

SOLID-INK DENSITY

	C	M	Y	K
WIDE WEB				
Paper Products	1.25	1.25	1.0	1.5
Film Products	1.25	1.20	1.0	1.4
NARROW WEB				
Paper Products	1.35	1.25	1.0	1.5
Film Products	1.25	1.20	1.0	1.4

Table 14

the press. *Table 14* lists recommended solid-ink densities for process inks.

Ink Hue/Spectral Data

In addition to making the proof with the proper solid-ink density, it should also be made with colors that are as close as possible to those that are used on press. While a perfect match is not always possible, both separator and printer need to be aware of the discrepancies between the two. This will aim toward achieving a better match on press.

The colorants used by the off-press proof and the press can be measured for comparison using a spectrophotometer. Combined with color management software and other techniques, the hue difference between the press inks and proofing inks can be compensated for in the proof. Using only densitometric or dot-gain methods to achieve the match will have a larger affect on the hue difference.

Substrate

Proofing substrates should have the same "cast" as the actual printing substrate, especially when using colored substrates. Color management techniques can simulate the substrate, while densitometric or dot-gain methods cannot.

CHECKING FILMS

Films should be checked for the following attributes to be accurate:

- D-min/D-max;
- dot shape and accuracy;
- screen rulings and angles;
- trap;
- distortion;
- color breaks; and
- completed job.

Table 15 summarizes what to look for in film separations.

D-min/D-max

All plate-ready film comes with a manufacturer's specification for the minimum (D-min) and maximum density (D-max). D-min represents the value obtained when reading the clear area of the film with a transmission densitometer, specified as a maximum value, typically 0.04 density units. D-max is measured in the exposed or "black" areas of the film, specified at a minimum value, typically 4.00 density units.

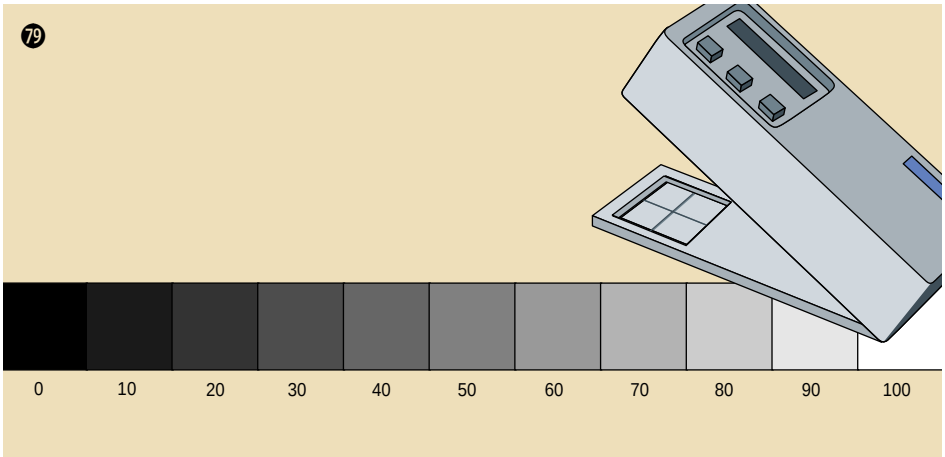
Dot Shape and Accuracy

Inspect the film's dot shape and accuracy to ensure it conforms to customer or printer specifications. Dot shape can be checked visually using a high-power magnification device. In flexo, the usual shape is a round dot. Dot accuracy is checked with a transmission densitometer. Dot values in the file should be checked to ensure there are no variations in the film output. It is good prac-

INSPECTION CHECKLIST FOR FILM SEPARATIONS

- **OVERALL QUALITY OF THE FILM SEPARATIONS,** look for streaking, scratches or other damage to the film, also make sure that areas that should be clear are not foggy.
- **MAXIMUM DENSITY,** the D-max of the black areas on the film are measured by a densitometer.
- **DOT VALUE** of the tints and halftones.
- **SCREEN ANGLE** and ruling for each separation.
- **TINTS AND HALFTONES** (including scanned images) look consistent and smooth.
- **DIMENSIONS** of the layout are correct.
- **OBJECTS** are printed on the correct separations.
- **FONTS** are printed correctly.
- **BLEED OBJECTS** extend beyond the crop marks.
- **TRAPS** are trapping
- **SEPARATIONS** are printed as specified and register marks align correctly.

Table 15



79 This typical step scale is used to check film from an imagesetter for stability; the illustration shows negative film output where a 0% dot is black and a 100% dot is clear film.

tice to daily output a step scale on the imagesetter and measure the values on a transmission densitometer. *Figure* 79 illustrates a step scale for negative film; clear is 100% dot, solid black is 0% dot. With a linear calibration on the imagesetter, the values should read the same as those in the digital file. Typically, the steps go from 0 to 100 in increments of 10. The scale can also be used to check the film's D-min and D-max.

Screen Rulings and Angles

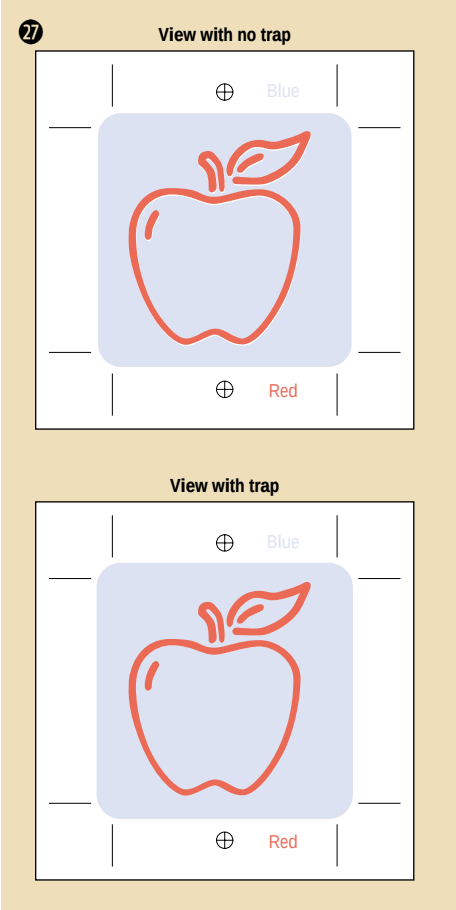
Check for line screen and screen angles to be consistent with the printer's specifications. A standard screen detector is a quick and easy way to verify correct screen ruling and angle. Screen rulings can also be directly measured with a high-power magnifier.

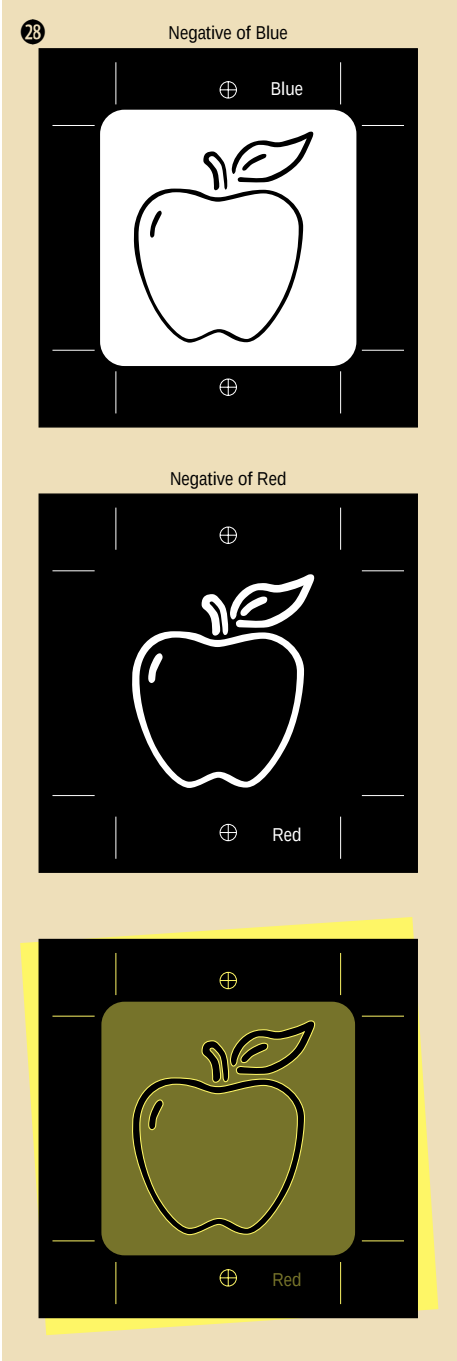
Trap

Check the film to make sure that all trapping is done correctly and sufficiently meets the printer's specifications. The best way to do this is to lay each film on top of the other and look for the "spillover" – the area where two colors meet. The technique is illustrated in *Figure* 80 and 81. *Figure* 80 shows an image with and without trap. The top image is trapped poorly, evident by the gap between the blue apple and red background. The bottom image is trapped properly. Viewing the negatives, one by one, is a difficult way to gauge trap. A simple, accurate method is by placing a piece of transparent, yellow overlay between the films (*Figure* 81).

Distortion and Compensation

Check the film to verify that the proper distortions and compensations have been applied. Distortions are checked easily with a machinist's hundred scale (ruler), a calculator and the job instructions. What is not so easy is knowing an object's dimension prior to distortion. Some prepress shops actually place a 0.5 point rule of a specific length on the job (outside the live area) and use that as a guide to check distortion. For example, suppose a 13" repeat job requires a 0.97 distortion factor. A 10" long, 0.5 point rule is placed. If the correct distortion is applied, this 10" rule should measure 9.70" on the films. Compensations are checked by measuring areas on the platemaking film and comparing them to precompensated film. In cases where the prepress shop works without compensating the film for dot gain on the back end and instead does all of the scanning and stripping with the compensations built in, then the film must be checked to ensure the minimum and maximum dot values are adhered to.





27 The printed image on top is trapped poorly, evident by the white line or gap between the blue gecko and the red background.

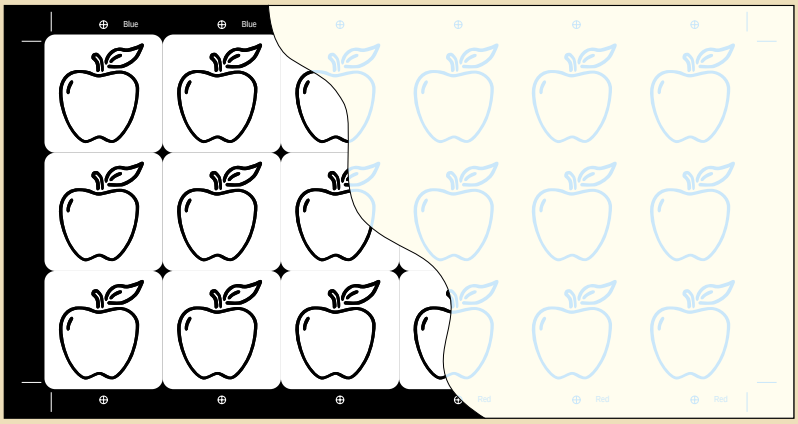
28 To check the trapping on the film negatives used to print the image of Figure 26, a transparent, yellow overlay is placed between the film to dramatically show the trap as the white outline around the gecko.

COLOR BREAKS

For analog proofs, nothing helps more than a Dylux of the plate negative and a laser proof of the original copy. A Dylux of each color will allow the inspector to see a positive image of what each negative will produce. If the Dylux is laid on top of a negative of another color, the relationship between the two colors can be easily checked for fit (negative-to-negative comparison is the most accurate way of doing this), relationship of register marks to each color and color break (*Figure* 81). This method is also used to verify the relationship of common negatives to each variable copy.

Table 16, on the following page, summarizes what one should look for in contract proof.

29 Color breaks are checked by overlaying a positive proof of the blue color onto the negative film of the red color.



CHECKING A CONTRACT PROOF

- **CHECK COLOR TINTS** to make sure they are accurate and do not look mottled.
- **CHECK COLORS** to make sure they are even and consistent throughout the proofs.
- **CHECK CUSTOM COLORS** selected from color-matching systems against printed swatches.
- **EXAMINE COLOR BARS** to determine if detail has been lost in the film because of overexposure.
- **CHECK TRIM MARKS** to make sure that bleeds and crossovers extend the required amount beyond the marks.
- **CHECK TYPE** to make sure it is not too weak or breaking up due to overexposure.

Table 16

THE LAST LOOK

Final inspection of the job requires a check for accuracy. This means making sure that all elements are present prior to the pressrun. Special care should be taken to check for missing marks such as "®", "TM"; incorrect UPC code, missing copy, kinks, scratches or other miscellaneous film defects. Even in this day of electronic step and repeat, it pays to check the film for squareness with a T-square and triangle. *Table 17* is a checklist of the review process for press proofs.

CHECKING A PRESS PROOF

- **IS THE TYPE SHARP?** Use a loupe to look for broken or double lines.
- **ARE THE DENSITIES CONSISTENT?** Check for consistency from one end of the sheet to the other.
- **IS THE COLOR CORRECT?** Compare the press sheet to the contract proof.
- **IS THE SUBSTRATE CORRECT?** Bring a sample to compare the printed substrate to the one specified.
- **ARE THE CROSSOVERS CORRECT?** Fold the press page and chek the alignment and color match.
- **ARE HALFTONE DOTS SHARP?** Use a loupe to make sure the details and highlights match the contract proof.
- **ARE SPOT COLORS CORRECT?**
- **ARE THERE BLEMISHES OR MOTTLING OF COLOR?** Check the entire sheet for spots caused by problems with the press.
- **ARE ALL GRAPHIC ELEMENTS PRESENT?** Compare the press sheet to the contract proof.
- **ARE SEPARATIONS IN REGISTER?** Check to make sure all separations align on the register marks. Under a loupe, four-color subjects using conventional screening should show a rosette pattern, with no more than a single line of dots of single color visible at the edge of the image

Table 17

Customer Service

The responsibilities of the customer service representative (CSR) vary from company to company. For our purposes here, we will discuss the abilities of the customer service representative who handles all facets of production prior to manufacturing. Even in a converting or in-house workflow, the same duties will apply.

JOB ENGINEERING/PREFLIGHT

A CSR with preflighting and some job engineering experience can be a valuable asset to the company and the end-use customer as well. When a CSR can detect possible print problems or out-of-specification elements minutes or hours after receipt of the order, it allows the customer to address those elements early in the process and make changes. These changes can generally be done without the customer incurring any additional cost.

ESTIMATING/QUOTING

The best CSR is able to estimate incoming work and also has a process in place to supply quotes to customers within a few hours after the job arrives at the plant in order to begin manufacturing.

A distinction must be made between "estimates" and "quotes". Estimates denote that the cost of the job is subject to change, even if the customer has not authorized any actual changes. Quotes, on the other hand, are firm commitments to manufacture the job at the stated price, regardless of any internal changes that occur on the job.

When a customer demands changes be made, the CSR should re-quote the job and submit a new quote. Initial and revised quotes should be faxed to and signed off by the customer prior to manufacturing.

It also is helpful to the customer if the CSR sends, as soon as possible, the final invoice of the job, while it is still fresh in his/her mind. An invoice received weeks after the project is completed may seem "too high" to the customer. Hhe/she may not remember authorizing a certain cost for retouching. If the signed-off quote arrives with the final invoice, in most cases, there is no need for the customer to review the invoice. If the quote and the invoice match, it will facilitate faster payment processing.

ORDER ENTRY

This involves entering job production information. This information, when presented in a clear, concise and easy-to-understand format, is a great benefit to the manufacturing process as a whole.

The CSR must be familiar with relevant manufacturing terminology and be detail oriented. The CSR should, whenever possible, spell out all relevant instructions and never assume that an operator knows what is intended. A CSR has to prepare the instructions as though the operator has never worked on that particular job before. The more questions that can be answered in the job instructions, before the operator has them, the better.

LIAISON BETWEEN CUSTOMER AND PLANT

CSRs act as the "face" or "voice" of the plant. While a customer knows that there are many people actually producing the work, the CSR is usually the recipient of the praise as well as the blame. Customers expect the CSR to look out for their projects and to be in their corner. A good CSR does this and balances it with the requirements of the company at the same time. It is important that a CSR's motto be: "Never let 'em see you sweat." A customer has to have confidence in the person handling his/her project and no matter what happens, that person will be there for him/her.

"LAST LINE OF DEFENSE"

The CSR is usually the last person in a shop to be able to review the materials before they ship out of the plant. It is OK to make a mistake, internally, but it's not OK to let the customer see it. The CSR must be focused on every element of the job to make sure that the materials going out to the customers or printers are right and exact.

Appendix A

FIRST SPECIFICATIONS IN PREFLIGHT

1. LASER SUPPLIED AT CORRECT SIZE: ☐ YES ☐ NO

Comments

2. TRANSPARENCIES COLOR:

Colors Required

Colors Available

3. SOFTWARE USED (CHECK ALL THAT APPLY):

☐ ADOBE PAGEMAKER	VERSION
☐ ADOBE ILLUSTRATOR	VERSION
☐ ADOBE PHOTOSHOP	VERSION
☐ MACROMEDIA FREEHAND	VERSION
☐ QUARK XPRESS	VERSION

4. INKS (COLORS REQUESTED):

5. PMS COLORS:

☐ SPOT ☐ SCREEN MIX ☐ MATCH ON 4/C PROCESS ☐ USE EXISTING SCREEN MIX

6. INK ROTATION: ☐ YES ☐ NO

7. RESIZED LOGOS: ☐ YES ☐ NO

8. TINT BUILDS: ☐ YES ☐ NO COLOR TYPE: ☐ 3/C ☐ 4/C

9. SCREENS:

ON LINE DECK ☐ YES ☐ NO LINE SCREEN FILM VALUE %

10. UPC WEB DIRECTION: ☐ YES ☐ NO LIST SIZE: ☐ BWA ☐ MAG

11. VIGNETTES: ☐ YES ☐ NO ☐ USE EXISTING ☐ RECREATE

12. TRAPPING: ☐ YES ☐ NO

Appendix B

PREFLIGHT CHECKLIST

1. CHECK FPOs

2. LIVE IMAGES PLACED ☐ YES ☐ NO

Comments

3. FONTS SUPPLIED ☐ YES ☐ NO

Comments

4. IMPORTED EPS SUPPLIED ☐ YES ☐ NO

Comments

5. IMAGES IF SUPPLIED ☐ HI RES DPI _____ ☐ RGB ☐ CMYK

Comments

6. RULES (SMALLEST ALLOWED) IN SPEC

0.007 POSITIVE	☐ YES	☐ NO
0.005 REVERSE	☐ YES	☐ NO

Comments

7. TEXT (SMALLEST ALLOWED) IN SPEC

POSITIVE	☐ SERIF	☐ SANS SERIF	6 PT	☐ YES	☐ NO
REVERSE	☐ SERIF	☐ SANS SERIF	6 PT	☐ YES	☐ NO

8. FONTS – MISSING

Screen	Printer

CHAPTER 3

Process Color

ACKNOWLEDGEMENTS

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Introduction

In the past, flexography was seen as a low-cost and low-quality printing process. That image has changed with advances in materials, equipment and techniques. The simplicity, efficiency and consistency of flexography's ink-metering system continues to improve. Printing plates continue to see new advancements, including digital output directly to plates. Anilox rolls are available in higher rulings and take advantage of high-strength inks. Presses have better control as well as on-line inspection and feedback systems. The entire production process, from design to press, is being specified by FIRST.

These are a few of the trends which enable flexo to achieve consistently high-quality results. The ultimate test of a major printing process is its ability to print consistent, high quality process color. That it can be done is demonstrated daily on the shelves of stores and by the ever increasing quality of entries in flexo printing competitions worldwide. Still, process-color printing with flexography remains a challenge for many printers. This section is intended to present material that is designed to facilitate better control of the process.

"Process printing", or "process-color printing", refers to the full-color reproduction of a subject by recreating the original's full, continuous-tone color. Subjects can range from paintings or color transparencies to full-color photographic prints. In today's environment, the subject can also be the image captured electronically by a digital camera.

Process printing is achieved by first converting the continuous-tone copy to halftones, separating the color into yellow, magenta and cyan process colors and printing these colors sequentially in register with each other. This "three-color process" is frequently converted to a "four-color process" by using black to improve the contrast and/or tone balance of the reproduction. It is essentially the same for all printing methods—flexography, offset lithography, or gravure—but corrections are made for the different mechanics of a given method.

Obviously, printing four colors in register is more difficult than printing only one color and should be attempted only when the printer has the equipment, materials and skills to achieve good-quality, single-color flexo printing.

To print process color successfully with flexography, it is important to understand each step in the process and how to perform it. This includes a basic understanding of color theory; what it is and how it is measured and controlled. The control of color applies to the entire process, from the original color object, to it's conversion to process colors, to the final printing on the press. The press itself needs to be optimized, characterized and controlled, in order to achieve consistent, quality process color.

More than anything else, successful process-color printing demands a dedicated team effort between the color separator, ink maker, platemaker, printer and print buyer. Clear communication among team members is essential.

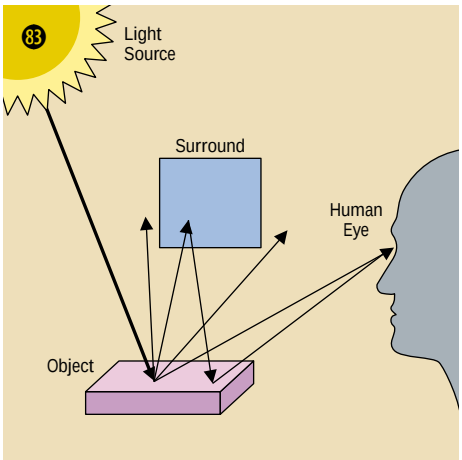
Color Theory

Color has been defined as "the perception of light that has been modified by an object." This definition actually refers to more than color. It alludes to what determines color; a light source, an object and observer. These elements are illustrated in *Figure* 83.

Note: *Light comes from a source and is modified not only by the object being observed, but also by the surroundings.*

The first element to examine is light itself. The light we see is part of a natural phenomenon that includes x-rays, ultraviolet radiation, visible light, infrared radiation, television and radio waves. The key word is waves. All are a class of what is called electromagnetic radiation and the key difference is in the wavelength. X-rays have the shortest wavelength and radio the longest.

Visible light ranges in wavelength from approximately 400 to 700 nanometers (nm). White light contains an equal amount of all of these wavelengths. It can be broken out or dispersed, such as with a glass prism, into light of the separate wavelengths that make up the "colors of the rainbow" (*Figure* 84). All visible light is a combination of these wavelengths.



83 Elements that determine color: light source, object and human observer. All are influenced by the surroundings.

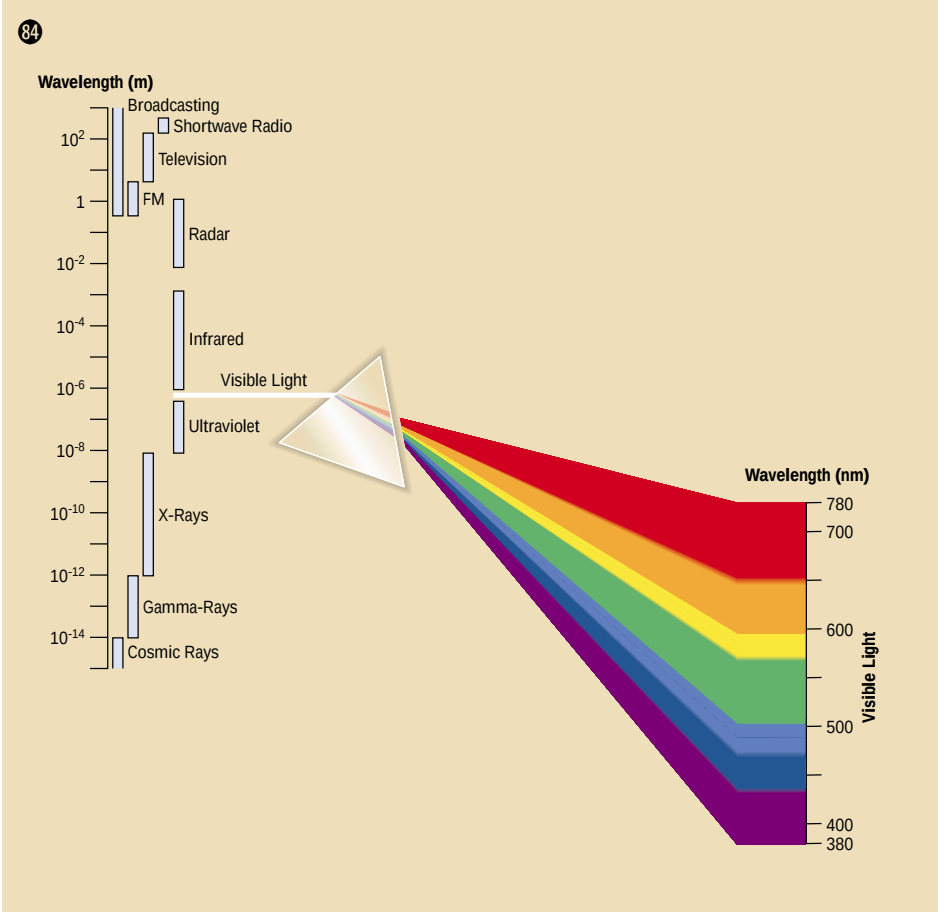
PERFECT SPECTRA

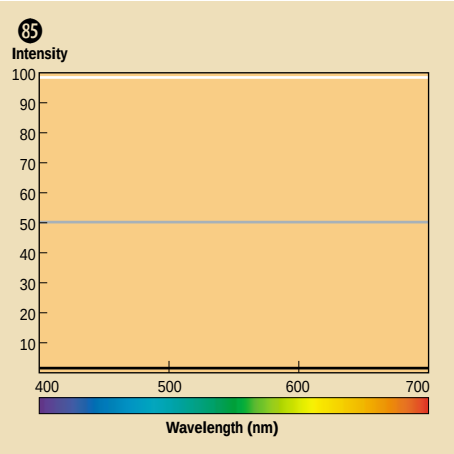
Beside the wavelength of the light, intensity is a key attribute. Light is composed of a combination of intensities of the visible wavelengths. A graph of this distribution is called the spectrum of the light. White light is composed of equal intensities of all wavelengths, shown in *Figure* 85. The vertical axis is the intensity of the light and the horizontal axis is the wavelength. The intensity scale goes from 0 to 100 and light that contains a uniform intensity of 100 at all wavelengths is white light. At a lower intensity, but still equally distributed, the light is gray, and then at a zero intensity, black or no light. *Figure* 85 shows the spectra of "perfect" neutrals.

Spectra are extremely useful when talking about color. The visible spectrum can be divided roughly into thirds, with each third representing one of the colors: red, green or blue. *Figure* 86 shows a "perfect" red. It would have no intensity for the first two thirds of the visible spectrum and then full intensity from about 600 to 700 nm. Similarly, *Figure* 87 shows a "perfect" green, which has intensity in the middle of the spectrum from about 500 to 600 nm and zero everywhere else. Finally, *Figure* 88 shows a "perfect" blue, which has intensity in the first third of the spectrum up to about 500 nm.

84 Dispersion of white light into the constituent wavelengths

85 Spectrum of three perfect neutrals: white, gray and black.



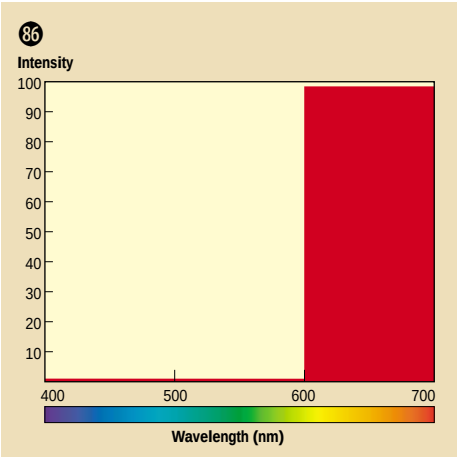


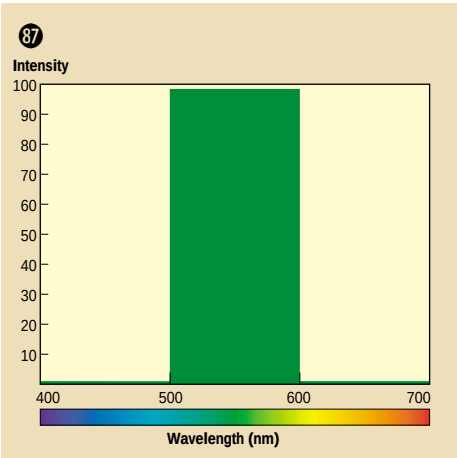
Additive Color

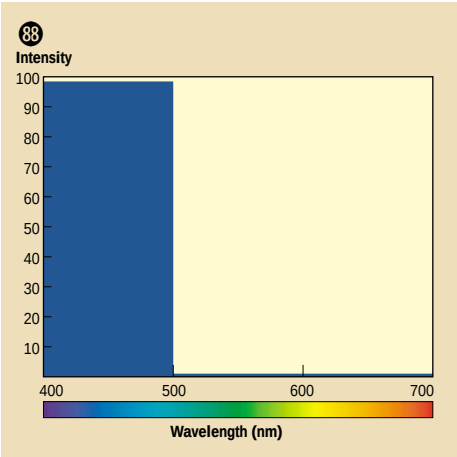
The three spectra in *Figures* 86, 87 and 88 are for the three additive primaries of red, green and blue. If we were to take all three spectra and add them together, the result would be the spectrum of *Figure* 85, that is white. Of course adding together the spectra is nothing more than combining or adding the light itself. It is the same as shining three beams of different colored light onto one area. The primary colors of red, green and blue combine as shown in *Figure* 89.

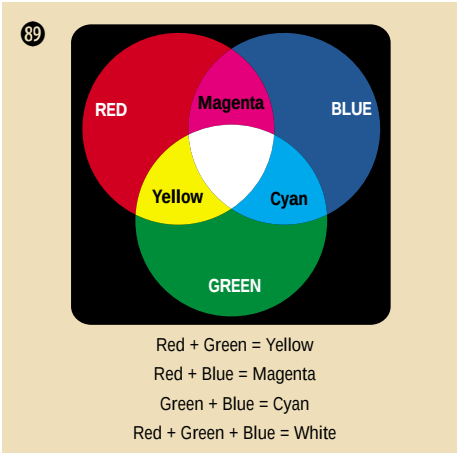
Subtractive Color

The spectrum for the addition of red and green light, which produces yellow, is shown in *Figure* 90. This spectrum can be thought of in two ways. One is as was just described. It is the addition of red and green light. Another way of describing the exact same spectrum is to say it is the subtraction of blue light. That is, instead of starting with no









86 Spectrum of perfect red showing light intensity in upper third of spectrum.

87 Spectrum of perfect green showing light intensity in middle third of spectrum

88 Spectrum of perfect blue showing light intensity in lower third of spectrum

89 The combination of the additive primaries, red, green and blue.

light and adding red and green, we start with white light and take away blue. Similarly, *Figure* 91 shows red and blue light combining to give magenta. This can be alternatively thought of as starting with white light and subtracting green. Finally, *Figure* 92 shows the case of blue and green combining to produce cyan. This can be thought of as starting with white light and subtracting red.

Starting with white and taking away one third of the light at a time is utilizing the subtractive primaries of yellow, magenta and cyan. This is what happens in printing. We start with a white (or at least highly reflective) substrate and the inks we use (cyan, magenta, yellow) each take away roughly one third of the visible spectrum. They, combine as shown in *Figure* 93.

Note: *The (+) symbols in Figure* 93 *mean combine, and connote adding or increasing something. "Adding" subtractive primaries means taking away light. All printing is a subtractive process* (*Figure* 94).

Using this concept of taking away, gives the same result as shown in *Figure* 93. Combining magenta and yellow inks takes away green and blue light, leaving red. Combining magenta and cyan inks, takes away green and red light, leaving blue. Combining yellow and cyan inks, takes away blue and red light, leaving green.

REAL-WORLD SPECTRA

Figure 95 shows three examples of real world cyan: a flexo cyan ink, an offset cyan

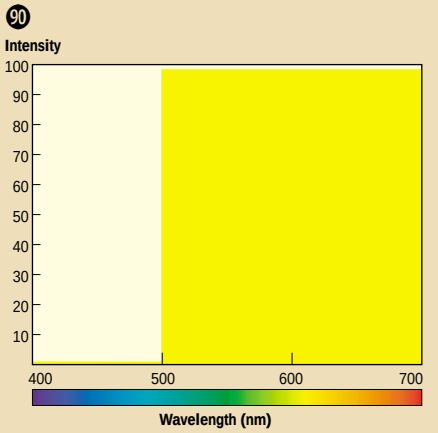
⑨⓪ Spectrum of perfect yellow showing NO light intensity in lower third of spectrum.

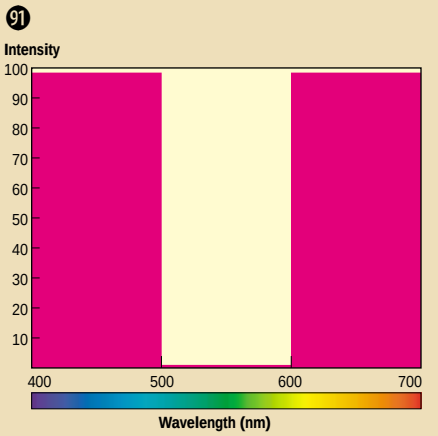
⑨① Spectrum of perfect magenta showing NO light intensity in middle third of spectrum.

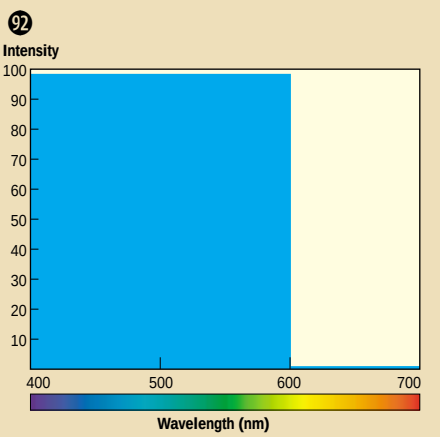
⑨② Spectrum of perfect cyan showing no light intensity in upper third of spectrum.

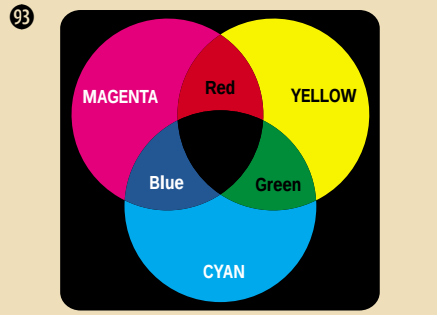
⑨③ The combination of the subtractive primaries, yellow, magenta, cyan.

⑨④ Printing is a subtractive process where the inks take away light.







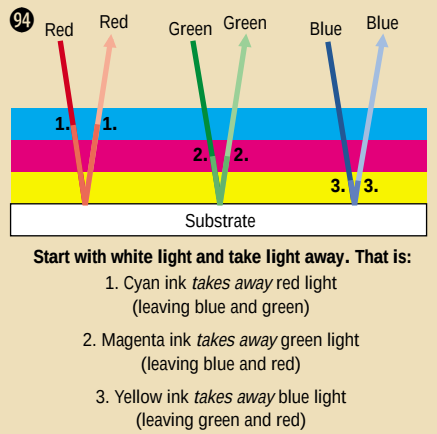


Magenta + Yellow = Red

Magenta + Cyan = Blue

Yellow + Cyan = Green

Magenta + Yellow + Cyan = Black

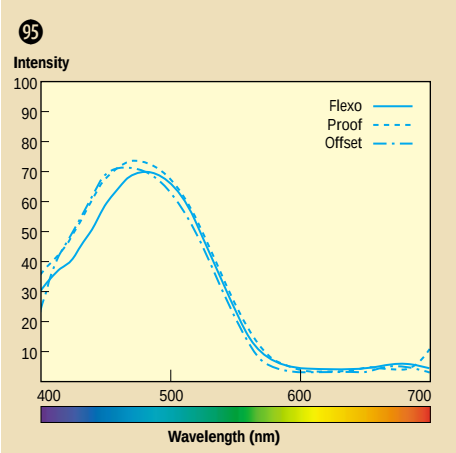


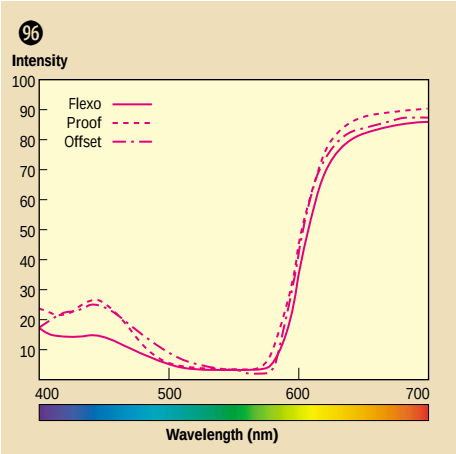
Start with white light and take light away. That is:

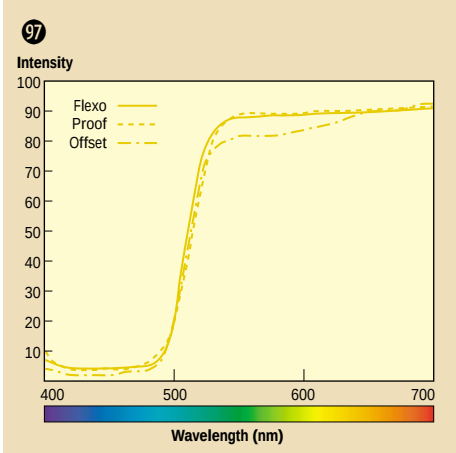
1. Cyan ink *takes away* red light (leaving blue and green)
2. Magenta ink *takes away* green light (leaving blue and red)
3. Yellow ink *takes away* blue light (leaving green and red)

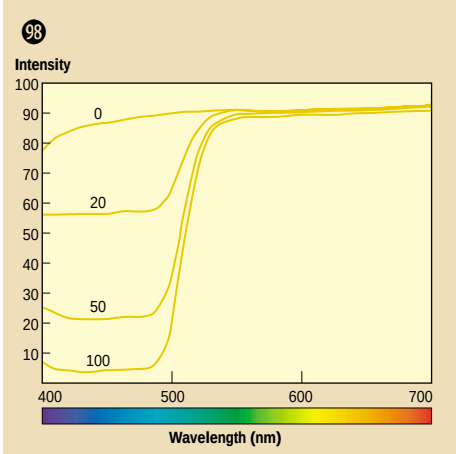
ink and a cyan from a digital proofing system. Regarding these spectra:

1. The perfect cyan of *Figure* ⑨②, compared to the real cyan has some light in the red portion of the spectrum. This means the cyan is not as pure a color as the perfect cyan. It is contaminated with some red.
2. The curves are different, as might be expected for three different types of cyan. The bigger the difference in spectra, the bigger the difference in the appearance or color of the ink. The offset and proof curves are closer together than the flexo curve. This is evidence of the fact that proofing systems have been optimized for offset printing, not for flexo. The proofing cyan is closer to the press cyan for offset than for flexo.
3. The peak in the blue and green portion of the spectrum is not as high as in the perfect cyan. This means the color is less saturated.









95 Spectrum of real cyan showing the curves for flexo, a digital proof and offset.

96 Spectrum of real magenta showing the curves for flexo, a digital proof and offset.

97 Spectrum of real yellow showing the curves for flexo, a digital proof and offset.

98 Spectra of real yellow showing the curves for different dot percentages.

Figure 96 shows the same three cases for magenta. Notice how much lower the peak is in the blue part of the spectrum for all three cases. The magenta ink takes away a lot of the blue light. Remember, magenta is supposed to take away only green. This dramatically demonstrates some of the limitations of the printing process. It leads to gamut compression, which will be covered in detail later. Again, the proof matches the offset curve much better than the flexo.

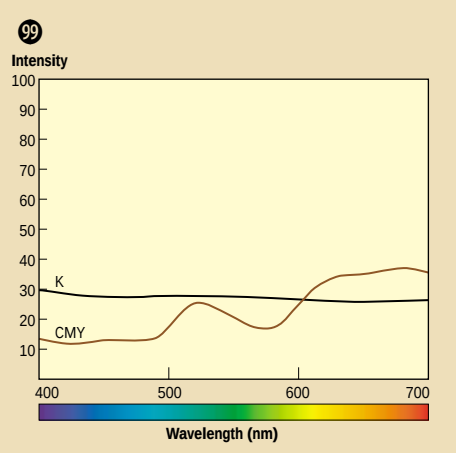
Figure 97 shows the case for yellow. In this case, the match of the proof is better to the flexo ink. Unfortunately, yellow is the least visible and the mismatch in the cyan and magenta means that for matching process colors, the proof is a better match for offset printing.

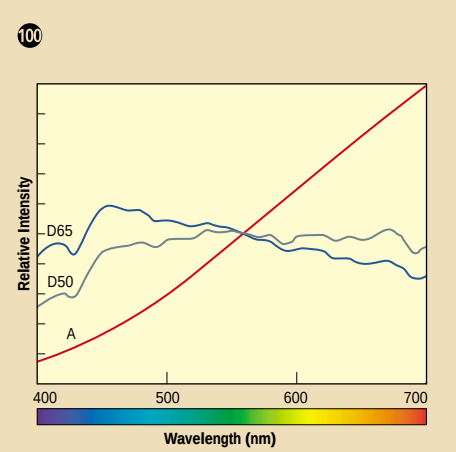
Figure 97 shows the spectra for the most saturated yellow possible, that is a solid yellow patch. What happens when a yellow dot is printed? Very simply, less yellow and more white light, resulting in the spectra shown in *Figure* 98. The numbers above the curves represent the dot percentages printed. The zero-dot percentage, which is nothing more than the substrate, indicates that the substrate itself is not a perfect white as was shown in *Figure* 85.

Finally, *Figure* 99 depicts the spectra of a black and an overprint of an equal combination of cyan, magenta and yellow. In the figure, the black line is the spectrum for the black ink and the brown line is the spectrum for the three-color overprint. As was the case for the perfect neutral of *Figure* 85, the

99 Spectra of real black (shown in black) and an overprint of cyan, magenta, yellow (shown in brown).

100 Spectra of CIE standard illuminants A, D50, D65. D50 is the graphic arts standard for making color evaluations.





black is nearly a horizontal line. It has equal intensity at all wavelengths, which gives a neutral gray or black. For the three-color overprint, there is more light intensity in the red end of the spectrum. If a more neutral black is desired, more red light needs to be taken away. What takes away red? Cyan. This is the reason why the cyan dot needs to be larger than the magenta and yellow to print a neutral using cyan, magenta and yellow.

QUANTITATIVE COLOR – CIELAB COLOR SPACE

In the last section, spectra were presented without taking into account the other two elements of what determines color: the light source and the human eye. They too can be described in terms of spectra.

CIE STANDARD ILLUMINANTS

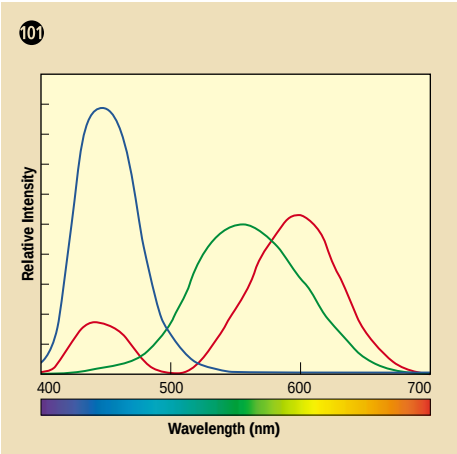
ILLUMINANT	
A	Incandescent lighting at a color temperature of about 2,850° K
B	Direct sunlight at about 4,874° K
C	Tungsten illumination simulating daylight at about 6,744° K
D50	Graphic arts standard viewing conditions at about 5,000° K
D65	Used by textile, paint and ink industries, about 6,500° K
F2	Cool-white fluorescent lamp at about 4,200° K
F7	Broad-band daylight fluorescent lamp at about 6,500° K
F11	Narrow-band white fluorescent lamp at about 4,000° K

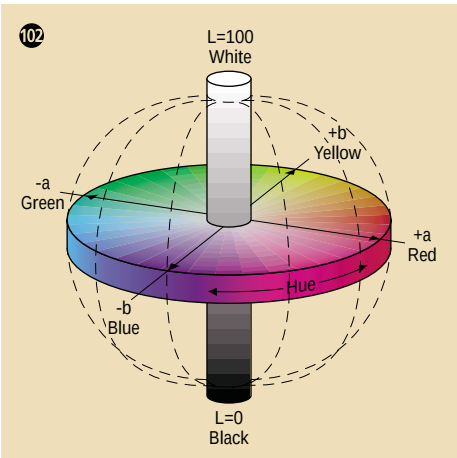
Table 18

Light Sources

Different light sources emit light which have different spectra. *Table 18* lists CIE standard light sources or illuminants, while *Figure* 100 shows the spectra of "A", D50 and D65. "A" is for a tungsten filament bulb (i.e., an ordinary light bulb) at a color temperature of 2,850° K. D50 and D65 represent light at color temperatures of 5,000° K and 6,500° K respectively. Degrees Kelvin is a temperature scale much like degrees Fahrenheit (° F) and degrees Celsius (° C). The different temperatures mean that a well-defined material heated to that temperature will emit light of a given spectral composition. This is called black body radiation. In the graphic arts, D50 or 5,000° K light is standard for making color evaluations. The light sources themselves are special types of fluorescent light bulbs.

Note: *As with any specification, nothing is ever exact, there is always a tolerance. For a D50 source, one measure of this tolerance is called the color rendering index (CRI). The higher this number, the more*





101 Spectral-response functions of the CIE standard observer.

102 CIELab perceptual color space model. Hues can be arranged in a "color circle". This "map" or color space provides the ability to specify colors in numerical terms (L, C, h), which can be accurately measured using a spectrophotometer.

closely the source matches D50, with 100 being a perfect match. For color evaluation in a light booth, a rendering index higher than 90 should be used. Not all D50 light tubes are created equal.

Eye Response

The spectrum is divided into the red, green and blue regions because this matches the way the human eye sees color. The eye has three sensors or receptors that detect the three primary colors. All colors perceived are a mixture of these primary colors. The spectral-response functions of the eye are shown in *Figure* 101. They are based on experiments conducted by the CIE and represent the standard observer. Because each person's eyes are not the same, each person will see color differently. This component of color represents an uncontrollable variable.

CIE Color Space

Each of the three components of color (source, object, observer) has a specific spectral response curve. These combine to give the final response curve. Rather than specifying color in terms of this final spectral curve, it is more useful to combine them mathematically and create a three-dimensional color space called the CIE perceptual color space (*Figure* 102). In this space, a color is uniquely specified by three numbers, making specification, tolerancing and communication about color feasible. The system is not perfect however; a unique color in CIE perceptual color space can be formed by more than one combination of source, object, observer. This will be explained in more detail in the section on metamerism.

CIE perceptual color space is the basis of quantitative color. There are different mathematical algorithms for combining the spectra leading to different numbers, but all have the general appearance of the model shown in *Figure* 102. In 1976, the CIE standardized on the model called L*a*b* and the model is commonly referred to as the CIELab color space. The additional descriptive term "perceptual" means that this color space is based on how the eye perceives color. This is in contrast to name-based description of color such as "warm red".

Every color an observer can see can be represented by its location in CIE perceptual color space, which is commonly described as L*a*b* and L*C*h°[2].

L*a*b*

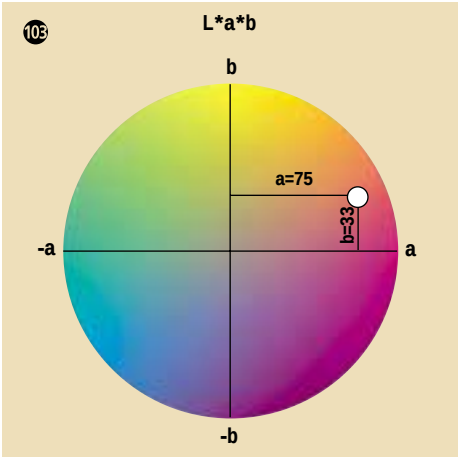
L stands for lightness and is the vertical dimension in color space. Every color has a lightness or L value. Unlike L, a and b do not

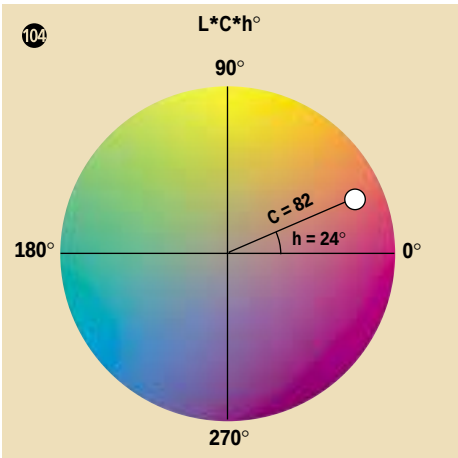
2 L, a, b without the (*) refers to another color model. Throughout this book, the L*a*b* model is implied, even if, for clarity, in some of the equations and diagrams the (*) is omitted.

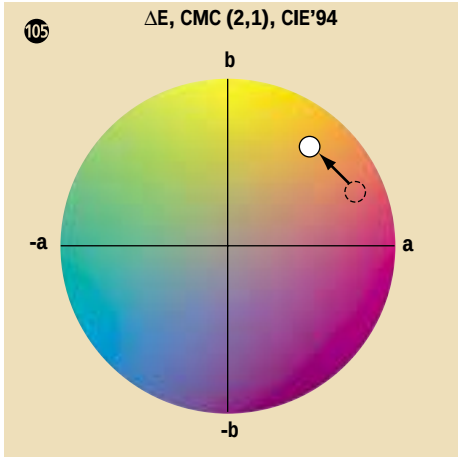
103 Location of red color in CIELab color space shown in the a*b* plane, which is a slice through CIELab color space at a constant value of L*.

104 Location of the same red color of figure 21 at the same value of L* and located by a distance from the center C* and an angle h.

105 The distance in CIELab color space between two colors is the color differnce called delta E.







stand for a perceptual attribute. Instead, they are the x, y coordinates of the chromatic plane. The chromatic plane is a cross section of perceptual space viewed from the top as a two-dimensional plane. Every color has a location in this plane (*Figure* 103). The red color indicated by the circle is located 75 units in the "a" direction and 33 units in the "b" direction.

L*C*h°

Referring to the same red color as in *Figure* 103, L*C*h° is simply a different way of navigating to that color (*Figure* 104). This time, however, the color is reached by going out 82 units (c) at a 24° angle (h). Geometrically, the difference between L*a*b* and L*C*h° is the difference between a cartesian and polar coordinate system. The much more important difference is that L*C*h° represents the perceptual attributes of color. These attributes are described as follows:

L , or lightness, is the lightness or darkness of the color. The scale goes from 0 for black to 100 for white.

C, or chroma, refers to the saturation of the color; zero along the central vertical axis. A color with a C of 0 is neutral or gray. The more saturated or pure the color, the higher the C value. Another descriptive word used is a strong color as opposed to a weak color. Values are not capped at any particular value but rarely exceed 100.

h, or hue, is the perception of the "color" attribute of color. This may seem like a circular definition but the best way to describe hue is to say it determines whether the color is red or green or purple. The hues are arranged in a circular fashion so that a particular direction represents a specific hue.

Color Difference

Once a color is described in terms of a point in space, the concept of a color difference follows naturally. It is the geometric distance between two colors (1 and 2 in *Figure* 105) and is called delta E (ΔE). Mathematically,

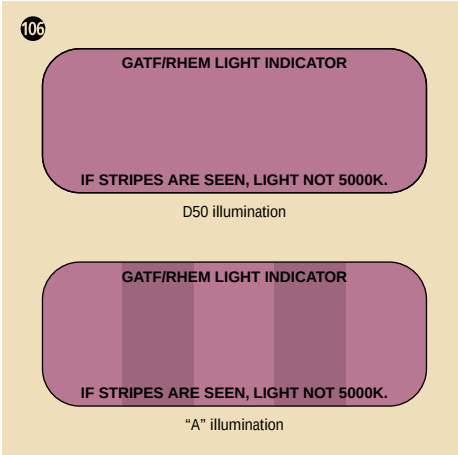
$$\Delta E = \sqrt{[(L_1 - L_2)^2 + (a_1 - a_2)^2 + (b_1 - b_2)^2]}$$

As a measure of the difference between two colors, ΔE serves as a specification of color tolerance. That is, two colors match if their difference is less than a certain value of ΔE. Unfortunately, specifying an acceptable ΔE value is not a simple matter. Ideally, the same ΔE would mean the same perceived color difference throughout color space. Experience shows that this is not the case. A small ΔE in a neutral gray would be more apparent than the same ΔE in a saturated dark red.

To overcome this deficiency, weighting factors are introduced into the ΔE calculation. Currently, the CMC weighting calculation has widespread acceptance. With some modification, this has been adopted by the CIE as CIE'94. When quoting ΔE values or tolerances, it is essential to know which calculation is being used. Othewise, the numbers will be different. Typically, reference is made to ΔE, CMC or CIE'94 tolerance or color difference. To complicate matters even further, there are additional adjustment parameters used in the CMC and CIE'94 calculations. The usual values for these are 2 and 1 and the CMC color difference may be quoted as CMC(2,1). Refer to *Appendix C* for details.

Metamerism

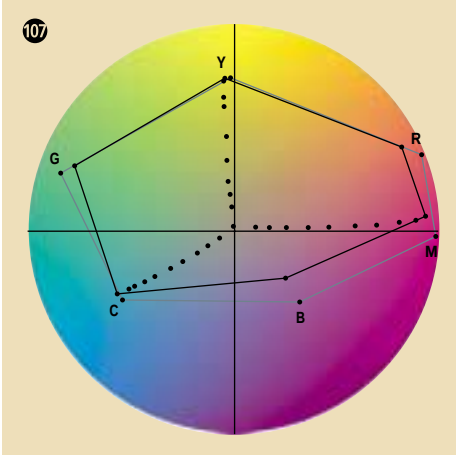
Every color has a unique point in CIELab color space—its own set of L*a*b or L*C*h° values. What is not unique is the combination of spectral curves of the source and object which can produce that color. This leads to the common phenomenon called metamerism. It means two colors are a match under one illumination, but not under a second illumination. Visually, the test for metamerism simply means looking at the sample under different illumination sources. Many light booths provide multiple sources for this purpose. If no light booth is available, the sample can be viewed near an open window to approximate D50 and then under a standard tungsten filament light bulb (illuminant A). A quick, inexpensive and less rigorous method to determine if a light source is the standard D50 is to use the RHEM light indicator. Available from GATF (Graphic Arts Technical Foundation), it is an illumination test target consisting of alternating patches of two colors that match under D50, but do not match under different illumination such as "A" or standard flourescent lights. *Figure* 106 illustrates a simulation of the indicator (actual appearance will be different). Simple visual examination reveals if the illumination is D50 (or at least close to it). Similar illumination test targets are available from other vendors. A more rigorous method requires a spectrophotometer and will be described in the measurement section.



106 A metamerism indicator, such as a RHEM Light Indicator, is used to test if a light source is D50.

Gamut

The range of colors that can be reproduced by C, M, and Y inks on a particular substrate is called the gamut of the system. Recall that different combinations of the process colors are used to create all printing colors. Even if inks of the "perfect" CMY shown in *Figures* 90, 91 and 92 were available, one still could not combine them to



107 The gamut of a flexo press (shown in black) and a digital proofing system (shown in blue). The dotted lines are the C*, h° values of different dot percentages of the process colors yellow, magenta and cyan.

create all colors that the human eye can perceive. A simple and real life example would be a red laser, the kind used in the supermarket to scan the bar codes. This has a light of only one wavelength. The spectrum is a sharp spike at 633 nanometers. The ultra-pure red color of the laser beam is considered an out-of-gamut color, and there is no way even "perfect" C, M, and Y inks could be combined to yield such a spectrum.

Every device, including monitors, scanners and proofers have their own specific gamut; colors they can read or render. *Figure* 107 shows the gamut of a digital proofing system and a flexo press. As is the case in this example, the proofing system usually has a larger gamut than the press. This is particularly true for high-end proofing systems used to make the final contract proof. In *Figure* 107, Y, M, C are the points of 100% yellow, magenta and cyan. R,B,G are the solid overprints of YM, CM and YC respectively. The colors which are inside the polygon connecting these six points make up the gamut of the device. On this same illustration (*Figure* 107), the gamut of a color transparency would be larger still.

The dots inside the diagram of *Figure* 107 show the C (chroma) and h (hue) locations for colors produced with different dot percentages of the process-color inks. The points are actual measurements of the L*C*h° values and clearly demonstrate that the hue remains constant when printing different tones of the same color. When printing on white paper, only the chroma and lightness should change. *Figure* 107 illustrates that this indeed happens in the real world.

Gamut mismatch is one of the great challenges in printing, and boils down to the question of what do to with the colors that are outside the gamut of the printing press. When reproducing a color transparency, for example, there are many colors the press can not reproduce. The gamut of the tranparency must be compressed. The methods to do this is what much of color management, scanner setup, and the conversion of RBG to CMYK is all about.

Color Measurement

Before discussing specific measurements in detail, some general comments regarding metrology are in order. Every measurement consists of two parts: the value and the measurement error associated with it. There is no such thing as "exactly" one inch. Measured with a ruler, the error might be 0.063". Using a machinist's micrometer, the error might be reduced to 0.001". Using even more sophisticated measurement techniques might reduce the error to the micron level or even less, but there will always be some error or uncertainty associated with the measurement.

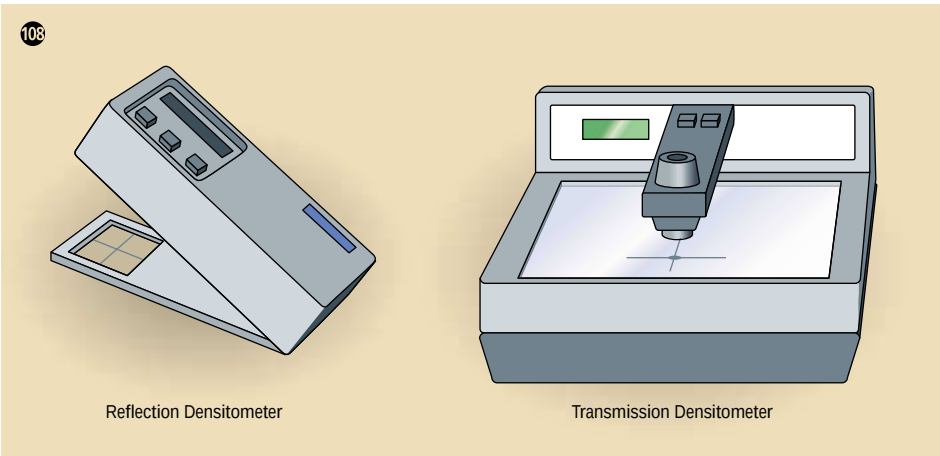
Because specifications are based on measurements, this means any specification has a tolerance. Beyond the mere impossibility of measuring the "exact" value, a tolerance is needed for economical and practical reasons. A 1" diameter curtain rod with a tolerance of ±0.063" would be fine. The same 0.063" tolerance on a shaft for a piece of machinery would be disastrous.

All specifications given in FIRST have a tolerance associated with them. They represent achievable values and tolerances. The actual values used for a particular process and job needs to be agreed upon by all the parties involved.

DENSITOMETER

There are several types of densitometers (*Figure* 108). A transmission densitometer measures the amount of light that has been passed through an object. This type of densitometer is used to measure films. A reflection densitometer is used to measure the amount of light reflected by an object, and is used to measure proofs and press sheets.

The second category of densitometer addresses the difference between black-and-white instruments and "color" instruments. The word color is in quotes because a color densitometer doesn't measure color as has been defined in CIELab color space. It sim-



108 Typical examples of a reflection densitometer and a transmission densitometer.

COLOR DENSITOMETER	
FILTER	MEASURES
R	C
G	M
B	Y
VIS	K

Table 19

DENSITY	
REFLECTANCE OR TRANSMISSION	DENSITY
100%	0.0
10%	1.0
1%	2.0
0.1%	3.0
0.01%	4.0

Table 20

ply measures the amount of cyan, magenta and yellow present. A black-and-white densitometer has a similar response as black-and-white sensors in the human eye and gives only one density value.

Color sensitivity is achieved by filtering the light. *Table 19* shows the filters used. The red, green and blue filters are the complementary colors of cyan, magenta and yellow and the filters are called the complementary filters or major filters for those printing colors. The filters may be called C, M, Y and visual, depending on the model of the densitometer.

Note: *The filters in Table 19 are specified for measuring C, M, Y. This means that the densitometer is specifically designed to measure those colors. Ideally, when measuring a cyan, for example, the measured densities of magenta and yellow should be zero. In reality, there will be some density in all channels. When measuring a color other than C, M, Y, the densitometer gives the densities of the C, M, Y components of that color. This can be used as a process control tool to keep the color at the same density. It cannot be used to determine if two colors match.*

Density

The scale used is called density. The higher the number, the less the light. In order to make the measurement, the densitometer needs to know how much light there was to start with. This is part of the measurement procedure when using a densitometer. Measurements are taken either relative or absolute to the substrate. Relative means the clear film (for transmission) or non-printed substrate (for reflection) is the reference. For absolute, it is no film for transmission and a white reference supplied by the manufacturer for reflection.

The density scale used by the densitometer is logarithmic. This means there is a factor of 10 between density units. A density of 1 has 10 times the light as a density of 2 (remember, higher density means less light). *Table 20* shows the density for different percent reflectance/transmission values. The reason to use a logarithmic scale is because, to a good approximation, it represents the way the eye responds to light. It means that a density of 0.2 added to a density of 0.3 will look very much like a density of 0.5; that is, densities add.

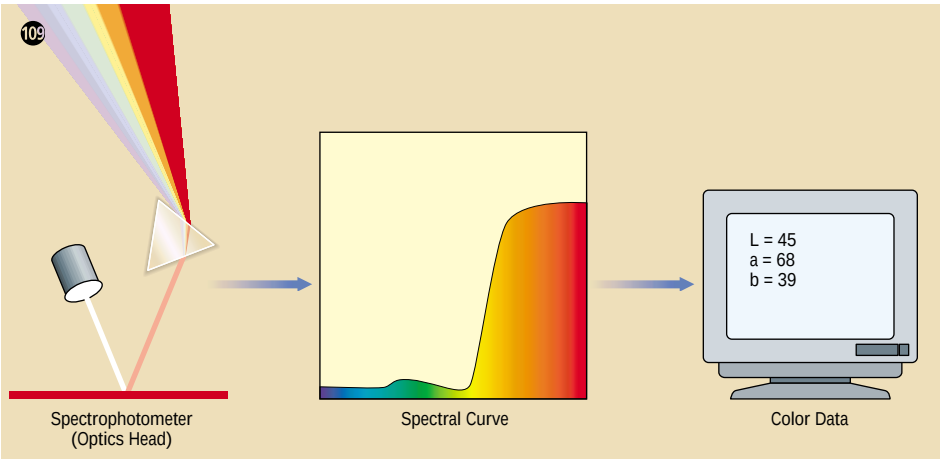
Using density measurements, other useful metrics can be calculated: dot percent, trap, print contrast and hue error/grayness. The formulas are given in *Appendix B*.

Dot Percent

One of the key measurements taken by a densitometer is dot percent. The dot percent is a calculation based on the measured density of the tint and the solid of that same color.

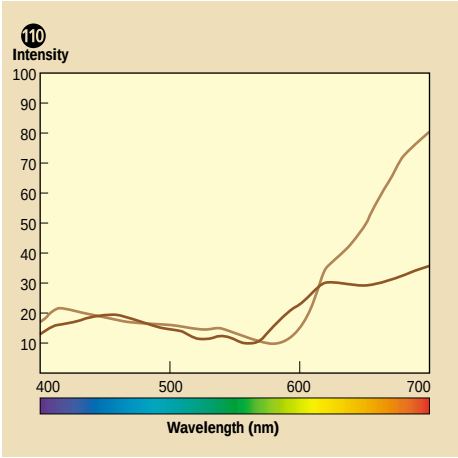
Trap

This is a measure of how well one ink overprints a second. Again, the measure-



109 Elements of a spectrophotometer showing the optics head which gathers the data to generate the spectrum which is used to calculate L*a*b* or L*C*h°.

110 Spectral curves of the two colors that match under D50 light but show a definite visible difference under "A" light.



ments are densities. The calculation uses the relative densities of the overprint, first-down ink and second-down ink. The measurements are done using the appropriate filter (*Table 19*) for the second-down ink.

Print Contrast

This is a measure of the sharpness of the print and uses the densities of the solid and a shadow tint (typically 70%).

Hue Error/Grayness

These are calculations using combinations of the densities applying all three filters. The metrics were developed to characterize the purity of process inks; how well they approach the "perfect" cyan, magenta and yellow. With the advent of spectrophotometers, the recommended metric is the actual color (i.e., L*a*b* or L*C*h° values) of the ink. This is what is specified in FIRST.

SPECTROPHOTOMETER

A spectrophotometer is used to measure the entire visible spectrum of a sample. The real color curves presented elsewhere in this chapter, were all taken with a spectrophotometer. The key part of the spectrophotometer is an optics head that contains a light source in a fixed geometry, an element like a prism which breaks up the light into its discrete wavelengths, and a detector of the dispersed light (*Figure* 109). The spectrophotometer can either display the spectrum, or it can send the spectrum to a computer. Physically, a reflection spectrophotometer looks very similar to the reflection densitometer illustrated in *Figure* 108.

Recall that the L*a*b* or L*C*h° values are a combination of the object and source spectra, taking into account the response of the standard observer. The optics head delivers the object spectrum and the standard observer is well defined and fixed. The effect of different light sources, such as D50 and D65, can be calculated, and the spectrophotometer can display the resulting L*a*b* or L*C*h° values under these different sources.

The ability of the spectrophotometer to do calculations enables it to also function as a densitometer. Recall that in a densitometer, the light is filtered as was shown in *Table 19*. This is nothing more than a modificaton of the light source. If the spectrum of the filter is known, all densitometric values can be calculated. The spectra of the filters have been defined and are known as status T. Using this standard, all the metrics used in densitometry can be calculated by a spectrophotometer. Like a densitometer, the spectrophtometer can make absolute measurements or measurements relative to the substrate.

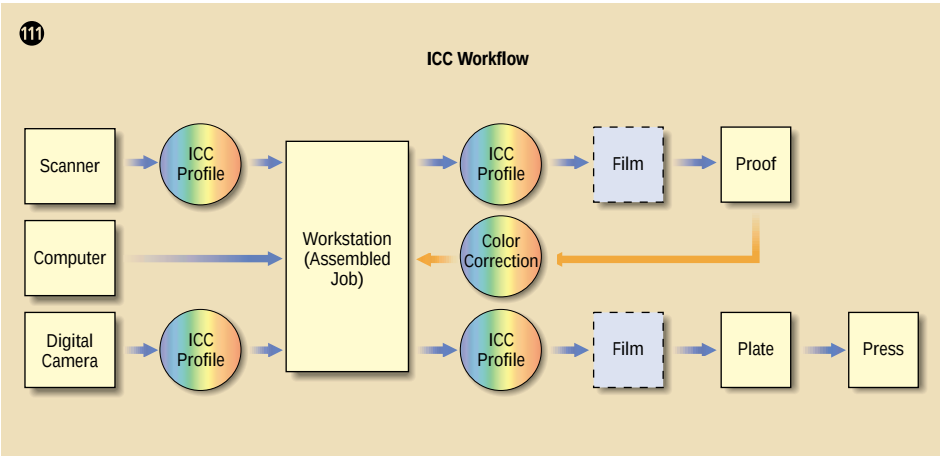
The spectrophotometer can be used to quantify metamerism. As an example, *Figure* 110 shows the spectra of the two colors in the RHEM light indicator. Note that the two spectra cross at several points, a condition required for two colors to be metameric. Illuminated with D50 light, the colors match to a CMC ΔE of less than 1. Illuminated with "A" light, the colors match to a CMC ΔE of 2.86, which is clearly visible. A common measure of metamerism is called the metamerism index (MI), which can also be calculated (*see Appendix C*). In this case, its value is 3.6. The metamerism index measures the difference between the colors under different light conditions. A low value doesn't mean the colors are the same, only that the visual difference is the same under both light conditions.

Color Management/Workflow

Color management has received a lot of attention in recent years. It has become associated with CIELab measurement and control of color. In a real sense, color has always been managed, it is just the tools and techniques which are changing. The particular method of how and where color is controlled and adjusted is determined by the particular workflow or specific procedures and programs used to put the job on press.

Figure 111 shows a highly simplified diagram of the traditional workflow. A scanner is the input device for the original art, which is to be printed in process color. The box labeled "computer" is the source of the rest of the design. Generally, process work is not originated in a software program. The design and scanned images are assembled into a single job in the workstation. The electronic file is then output to film for proofing, or to make plates for printing.

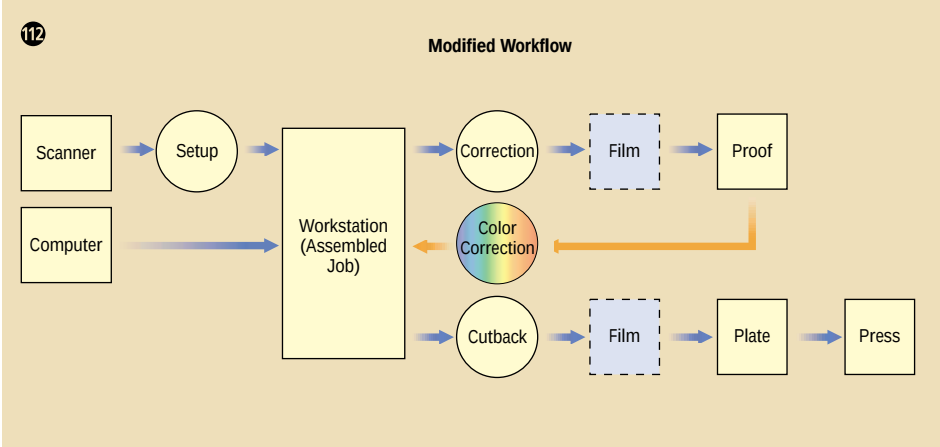
The key to the management of color, are the functions labeled in the circles of *Figures* 111, 112 and 113. The circle next to the scanner, labeled "setup", is part of the scanning function. A scanner operator typically sets highlights and shadows and adjusts tone curves for the original to be scanned. On high-end scanners, the setup will typically include color corrections or manipulations. When scanning directly to a CMYK file, the scanner operator must choose many of the parameters of the RGB-to-CMYK conversion. Setups for different types of originals come from experience, which is based on how the proof looks. If the color of the proof is not right, there is a color correction cycle, either to the file or the original can be scanned again with a different setup. In many flexo operations, in order for the press to print what is shown on the proof, the process image needs to be modified. This is done with a cutback curve. This is because proofing systems have less dot gain and the films used to make proofs can not be used to make plates for the press. *Figure* 111 a summarizes the color changes

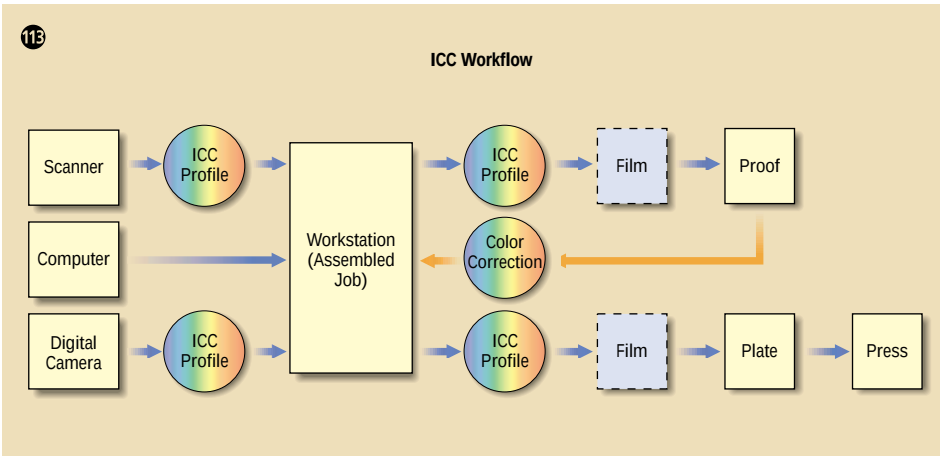


111 A simplified flowchart of traditional color management workflow.

112 This modified flowchart uses CIELab metrics in the workflow; a correction step has been added to the proofing path.

113 In this flowchart, full implementation of color management uses ICC profiles for all input and output devices.

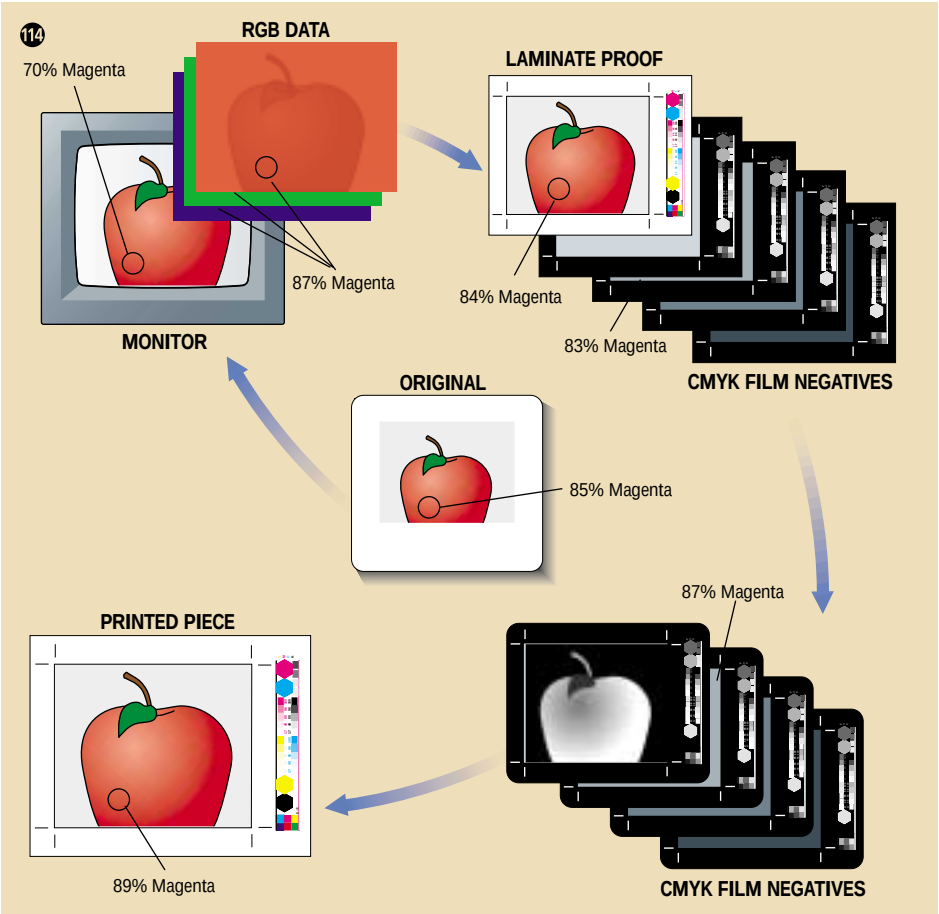




that occur during the process of reproducing a photo as a printed piece.

In order to discuss color management using CIELab-based metrics, it is necessary to modify *Figure* 111 as shown in *Figure* 112. The biggest change as far as color management is concerned is the addition of a correction in the proofing path of the process. The dashed lines around film indicate that there may or may not be film produced at all. While digital platemaking is not yet as common, digital proofing certainly is gaining wide acceptance. Color is handled as before with one important difference. The correction in the proofing path modifies the proof to match the press. The correction is not a simple cutback curve but rather a complex set of corrections based on L*a*b* measurements. This correction can be applied to CMYK files and is a CMYK-to-CMYK conversion. This means that the RGB-to-CMYK conversion is not part of the correction process. Any separator or scanner operator who has invested years of learning how to make a separation can still use that experience to make the separations. The aim of this workflow is to match the proof to the press.

The last case to consider is shown in *Figure* 113. This is what many people have in mind when they talk about color management using ICC profiles. Notice that a digital camera has been added as an input device. In this workflow, every device is characterized in terms of how it sees or outputs color. If those characteristics are known, it is pos-



114 As images go through the production process, the image information is transformed and displayed first as photographic data in the original image; second, as digital information in the scanned image file; third, as pixels of red, blue and green light on screen; and finally as printed dots of CMYK on a substrate. Each of these steps introduces color changes.

sible to associate a correction with each device. The image to be scanned or proofed or output is stored in terms of L*a*b* values; that is, the color values in CIELab color space. Each device then handles the color to the best of its capability. Implicit in this workflow is the RGB-to-CMYK conversion. That is, the color management system will have a RGB-to-CMYK conversion engine. In actual practice, the image might be stored in "tagged RGB." This means RGB values are stored along with the profile or characterization information for the input device that captured the image.

In all the workflows shown, the corrections can take place at different stages of the process. For example, the correction to the plate film could be made in the workstation before being sent to the imagesetter for film output. Alternatively, it could happen when the film is output. Similarly, other corrections can take place at different stages and in different programs in the process. Color management is a process or function that addresses the details and decisions associated with where and when to make the corrections shown "logically" in *Figures* 111, 112, and 113.

The color-correction loop is present in all the workflow diagrams. Even if the CIELab method were to give acceptable color matches the first time around, this loop would still be required. Many times color corrections are done not to achieve "match copy" but to satisfy personal editorial desires of the customer. The truth will always still be in the eye of the beholder.

Achieving Optimum Press Performance

Before any corrections can be applied in process-color printing, two tasks need to be accomplished. The first is press optimization and the second is press characterization. Press optimization refers to finding the best or optimal values for the myriad of variables encountered for a given printing process. It means printing to a consistent set of specifications and tolerances. The most comprehensive set of specifications and tolerances for flexography are found in FIRST.

Press characterization, to be covered in detail later, refers to measuring key print variables once the variables which affect the print have been set. This means that the printing process must be stable, repeatable and under control before it is characterized. The purpose of characterization is to quantify or document the printing process; the purpose of optimization is to improve the printing process.

SOLID-INK DENSITY

	PAPER	FILM
CYAN	1.37 (0.07)	1.25 (0.07)
MAGENTA	1.25 (0.07)	1.20 (0.07)
YELLOW	1.00 (0.05)	1.00 (0.05)
BLACK	1.50 (0.07)	1.40 (0.07)

Note: *(+/–) tolerance values in parentheses.*

Table 21

PRESS OPTIMIZATION

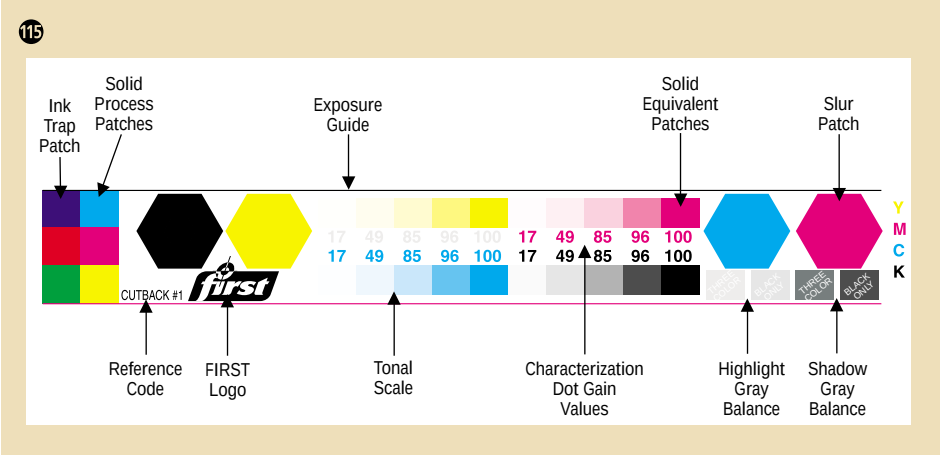
In order to optimize the press, tests need to be conducted. For example, a banded anilox test is a good way to find the optimum anilox configuration for process printing. This is a test print with different anilox rulings and volumes engraved on the same roll. Some may choose to combine part of the optimization effort with characterization. It is also called fingerprinting the press.

One of the major specifications for the printed sheet is the solid-ink density. The values are found in FIRST and reproduced in *Table 21*. Other variables to optimize include:

- **film:** screen angles, D-min, D-max and screen ruling
- **plate:** durometer, relief and caliper
- **mounting material:** density, thickness
- **ink:** pH, viscosity and density
- **substrate:** dyne level, tension
- **anilox roll:** cell count, cell volume, cell angle
- **press settings:** impression, speed, dryer temperature

These individual topics are covered in detail in the other chapters of this work. It is vital that the result of optimization is a set of achievable conditions that can be maintained during normal production. It does not mean the best possible that the press can do if everything is tweaked to perfection. Achievable, realistic target values which represent quality printing are documented in FIRST.

When running any press evaluations,



115 Components of a FIRST control target.

include a control target which will be used during production to maintain control of the press. *Figure* 115 is the FIRST control target.

PRESS CHARACTERIZATION

Press characterization follows press optimization. It accomplishes two goals. One is to document the values of key print variables such as dot gain, ink trap, minimum highlight dot and maximum shadow dot, L*a*b* values for selected patches (solid-ink patches, gray-balance patches and overprint patches).

The second is to provide the data used to calculate the corrections necessary for matching color. The procedure is to print a characterization target using the optimized conditions. The target is evaluated both visually and by measurements. The measurements are used to develop the corrections by either conventional cutback curves or CIELab-based corrections (ICC profiles).

Target

There are numerous targets available. *Figure* 116 depicts the FIRST press characterization target. The largest number of target elements are the overprint patches arranged in 42 rows by 32 columns for a total of 1,344 patches. Included are single-color step wedges used to calculate cutback curves. The patches are all combinations of six tint values arranged in random order. This arrangement serves to distribute any local press variations throughout all color values. Spectrophotometric (L*a*b*) measurements of these overprint patches provide the data for the CIELab-based corrections.

Additonal elements in the target, used for different types of characterization, include:

- slur target;
- linear blends to determine minimum and maximum dot;
- positive and reverse lines; and
- microdots and register marks.

TYPES OF CHARACTERIZATION

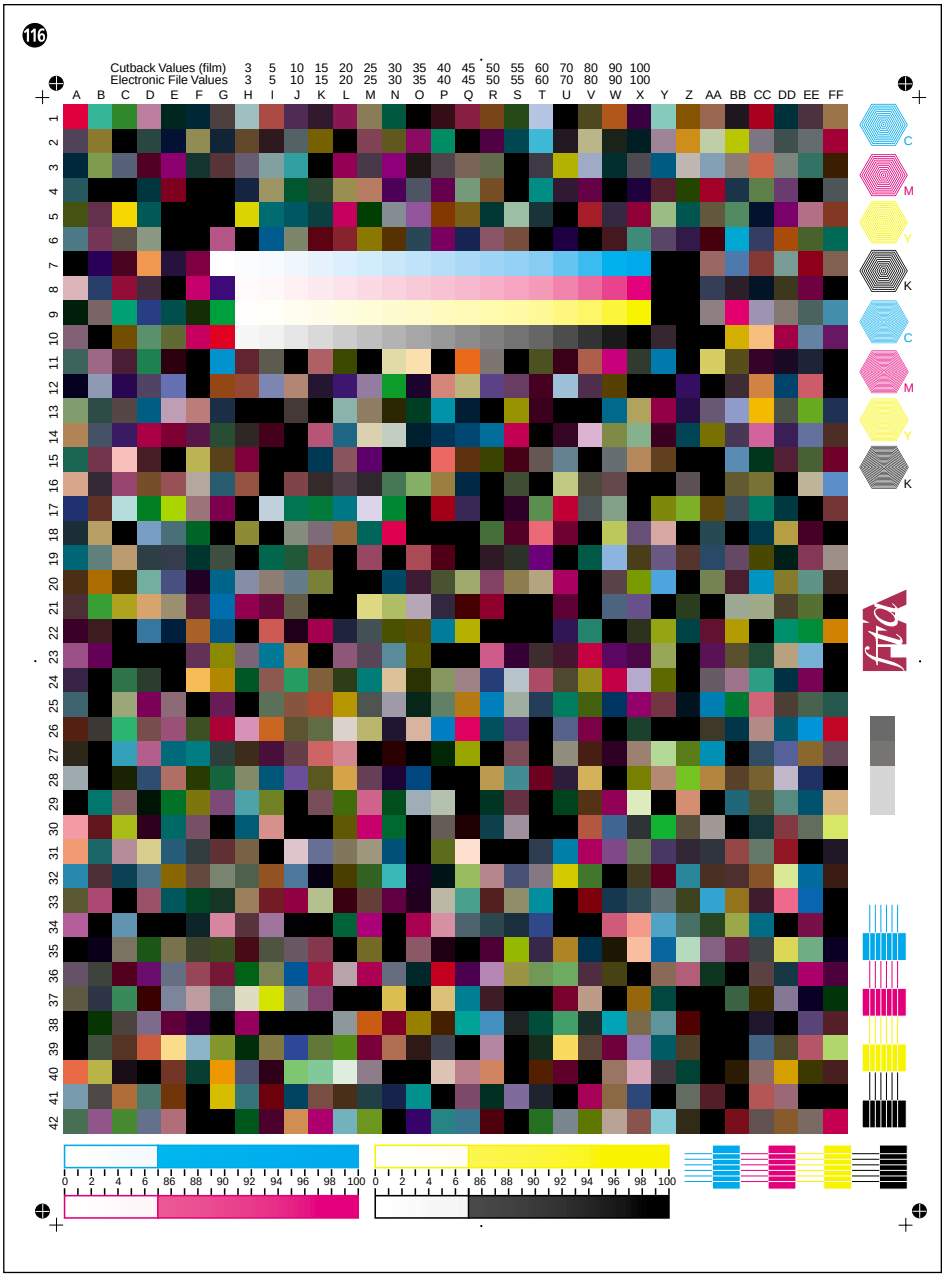
Characterization can be broken out into different types: visual, line, screen and process. Clearly, for process printing, process characterization needs to be done. For completeness, the other types will be mentioned and briefly described.[3]

Visual Characterization

The main purpose of characterization is to quantify the process. Nevertheless, visual

3 A good tutorial on the subject of press characterization is available on CD from the FTA.

116 FIRST press characterization target.



examination of the press sheet is always part of the characterization. It would be foolish to spend a great deal of time and effort quantifying a press using a press sheet that exhibits unacceptable slur, or is in misregister. Perhaps this is stressing the obvious, but before any quantitative analysis is done, the press sheet needs to be carefully examined to assure that no defects are present. Faults which are best examined visually include:

- misregister;
- sharpness;
- slur;
- ink trap;
- streaking;
- ghosting;
- solid coverage; and
- clarity of the graphics.

Line Characterization

Line characterization is aimed at quantifying the growth of positive lines and reduction of reverse lines. The information can be used to calculate bar-width reductions for printing bar codes and to determine the minimum type size and fonts which can be printed. The positive and reverse lines in the FIRST target (*Figure* 116) show how small a line, in points, can be held and what size will fill in. To quantify the growth or reduction, the lines are measured with a 50x or 100x magnifier that has a built-in scale. An alternative method is to print actual bar codes and type and visually examine the result. The bar codes can also be tested with a bar-code verifier. Specifications and test plates can be found in the second edition of FIRST.

Screen Characterization

Screen characterization is used to determine cutback curves when printing screen work only. The procedure for process-color screens is the same as it is for process characterization using conventional cutback curves (described in the next section). It is usually not practical to develop cutback curves for spot colors because of the large number of spot colors used. The curves developed for process colors can be used as a starting point, and the cutback curves can be adjusted on subsequent print runs using the same spot color.

It might be practical to develop a cutback curve for a specific spot color which is used frequently, or one which is critical, such as a customer's logo color. Keep in mind that the spot colors referred to here are those made up of screens of a spot-color ink. Spot colors printed as a solid are controlled by the ink formulation and achieve target solid density.

Process-color Characterization

Often referred to as fingerprinting a press, the goal of this process is to measure and analyze the press sheet in order to develop the corrections used in the workflow diagrams presented in *Figures* 111, 112 and 113. The methods fall into two categories: densitometric and perceptual. Densitometric refers to the measurement of densities and dot gain in order to calculate a cutback curve. Perceptual refers to spectrophotometric L*a*b* measurements of the overprint colors. The data is used to calculate CIELab-based corrections (ICC profiles).

It is important to keep the goal of the characterization in mind. In the workflow section, it was pointed out that a cutback curve matches the press to the proof. For CIELab there can be different goals depending on the particular workflow used. One is to match an absolute L*a*b* value. That is, if the desired output L*a*b* value is known, the press can be adjusted or corrected to print that value subject to gamut limitations. The second approach is to match the proof to the press.

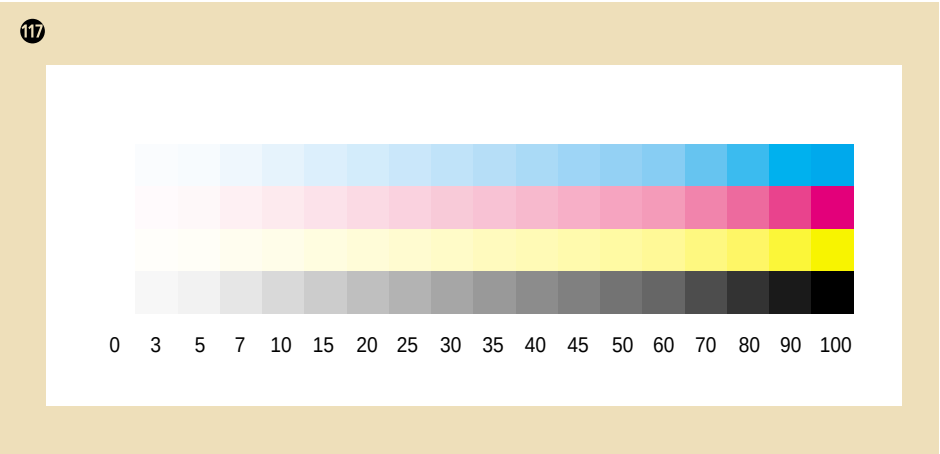
CUTBACK CURVE

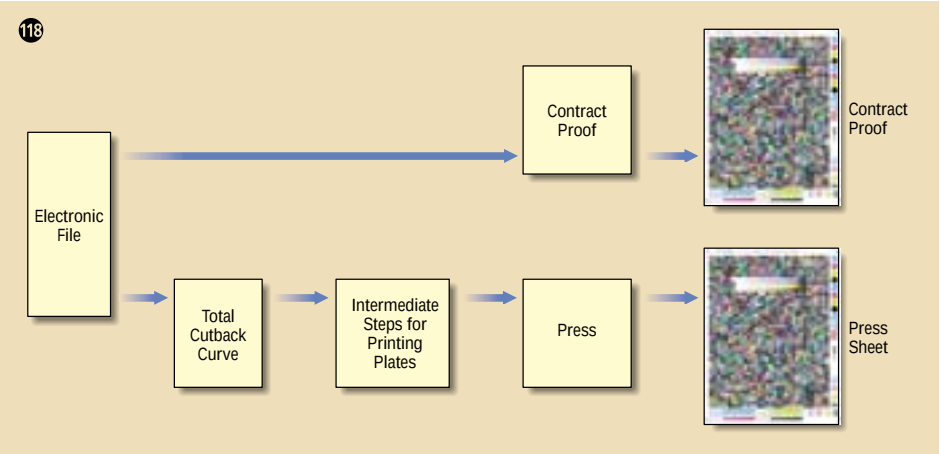
The general objective of a cutback curve is to apply a correction to the dot percentage of one device, so that the measured size of the dots match that of a second device. This will lead to color matching, provided some of the other print variables – notably the hue of the process inks, ink trap and the substrate – are similar. Relative density measurements of single-color step scales (*Figure* 117) facilitate calculation of dot percentages. The cutback curve is essentially a gradation curve applied to each process color. The process of generating the curve is the same, whether the curve is applied to a file going to a proofing device, platesetter, imagesetter or any other output device.

The specific place and method where it is actually applied can vary depending on the particular workflow, software and hardware involved. The usual application of cutback is illustrated in *Figure* 118, which is similar to *Figure* 111 and shows a conventional work-

117 Single-color step scales are used to measure dot percentages for cutback curve.

118 A cutback correction called "total cutback curve" is applied in the conventional workflow. This correction is applied to the electronic file before outputting to film for platemaking or outputting direct-to-plate.





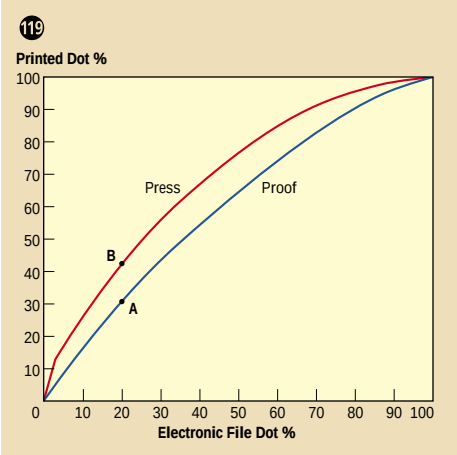
flow path where the electronic file is modified by a cutback curve before output to films for platemaking. The correction step is called "total cutback curve" because a default cutback curve could have been used originally when the press characterization, or fingerprinting, was carried out. Example 1 and Example 2 will show the details with and without the use of a default cutback curve. In these examples, the press is matched to the proof.

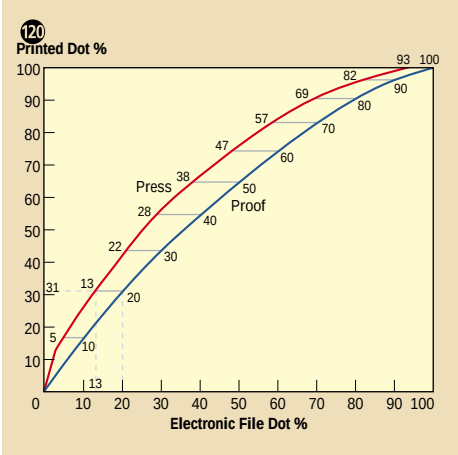
Example 1: *Table 22* shows the measured dot percentages for the proof and press sheet. These are the dot-gain curves for the proof and press sheet. The values are shown graphically in *Figure* 119.

It is a common mistake to calculate the cutback required by taking the difference between the measured dot-percent values between the proof and press sheet at a particular value of the electronic file dot percent. In *Table 22*, for example, at a value of 20% in the electronic file, the proof has a 31% dot and the press a 43% dot (points A and B in *Figure* 119). This would give a correction of 12 and a cutback curve value of 8 (20 minus 12). This *incorrect* process for the entire curve is detailed in *Table 22*. The reason for showing the entire curve generated is to highlight the fact that this incorrect method yields negative dot-percent values for the cutback curve.

The key to the correct procedure is to ask the following question:

For a given dot percent in the electronic file, what dot percent must be sent to the





119 This chart compare a dot gain curve for proof and press sheet with no default corrections applied.

120 Reading cutback values from the dot-gain curves of Figure 36.

DOT-GAIN CURVE

FILM DOT%	PROOF DOT%	PRESS DOT % WITH DEFAULT	PRESS DOT % WITHOUT DEFAULT
0	0	0	14
3	5	13	14
5	9	17	14
7	12	21	14
10	17	26	20
15	24	34	27
20	31	43	33
25	38	50	39
30	44	56	43
35	49	62	48
40	55	67	53
45	60	73	57
50	65	78	62
60	75	86	71
70	83	92	80
80	91	96	87
90	96	99	94
100	100	100	100

Table 22

press to get the same measured result as on the proof?

In *Figure* 119, the 20% dot prints as a 31% dot on the proof (Point A). The question is, which dot-percent value in the electronic file also prints as a 31% dot on the press sheet? Examination of *Table 22* reveals there is no measured dot-percent value of 31% in the press dot percent. To get the answer, a horizontal line is drawn at the 31% output value as shown in *Figure* 120 with the line labeled 13-20. The press prints a 31% dot for an electronic dot-percent value of 13%. The 13% was obtained by reading it from the graph in *Figure* 120 which shows the same procedure for all dot-percent values in the electronic file from 0 to 100 in steps of 10.

Put in a slightly different way, *Figure* 120 indicates that in order to print a 31% dot, a 20% dot needs to be sent to the proofing device and a 13% dot needs to be sent to the press. This implies a correction to the press of 7% (20 minus 13). All values are listed in *Table 23*.

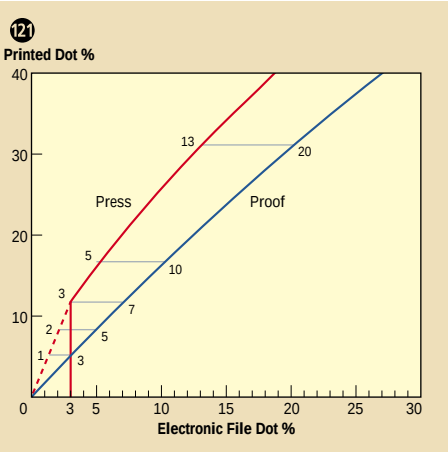
Figure 120 shows the values above 10%, while *Table 23* lists some of the values below 10%. This area needs some special consideration, especially considering the minimum-dot value that will be printed. *Figure* 121 shows an enlarged part of the highlight area of *Figure* 120. The dashed line shows the line drawn in for the dot-gain curve while the solid line signifies the actual curve, assuming a minimum printing dot of 3%. Below 3%, the output is zero-dot percent or a drop out. *Table 23* reflects this drop out and keeps the value at 3% for all electronic dot values of 3% or less.

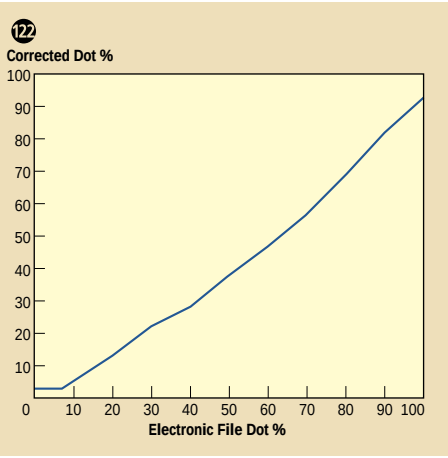
A similar cutoff can be applied in the shadow end. In this case, the value of 93% would

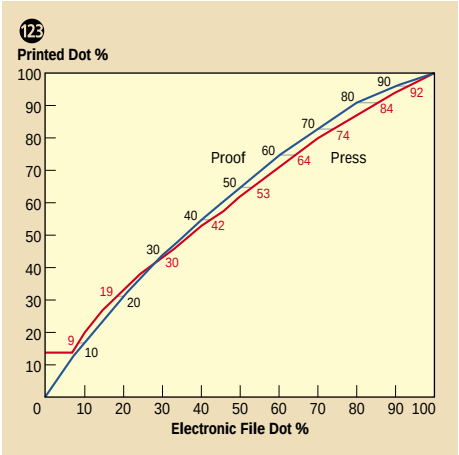
CUTBACK

	WHAT TO DO		WHAT NOT TO DO	
FILM DOT %	CORRECTION (FIG. 37)	CUTBACK CURVE	INCORRECT CORRECTION	INCORRECT CUTBACK
0	0	3	0	0
3	0	3	8	-5
5	2	3	8	-5
7	4	3	9	-2
10	5	5	9	1
20	7	13	12	8
30	8	22	12	18
40	12	28	12	28
50	12	38	13	37
60	13	47	11	49
70	13	57	9	61
80	11	69	5	75
90	8	82	3	87
100	7	93	0	100

Table 23







121 A magnified section of dot-gain curves of Figure 36 shows the drop out (no printed dot) in the press sheet below an electronic file dot of 3%.

122 The resultant cutback curve shows the original electronic file dot on the horizontal axis and the corrected file to be output to plate-making film on the vertical axis.

123 The dot-gain curve for the proof and press sheet with default correction applied.

not present a problem if the maximum printing dot is 93% or higher. *Figure* 122 shows the resultant cutback curve. The graph reveals the corrected values (those to be output to press) vs. the original electronic file dot-percent values.

Example 2: It is assumed that the cutback corrections derived in Example 1 have been applied. That is, the cutback curve derived in Example 1 is the default cutback curve used. This could be the case where a press characterization has been used to generate the cutback curve and perhaps a different but similar press is being characterized. The task is to generate a new cutback curve (Total Cutback Curve in *Figure* 118).

As before, the proof and press sheets are measured, the dot-gain curves generated and the horizontal lines drawn in (*Table 22* and *Figure* 123). At first glance, this may seem like a strange dot-gain curve. The press has more gain than the proof in the quarter tones and less gain than the proof in the mid tones and higher. It seems to hold dots all the way to 100% and in the highlight, prints a 14 % dot all the way to 7%. The answer is, of course, that a cutback curve has already been applied to the electronic file before it went to press. Ideally, the two dot-gain curves of *Figure* 123 would overlap; this is simply a correction to that cutback curve.

TOTAL CUTBACK

FILE DOT %	DEFAULT CUTBACK*	CORRECTION (FIG. 40)	TOTAL CUTBACK	TOTAL CUTBACK CURVE
0	0	3	0	3
3	0	3	0	3
5	2	3	2	3
7	4	3	4	3
10	5	5	6	4
20	7	13	8	12
30	8	22	8	22
40	12	28	10	30
50	12	38	9	41
60	13	47	9	41
70	13	57	9	41
80	11	69	7	73
90	8	82	6	84
100	7	93	7	93

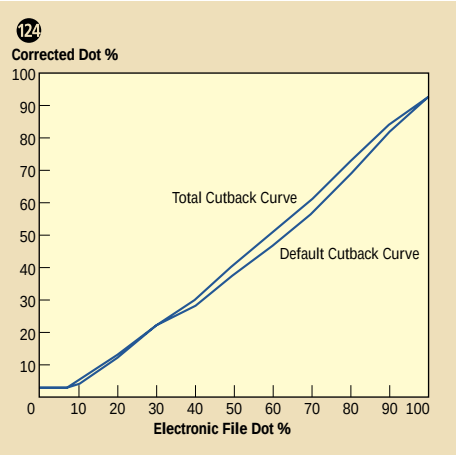
Table 24

The procedure is exactly the same as before. One thing to be cautious about is to make sure the horizontal lines in *Figure* 123 are keyed to the proof curve since the aim is to match the press to the proof. *Table 24* shows the numbers and *Figure* 124 the default and total cutback curves.

Note: *Throughout this section and in Figures* 119 *through* 124*, the output dot percentage are plotted on the vertical axis. This is the correct procedure if the solid-ink density of the proof and press sheet are the same. The same methodology can be applied and cutback curves can be calculated if the solid-ink densities are not the same. In that case, density would be plotted on the vertical axis. Everything else follows in the same manner as described.*

CIELab CORRECTION (ICC PROFILES)

The objective of CIELab correction is to match the colors of one device to another. The colors are measured with a spectrophotometer in CIELab perceptual color space.



124 The default cutback curve (same as the curve of Figure 39) is corrected to total cutback curve.

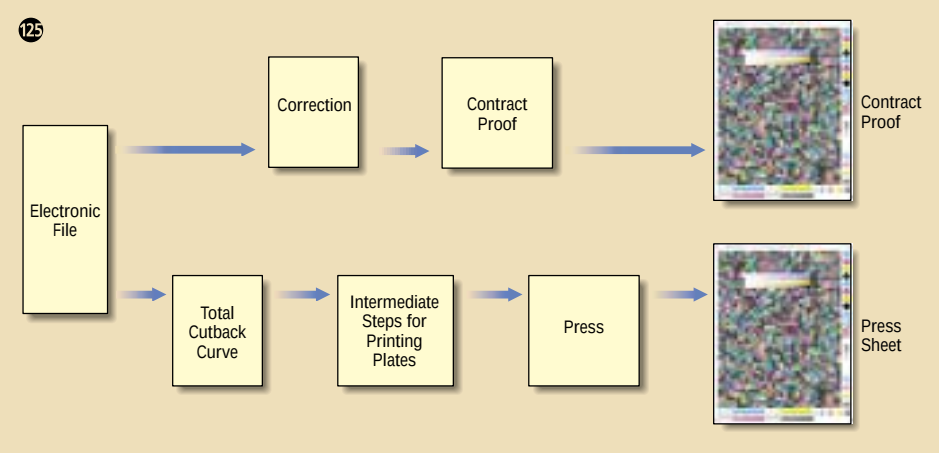
Because the colors are measured as the eye perceives them, all variables, such as substrate, ink trap and changes in the hue of the process inks are taken into account. Measurements are taken in absolute mode, not relative to the substrate.

Corrections are made using ICC profiles. Basically, an ICC profile identifies or maps the device-independent L*a*b* color values to the particular color values of the specific device. For a press, it means for a given L*a*b* value, the press must print a specific CMYK combination. For example, in order to achieve a color specified by L*a*b* values of 46-62-51 the press needs to print CMYK values of 0-100-80-0. For a proofing system, to print these same L*a*b* values, it needs to print CMYK values of 3-100-75-0. This means the electronic file to be output needs to be in L*a*b* values, or the equivalent "tagged RBG." When color 46-62-51 needs to be printed, 0-100-80-0 is sent to the press and 3-100-75-0 is sent to the proofing device.

ICC profiles can also be used when the starting point is a CMYK file. Suppose we start with a CMYK file which has been separated for a flexo press using a cutback curve. The goal is to match the proof to the press. The CMYK values to be sent to the proofing device need to be modified so that for a given L*a*b* color printed on the press, the

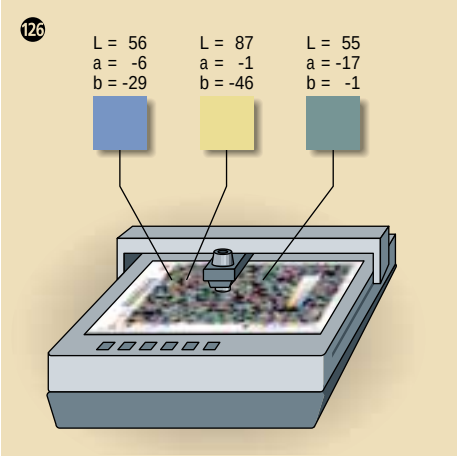
125 An ICC profile correction is applied to the proof in order to match the press sheet. The original is an electronic CMYK file .

126 Readings of a FTA press characterization target taken by a spectrophotometer mounted on an x-y table.



same L*a*b* color is printed on the proof. The modification or correction is shown in *Figure* 125, which is similar to *Figure* 122. As before, printing 0-100-80-0 on the press gives Lab values of 46-62-51. When output to the proofing device, the CMYK values need to be modified to 3-100-75-0 to print the same L*a*b* values of 46-62-51.

Details specifying how and where to apply the profiles depend on which of the corrections are done. Corrections can be done at different stages of the process, whether it be at the final output stage (RIP) or within an image-editing program such as Adobe Photoshop. This can be confusing. There are many different profiles to deal with and different corrections can be applied at various stages of the workflow. True device-independent color management (i.e., images are stored in L*a*b*) is still in its infancy and will undoubtedly experience some growing pains before gaining full acceptance. CMYK is certainly attainable and is a good place to start. The best advice is to have a clear understanding of the goal, which is to match the proof to the press. Procedurally, a press sheet is measured and the proof is corrected to match that sheet The process is verified by outputting a second proof with the correction applied to verify the match. Example 3, which follows, illustrates the process with real-world data.



ELECTRONIC FILE VALUES

OVERPRINT	C	M	Y	K
1A	0	100	80	0
1B	80	0	60	0
1C	80	20	100	20
1D	20	60	0	20
1E	100	40	80	80

Table 25

Example 3: The overprint patches of the press characterization target are measured with a spectrophotometer. Recall, that these targets have many of these patches. The FTA target (*Figure* 116) has 1,344 of them. While these measurements can be made manually, it is much more reliable and efficient to use a spectrophotometer that reads strips or one mounted on an x-y table (*Figure* 126). The

PRESS VS. PROOF

	PRESS			PROOF			
OVERPRINT	L*	a*	b*	L*	a*	b*	CMS(2, 1)
1A	46.03	62.03	51.07	49.02	71.85	32.78	11.91
1B	53.45	–49.54	27.35	63.74	–52.94	13.33	8.39
1C	38.70	–31.06	33.21	48.22	–37.51	42.36	6.09
1D	44.31	27.44	–7.21	55.18	31.05	–19.14	8.53
1E	18.07	–11.20	8.40	21.26	–19.47	–0.32	9.63

Table 26

PRESS VS. PROOF (CIELab CORRECTED)

	PRESS			PROOF			
OVERPRINT	L*	a*	b*	L*	a*	b*	CMS(2, 1)
1A	46.03	62.03	51.07	47.71	59.94	47.84	1.45
1B	53.45	–49.54	27.35	53.51	–49.80	30.71	1.50
1C	38.70	–31.06	33.21	42.61	–33.96	27.99	3.76
1D	44.31	27.44	–7.21	42.87	26.49	–8.09	1.12
1E	18.07	–11.20	8.40	17.62	–5.50	7.00	5.53

Table 27

PRESS VS. PROOF (DOT GAIN CORRECTED)

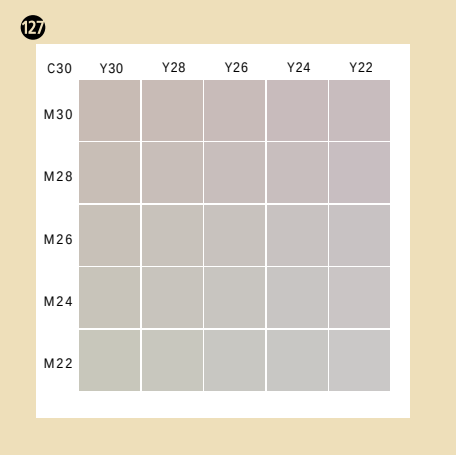
	PRESS			PROOF			
OVERPRINT	L*	a*	b*	L*	a*	b*	CMS(2, 1)
1A	46.03	62.03	51.07	49.11	70.23	45.73	5.53
1B	53.45	–49.54	27.35	61.00	–57.84	24.18	4.82
1C	38.70	–31.06	33.21	45.53	–36.52	36.07	4.41
1D	44.31	27.44	–7.21	50.78	32.90	–21.80	8.93
1E	18.07	–11.20	8.40	23.38	–16.85	6.03	5.99

Table 28

measured L*a*b* values are then input to profile building software. The profile is used to make the corrections to the proof.

Some sample numbers are shown in *Tables 25 to 28*. *Table 25* shows the C, M, Y and K values of the first five patches of the FTA press characterization target. *Table 26* shows the values from a press sheet (using a default cutback curve) and a digital proof. After the profiles were generated, the proof was corrected to match the press sheet and the target was again output on the digital proofer using these corrections. *Table 27* shows the results.

Also listed in *Tables 26* and *27* are the CMC (2,1) color difference values calculated for each patch between the press and proof. As a comparison, *Table 28* shows the degree of match achieved using dot-gain compensation. Of course, with the full 1,344 overprint patches, a more useful metric is needed for



127 This sample target visually evaluates the best combination of C, M and Y to give a gray balance for a cyan value of 30.

the degree of match. One such metric is the average color difference for all 1,344 patches. For this case, the averages were 2.5 using CIELab and 6.9 using dot gain.

GRAY BALANCE

One of the key parameters in process printing is gray balance. Recall that printing equal dot percentages of cyan, magenta and yellow results in a brown color, not a neutral. In order to print neutrals and process images without a cast, it is important to know the correct combination of cyan, magenta and yellow that gives the best neutral for the particular printing process. The information is used in the conversion to C, M, Y and K. When a neutral color is converted to C, M, Y and K, the proportion of C, M, Y is adjusted to the gray-balance value.

Table 29 shows some typical values for gray balance (from FIRST). The values are the dot percentages in the electronic file that will result in a neutral color when overprinted. For example, a combination of 30% cyan, 24% magenta and 24% yellow would print as a neutral, equivalent to a 35% black. These are the dot-percent values in the electronic file before output to film, platemaking and printing on the press. Once the press has been characterized and all corrections applied, these values can be adjusted to give a visual neutral in gray-balance test patches, such as those found in the FIRST control target (*Figure* 115, 118).

A more systematic way of determining the gray-balance values is to print a special test target. If the proof has been matched to the press as outlined earlier, this target can be printed on the proofing device as opposed to the press – a much more cost-effective method. *Figure* 124 shows an example of a target used to determine the magenta and yellow values needed to combine with a cyan of 30 in order to print a neutral. The target is arranged as a set of overprints where every patch has a cyan value of 30. Along the columns, the yellow values increase with the magenta at a constant value. Along the rows, the magenta values increase with the magenta at a constant value. The net effect is a systematic combination of many different C, M, Y values, all with cyan of 30. Once the target has been printed, a visual determination can be made as to which patch is the best neutral. The C, M, Y values can then be read directly from the target. Many times, particularly if the dot-percent increment is small, it is difficult to tell which patch is the best neutral. Using a spectrophotometer, the L*a*b* values of the patches can be measured. The patch with the a and b values closest to 0 and 0 is the most neutral patch.

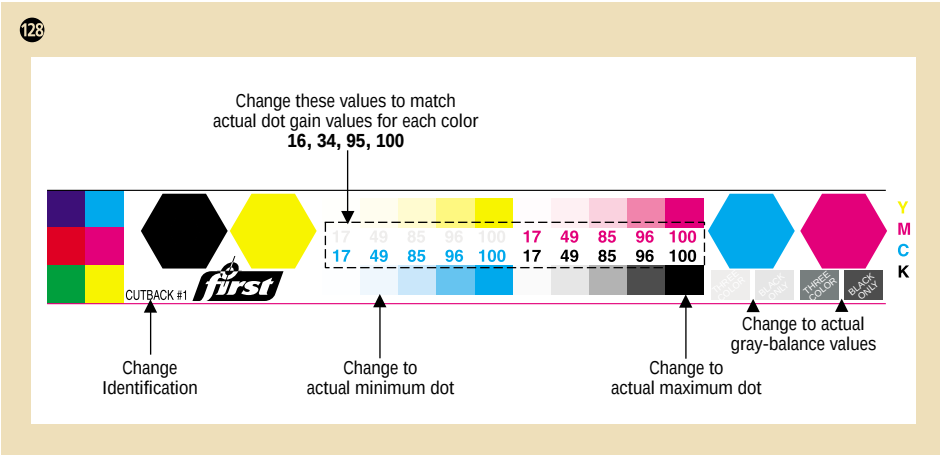
Note: *Figure* 125 *is not meant to represent flexo printing and flexo gray balance. It is for illustration only, not for color accuracy.*

Using spectrophotometric measurements

GRAY BALANCE

	FILM DOT PERCENTAGE				
CYAN	5	10	30	70	90
MAGENTA	3	7	24	58	78
YELLOW	3	7	24	58	78
BLACK	8	14	35	76	98

Table 29



128 This FIRST control target indicates values which are changed for the specific press.

and CIELab ICC profiles, gray-balance values are inherently evaluated. An ICC profile links a L*a*b* value with a particular CMYK value for a given device, such as the press. Once the profile is generated, CMYK values for any given L*a*b* value are available. Gray-balance values are the CMYK values where K equals to zero, corresponding to L*a*b* values with a* and b* of 0 and 0.

PROCESS CONTROL

It was mentioned in the beginning of this section that process-color printing requires consistency, first and foremost. Once the press and the entire process have been optimized and characterized, it is imperative to keep all the variables to specification and within tolerance.

A control target should be printed on every job. The FIRST control target is shown again in *Figure* 128. After press characterization, the tint values next to the tint patches should be changed to the actual values determined. This will allow the press operator to simply read the values and verify that the values remain within specification. Likewise, actual minimum and maximum dot should be used, as well as the actual gray-balance values. With these changes, the control target becomes specific for the particular press that was characterized. The target has an area to put an identification name or number (Cutback #1 in *Figure* 128).

CONTROL TARGET ELEMENTS

ELEMENT	METHOD OF MEASUREMENT
Slur	visual
Dot Gain	densitometer
Density	densitometer
Ink Trap	visual, densitometer
Gray Balance	visual, densitometer

Table 30

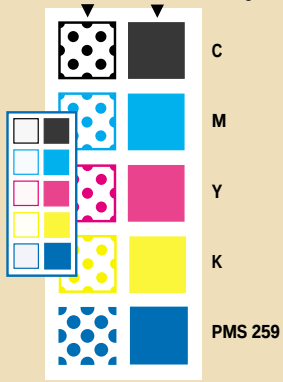
The control target gives a continual visual indication and with simple densitometric measurments assures that the press is still running to specifications. The elements, along with their method of measurement, are summarized in *Table 30*.

Some of the elements listed can be checked both visually and with a densitometer. The ink trap and gray-balance values are measured during characterization and serve as the reference point during production. The consistency of the values is more important than the actual values. The gray-balance patches are a good example of a key visual indicator of press variation. The gray in the three-color overprint patch is extremely sensitive to even small shifts in values of the cyan, magenta or yellow. Even small varia-

129 A FIRST run target is used instead of the control target, when limited space on the package is available.

130 In this typical production run spec sheet, the target viscosity and density for each ink is specified.

129



130

ABC Printing Company
Production Run Spec Sheet

Order #: 3064A
Customer: America's Favorite Bread
Linear Feet: 35,000
Substrate: 140#/liner board

Print Deck #	Metering	Volume	Line Count
1	Two-Roll	5.1	360
2	Chambered	1.9	600
3	Chambered	1.9	600
4	Chambered	1.9	600
5	Chambered	1.9	600
6	Chambered	5.1	360

Print Station	Color	Aim Viscosity	Acutal Viscosity	Aim Density	Actual Density
1	White	30		0.19	
2	Cyan	25		1.35	
3	Magenta	25		1.25	
4	Yellow	25		1.00	
5	Black	28		1.50	
6	Varnish	22		n/a	

tions, not readily visible in other colors, will be apparent in these patches.

Certain press configurations or package types do not have trim areas where control targets fit. In these cases, a smaller, more limited target, called a run target should be placed in an inconspicuous place in the image area. *Figure* 129 shows the run target specified in FIRST. Good places include the back panel, flaps which will not be visible in the final product or even in the nutrition information area. These targets provide the minimum information required to maintain dot gain and density. On special colors, they can be used to provide CIELab color data.

Each production run should have a production run spec sheet. An example is shown in *Figure* 130. In this example, the target viscosity and density for each ink is specified. There is room on the sheet to record the actual values during the production run. The actual values of viscosity and density can then be plotted on a control chart to monitor the variables for many jobs. On a long production run, the variables should be frequently measured and a control chart created for the job itself. Details of control charts are covered in the Quality chapter, Book 3.

An important part of production control that should not be overlooked is the calibration of all measurement instruments.

- Densitometers should be periodically checked against reference standards supplied by the manufacturer. Each instrument comes with calibration procedures in case adjustment is needed.
- Spectrophotometers come with a white standard and a table of what the readings should be on that standard. They too need to be periodically checked.
- As simple as it sounds, even a micrometer needs to be checked. This is as simple as making sure it reads zero when it closes with no sample.

Appendix A

A: REFERENCE RESOURCES

ANSI/CGATS.4-1993
Graphic Technology – Graphic Arts Reflection Densitometry Measurements – Terminology, Equations, Image Elements and Procedures.

ANSI/CGATS.9-1993
Graphic Technology – Graphic Arts Transmission Densitometry Measurements – Terminology, Equations, Image Elements and Procedures.

ANSI/CGATS.5-1993
Graphic Technology – Spectral Measurement and Colorimetric Computation for Graphic Arts Images.

ANSI/IT8.7/1-1993
Graphic Technology – Color Transmission Target for Input Scanner Calibration.

ANSI/IT8.7/2-1993
Graphic Technology – Color Reflection Target for Input Scanner Calibration.

ANSI/IT8.7/3-1993
Graphic Technology – Input Data for Characterization of 4-Color Process Printing.

ANSI PH2.30-1989
Graphic Arts and Photography – Color Prints, Tranparencies and Photomechanical Reproductions – Viewing Conditions.

ISO 3664-1999 (replaced ANSI.PH2.30-1989)
Viewing Conditions for Graphic Technology and Photography.

Appendix B

B: DENSITY-BASED MEASUREMENTS

TRANSMISSION:

DOT PERCENT (MURRAY-DAVIES EQUATION):
The equation shown is for the case of D-max greater than 3.0 with the densitometer zeroed on clear film. A black-and-white densitometer is used.

$$\text{\% dot} = 100 \times \left(1 - 10^{-DT}\right)$$

where
DT is the density of the tint

REFLECTION:

In all these calculations, the appropriate filter needs to be used for the process color (CMY) being measured. Refer to Chapter 3, *Table 2*.

DOT PERCENT (MURRAY-DAVIES EQUATION):

$$\text{\% dot} = \frac{100 \times \left[1 - 10^{-(DT - DP)}\right]}{\left[1 - 10^{-(DS - DP)}\right]}$$

where
DS is the density of the solid
DP is the density of the paper or substrate
DT is the density of the tint

TRAP (use filter for second down ink)

$$\text{\% Trap} = \frac{100 \times \left(D_{OP} - D_1\right)}{D_2}$$

where
D_{OP} is the density of overprint
D_1 is the density of first down ink
D_2 is the density of second down ink

GRAYNESS

$$\text{\% grayness} = 100 \times \left(\frac{D_L}{D_H}\right)$$

where
D_L is the density using the filter which gives the lowest reading
D_H is the density using the filter which gives the highest reading

HUE ERROR

$$\text{\% hue error} = \frac{100 \times \left(D_M - D_L\right)}{\left(D_H - D_L\right)}$$

where
D_L is the density using the filter which gives the lowest reading
D_M is the density using the filter which gives the middle reading
D_H is the density using the filter which gives the highest reading

PRINT CONTRAST

$$\text{\% Contrast} = \frac{100 \times \left(D_S - D_T\right)}{D_S}$$

where
D_S is the density of the solid
D_T is the density of the shadow tint; typically 70%

Appendix C

C: COLORIMETRIC CALCULATIONS

COL0R DIFFERENCE EQUATION – DELTA E (ΔE)

Note: These calculations are in the L*a*b* color space. For clarity, the (*) have been omitted.

L*a*b*

$$\Delta E_{Lab} = \sqrt{\left[(L_1 - L_2)^2 + (a_1 - a_2)^2 + (b_1 - b_2)^2\right]}$$

CMC

$$\Delta E_{CMC} = \sqrt{\left[\frac{(L_1 - L_2)^2}{l\,S_l} + \frac{(C_1 - C_2)^2}{c S_C} + \frac{(H_1 - H_2)^2}{S_H}\right]}$$

where

l **and c** are adjustable parameters (usually set to 2 and 1)

$C_1 = \sqrt{(a_1^2 + b_1^2)}$

$C_2 = \sqrt{(a_2^2 + b_2^2)}$

$H_1 - H_2 = \sqrt{[(\Delta E_{LAB})^2 + (L_1 - L_2)^2 + (C_1 - C_2)^2]}$

$S_L = \dfrac{0.040975L}{(1 + 0.01765° L)}$ if L is greater than 16

$S_L = 0.511$ if L is less than or equal to 16

$S_C = 0.638\left(\dfrac{1 + C}{1 + 0.0131C}\right)$

$S_H = SC\,(Tf + 1 - f)$

$f = \sqrt{\left(\dfrac{C^4}{C^4 + 1900}\right)}$

$T = 0.56 + ABS[0.2\cos(h+168)]$ for h equal to 164° to 345°

$T = 0.36 + ABS[0.4\cos(h+35)]$ for angles not 164° to 345°

$h = \arctan(b/a)$

In the equations starting with S_L, non-subscripted values refer to the standard. The result of the CMC calculation depends on which of the two points is the standard.

CIE'94

$$\Delta E_{CIE'94} \quad \sqrt{\left[\frac{(L_1 - L_2)^2}{K_L S_L} + \frac{(C_1 - C_2)^2}{K_C S_C} + \frac{(H_1 - H_2)^2}{K_H S_H}\right]}$$

where

K_L, K_C and K_H are adjustable parameters (usually set to 2, 1 and 1)

$S_L = 1$

$S_C = 1 + 0.045C$

$S_H = 1 + 0.015C$

C refers to the C value of the standard, as in the CMC case.

CONT'D ON FOLLOWING PAGE

Additional material on press characterization is available from the FTA.

METARISM INDEX (MI)

$$\mathbf{MI} = \sqrt{\left[(\Delta \mathbf{L_1} - \Delta \mathbf{L_2})^2 + (\Delta \mathbf{a_1} - \Delta \mathbf{a_2})^2 + (\Delta \mathbf{b_1} - \Delta \mathbf{b_2})^2\right]}$$

where

ΔL_1 = Difference in L value between the two samples under illuminant 1.

ΔL_2 = Difference in L value between the two samples under illuminant 2.

Δa_1 = Difference in a value between the two samples under illuminant 1.

Δa_2 = Difference in a value between the two samples under illuminant 2.

Δb_1 = Difference in b value between the two samples under illuminant 1.

Δb_2 = Difference in b value between the two samples under illuminant 2.

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FLEXOGRAPHY:
Principles & Practices

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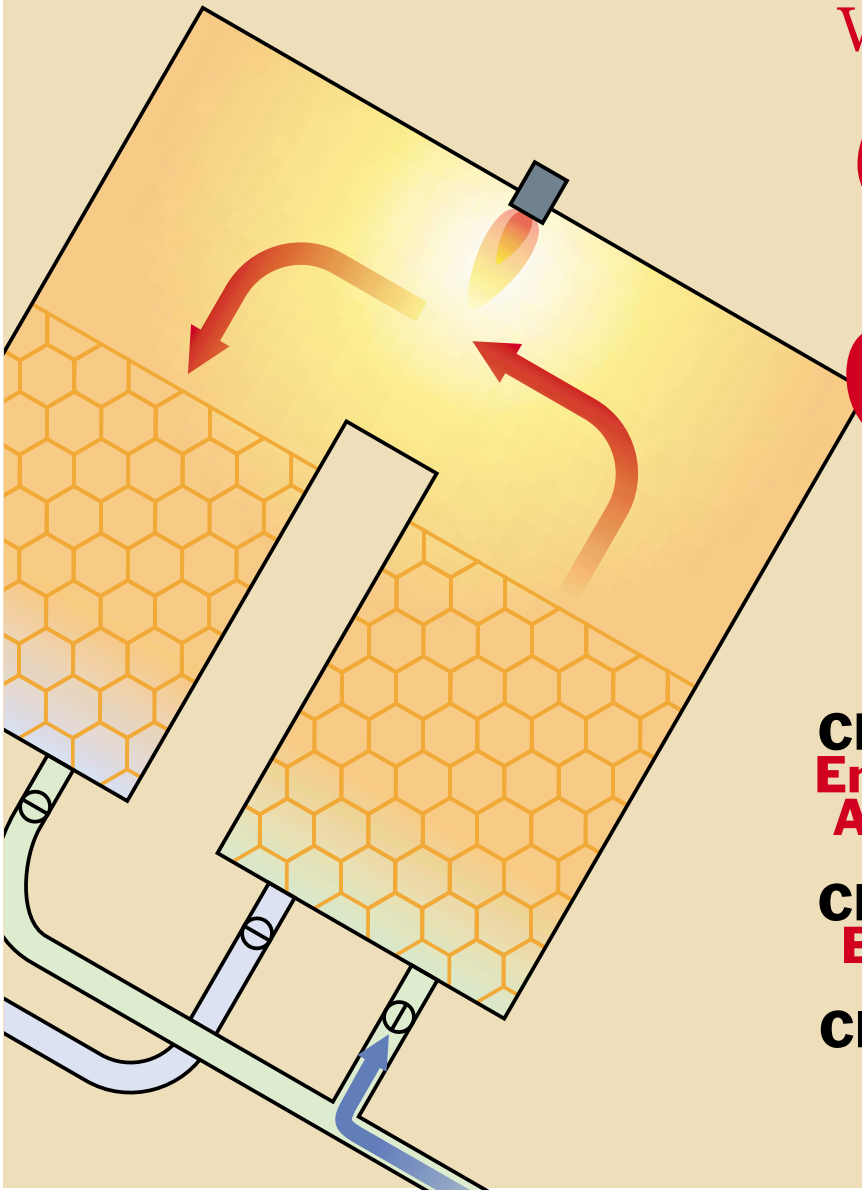

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Environment And Safety

CHAPTER 2
Bar Codes

CHAPTER 3
Quality Control

Flexography: Principles & Practices

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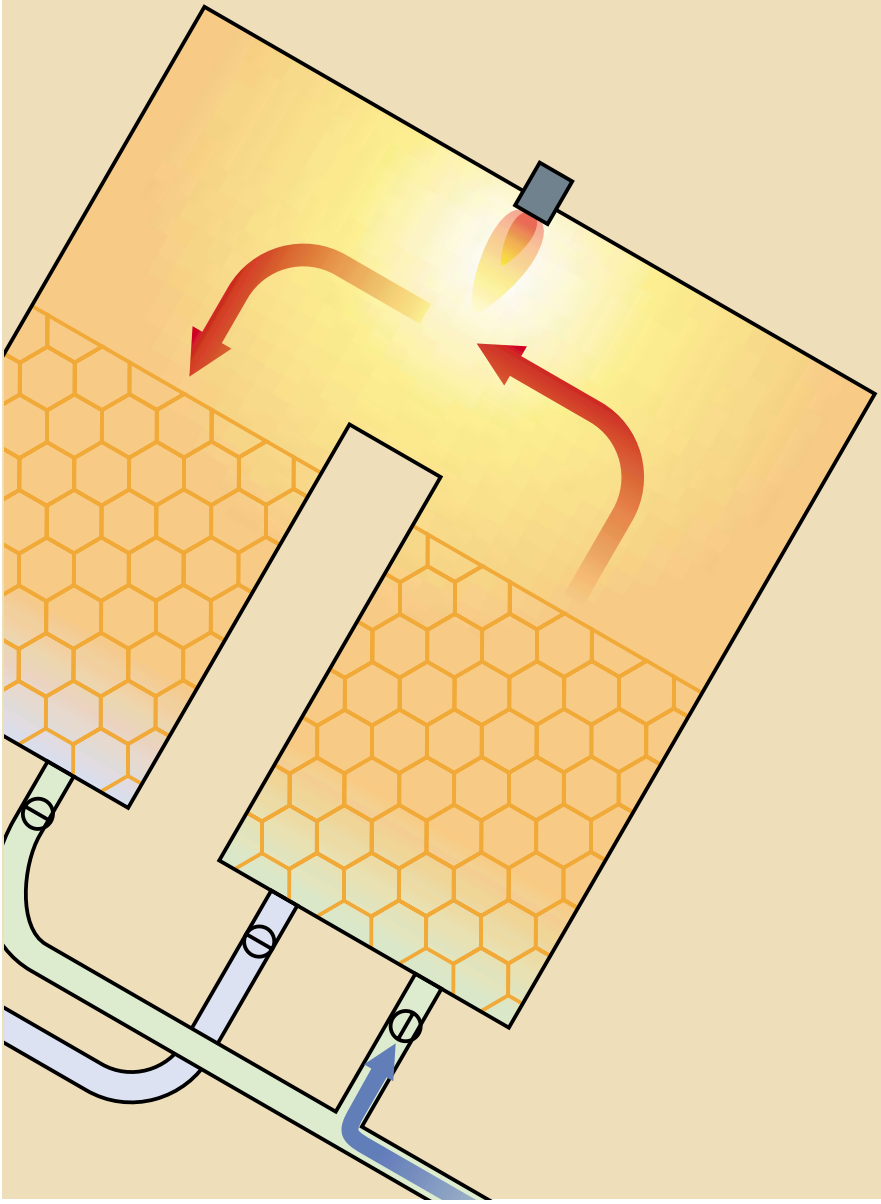
CHAPTER 1

Environment And Safety



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Introduction

Printing is a chemically intensive process and the pollution it produces affects the lives of millions of people. Environmental laws have been enacted to help create and maintain a healthy environment for all. Laws also have been promulgated to protect the worker. To the printer, this means that the amount of pollutants emitted from their operation must fall within certain limitations.

Since the creation of the United States Environmental Protection Agency (USEPA) more than 25 years ago, numerous federal regulations to protect the air, water and land have been enacted that affect the flexographic printer. These regulations are based on several federal statutes, including the Clean Air, Toxic Substances Control, Resource Conservation and Recovery, Comprehensive Environmental Response, Compensation and Liability, Clean Water, and Pollution Prevention acts. In addition, the Occupational Safety and Health Act, administered by the Occupational Safety and Health Administration (OSHA) provides guidelines for workers' protection.

Compliance with these regulations requires the reduction of pollutants emitted from facilities into the environment. Additional benefits from reducing pollution emissions are improved working environment: reduced indoor air pollutants, reduced handling of hazardous solvents by employees, and the appreciation by company employees of the need to make a conscious effort to further reduce waste generation.

Although the statutes discussed in this chapter originate at the federal level, very often it is the state or local environmental regulatory agency that implements the actual regulations. State/local laws can be more restrictive in some cases.

Because of the many acronyms used in this chapter, a referral list is provided in *Appendix A*.

Clean Air Act

In 1970, the United States Congress found that the growth of urban areas and industrial activities would bring mounting dangers to public health and welfare. To improve air quality by reducing the amounts of pollutants emitted, the Clean Air Act was signed into law.

Perhaps the most extensive statute in recent years to impact flexographic printers were the Clean Air Act Amendments of 1990 (CAAA). The CAAA included new provisions to control emissions of volatile organic compounds from large and small operations. To meet new national ambient air quality standards established by the USEPA, many facilities either had to tighten controls of air pollutants such as volatile organic compounds, or reduce emissions for the first time. In 1996, the USEPA issued new rules under the CAAA which affected wide-web flexographic facilities, in response to the need for National Emission Standards for Hazardous Air Pollutants (NESHAP). In addition a revised New Source Review is expected to be released in the late 1990s.

The CAAA was intended to meet unaddressed or insufficiently addressed problems such as acid rain, ground-level ozone, stratospheric ozone depletion and air toxics. The CAAA gave the USEPA the authority to set National Ambient Air Quality Standards (NAAQS) for six criteria pollutants: sulfur dioxide, oxides of nitrogen, particulate matter, carbon monoxide, lead and ozone. It also established a list of nearly 200 toxic air pollutants and had provisions for fixing the upper-atmosphere ozone layer. Once the USEPA established a NAAQS for these compounds, each state became responsible for developing its own program for achieving and maintaining these standards. Because of its impact on small businesses, the CAAA also provided for assistance programs to help them comply with the new regulations. These amendments also signaled a change from past pollution control approaches by promoting pollution prevention. Innovations in this law include programs based on cooperation between government and industry, and pollution-prevention incentives based on market forces.

The goal of the CAAA was to reduce air pollution by 56 billion pounds per year. These reductions are expected to come from cutting emissions from major, as well as many minor, sources. In particular, control of ozone and air toxics have an impact on flexographic printing facilities.

NATIONAL AMBIENT AIR QUALITY STANDARDS FOR OZONE

Title I of the CAAA defines the NAAQS for ozone precursors and places more than 90 urban areas with ozone problems into one of five non-attainment classifications. A non-attainment area is one which does not meet the NAAQS for a particular pollutant. Once a region has been designated as a “non-attainment” area, USEPA mandates that the state must achieve attainment by a certain date. Areas range from the least polluted (marginal) and progress upward through moderate, serious, severe and extreme.

An area is designated non-attainment when the area fails to meet the national ambient air quality standard, which for ozone is 0.12 parts per million (ppm). Ground-level ozone (smog) is produced when volatile organic compounds

(VOCs) and oxides of nitrogen (NO_X – a product of combustion) are exposed to ultraviolet light emitted from the sun.

Despite strong industry opposition, on July 16, 1997 USEPA Administrator Carol Browner signed the final rules which set new NAAQS for ozone and particulate matter (PM). For ozone, the recommended final standard was changed to a standard of 0.08 parts per million measured over eight hours, with the average fourth highest concentration over a three-year period determining whether an area is out of compliance. The new rule sets an annual concentration of 15 micrograms per cubic meter of PM 2.5 microns or less in diameter and a 24-hour standard of 65 micrograms per cubic meter.

The USEPA has been strongly criticized for not complying with the Small Business Regulatory Enforcement Fairness Act (SBREFA), which requires federal agencies to follow certain procedures in assessing the impact of major regulations on small businesses. USEPA explains that the rule does not establish any requirements applicable to small businesses. Yet, because of the 1997 changes in the NAAQS, nearly double the number of counties will be considered in ozone non-attainment. Many more businesses will, therefore, be subject to new or additional emission controls depending on the implementation plans developed by the states.

A single ozone transport region exists for the northeastern United States (CT, DE, ME, MD, MA, NH, NJ, NY, PA, RI, VT and the District of Columbia) whereby all areas are considered at least moderate non-attainment.

REDUCING VOLATILE ORGANIC COMPOUND EMISSIONS

Control of ozone smog has had a significant effect on the flexographic printer. VOCs are released from inks, solvents, coatings and other materials. Therefore, to reduce ground level ozone, emissions of VOCs had to be reduced through either pollution prevention (such as a water-based ink system) or control technologies (such as adding oxidizers).

Control requirements for printers can be classified as requirements that are imposed on existing and new business or equipment. The distinction between the two is that control requirements for existing operations are usually not as stringent as those for new installations. New installations are expected to meet more stringent requirements because of technological advances.

The Control Techniques Guidelines (CTGs) for the graphic arts industry were published in December 1978 and defined Reasonably Available Control Technology (RACT) for flexography. Subsequent USEPA guidance limited the applicability of RACT requirements to sources that emit 91 tons per year or more of VOCs. The CAAA now require the use of RACT for VOC sources that emit as little as 9 tons per year in extreme ozone non-attainment areas. Therefore, states are now required to establish and implement RACT for those smaller sources as well. In some areas of the country, such as the New York metropolitan area, all flexographic facilities, regardless of the amount of VOC emissions, are required to comply with RACT under state law.

The USEPA has studied the economic and technical feasibility of control options for small (less than 100 tons per year potential uncontrolled emissions)[1] flexographic printing facilities. A 1992 USEPA document, *Alternative VOC Control Techniques Options for Small Rotogravure and Flexography Facilities*, PB93-1223071, identifies capture and control technologies and the costs associated with these technologies. Industry representatives caution that the costs for capture and control technologies may be severely

[1] A potential emission is the capacity of a press operating under maximum operational design for 24 hours a day and 365 days a year.

underestimated. Another USEPA publication, *Best Demonstrated Control Technology Guidelines for Graphic Arts*, PB91-168427, compiles numerous case studies of flexographic facilities that have achieved VOC control efficiencies of 90% or better.[2]

Solvent Recovery

Carbon adsorption systems work by capturing organic solvents in a vapor form, removing them from the air and then turning them back into a liquid state, thus recovering the solvent. After this process, the airstream will contain minimal amounts of VOCs and will be well within the allowable limits. The process uses activated charcoal or carbon to separate solvents from an airstream. When the vapor-laden air from the dryers passes through a bed of this carbon, the carbon simply catches and retains the solvent.

There should be two carbon beds. After one has absorbed its limit of solvents, the airstream shifts to a second bed while the first is regenerated. To regenerate, the carbon is heated until it desorbs the solvent. Steam is often used for this because it provides excellent heat transfer to the carbon and because it is an inert medium for carrying away the desorbed solvent. The condensate that results is a mix of water and solvent. For carbon adsorption to be technically feasible, the water-solvent mixture must be separated by decantation or distillation.

Solvent mixtures that are insoluble in water are often used in the graphic arts industry. When the solvent can be separated readily from the water and reused as raw material, then the cost savings make solvent-recovery systems a good choice.

Unfortunately, most solvents used in flexographic printing are blends of alcohols and acetates, many of which are water-soluble. In distillation, a liquid is boiled and the resulting vapor is condensed. If the vapor and liquid have different boiling points, separation of the components results. But if the boiling points are the same, the end product is essentially inseparable and the mixture is termed an azeotrope.

Acetate solvents' components are known to hydrolyze in the recovery process to acetic acid. Any acid carried into the final product must be neutralized.

With all the problems in trying to separate solvents into reusable blends, carbon adsorption is not widely used by flexographic printers. Those facilities that can utilize azeotropic mixtures, such as an alcohol-acetate blend, may use carbon adsorption systems.

Oxidation

Destroying solvents by oxidation is a process that uses heat and oxygen to convert organic, hydrocarbon solvents to carbon dioxide and water vapor.

$$\left(HC + O_2 \xrightarrow[\text{heat}]{} H_2O + CO_2 \right)$$

There are two oxidation techniques appropriate for compliance: thermal and catalytic oxidation.

Thermal oxidation relies on the combination of high temperature (typically 1,350 to 1,800° F) , sufficient retention time (0.7 to 1.0 seconds) and effective gas-phase mixing to achieve VOC destruction in the target range of 98% to 99%. A basic thermal oxidizer airflow pattern is depicted in *Figure* ❶.

Because fuel is so expensive, virtually all thermal oxidizers come equipped with some capacity for heat recovery to minimize fuel consumption. When the heat exchanger is an integral part of the oxidizer, the incoming, solvent-laden air is preheated by the hot exhaust. This is known as primary heat recovery. The closer the preheated air temperature is to the final oxidation temperature, the less fuel that is used.

There are two basic types of thermal oxi-

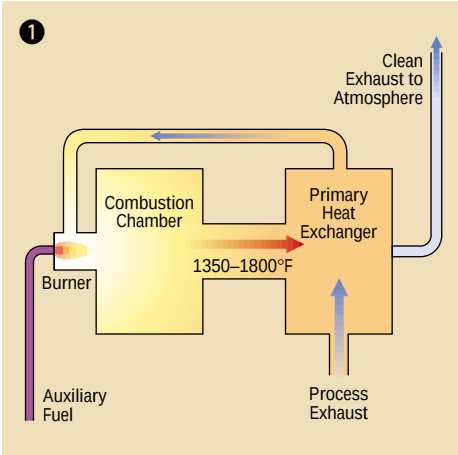
[2] These documents are available to the public through the National Technical Information Service, 5285 Port Royal Road, Springfield, VA 22161 (800) 553-6847.

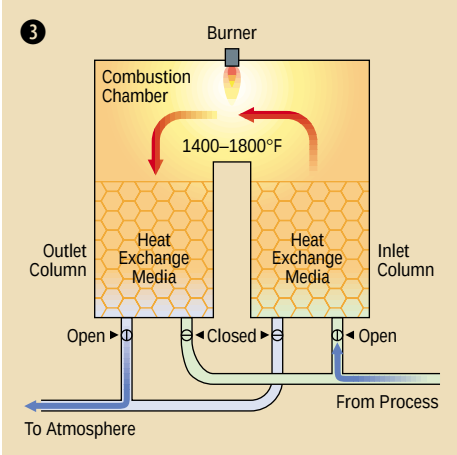
❶ A basic thermal oxidizer air-flow pattern. High temperatures, sufficient retention time and effective gas-phase mixing combine to achieve VOC destruction.

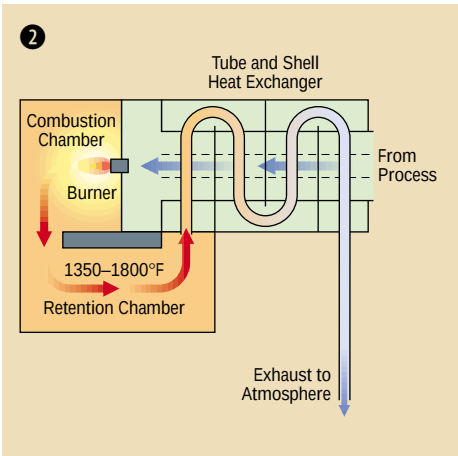
❷ Air flow pattern through recuperative thermal oxidizer. In this process, there is a direct transfer of heat from the clean exhaust to the process gases.

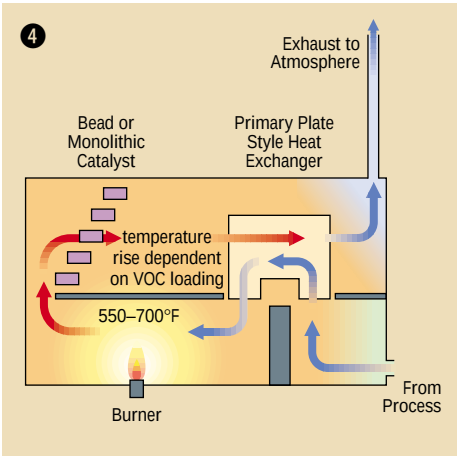
❸ Regenerative heat exchanger efficiency increases where recupertive technology leaves off (i.e., at 80–95% efficiency).

❹ A typical catalytic oxidizer flow diagram. Here, a catalyst is used to lower the total energy required to achieve the conversion from hydrocarbon to carbon dioxide and water vapor.









dizers each with a different method of heat exchange: recuperative and regenerative. Recuperative oxidizers are distinguished by the direct transfer of heat from the clean exhaust to the process gases (typically via a shell and tube style heat exchanger). Recuperative heat exchangers' efficiencies typically vary from 4% to 80% depending on the expected solvent loading conditions. The air flow pattern through a recuperative thermal oxidizer is illustrated in *Figure* ❷.

Regenerative thermal systems differ from recuperative in that heat is transferred from the cleaned exhaust to the process gases via a heat exchange medium such as ceramic saddles or rock. The medium is alternately heated by the clean exhaust and cooled by lowering the air temperature prior to discharge into the atmosphere. Then, the medium desorbs heat to the incoming process gases, heating the air stream to nearly the operating control temperature at which complete conversion will occur. At least two regenerative beds are required so that process air can be cycled back and forth between the beds, alternately heating and cooling the media (*Figure* ❸). Regenerative heat exchanger efficiency increases where recuperative technology leaves off (i.e., at 80% to 95% efficiency).

Catalytic oxidation is a form of thermal oxidation that uses a catalyst to lower the total energy required to achieve the conversion from hydrocarbon to carbon dioxide and water vapor. Typical destruction efficiencies range from 95% to 99%. In this form of technology, the catalyst induces oxidation at tem-

peratures ranging from 550° to 700° F, depending on the chemical make-up of the air stream. Recently introduced catalysts, designed for specific solvent chemistry and concentrations, are being tested at inlet temperatures as low as 450° F. *Figure* ❹ illustrates a typical catalytic oxidizer flow diagram.

Many chemicals exhibit catalytic activity. Precious metal catalysts are available in bead and block monolith form as well as other geometric configurations. Base metal catalysts such as manganese dioxide are also used in some cases for VOC applications.

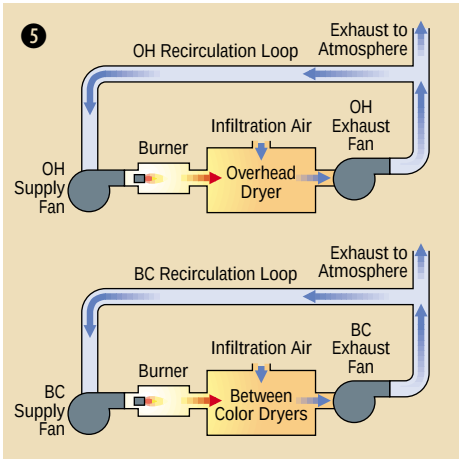
Catalysts have a normal life expectancy of 5 to 15 years, depending on operating temperature conditions and the airstream chemistry. With respect to temperature, too little heat at the inlet to the catalyst can result in a build up of VOCs on the surface of the catalyst, which in turn can result in damage to both the catalyst and machinery when these solvents finally ignite within the bed. Continuous exposure to high-metal catalysts can result in temperatures as high as 1,200° F. In any case, a properly designed system will include safeties to protect against either temperature extreme.

With respect to air-stream chemistry, there are a number of chemical substances that can influence catalyst activity. These substances fall under the categories of poisons and masking agents. Fast acting poisons such as lead, mercury, arsenic, antimony, iron, tin and lead will reduce catalyst activity at a rate dependent upon the concentration and temperature, and catalyst regeneration is often not possible. Some reversible poisons and masking agents include sulfur, halogens, zinc, phosphorus and silicon. These chemicals tend to coat the surface of the catalyst and can usually be removed with washing techniques and/or increases in temperature. Organic and inorganic solids (particulates) can also block the pores of the catalyst, resulting in reduced activity. However, these particles can normally be removed by either temporarily increasing temperature or by cleaning. Finally, it should be noted that a significant advancement has been made in the development of poison-resistant catalysts and special equipment designs are available to minimize the impact of catalyst-masking problems.

Because each source and facility is unique, choosing the right oxidation technology for any given application will require a thorough analysis of applicable USEPA regulations, the types and concentrations of VOCs generated and the air volume being treated, as well as the typical plant operating parameters. Some generalizations can be made. For instance, capital cost and operating cost are closely tied to the air volume processed and the solvent concentration within the air stream. Therefore, airflow reductions through dryer recirculation loops should be considered, since this will reduce the total volume of air processed while proportionately increasing the solvent concentration (*Figure* ❺).

When multiple presses are connected to a single oxidizer, the overall operating cost is reduced as the unit spends much less time idling at zero solvent load. In addition, heat exchanger efficiency is improved due to the higher heat transfer within the exchanger. The majority of oxidizers being sold at this time are for multiple press applications.

Finally, the oxidation process results in



❺ Oxidizers can be sized to treat the emissions from one or more presses with the latter configuration providing multiple benefits to the flexographic printer.

the discharge of hot, clean air into the atmosphere. Flexographic printers should consider directing this energy back to their process, either through a secondary heat exchanger or thermostatically controlled mixing boxes. Properly designed, a secondary heat recovery system will often reduce operating costs enough to provide an economic payback on the initial investment.

Low-VOC Inks and Solvents

Emissions of VOCs from flexographic printing can be reduced or eliminated at the source by pollution-prevention techniques such as converting from a solvent-based system to a water-based or ultraviolet/electron beam (UV/EB) cured system. Limitations are associated with each approach and with individual circumstances, including the type of production, customer base, end-use and type of ink used.

According to the CTG for flexography, in use at the press, the allowable VOC content in water-based ink must be 25% by volume or less of the solvent portion. These inks, in many states, are exempt from emissions controls because the VOC content meets the definition of a high-solid, waterborne ink. However, as air emission regulations have become more strict, companies using inks with even significantly less than 25% VOCs are no longer exempt from further control.

Water-based inks are more commonly used in publication and corrugated flexographic printing. Paper is an excellent substrate for waterborne inks. Some lower-VOC inks can be applied to non-adsorbent substrates, such as film or foil, by installing a corona treater and altering the surface tension.

Today, UV-cured inks are being used in narrow-web and a few wide-web flexographic operations. UV will continue to grow in importance because of its advantages in environmental areas and print quality. *(See Ink Chapter for additional information on flexographic inks and solvents.)*

TITLE V PERMITTING PROGRAM

Under Title V of the CAAA, every major source of air pollutants, and all other sources regulated will have to obtain a federally enforceable operating permit. This permit program covers both major sources of VOC emissions and major sources of emissions of hazardous air pollutants.

The major source threshold for VOC emissions is dependent on the non-attainment status accorded a particular region. A source in a non-attainment area that is defined as "major" must install Reasonably Available Control Technology (RACT) as prescribed in the local State Implementation Plan. A major source is defined both by the size of the source's facility-wide emissions and the category of the non-attainment area. For example, a facility in a severe non-attainment area is considered major if its potential to emit is more than 25 tons per year, while a facility in a moderate non-attainment area is major when its potential to emit is more than 50 tons per year *(Table 1)*.

However, the major source threshold for hazardous air pollutants is 10 tons of one or 25 tons of a combination of hazardous air pollutants, regardless of where the facility is located.

Each state permit program must contain all of the following elements:

- requirements for permit applications;
- monitoring and reporting requirements;
- a permit fee system;

MAJOR SOURCES OF VOLATILE ORGANIC COMPOUNDS

NON-ATTAINMENT LEVEL	THRESHOLD TONS PER YR
Marginal	100
Moderate	100
Serious	50
Severe	25
Extreme	10

Table 1

- provisions for adequate personnel and funding to administer the program;
- authority to terminate, modify or revoke and reissue permits;
- authority to enforce permits, permit fees and the requirement to obtain a permit, including civil penalties of not less than $10,000 per day, and appropriate criminal penalties;
- authority to assure that no permit will issue if the USEPA objects to its issuance in a timely manner;
- procedures to expedite the application process;
- authority for public review of all permit applications; and
- provisions to allow operational flexibility at the permitted facility.

The permit document itself must meet all of the following requirements:

- be issued for a fixed term, not to exceed five years;
- contain limits and conditions to assure compliance;
- include a schedule of compliance; and
- include inspection, entry, monitoring, compliance, certification and reporting requirements to assure compliance.

A state permitting authority may opt to issue general permits for groups of similar non-major sources. Under this approach, each individual source would still be required to file an application. All sources required to obtain a permit must file an application with the state agency within 12 months after the date the USEPA approves or develops a program applicable to that source. The state must notify all contiguous states and any state within 50 miles of the source of any permitting activity and provide an opportunity to comment. The state must also send a copy of the permit application to the USEPA. The USEPA has 45 days to review and object to any permit application.

NEW SOURCE REVIEW AND EMISSION OFFSETS

New major stationary sources of air pollution and major modifications to major stationary sources are required by the Clean Air Act to obtain an air pollution permit before commencing construction under the Code of Federal Regulations (CFR), Title 40, Parts 51 and 52 (commonly written in the format 40 CFR Parts 51 and 52)[3]. The process is called new source review and is required whether the major source or modification is planned for an area where the national ambient air quality standards are either exceeded (non-attainment areas) or acceptable (attainment). Permits for sources in attainment areas are referred to as prevention of significant deterioration (PSD) permits, while sources located in non-attainment areas are referred to as non-attainment area (NAA) permits.

The PSD and NAA requirements are pollutant-specific. For example, although a facility may emit many air pollutants, only one or a few may be subject to PSD or NAA permit requirements, depending on the magnitude of the emissions of each pollutant. Also, a source may have to obtain both PSD and NAA permits if the source is in an area designated non-attainment for one or more of the pollutants.

The basic goal of the PSD regulations are:

- to ensure that economic growth will occur in harmony with the preservation of existing clean air resources;
- to protect the public health and welfare from any adverse effect which might occur, even at air pollution levels better than the NAAQS; and
- to preserve, protect and enhance the air quality in areas of special natural recreational, scenic or historic value, such as national parks and wilderness areas.

The primary provisions of the PSD regula-

[3] The Code of Federal Regulations can be purchased from the U.S. Government Printing Office, Superintendent of Documents, (202) 512-1800.

tions require that the major new stationary sources and major modifications be carefully reviewed prior to construction to ensure compliance with the NAAQS, the applicable PSD air quality increments and the requirement to apply Best Available Control Technology (BACT) to minimize the project's emissions of air pollutants.

A major new source or major modification that would be located in an area designated as non-attainment and subject to an NAA permit must meet stringent conditions designed to ensure that:

- the new source's emissions will be controlled to the greatest extent possible;
- more-than-equivalent offsetting emissions reductions will be obtained from existing sources; and
- there will be progress toward achieving NAAQS.

If a company wants to expand or change a production process or otherwise increase its output of a criteria air pollutant, an offset (a reduction of the criteria pollutant by an amount somewhat greater than the planned increase) must be obtained somewhere else, so that permit requirements are met and the non-attainment area keeps moving toward attainment *(Table 2)*. The company must also install tight pollution controls. An increase in a criteria pollutant can be offset with a reduction of the pollutant from some other stack at the same plant or at another plant owned by the same or some other company in the non-attainment area. Since total pollution will continue to go down, trading offsets among companies is allowed.

EMISSION OFFSET RATIOS FOR VARIOUS NON-ATTAINMENT AREAS

NON-ATTAINMENT LEVEL	THRESHOLD TONS PER YR	NEW SOURCE OFFSET
Marginal	100	1.10 to 1
Moderate	100	1.15 to 1
Serious	50	1.30 to 1
Severe	25	1.30 to 1
Extreme	10	1.50 to 1

Table 2

The preconstruction review requirements for major new sources or major modifications locating in areas designated non-attainment differ from PSD requirements. The emission control equipment for non-attainment areas, lowest achievable emission rate, is defined differently than Best Available Control Technology (BACT) emission control requirement. The source must obtain any required emission reductions (offsets) of the non-attainment pollutant from other sources which impact the same area as the proposed source. The applicant must certify that all other sources owned by the applicant in the state are complying with all applicable requirements of the CAAA, including all applicable requirements in the State Implementation Plan. Such sources, impacting visibility in special areas, must be reviewed by the Federal Land Manager.

The 1997 revision to New Source Review requirements provides industry with greater flexibility, reduces time delays in issuing permits and creates incentives for use of innovative technologies. The reform reduces the regulatory burden on industry, while still ensuring sound environmental protection.

New Source Review ensures that industrial expansion occurs in harmony with environmental protection. New Source Review requires large industrial facilities to obtain permits to either build new facilities or significantly increase emissions at existing ones. Non-attainment New Source Review applies to large facilities in areas of the country that have air pollution levels that exceed the national ambient air quality standards set for a number of air pollutants, including ground level ozone (smog).

The PSD component of New Source Review applies to new or changed large facilities in areas of the country that have clean air and meet air quality standards for the air pol-

lutants to be emitted by a proposed source. Many states have New Source Review programs in place and have already implemented most of those provisions in the CAAA.

HAZARDOUS AIR POLLUTANTS

Air toxics or hazardous air pollutants (HAPs) include chemicals that may cause serious health problems, such as birth defects and gene mutations. Under Section 112 of the CAAA, nearly 200 chemicals were listed as toxic air pollutants, and according to USEPA, about 30 are used in the printing industry (*Table 3*). These chemicals are managed under the National Emission Standards for Hazardous Air Pollutants (NESHAP) regulations. Toxic air polluters are identified as major (large) or area (small) sources.

Of those HAPs listed above, the following are sometimes used in the flexographic industry:

- **Methanol:** As a denaturant for ethanol (isopropanol is an alternate denaturant for ethanol).
- **Toluene:** Used in small amounts in ink formulas to keep printing clean (toluene is being replaced by a variety of other slow solvents).
- **Hexane:** Used in small amounts as a cleaning agent, but being replaced.
- **Ethylene glycol:** Used in small amounts in some water-based inks, but being replaced.
- **Methyl ethyl ketone:** Small amounts used in UV curing tests. Found in coatings and adhesives.

On July 16, 1992, USEPA published a list of source categories that emit one or more HAPs. For listed categories of "major" sources (those that have the potential to emit 10 tons per year or more of a listed hazardous pollutant, or 25 tons per year or more of a combination of hazardous pollutants), the CAAA requires USEPA to develop standards that will require the application of stringent air pollution controls, known as maximum achievable control technology (MACT). This emission level is considered separate from emissions of VOCs, and is an entirely different program area. The previous discussion on ozone non-attainment does not apply to hazardous air pollutants.

USEPA's published list of industry groups (known as "source categories") to be regulated includes major sources in the printing and publishing industry, including publication rotogravure printers, package-product rotogravure and wide-web flexographic printers (greater than 18" web width).

In a NESHAP regulation, all technology-based emission standards must achieve the maximum degree of emission reduction deemed achievable by the USEPA for new or existing sources. When setting these standards, the cost of achieving the emissions reduction, as well as any health and environmental effects and energy requirements, are to be considered. Measures to implement

HAZARDOUS AIR POLLUTANTS

Chemicals used in the printing industry that are listed as hazardous air pollutants in the CAAA.

Benzene	Lead compounds
Cadmium compounds	Methanol
Carbon tetrachloride	Methyl ethyl ketone
Chromium compounds	Methyl isobutyl ketone
Cobalt compounds	Methylene chloride
Cumene	Perchloroethylene
Dibutyl phthalate	Polycyclic organic matter
Diethanolamine	Propylene oxide
Ethyl benzene	Toluene
Ethylene glycol	2,4-Toluene diisocyanate
Ethylene glycol ethers	1,1,1-Trichloroethane
Hexane	Trichloroethylene
Hydrochloric acid	Vinyl chloride
Isophorone	Xylenes

Table 3

the standards may include, but are not limited to, process changes or material substitutions; enclosure; measures to collect, capture or treat emissions; work practice or operational requirements, or any combination of the above.

USEPA's final NESHAP for the Printing and Publishing Industry, adopted in May 1996, established emission limits for publication rotogravure printing, and package-product rotogravure/wide-web flexographic printing, and provides industry with several compliance options[4] (existing facilities will have three years to comply with the rule [until May 1999]. Facilities may comply with the rule's requirements through the use of:

- pollution prevention methods that allow printers to eliminate the use of toxic chemicals by substituting non-toxic chemicals for toxic ones;
- traditional emissions capture and control equipment that eliminates more than 95% of the HAP emissions; or
- a combination of the two compliance options.

Because of the NESHAP, air toxics emissions are expected to be reduced from package-product rotogravure and wide-web flexographic printers by about 2,100 tons annually, representing a 40% reduction from current levels. The final version of NESHAP also outlines the monitoring, record keeping and reporting requirements.

The Printing and Publishing NESHAP allows for the use of inks, coatings and other materials that contain low quantities of hazardous air pollutants without having to install additional control equipment. This provides a pollution prevention approach to compliance. Most HAPs used by printers are also VOCs. The use of materials that contain low amounts of VOCs, such as in water-based systems, has provided a popular, alternative method for printers to meet state and federal VOC emission requirements without the costs of additional control equipment. The pollution prevention options in the final rule build upon this alternative method for meeting VOC emissions requirements by extending it to HAPs.

The regulation allows all affected facilities to assess compliance across all of the printing presses present at the facility. During the regulatory development process, compliance was assessed for package-product rotogravure/wide-web flexographic printing facilities on a press-by-press basis. The multi-press approach in the final regulation will allow for the most cost-effective reduction of HAP emissions and provide printers with the most flexibility in scheduling production in their facilities.

USEPA's final regulation applies to about 200 printing and publishing facilities nationwide. This includes some facilities that are major sources because of non-printing activities and only emit small amounts of HAPs from printing operations. Simplified requirements for these facilities are included in the final rule.

The estimated industry-wide annualized costs of the final regulations are estimated at $40 million. These costs include $21 million per year for publication rotogravure printers and $19 million per year for package and product rotogravure and wide-web flexographic printers. The annual costs associated with the final regulation could be considerably lower for facilities that use inks, solvents and other materials that contain low amounts of HAPs.

OZONE-DEPLETING CHEMICALS

The ozone layer in the upper atmosphere provides protection by absorbing harmful ultraviolet radiation emitted from the sun, and should not be confused with the ozone smog that we breathe. Without the ozone

[4] Refer to 40 CFR (Code of Federal Regulations), parts 9 and 63.

layer, life on Earth could not exist. Ozone in the stratosphere serves as a protective shield, filtering out harmful ultraviolet radiation emitting from the sun. Exposure to UV light has been linked to the development of cataracts and skin cancer.

In the mid-1970s, scientists suggested that chlorofluorocarbons (CFCs) could destroy stratospheric ozone. Evidence that the ozone layer is dwindling led 93 nations, including the major industrialized nations, to agree to cooperate in reducing production and use of chemicals that destroy the ozone layer. Many ozone-destroying chemicals have been, and still are being, phased out of production because of the CAAA.

Title VI of the CAAA deals with ozone-depleting chemicals. Two solvents in particular, carbon tetrachloride and methyl chloroform (1,1,1-trichloroethane), used in the printing industry, are affected by this law. As such they were no longer produced in the United States as of January 1, 1996.

IMPACT ON SMALL BUSINESS

To attain the NAAQS and control toxic emissions, air pollutants from hundreds of thousands of small businesses[5] are now being controlled. The specific requirements affecting small businesses depend on how badly the local air is polluted and the kinds and quantities of pollutants the businesses emit.

Small businesses may or may not be required to obtain a Title V operating permit depending on their potential to emit (PTE). Potential to emit currently is the only federally acceptable method to determine applicability of air pollution regulations, for both VOCs and HAPs[6]. The concept of PTE assumes that the given piece of equipment runs 24 hours a day and 365 days per year, with maximum material consumption or maximum design capacity, unless the current operating permit imposes limitations on hours of operation, materials consumption or other process variables.

SMALL BUSINESS ASSISTANCE

To ensure that small businesses would have access to the technical and compliance information necessary to comply with the CAAA of 1990, every state was required under Section 507 to establish a Small Business Stationary Source Technical and Environmental Compliance Assistance Program. The program's components include a Small Business Ombudsman (SBO) and Small Business Assistance Program (SBAP). The Small Business Ombudsman serves as a representative of small businesses, cuts red-tape, provides outreach and education, and works closely with the Small Business Assistance Progam, which provides technical and compliance assistance.

Every state now has a small business program, but the degree to which they provide assistance is dependent on funding levels. They typically provide seminars, workshops, pollution prevention and assistance guides, and on-site audits. At a minimum, all programs can provide information and assistance over the telephone. Some programs are confidential and/or separate from the regulatory agency, so businesses can talk freely about their compliance status.

For a list of the current ombudsman and assistance programs, contact the USEPA Small Business Ombudsman at (800) 368-5888, or visit their web site: www.icubed.com/epa_sbo/index.html.

[5] Small businesses have been defined as a stationary source that is owned or operated by a person that employs 100 or fewer employees, is a small business concern as defined by the US Small Business Administration, is not a major stationary source, does not emit 50 tons or more per year of any regulated pollutant, and emits less than 75 tons per year of all regulated pollutants.

[6] The USEPA is considering a rule by which businesses operating below 50% of the major source threshold could avoid the Title V permit.

Toxic Substances Control Act

Some hazardous substances are regulated under the Toxic Substances Control Act (TSCA). TSCA was enacted by Congress to test, regulate and screen all chemicals produced or imported into the United States. Many thousands of chemicals and their compounds are developed each year with unknown toxic or dangerous characteristics. TSCA requires that any chemical used for commercial purposes must either appear on or be exempt from the TSCA Chemical Substance Inventory. In addition, records of allegations of previously unknown adverse health effects from exposure to any chemical must be maintained.

Any existing chemical that poses health and environmental hazards is tracked and reported under TSCA. Procedures also are authorized for corrective action under TSCA in cases of cleanup of toxic materials contamination. TSCA supplements other federal statutes, including the Clean Air Act and the Toxic Release Inventory under Emergency Planning and Community Right-to-Know.

Of importance to the printing industry are Sections 4, 5, 6 and 8 of TSCA:

Section 4: Authorizes the USEPA to require testing of chemical substances or mixtures that the USEPA determines could be a risk to human health or to the environment.

Section 5: Grants the USEPA the right to test all new chemical substances to determine their toxicity and subsequent risk 90 days before manufacturing, processing or importing of said chemical.

Section 6: This section is the official notification that the USEPA may regulate the manufacture, processing, distribution in commerce, and use and disposal of any chemical substance determined to be toxic.

Section 8: Requires all users and manufacturers to keep records and submit reports to the USEPA. For example, printers using film developers or replenishers should contact the local environmental agency to determine reporting requirements. Also, printers who import inks are also subject to all TSCA reporting requirements.

Resource Conservation And Recovery Act

Current operating industries that produce hazardous wastes are regulated by the provisions of the Resource Conservation and Recovery Act (RCRA). One major requirement is a cradle-to-grave reporting system that tracks hazardous wastes from the factory through transportation, treatment and disposal. Most states have received authority from USEPA to regulate and enforce RCRA. All the RCRA hazardous waste regulations can be found in 40 CFR Parts 260 and 279.

To be considered hazardous waste, a material must first be classified as a solid waste. USEPA defines solid waste as garbage, refuse, sludge or other discarded material (including solids, semisolids, liquids and contained gaseous materials). Wastes are defined as hazardous if they are specifically named on one of four lists of hazardous wastes (listed wastes), or if they exhibit one of four characteristics (characteristic wastes).

LISTED WASTES

There are four separate lists of hazardous wastes. If any of the wastes from a printing facility is on any of these lists, the facility is subject to regulation under RCRA. The listing is often defined by industrial processes, but all wastes are listed because they contain particular chemical constituents. These constituents are listed in Appendix VII to 40 CFR Part 261 with code letters F, P, K and U[7].

For wastes from non-specific sources and including wastes generated by industrial processes that may occur in several different industries, the code always begins with F. F001 through F005 designate various types of spent solvent waste. Examples include methylene chloride, 1,1,1,-trichloroethane, xylene, acetone, benzene and n-butyl alcohol. The second category of listed wastes includes hazardous wastes from specific sources; these wastes have codes that begin with the letter K, but are not used in the printing industry.

The remaining lists cover commercial chemical products that have been or are intended to be discarded; these have two letter designations, P and U. Waste codes beginning with P are considered acutely hazardous, while those beginning with U are simply considered hazardous *(Table 4)*. No chemicals used in the printing industry are considered as acutely hazardous Code P.

Due to the 1980 adoption of the "mixture rule" and the "derived-from" rule, generators cannot evade hazardous waste regulations by diluting or otherwise changing the composition of listed waste. The mixture rule provides that any mixture of a listed hazardous and non-hazardous waste is a hazardous waste. The derived-from rule provides that waste derived from a listed hazardous waste is also deemed hazardous waste. These rules were struck down in 1991, but at the court's suggestion, the USEPA has temporarily reen-

[7] Lists of the F, P, K and Hazardous wastes can also be obtained by calling the USEPA RCRA/Superfund/EPCRA Hotline at (800) 424-9346.

CODE U LISTED PRINTING WASTES

Waste Code	Name or Description of Waste
U002	Acetone*
U019	Benzene
U211	Carbon tetrachloride
U055	Cumene
U056	Cyclohexane
U069	Dibutyl phthalate
U112	Ethyl acetate
U359	Ethanol, 2-ethoxy
U359	Ethylene glycol monoethyl ether
U122	Formaldehyde
U154	Methanol
U226	Methyl chloroform
U080	Methylene chloride
U159	Methyl ethyl ketone (MEK)
U161	Methyl isobutyl ketone
U210	Tetrachloroethylene (perchloroethylene)
U220	Toluene
U223	Toluene diisocyanate
U228	Trichloroethylene
U043	Vinyl chloride
U239	Xylene

**recently delisted.*

Table 4

acted the rules on an interim basis while it conducts a new rulemaking review.

CHARACTERISTIC WASTES

Even if a waste does not appear on one of the hazardous waste lists, it still might be regulated as hazardous waste if it exhibits one or more of the following characteristics:

Ignitability: Wastes which create fires under certain conditions or are spontaneously combustible and have a flash point less than 60° C (140° F). Examples include used solvents which have a waste code of D001.

Corrosivity: Corrosive wastes are acids or bases that are capable of corroding metal containers, such as storage tanks, drums and barrels. Acid and alkaline process baths are a good example. The waste code for these materials is D002.

Reactivity: Reactive wastes are unstable under "normal" conditions. They can cause explosions, toxic fumes, gases or vapors when mixed with water. The waste code for these materials is D003.

Toxicity: Toxic wastes are harmful or fatal when ingested or absorbed. When toxic wastes are disposed of on land, contaminated liquid may drain (leach) from the waste and pollute the ground water. Toxicity is defined through a laboratory procedure called the Toxicity Characteristic Leaching Procedure. Toxic printing wastes include silver (D011), carbon tetrachloride (D019) and trichloroethylene (D040). Waste codes for toxic materials range from D004 to D040.

GENERATOR STATUS

Generator status defines how to dispose of a listed or characteristic waste. The hazardous waste generator is defined as any person, by site, who creates a hazardous waste or makes a waste subject to RCRA Subtitle C. Generators are divided into three categories:

Large Quantity Generators (LQG): These facilities generate at least 1,000 kg. (2,200 lbs.) of hazardous waste per month, or more than 1 kg. (2.2 lbs.) of acutely hazardous[8] waste per month.

Small Quantity Generators (SQG): These facilities generate more than 100 kg. (220 lbs.) but less than 1,000 kg. (2,200 lbs.) hazardous waste per month and up to 1 kg. (2.2 lbs.) of acutely hazardous waste per month.

Conditionally Exempt Small Quantity Generators (CESQG)[9]: These facilities generate no

8 Not likely to affect printers.

9 Some states do not recognize the CESQG class. Contact the state environmental agency to find out if the CESQG is recognized. To find the appropriate state contact, call the RCRA Hotline at (800) 424-9346.

more than 100 kg. (220 lbs.) per month of hazardous waste and up to 1 kg. (2.2 lbs.) per month of acutely hazardous waste.

Large and small quantity generators must meet many similar requirements. Small Quantity Generators may accumulate up to 6,000 kg. (13,200 lbs.) of hazardous waste on-site at any one time for up to 180 days without being regulated as a treatment, storage or disposal facility (TSD) and thereby having to apply for a TSD permit. Small Quantity Generators are allowed to store waste on-site for 270 days without having to apply for TSD status provided the waste must be transported over 200 miles. Large Quantity Generators have only a 90-day window to ship waste off-site without needing a TSD permit. Most provisions do not apply to generators who send their wastes off-site within the 90- or 180-day window wherever applicable.

Hazardous waste generators that do not meet the conditions for Conditionally Exempt Small Quantity Generators must:

- obtain a generator identification number;
- store and ship hazardous waste in suitable containers or tanks;
- manifest the waste properly;
- maintain copies of the manifest, a shipment log covering all hazardous waste shipments and test records;
- comply with applicable land disposal restriction requirements; and
- report releases or threats of releases of hazardous waste.

TRANSPORTATION

Under the Superfund Amendment and Reauthorization Act, no one without a generator number may transport or offer for transportation a hazardous material. This number must appear on the manifest and on all labels.

Most states supply numbered manifest forms with enough duplicates for the state agency, the generator, each transporter, and the designated TSD facility, with another copy signed and returned to the generator.

A manifest must contain all of the following information:

- a manifest document number;
- the generator's name, mailing address, telephone number and USEPA identification numbers;
- the name and USEPA identification number of each transporter;
- the name, address and USEPA identification number of the TSD facility and an alternative facility, if any;
- all items required by the US Department of Transportation regulations, such as a description of the wastes and proper shipping name; and
- the quantity of each hazardous waste item, by units of weight or volume, and the type and number of containers as loaded into the transporter's vehicle.

The following certification must appear verbatim on the manifest: "This is to certify that the above-named materials are properly classified, described, packaged, marked and labeled and are in proper condition for transportation according to the applicable regulations of the Department of Transportation and the USEPA." For an example of a hazardous waste manifest, see *Appendix B*.

The generator must sign the manifest by hand and so must the initial transporter, who must also write the date of acceptance. The remaining copies accompany the shipment to the TSD facility.

If the generator doesn't receive a hand-signed copy of the manifest from the TSD facility within 35 days, the transporter and/or the facility must be contacted. If the manifest is not located in 10 days, the generator must send a copy of the manifest with a cover letter to the regional USEPA administrator explaining efforts made to locate the shipment and any results. This will give the USEPA the basis for an investigation.

The generator must keep the signed copy of the manifest and any related papers for at least three years. They must also file an annual report for the preceding year no later than March 1, listing transporters and facilities used that year. In some states, reporting is required every two years; this can be checked with the local regulatory agency.

The records may be inspected at any time, and generators should put them in a permanent file.

UNDERGROUND STORAGE TANK MANAGEMENT

RCRA establishes a program to control and prevent leaks from underground storage tanks. A storage tank is defined as underground if 10% or more of the volume, including the volume of underground pipes, is beneath the surface of the ground. In the printing industry, any of the following exemptions may apply:

- underground storage tanks storing heating oil used on premises;
- septic tanks and other tanks for collecting waste water and storm water;
- flow-through process tanks;
- emergency spill tanks that are emptied immediately after use.

Tanks that are not exempt must be approved and must have *all* requirements for:

- design, construction, installation and notification;
- general operations;
- release detection;
- release reporting, investigation and confirmation;
- release response and corrective action (for petroleum underground storage tanks);
- closure of underground storage tanks; and
- financial assurance (for petroleum and ground storage tanks).

SPILLS

Every facility that generates hazardous waste should have a contingency plan in case of leaks or spills.

If a truck carrying hazardous waste has a leak or spill, the vehicle must leave the highway and stop at the safest available place. The driver must contact the National Response Center (800) 424-8802, and a hazardous material incident report must be filed within 15 days. A generator should inspect all waste containers for leakage before they are transported. If a driver accepts a leaking container, the driver, the carrier and shipper are equally liable for the violation.

SHOP TOWELS

Application of regulations to shop towels currently varies from state to state, and interpretation of the federal regulations varies from region to region within the USEPA. For example, the state of California passed a bill in October 1993 that exempts reusable soiled textiles from hazardous waste regulations, but to meet this exemption, the textiles must not bear any free liquids. In New Mexico, both reusable and disposable shop towels are considered hazardous waste. Any determinations or interpretations regarding this diverse and variable waste stream should be made by the regulatory agency implementing the RCRA program for a particular state.

A towel is considered a listed hazardous waste if it either contains listed waste, or is otherwise mixed with hazardous waste. Reusable or disposable towels must be used and handled in an environmentally sound manner to ensure compliance with applicable state and federal regulations.

It is important when choosing reusable rental towels, that the rental company is reputable and is handling the towels properly. The user (the printer) is ultimately responsible for the destiny of the effluents.

The USEPA is expected to issue a shop-towel rule in the next two years.

LIFE CYCLE OF A TYPICAL PRINTING WASTE

Below is an example of the stages in the life cycle of a typical printing waste for a Small Quantity Generator that is sending solvent waste off site for treatment.[10] It illustrates the most common scenario of activities. Other life cycles could apply depending on the waste, whether on-site treatment will occur and the type of waste management units used, and the generator status.

1. Identify waste: By running tests or using knowledge of the waste, identify whether the waste is hazardous. Based on these analyses, determine the appropriate waste code.
2. Count waste: Determine the quantity of waste produced during a calendar month. Solvents directly in a solvent recovery still should not be counted. Count solvent still bottoms when they are recovered.
3. Determine generator status: Based on waste counting, determine generator status. This example assumes Small Quantity Generator status.
4. Obtain USEPA identification number: To identify a business as a hazardous waste generator, a hazardous waste identification number must be obtained.[11]
5. Place waste in an accumulation unit: Accumulated waste must be placed in a marked tank or container with the date the waste was placed in the unit and marked with the words "Hazardous Waste." Containers must not be rusty or leaking. They must be stored in areas with adequate ventilation and drainage and kept closed except to add or remove waste.
6. Implement Large Quantity Generator preparedness and prevention requirements: Emergency preparedness and prevention requirements must be met. These include adequate emergency response systems and notification to local emergency response authorities.
7. Prepare a contingency plan: A contingency plan must be prepared according to standards. The plan is designed to minimize hazards from fires, explosions and unplanned releases. A copy of the plan must be kept on-site and a facility emergency coordinator must be on site at all times.
8. Implement personnel training: Personnel must be familiar with hazardous waste handling and emergency procedures.
9. Contract with hazardous waste transporter: Contract a registered hazardous waste transporter to send waste off site to a licensed facility.
10. Follow US Department of Transportation (USDOT) packaging standards: Before shipping waste off site for treatment, storage or disposal, package, label and mark waste containers in accordance with all applicable USDOT requirements.[12]
11. Prepare hazardous waste manifest: A manifest is to be sent along with all hazardous waste sent off site to a registered facility. Copies should be kept for three years.
12. Prepare appropriate notification and certification: All hazardous waste sent off site for treatment, storage or disposal must be accompanied by appro-

[10] Taken from RCRA in Focus, Printing, EPA530-K-97-007

[11] Hazardous waste generator numbers can be obtained from the USEPA by submitting Form 8700-12 (Notification of Regulated Waste Activity), which is obtained from the state hazardous waste agency.

[12] The USDOT hotline is (800) 467-4922.

priate notification and certifications (initial shipment only).

13. Send waste off site for treatment, storage or disposal: Using a registered hazardous waste transporter, send the waste to an RCRA hazardous waste registered facility accompanied by the appropriate manifest and land-disposal-restrictions notifications and certifications. A permitted or interim status facility can be used. Optional destinations for solvents include a hazardous waste incinerator that will landfill the incinerator ash, a hazardous waste fuel blender who will blend the solvents with other wastes and then burn them for energy recovery in a boiler or industrial furnace, or a facility that will recycle the solvents.

Comprehensive Environmental Response, Compensation And Liability Act

In addition to active facilities regulated under RCRA, some sites also contain abandoned hazardous wastes for which ownership is unclear or unknown. In these situations, control and cleanup is possible through the Comprehensive Environmental Response, Compensation and Liability Act (CERCLA), commonly known as Superfund. Under the Superfund program, USEPA has the authority to clean up the nation's worst hazardous waste sites. CERCLA was reauthorized by the Superfund Amendments and Reauthorization Act of 1986 (SARA).

HAZARDOUS CHEMICAL REPORTING

When CERCLA was amended by SARA, Title III, Section 302 of SARA authorized the

HAZARDOUS CHEMICALS USED BY THE PRINTING INDUSTRY AND REPORTABLE UNDER CERCLA

CHEMICAL	REPORTABLE QUANTITY (LBS)	CHEMICAL	REPORTABLE QUANTITY (LBS)
Acetone	5,000	Methyl chloroform	1,000
Ammonia	100	Methylene chloride	1,000
Benzene	10	Methanol	5,000
Cadmium and compounds	1	Methyl ethyl ketone	5,000
Carbon tetrachloride	10	Methyl isobutyl ketone	5,000
Chloroform	10	Perchloroethylene	100
Chromium and compounds	1	Phosphoric acid	5,000
Cumene	5,000	Propylene oxide	100
Cyclohexane	1,000	Sulfuric acid	1,000
Dibutyl phthalate	10	Toluene	1,000
Ethanol, 2-ethoxy	1,000	Toluene diisocyanate	100
Ethyl acetate	5,000	1,1,1-Trichloroethane	1,000
Ethylbenzene	1,000	1,1,2-Trichloroethane	100
Formaldehyde	100	Trichloroethylene	100
Hydrochloric acid	5,000	Vinyl chloride	1
Isophorone	5,000	Xylene (mixed)	1,000
Lead and Compounds	1		

Table 5

TOXIC CHEMICALS USED IN THE PRINTING INDUSTRY

The following are chemicals used in the printing industry and considered toxic in the Toxic Release Inventory.

Acetone	Hydroquinone
Ammonia	Lead
Barium	Methanol
Cadmium	Methyl ethyl ketone
Chromium	Methyl isobutyl ketone
Copper*	Methylene chloride
Cumene	Phosphoric acid
Cyclohexane	Silver
Ethylbenzene	Sulfuric acid
Ethylene glycol	Tetrachloroethylene
Ethylene oxide	Toluene
Formaldehyde	Trichlorothylene
Freon 113	1,1,1-Trichloroethylene
Glycol Ethers	Xylene
Hydrochloric acid	

*Copper phthalocyanine pigments were delisted in May 1991.

Table 6

Emergency Planning and Community Right-to-Know Act (EPCRA). EPCRA has two main purposes: to encourage planning for accident response, and to provide the public and the government with information about possible chemical hazards in communities. This law is based on the premise that citizens have a right to know about hazardous chemicals in their communities *(Table 5)*.

Any person in charge of a facility must immediately notify the National Response Center[13] as soon as that person has knowledge of a release (within a 24-hour period) of an amount of a hazardous substance that is equal to or greater than the values in *Table 5*. There are some exceptions to this requirement, including exceptions for certain continuous releases and for federally permitted releases.

[13] The toll-free number for the National Response Center is (800) 424-8802; in Washington DC call (202) 426-2675.

TOXIC CHEMICAL REPORTING

Section 313 of the EPCRA requires manufacturers (Standard Industrial Classification Codes 20-39), including flexographers, to report to the USEPA and the states the amounts of over 300 toxic chemicals and 20 chemical categories that they release directly to air, water or land; inject underground; or transfer to off-site facilities *(Table 6)*. Toxic release inventory (TRI) reporting is required of facilities that have more than 10 employees and that manufacture, process or otherwise use more than 10,000 or 25,000 lbs. per year (depending on how the chemical is used) of these chemicals. The printing industry releases 99% of its total toxic release inventory poundage to the air, while the remaining one percent of releases is split between water and land disposal.

Suppliers of products containing toxic release inventory chemicals are required to notify each printer (to whom the mixture or trade name product is sold or otherwise distributed from the facility) of the name of each toxic chemical and the percent by weight of each toxic chemical in the mixture of trade name product.

EPCRA specifies that USEPA must compile these reports into an annual TRI of releases and transfers and make that inventory available to the public.

In addition, the Pollution Prevention Act of 1990 requires that all TRI facilities provide information on pollution prevention and recycling efforts for each chemical on their reporting forms.

Right-to-know efforts have been enhanced by a 1994 Executive Order committing USEPA and other federal agencies to environmental justice for minority and low-income populations.

Clean Water Act

The Clean Water Act (CWA) is the basic federal law that governs water pollution control in the United States. The commercial printing industry produces a number of pollutants that are potentially regulated under the CWA.

WASTEWATER DISCHARGE

The National Pollutant Discharge Elimination System (NPDES) regulates discharges into navigable waters, such as lakes, streams, creeks and rivers. Thirty-nine states and territories are authorized to administer NPDES programs that are at least as stringent as the federal program. The USEPA administers the programs in the states not so authorized.[14]

The NPDES program requires permits for discharge of pollutants from any point source into navigable waters. Because the CWA defines all of these terms broadly, a source will be required to obtain an NPDES permit if it discharges almost anything directly into surface waters. A source that sends its wastewater to a publicly owned treatment works (POTW) will not be required to obtain an NPDES permit, but may be required to obtain an industrial user permit from the POTW to cover its discharges.

Most states prohibit discharge of industrial wastewater effluent into a septic system.

[14] The 12 States that are not authorized are AK, AZ, FL, ID, LA, ME, MA, NH, NM, OK, SD and TX. Washington D.C. Puerto Rico, American Samoa, Guam, Northern Marianas and Trust Territories Pacific Islands also do not have approved NPDES Programs. No federally recognized Indian tribes have authorized programs.

DISCHARGE REQUIREMENTS

General pretreatment standards apply to all facilities discharging into a POTW. The appropriate POTW should be contacted for permission to discharge process wastewater effluent and for permitting requirements. The general pretreatment standards prohibit the following from being introduced into a POTW:

- pollutants that create a fire hazard in the POTW;
- pollutants that will cause corrosive structural damage to the POTW, but in no case discharges with pH lower than 5.0, unless the facility is specifically designed to accommodate such discharges;
- solid or viscous pollutants in amounts that will cause obstruction to the flow in the POTW, resulting in interference;
- any pollutant, including oxygen demanding pollutants, released in a discharge at a flow rate and/or pollutant concentration that will cause interference with the POTW;
- heated effluents in amounts that will inhibit biological activity in the POTW, resulting in interference, but in no case heat in such quantities that the temperature at the POTW exceeds 40° C, unless the approval authority, upon the request of the POTW, approves alternate temperature limits;
- petroleum oil, non-biodegradable cutting oil, or products of mineral oil in amounts that will cause interference or pass-through;
- pollutants that result in the presence of toxic gases, vapors or fumes within the POTW in a quantity that may cause acute worker health and safety problems;

- any trucked or hauled pollutants, except at discharge points designated by the POTW.

There are numerous requirements for dischargers into POTWs. A business must keep records, monitor discharges and prepare and submit periodic monitoring reports, as determined by the POTW. When there is a discharge that could "cause problems," the POTW must be notified immediately. A business must give prompt notice to the POTW if there is a significant change in the discharge. If a POTW is to be bypassed, it must be notified 10 days in advance of the known need for an intentional diversion of wastewater stream; or orally within 24 hours and in writing within five days of becoming aware of a bypass. A business that discharges to a POTW a substance which, if otherwise disposed of, would be a hazardous waste must give a one-time notice to the local sanitary district, USEPA and the appropriate state agency unless exempted. Discharges of more than 33 pounds per month of hazardous waste or any acute wastes mixed with domestic sewage require written notification to the local USEPA office, state waste agency, and the POTW. Significant industrial users, whose discharge is more than 25,000 gallons per day, must submit to the POTW a semiannual description of the nature, concentration and flow of pollutants.

STORM WATER PERMITS

Storm-water permits are required for areas where material-handling equipment or activities, raw materials, intermediate products, final products, waste materials, by-products, or industrial machinery are exposed to storm water which drains to a municipal seperate storm-sewer system or directly to a receiving body of water.

Storm water permit applications include a site map including:

- topography;
- drainage area;
- areas used for outdoor storage or disposal;
- materials loading and access areas;
- each of the facility's hazardous waste treatment, storage or disposal facilities;
- each well where fluids from the facility are injected underground; and
- springs and other surface-water bodies that receive storm-water discharges.

A certification that all outfalls have been tested or evaluated for the presence of non-storm water discharges that are not covered by an NPDES permit must be made, and this certification must include a description of the method used, dates and the observed on-site drainage points.

USEPA's general permits cover the majority of storm-water discharges associated with industrial activity. Storm-water discharges associated with industrial activity that cannot be authorized by USEPA's general permits include those:

- with an existing effluent limitations guideline for storm water;
- that are mixed with non-storm water, unless the non-storm water discharges are in compliance with a different NPDES permit;
- with an existing NPDES individual or general permit for the storm water discharges;
- that are or may reasonably be expected to be contributing to a violation of a water quality standard; or
- that are likely to adversely affect a listed or proposed to be listed endangered or threatened species or its critical habitat.

A facility must submit a Notice of Intent to the USEPA to be authorized by the general permit. A Notice of Intent does not require the collection of discharge sampling data.

Facilities which discharge to a large or medium municipal storm-sewer system must also submit copies of the Notice of Intent to the operator of the municipal system. Operators of all facilities covered by USEPA's general permits must prepare and implement a storm water pollution prevention plan. Questions can be directed to the Storm Water Hotline at (703) 821-4823. Facilities in authorized NPDES states should contact their state permitting agencies to determine the status of the general permitting program.

SILVER RECOVERY

In photoprocessing, silver compounds are the basic light-sensitive material used in most of today's photographic films and papers. During processing, particularly in the fixing bath or bleach-fix, silver is removed from the film or paper and is carried out in the solution, usually in the form of a silver thiosulfate complex. There are several reasons to recover silver from photoprocessing waste. Silver is a valuable natural resource of finite supply, it has monetary value as a recovered commodity, and its release into the environment is strictly regulated.

The regulation of wastes from photographic processing units can be very complicated. Regulation of the effluent from the developing equipment or the silver recovery unit depends on the method used to convey the waste to treatment or disposal. If the waste is discharged directly into a sanitary sewer as a process waste water, it is regulated as a point source under the Clean Water Act. However, if the waste is collected and stored in a container prior to treatment, it will be regulated as a hazardous waste under RCRA if it contains silver in excess of 5 milligrams per liter or if it exhibits other properties which may render the containerized waste hazardous.

The Clean Water Act strictly prohibits discharges of silver to the POTW that would lower the pH of the waste water entering the POTW to less than 5, or would interfere with the proper operation of the POTW (stop biological activity). To ensure that waste is properly treated, the POTW establishes a program to regulate discharges of industrial waste to the facility. The POTW operator will determine the concentration of silver that can be discharged to the plant, based on the ability of that plant to treat the waste.

Many of the currently available technologies for silver recovery from waste waters are most effective at a restricted range of silver concentrations. For this reason, some technologies are appropriate only for silver recovery from high concentration fixer solutions, and others are more suited to low concentration rinse water silver recovery. Silver recovery technologies for fixer solutions include metallic replacement, galvanic plating, electrolytic plating and precipitation.

Although there is little economic benefit to silver recovery from rinse waters, the primary consideration is meeting effluent discharge standards. Effective technologies for silver recovery from low concentration rinse waters include ion exchange, reverse osmosis and metallic replacement.

Pollution Prevention Act

The Pollution Prevention Act of 1990 (PPA) focused industry, government and public attention on reducing the amount of pollution produced. The Pollution Prevention Act emphasizes that pollution can be prevented at the source through cost-effective changes in production, operation and raw materials use. Opportunities for source reduction are often not realized because existing regulations, and the industrial resources required for compliance, focus on treatment and disposal. Source reduction is fundamentally different and more desirable than waste management or pollution control. Pollution prevention also includes other practices that increase efficiency in the use of energy, water or other natural resources best through conservation.

The best way to reduce pollution is to prevent it in the first place. Industries have creatively implemented pollution prevention techniques that improve efficiency and increase profits while at the same time minimizing environmental impact. This can be done in many ways such as reducing material inputs, reengineering processes to reuse by-products, improving management practices, and employing substitution of toxic chemicals. Some smaller facilities are able to actually get below regulatory thresholds just by reducing pollutant releases through aggressive pollution prevention policies. Better operating practices such as maintaining equipment to prevent failures, labeling and dating containers to help identify the contents and life expectancy, and keeping the shop clean to prevent contamination of raw materials, are all easy ways to reduce waste.

WASTE INKS AND SOLVENTS

Most press return inks can be recycled. One recycling technique relies on blending waste inks of different colors together to make "black" ink. Small amounts of inks or black toner may be needed to obtain an acceptable color. Other inks of like colors can be blended to maintain color consistency.

Improvements are continually being made to make solvents less hazardous. Aqueous solvents and other organic solvents that are not hazardous wastes after use are often good alternatives.

PREPRESS

Image-making most frequently involves typesetting and photo developing. Typical waste streams include: photographic chemicals, paper and films, silver, and solid wastes. Pollution prevention opportunities during prepress include the following:

- implementing operational and work practice changes that can extend the life of chemical baths, reduce the amount of chemicals used and reduce wastewater generation;
- using chemical substitutes, such as non-silver photographic films, which are currently being developed;
- replacing the sometimes repetitive steps of photographing, editing, reshooting, and developing with electronic imaging (including the capability to edit images on a computer);
- developing inventory-control programs that offer the advantage of reducing spoilage of photo developing chemicals and supplies such as paper and film.

PRESS OPERATIONS

During printing, the image is transferred to a substrate of paper or some other material. Typical waste streams include: inks, substrates and cleaning solutions. Pollution prevention opportunities include:

- minimizing solvent losses by improving housekeeping and utilizing better operating practices, such as covering reservoirs and containers, scheduling jobs according to increasing darkness of ink color, using wipes as long as possible, and controlling inventory;
- reducing ink vaporization by using diaphragm pumps which do not heat ink as much as mechanical-vane pumps;
- recycling waste solvents on site or off site. Segregation of solvents may allow asecond use (e.g., for equipment cleaning or ink thinning);
- recycling of certain waste inks where possible;
- recycling of product rejects where possible;
- using alternative ink and cleaning products with reduced VOC emissions. Lowering the VOC emissions from printing and press cleanup may be accomplished using water-based inks where possible and using low-VOC or VOC-free cleaning solutions;
- using automatic cleaning equipment which can often be retrofitted to existing presses and operations. Typically, lower volumes of cleaning formulations are applied with such cleaning equipment. Air contact, and thus volatilization, is thereby reduced, and most systems are designed to include recycling and reuse of cleaning solutions;
- minimizing finished product rejects by automating (non-contact) monitoring technologies which detect tears in web and press performance.

POST-PRESS OPERATIONS

The final steps in making a printed product may involve folding, trimming, binding, laminating and embossing. Typical waste streams include: scrap substrate from trimming, rejects from finishing operations, and VOCs released from adhesives. Pollution prevention opportunities include: collecting and reclaiming recyclable materials; and replacing VOC-based adhesives with water-soluble adhesives (binding adhesives that are not water-soluble may interfere with later recycling), hot-melt adhesives or mechanical methods in binding operations.

Occupational Safety And Health Act

Last amended in 1990, the Occupational Safety and Health Act (OSH Act) is meant to assure safe and healthful working conditions for working men and women by:

- authorizing enforcement of the standards developed under the Act;
- assisting and encouraging the states in their efforts to assure safe and healthful working conditions;
- providing for research, information, education, and training in the field of occupational safety and health.

Employers are responsible under the OSH Act to provide a workplace free from recognized hazards that are causing or are likely to cause death or serious physical harm to its employees. Companies must comply with all standards, rules and regulations issued by Occupational Safety and Health Administration (OSHA) under the act. Copies of the OSHA standards must be made available to employees for review upon their request.

STATES WITH APPROVED JOB SAFETY AND HEALTH PLANS

Alaska	Michigan	Tennessee
Arizona	Minnesota	Utah
California	Nevada	Vermont
Connecticut	New Mexico	Virginia
Hawaii	New York	Virgin Islands
Indiana	North Carolina	Washington
Iowa	Oregon	Wyoming
Kentucky	Puerto Rico	
Maryland	South Carolina	

Table 7

STATE PROGRAMS

The OSH Act encourages states to develop and operate their own job safety and health plans. OSHA approves and monitors these state plans and provides up to 50% of an approved plan's operating costs. States must set job safety and health standards which are at least as effective as comparable federal standards (most states adopt standards identical to federal ones). Twenty-three states or jurisdictions operate complete state plans covering both the private sector and state and local government employees *(Table 7)*. Two others, Connecticut and New York, cover public employees only. States with plans must adopt standards comparable (but not necessarily identical) to federal standards within six months of promulgation of the federal standards. Until a state standard is promulgated, OSHA will provide interim enforcement assistance, as appropriate, in these states.

A fact sheet, State Job Safety and Health Programs, (OSHA Program Highlights No. 15) is available through the OSHA Publications Office.[15]

RECORD-KEEPING

Most employers with 11 or more employ-

15 OSHA Publications Office, Room N-3101, Frances Perkins Building, 200 Constitution Avenue, Washington DC 20210, (202) 219-4667.

ees are required to maintain records of occupational injuries and illnesses as they occur.

Employers with 10 or fewer employees and employers regardless of size in certain industries are exempt from keeping such records unless they are selected by the Bureau of Labor Statistics (BLS) to participate in the annual survey of occupational injuries and illnesses.

Two forms are needed for record-keeping: OSHA No. 200, Log and Summary of Occupational Injuries and Illnesses, and OSHA No. 101, Supplementary Record of Occupational Injuries and Illness. Employers selected for the BLS survey receive a form, OSHA 200S, in the mail.

Copies of OSHA record-keeping forms and publications on the record-keeping requirement are available through the OSHA Publication Office. The publications are titled A Brief Guide to Recordkeeping Requirements for Occupational Injuries and Illnesses, and Recordkeeping Requirements Under the Occupational Safety and Health Act of 1970.

OSHA POSTER

Every employer must post in a prominent location in the workplace the Job Safety and Health Protection workplace poster (OSHA 2203 or state equivalent) which informs employees of their rights and responsibilities under the Act. The poster may be obtained through the OSHA Publications Office.

MATERIAL SAFETY DATA SHEETS

Material Safety Data Sheets (MSDS's) are obtained from manufacturers or suppliers of chemicals (see *Appendix C* for examples). Employees are required by law to have MSDS's on hand for materials they use that OSHA considers hazardous (capable of causing harm or injury to workers under normal use). Although they are not a uniform format and can vary in detail, they must include the following information:

Section I: Material identification including manufacturer name and address and the chemical's common name.

Section II: List of any hazardous ingredients that comprise more than 1% of the chemical and any carcinogenic ingredient that is more than 0.1% of the chemical.

Section III: Physical properties of the chemical, including vapor density, specific gravity, and evaporation rate.

Section IV: Fire and explosion information.

Section V: Stability of the product, as well as reactivity data and special handling procedures.

Section VI: Health hazard information (such as whether it causes eye irritation, nausea, headaches) and treatment.

Section VII: Spill leak, handling, storage and disposal procedures.

Section VIII: Recommended safety equipment for handling the chemical.

Section IX: Special precautions.

If the MSDS does not contain all information needed for environmental or health reasons, the supplier should be contacted promptly. It makes good business sense to use MSDS to evaluate a product before purchase.

HAZARD COMMUNICATION

The OSHA Hazard Communication Standard, issued in 1986, requires employers to inform their workers of the potential dangers of any chemical hazards on the job, and to train them in proper safeguards. This includes information on the hazards and identities of chemicals they are exposed to when working and the protective measures available to prevent adverse effects.

Employers who use the chemicals, rather than produce or import them, are not required to evaluate the hazards of those chemicals. Hazard determination is the responsibility of the producers and importers of the materials,

❻ By using colors, numbers and symbols, the Hazardous Materials Identification System standard label identifies the chemical and lists hazard warnings.

who then must provide the hazard information to employers who purchase their products. All employers must have a written workplace compliance program. Under the Act, companies must:

- list all hazardous chemicals;
- maintain Material Safety Data Sheets for each of those chemicals;
- label each container that contains those chemicals;
- have ongoing employee safety training;
- have a hazardous communications program written and implemented.

Chemicals are considered hazardous based on their physical or health hazards. Physical hazards include chemicals that are flammable, combustible or explosive. Health hazards include both acute or chronic effects such as eye irritation or cancer.

Copies of the Hazard Communication Standard and the publication, Chemical Hazard Communication, (OSHA 3084 Revised) are available through the OSHA Publications Office. Another publication, Hazard Communication Guidelines for Compliance, (OSHA 3111; GPO Order No. 029-016-00127-1) can be purchased from the Superintendent of Documents, United States Government Printing Office.

A compliance kit on the standard with more detailed information and which can be used for filing the employees hazard communication and training programs, requests for MSDS's, and training or other records can also be purchased from the Government Printing Office. It is GPO Order No. 929-022-00000-9 (OSHA 3104 Hazard Communication Compliance Kit).

PERSONAL PROTECTION EQUIPMENT

The OSH Act (29 CFR 1910.132-134) specifies situations when personal protection equipment (PPE) should be used. For example, gloves and safety glasses are required equipment when handling certain solvents and inks. As mentioned above, these requirements should be listed on the chemical's labels. Emergency eye washes should be installed in areas where eye irritants are handled. If respirators are required, employees must be properly trained and fit-tested. A respirator program must be written showing how respirators are selected.

Most press rooms are high noise areas. If noise levels are equal to or exceed an 8-hour time-weighted average of 85 decibels, employers must administer a hearing conservation program (29 CFR 1910.95).

HAZARDOUS MATERIALS IDENTIFICATION SYSTEM

The Hazardous Materials Identification System (HMIS) standard labels are used on chemicals to indicate the degree of physical hazard using colors, numbers and symbols. The label identifies the chemical and lists hazard warnings (*Figure* ❻):

- Health hazards are indicated in the blue area and are graded from 0H (minimal hazard) to 4H (severe hazard).
- Flammability is indicated in the red zone, with 4F indicating an extremely flammable chemical, and 0F indicating

chemicals which will not burn.

- Reactivity is indicated in the yellow area, with 4R chemicals having the capability to detonate or explode and 0R chemicals being stable (not many chemicals used in the printing industry are reactive).

Recommended equipment to wear when handling a chemical is indicated in the white area of a label using codes *(Table 8)* or symbols (*Figure* ❼).

EQUIPMENT USE AND LOCKOUT/TAGOUT

Belts, pulleys, sprockets and chains gears and rollers are obvious danger points, so all converting equipment must be properly guarded. Most new equipment manufacturers supply machines this way, but sometimes there are in-house modifications made. If this happens, they should include proper guards. If a guard is removed for any reason, it must be back in place before the machine starts up again. Guards should always be given high priority during periodic inspections.

All power hoists must be properly sized and not overloaded. OSHA requires that the load capacity of each hoist be conspicuously posted. Indeed, this equipment should get the same priority as guards during periodic inspections.

The National Electrical Code (NEC) has been adopted as part of the OSHA standards. When installing electrical equipment in a hazardous area such as a press or ink room all codes should be checked. It is necessary to comply not only with local regulations and insurance rules, but with OSHA's specific provisions for hazardous areas.

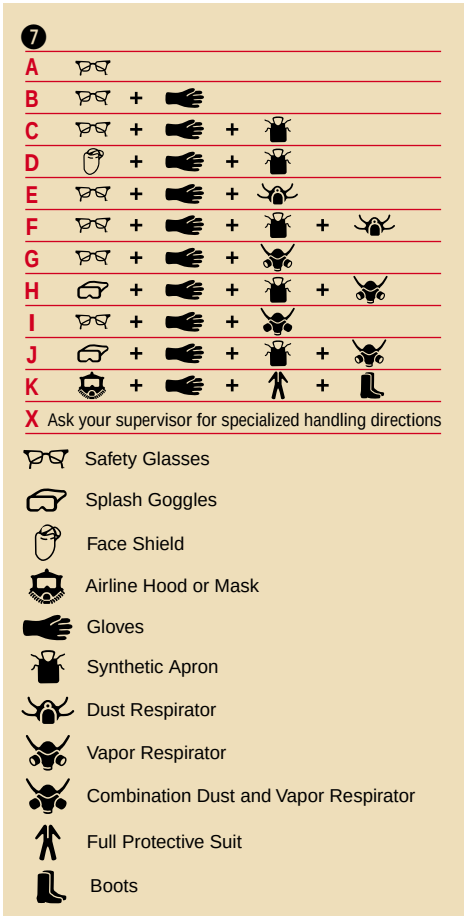
The OSHA lockout/tagout standard (29 CFR 1910.147) requires employers to establish an energy control program to prevent unexpected energization or accidental release of potentially hazardous energy during servicing and maintenance activities on machinery. Any time an employee performs maintenance or service work, all of the machine's energy sources must be locked out or tagged out. For a lockout, a lock or other device must be used. A tagout is done with a prominent sign and fastener. Programs must be audited annually.

For printing, the exception is that setup

PPE CODES AND RECOMMENDED EQUIPMENT

CODE	RECOMMENDED PPE
SA	dust respirator
SB	synthetic gloves
SC	synthetic gloves, apron and goggles
SF	gloves and goggles

Table 8



❼ Hazardous Material Identification System labels may use a combination of letters and symbols to indicate recommended safety apparel.

and minor servicing can be done with an alternative method such as inch/safe-service.

FACILITIES PLAN

A facilities plan of a plant or building, along with detailed plans for each subdivision or department should be prepared. These plans will let anyone see at a glance the arrangement of aisles, exits, storage areas and other plant features. The facilities plan can help determine the best places to put first aid supplies, fire extinguishers, emergency exits and recommended routes of travel in case of emergency. It can also flag the locations of power and utility switches and valves. The facilities plan is an important part of chemical contingency and disaster plans.

Most fire insurance companies require periodic inspections, and many firms have self-inspection programs. A facility might also be divided into inspection sections so that different area plans can be prepared in advance for the use of inspectors. Forms for these inspections can be standardized to include all required details and to be documents of inspection.

Items that are helpful in any facilities plan include all of the following:

- aisles and passable ways;
- access and egress (exit) locations;
- sprinkler system control valves;
- emergency lighting;
- areas requiring ventilation;
- location of spill-control stations;
- locations of emergency supplies such as protective equipment and first aid materials; and
- location of alarms, master switches, valves and controls.

CONSULTATION

Employers who want help in recognizing and correcting hazards and in improving safety and health programs can get it from a free consultation service largely funded by OSHA and delivered by state governments using well-trained professional staff. The states offer the expertise of highly qualified occupational safety and health professionals to employers who request help to establish and maintain a safe and healthful workplace.

No citations are issued for hazards identified by the consultant, and no penalties are ever imposed. OSHA consultation is a confidential service that is completely separate from OSHA enforcement operations. Only if an employer fails or refuses to eliminate or control a serious hazard or imminent danger situation within the agreed upon time frames will OSHA enforcement staff be notified. Such instances, according to OSHA, are rare.

The booklet, Consultation Services for the Employer, (OSHA 3047) is available through the OSHA Publications Office.

TRAINING

Employers are required by OSHA to provide workers with information and training on hazardous chemicals in their work areas when they are first assigned and whenever a new hazardous chemical is introduced. Employees must be told about the OSHA requirements, the operations in their work area where hazardous chemicals are present, and the location and availability of the company's written hazard communication program (including chemical lists and MSDS's).

The standards require that employee training must cover:

- methods and observations that employees can use to detect the presence or release of the hazardous chemical;
- physical and health hazards of the chemical; and
- measures employees can take to protect themselves from such hazards, including specific company procedures.
- details of the company's hazard com-

munication program, including explanation of workplace labeling systems, the MSDS's, and how employees can get and use the information.

Training courses in safety and health subjects are available to the private sector through the OSHA Training Institute. [16]

INSPECTIONS

An OSHA compliance safety and health officer (CSHO) conducts an inspection of a workplace, in accordance with the OSH Act of 1990. Inspections can occur at random or as a result of a report made to OSHA. After the inspection, the CSHO reports the findings to the Area Director who evaluates them. If a violation exists, OSHA will issue a Citation and Notification of Penalty detailing the exact nature of the violation(s) and the associated penalties. A citation informs the business of the alleged violation(s), sets a proposed time period within which to correct the violation(s) and proposes the appropriate dollar penalties. There are a number of typical violations for printing facilities *(Table 9)*.

[16] OSHA Training Institute, 1555 Times Drive, Des Plaines IL 60018. For information on the subjects, dates, tuition and location of these courses, telephone the Institute Registrar at (708) 297-4913 or write to the Institute.

COMMON OSHA VIOLATIONS

Frequently cited violations in the printing industry, January 1, 1993-May 1, 1996.

OSHA STANDARD	DESCRIPTION
1910.1200(e)(1)	No written hazard communication program
1910.1200(f)(5)	No labels, tags or marking on hazardous chemical containers
1910.1200(h)	No hazard communication training program
1910.212(a)(1)	Lack of machine guarding, general duty
1904.2(a)	No OSHA 200 form
1910.147(c)(1)	Lack of energy control program
1910.151(c)	Eye or body quick drenching or flushing facilities unavailable
1910.1200(g)(1)	No Material Safety Data Sheets (MSDS's)
1910.219(d)(1)	Improper guarding of pulleys
1910.147(c)(4)	Lack of energy control procedures
1910.147(c)(7)	Lack of energy control program training
1910.106(e)(2)	Improper use or storage of flammable & combustible liquids
1910.133(a)(1)	Appropriate eye and face protection not used during exposure
1910.212(a)(3)	Point of operation on machines not guarded
1903.2(a)(1)	No OSHA poster
1910.157(g)(1)	Fire extinguisher education was not provided
1910.219(e)(3)	Vertical and inclined belts not enclosed by a guard
1910.37(q)(1)	Exits not marked by readily visible sign
1910.38(a)(1)	No written emergency action plans
1910.305(g)(1)	Extension cords not approved or suitable for conditions

Table 9

Summary

It must be stressed that, in almost every area, most states have their own versions of regulations and their own agencies. So, before any decisions are made about regulations, state government should be consulted.

For up-to-date publications and regulations, contact regional offices of the US Environmental Protection Agency, the US Department of Labor (Occupational Safety and Health Administration) or other government agencies *(see Appendices E and F)*.

Resources

INTERNET ADDRESSES (Valid as of Publication Date)

There is an abundance of information that is easily accessible through the Internet. Nearly every state's regulatory program has a web site where regulations can be downloaded. Numerous programs within the USEPA also have web sites with regulations, fact sheets, press releases, programs and general information included.

Chemical Emergency Preparedness & Prevention Office
www.epa.gov/swercepp/

Code of Federal Regulations
www.epa.gov/docs/epacfr40

Common Sense Initiative
www.epa.gov/commonsense

Design for the Environment Flexography Project
www.epa.gov/dfe

Enviroene
www.epa.gov/envirosense

Environment Canada
www.ec.gc.ca

Federal Register
www.access.gpo.gov/su_docs/aces/aces5410.html

Flexographic Technical Association
www.fta-ffta.org

International Organization for Standardization
www.iso.ch

Occupational Safety and Health Administration
www.osha.gov

Office of Air and Radiation
www.epa.gov/oar

Office of Enforcement & Compliance Assurance
www.epa.gov/oeca

Printers' National Environmental Assistance Center
www.pneac.org

Printing Industry Sector Notebook
es.epa.gov/oeca/sector/index.html#print

RCRA Hotline
www.epa.gov/epaoswer/hotline

Small Business Assistance Program
www.epa.gov/ttn/sbap

Small Business Ombudsman
www.icubed.com/epa_sbo/index.html

Standards and Related Documents
www.osha-slc.gov/OCIS/standards_related.htm

Technology Transfer Network 2000
www.epa.gov/ttn

U. S. Environmental Protection Agency
www.epa.gov

Waste Reduction Resource Center
www.p2pays.org/wrrc

REGIONAL OFFICES OF USEPA, USDOL, OSHA (Valid as of Publication Date)

REGION (STATE)	UNITED STATES ENVIRONMENTAL PROTECTION AGENCY (USEPA)	UNITED STATES DEPARTMENT OF LABOR (USDOL) (OCCUPATIONAL SAFETY AND HEALTH OFFICES [OSHA])
Region I (CT,ME,MA,NH,RI,VT)	JFK Federal Building One Congress Street Boston, MA 02203 (617) 565-3420	JFK Federal Building One Congress Street Boston, MA 02203 (617) 565-9860
Region II (NJ,NY,PR,VI)	290 Broadway New York, NY 10007 (212) 637-3000	201 Varick Street, Room 670 New York, NY 10014 (212) 337-2378
Region III (DC,DE,MD,PA,VA,WV)	1650 Arch Street Philadelphia, PA 19106 (215) 814-5000	3535 Market Philadelphia, PA 19104 (215) 596-1201
Region IV (AL,FL,GA,KY,MS,NC,SC,TN)	61 Forsyth Street Atlanta, GA 30303 (404) 562-9900	1375 Peachtree Street, NE Atlanta, GA 30367 (404) 347-3573
Region V (IL,IN,MI,MN,OH,WI)	77 West Jackson Boulevard Chicago, IL 60604 (312) 353-2000	230 South Dearborn Street Chicago, IL 60604 (312) 353-2220
Region VI (AR,LA,NM,OK,TX)	Fountain Place 1445 Ross Avenue Dallas, TX 75202 (214) 665-6444	525 Griffin Street, Room 602 Dallas, TX (214) 767-4731
Region VII (IA,KS,MO,NE)	726 Minnesota Avenue Kansas City, KS 66101 (913) 551-7000	1100 Main Street, Suite 800 Kansas City, MO 64115 (816) 426-5861
Region VIII (CO,MT,ND,SD,UT,WY)	999 18th Street, Suite 500 Denver, CO 80202 (303) 293-1603	1999 Broadway, Suite 1690 Denver, CO 80202 (303) 844-1600
Region IX (AZ,CA,GU,HI,NV)	75 Hawthorne Street San Francisco, CA 94105 (415) 744-1305	71 Stevenson Street, Room 420 San Francisco, CA 64105 (415) 975-4310
Region X (AK,ID,OR,WA)	1200 Sixth Avenue Seattle, WA 98101 (206) 553-1200	111 Third Avenue, Suite 715 Seattle, WA 98101 (206) 553-5930

OTHER GOVERNMENT OFFICE TELEPHONE NUMBERS (Valid as of Publication Date)

Occupational Safety and Health Administration	
■ Publications Office	(202) 219-4667
■ Training Institute	(708) 297-4913
US Department of Transportation	
■ Hazardous Materials Information Center and Hotline	(800) 467-4922
US Environmental Protection Agency	
■ National Response Center	(800) 424-8802
■ RCRA Hotline	(800) 424-9346
■ RCRA Information Center	(703) 603-9230
■ Small Business Ombudsman	(800) 386-5888
■ Storm Water Hotline	(703) 821-4823
US Government Printing Office	
■ Superintendent of Documents	(202) 512-1800

Appendix A - Acronyms

BACT	Best Available Control Technology
BLS	Bureau of Labor Statistics
CAAA	Clean Air Act Amendments of 1990
CERCLA	Comprehensive Environmental Response, Compensation and Liability Act
CESQG	Conditionally Exempt Small Quantity Generator
CFR	Code of Federal Regulations
CSHO	Compliance Safety and Health Officer
CTG	Control Techniques Guidelines
CWA	Clean Water Act
EB	Electron Beam
EPCRA	Emergency Planning and Community Right-to-Know Act
HAP	Hazardous Air Pollutant
HMIS	Hazardous Materials Information System
LAER	Lowest Achievable Emission Rate
LQG	Large Quantity Generator
MACT	Maximum Achievable Control Technology
MSDS	Material Safety Data Sheet
NAA	Non-attainment Area
NAAQS	National Ambient Air Quality Standard
NEC	National Electric Code
NESHAP	National Emission Standard for Hazardous Air Pollutant
NOI	Notice of Intent
NO_X	Oxides of Nitrogen
NPDES	National Permit Discharge Elimination System
NSR	New Source Review
OSH	Occupational Safety and Health
OSHA	Occupational Safety and Health Administration
PM	Particulate Matter
POTW	Publicly Owned Treatment Works
PPA	Pollution Prevention Act
PPE	Personal Protection Equipment
PSD	Prevention of Significant Deterioration
PTE	Potential to Emit
RACT	Reasonably Available Control Technology
RCRA	Resource Conservation and Recovery Act
SARA	Superfund Amendments and Reauthorization Act
SBAP	Small Business Assistance Program
SBO	Small Business Ombudsman
SBREFA	Small Business Regulatory Enforcement Fairness Act
SQG	Small Quantity Generator
TRI	Toxic Release Inventory
TSD	Treatment, Storage and Disposal
TSCA	Toxic Substance Control Act
USEPA	United States Environmental Protection Agency
UV	Ultraviolet
VOC	Volatile Organic Compound

Appendix B - Waste Manifest

PRESS HARD—You Are Writing Through Eight Copies (See Reverse Side)

STATE OF NEW YORK
DEPARTMENT OF ENVIRONMENTAL CONSERVATION
DIVISION OF SOLID & HAZARDOUS MATERIALS

NYG0611181

HAZARDOUS WASTE MANIFEST
P.O. Box 12820, Albany, New York 12212

Please type or print. Do not staple. (Rev. 3/97)

UNIFORM HAZARDOUS WASTE MANIFEST

1. Generator's US EPA No. | Manifest Doc. No. | 2. Page 1 of | Information within heavy bold line is not required by Federal Law.

3. Generator's Name and Mailing Address

4. Generator's Telephone Number ( )

5. Transporter 1 (Company Name) | 6. US EPA ID Number

7. Transporter 2 (Company Name) | 8. US EPA ID Number

9. Designated Facility Name and Site Address | 10. US EPA ID Number

A. NYG0611181
B. Generator's ID
C. State Transporter's ID
D. Transporter's Telephone ( )
E. State Transporter's ID
F. Transporter's Telephone ( )
G. State Facility ID
H. Facility Telephone ( )

11. US DOT Description (Including Proper Shipping Name, Hazard Class and ID Number)	12. Containers Number	Type	13. Total Quantity	14. Unit Wt/Vol	I. Waste No.
a.					EPA / STATE
b.					EPA / STATE
c.					EPA / STATE
d.					EPA / STATE

J. Additional Descriptions for Materials Listed Above
a. c.
b. d.

K. Handling Codes for Wastes Listed Above
a. c.
b. d.

15. Special Handling Instructions and Additional Information

16. **GENERATOR'S CERTIFICATION:** I hereby declare that the contents of this consignment are fully and accurately described above by proper shipping name and are classified, packed, marked and labeled, and are in all respects in proper condition for transport by highway according to applicable international and national government regulations and state laws and regulations.
If I am a large quantity generator, I certify that I have a program in place to reduce the volume and toxicity of waste generated to the degree I have determined to be economically practicable and that I have selected the practicable method of treatment, storage, or disposal currently available to me which minimizes the present and future threat to human health and the environment; OR if I am a small generator, I have made a good faith effort to minimize my waste and select the best waste management method that is available to me and that I can afford.

Printed/Typed Name | Signature | Mo. Day Year

17. Transporter 1 Acknowledgement of Receipt of Materials
Printed/Typed Name | Signature | Mo. Day Year

18. Transporter 2 Acknowledgement of Receipt of Materials
Printed/Typed Name | Signature | Mo. Day Year

19. Discrepancy Indication Space

20. Facility Owner or Operator: Certification of receipt of hazardous materials covered by this manifest except as noted in Item 19.
Printed/Typed Name | Signature | Mo. Day Year

GENERATOR
TRANSPORTER
FACILITY

In case of emergency or spill immediately call the National Response Center (800) 424-8802 and the NYS Department of Environmental Conservation (518) 457-7362

COPY 1 — Disposer State — Mailed by TSD Facility
COPY 3 — Disposer State — Mailed by Generator

Appendix C - MSDS Sample 1

Two samples of Material Safety Data Sheets illustrate the diversity allowed by the format. Sample 1 is provided courtesy of Diversified Enterprises and is the MSDS for test pens used to determine dyne level. Sample 2 is provided courtesy of Sun Chemical Corporation and is the MSDS for a solvent ink.

MATERIAL SAFETY DATA SHEET

Product Name: Accu Dyne Test Marker Pens
Formula: $HCONH_2 + C_2H_5OC_2H_4OH$
Chemical Family: Amide/Glycol Ethers

I. INGREDIENTS

CONSTITUENT	CAS NO.	TLV	OSHA PEL
Ethyl Cellosolve (C)*	110-80-5	200 ppm	29 CFR 1910.1000
Formamide (F)	75-12-7	20 ppm	
Victoria Blue Dye	2185-86-6	n/a	
Water (H)	n/a	n/a	

*ethyl Cellosolve is a registered trademark of Union Carbide Corporation for 2-ethoxyethanol (ethylene glycol monoethyl ether).

PERCENTAGES BY DYNE LEVEL

LEVEL	C (VOL)	F (VOL)	LEVEL	C (VOL)	F (VOL)
30	100.0%	0.0%	48	13.0%	87.0%
32	89.5%	10.5%	50	9.3%	90.7%
34	73.5%	26.5%	52	6.3%	93.7%
36	57.5%	42.5%	54	3.5%	96.5%
38	46.0%	54.0%	56	1.0%	99.0%
40	36.5%	63.5%			
42	28.5%	71.5%	LEVEL	F (VOL)	H (VOL)
44	22.0%	78.0%	58	81.2%	18.8%
46	17.2%	82.8%	60	65.0%	35.0%

Concentration of Victoria blue dye is 2 grams per liter.

II. HAZARD SPECIFICATIONS: (UNDER 29 CFR 1910.1000)

These hazards are associated with the fluids contained in ACCU DYNE TEST Marker Pens:

Reproductive Toxin	Skin Hazard	TLV = 20 to 200 ppm
Eye Hazard	Kidney Toxin	PEL = 5 ppm (8 hr weighted avg)
Sensitizer	Toxic Agent	EPA Hazardous Waste Class: n/a
Combustible Liquid	Skin Irritant	DOT Hazard Class: n/a

NFPA Hazard Signal: HEALTH - 1; STABILITY - 0; FLAMMABILITY - 0; SPECIAL - C

— continued on next page —

III. PHYSICAL DATA:

Boiling Point (at 760 mm Hg)	135° C to 210° C	**Freezing Point** (at 760 mm Hg)	-90° C to +2° C
Specific Gravity at 20°C (H_2O = 1.0)	0.93 to 1.13	**Vapor Pressure** mm Hg, at 20°C	0.08 to 3.75
Vapor Densit, at 20°C (air = 1)	3.1	**Solubility in Water** % by wt. at 20°C	Complete
Percent Volatiles (by volume)	100%	**Evaporation Rate** (Butyl Acetate = 1)	0.32 to 0.60

Appearance and odor: Blue solution with mild, non-residual odor.

IV. FIRE AND EXPLOSION DATA:

Flash Point: 108°F to 245°F, per ASTM D56; tag closed cup.

Autoignition Temperature: n/a

Flammability Limits in Air (by vol. at 200° F): 1.7% to 15.6%

Extinguishing Media: Water fog recommended; CO_2, dry chemical, and universal foam media, as applied by manufacturer's recommendations, can also be used.

Unusual Fire/Explosion Hazards: Can react with oxidizing materials

V. HEALTH HAZARD DATA:

Inhalation: Vapors are irritating to eyes, nose and respiratory tract. May cause headache, nausea, vomiting, weakness.

Skin Contact: May cause irritation.

Ingestion: See inhalation; can also cause breathing difficulty. Kidney damage may result from ingestion of large quantities of test solution.

Skin Absorption: Prolonged or widespread contact with skin may lead to absorption of harmful amounts of material resulting in symptoms as described under ingestion.

Eye Contact: Causes marked irritation.

SPECIAL WARNING: Pregnant women should not use this product; laboratory studies of animal subjects have shown birth defects, delayed fetal development, and increased fetal mortality at air concentrations of 150 to 200 ppm.

VI. EMERGENCY AND FIRST AID PROCEDURES:

Eyes: Flush liberally with running water. Call a physician.

Skin: Immediately remove contaminated clothing. Thoroughly wash affected area with soap and water.

Inhalation: Remove to fresh air. If breathing is difficult, give oxygen and call a physician.

Ingestion: Give large quantities of water. Induce vomiting. Call a physician.

VII. REACTIVITY DATA:

Decomposes partially at temperatures above 180°C. Do not combine with concentrated alkali at elevated temperatures.

Hazardous combustion or decomposition products: CO, NH_2.

VIII. SPILL OR LEAK PROCEDURES:

Absorb spill with paper toweling or vermiculite. Once absorbed, evaporate outdoors or incinerate in a chemical burner equipped with an after-burner and scrubber.

Dispose of wate product by high temperature incineration, as approved under appropriate federal, state, and local legislation. Do not discharge without prior written approval from health and pollution authorities.

— continued on next page —

IX. SPECIAL PRECAUTIONS

NOT FOR USE AS A CONSUMER PRODUCT. FOR INDUSTRIAL USE ONLY.

Keep this product away from heat and flame. Always use with adequate ventilation. Do not allow fluid to contact skin.

WARNING TO PREGNANT WOMEN: Do not use ACCU DYNE TEST marker pens unless exposure is extremely low. Even small amounts, if repeatedlly inhaled, ingested, or absorbed through skin, may cause fetal malformations.

While Diversified Enterprises believes the information contained herein is factual and the opinions expressed are those of qualified experts, this information is not to be taken as a warranty for which Diversified Enterprises assumes legal responsibility. It is provided solely for consideration, investigation and verification.

Russell E. Smith, President

Diversified Enterprises

Date: June 4, 1996

Appendix C - MSDS Sample 2

MSDS - TXG53346F

MATERIAL SAFETY DATA SHEET

Sun Chemical Corporation
631 Central Avenue
Carlstadt, NJ 07072

MSDS Distribution:	(201) 933-4500
Regulatory Information:	(201) 933-4500
Emergency Phone No.:	(201) 804-8228 (24 hours)

1. PRODUCT IDENTIFICATION

Product Name	TXG53364F
Product Description	INK
Product Category	Flexo Ink
MSDS Identification No.	000000000000
MSDS Date	06/12/98

2. COMPOSITION (Hazardous Components)

The component listed below is identified as a hazardous chemical based upon the criteria of the OSHA Hazard Communications Standards (29 CFR 1910 1200).

Chemical Name	CAS Number	Concentration (wt.%)
Diethylene Glycol Monobutyl Ether	112-34-5	1.71

For further information on the individual hazardous component(s) listed above, please refer to the Toxicological Information section of the MSDS (section 11).

3. PRODUCT HAZARDS IDENTIFICATION

Emergency Overview

Material may be irritating to skin and eyes.

Potential Health Effects

Dermal contact is expected to be the primary route of occupational exposure. The following statements are based upon an assessment of the health effects associated with the components in this product mixture.

Eye

This product may cause mild to moderate eye irritation. Direct contact or excessive exposure to vapors may cause redness, tearing and stinging.

Skin

This product may cause mild to moderate eye irritation. Prolonged or repeated exposure may result in contact dermatitis which is characterized by redness, itching, drying and/or cracking of the skin.

Inhalation

This product is not expected to cause respiratory tract irritation under conditions of intended use.

Ingestion

Ingestion of amounts incidental to normal industrial handling are unlikely to cause adverse health effects. Deliberate ingestion of excessive quantities may result in gastrointestinal irritation, nausea, vomiting and diarrhea.

— continued on next page —

Chronic Effects

Chronic overexposure may result in kidney damage and blood disorders.

Medical Conditions Aggravated by Exposure

Preexisting skin disorders may be aggravated by exposure to this product.

4. FIRST AID MEASURES

Eye Contact: In case of direct content, flush eyes with clean water for at least 15 minutes. Seek medical attention if irritation or redness develops and persists.

Skin Contact: Remove contaminated clothing. Wash affected area thoroughly with soap and water. Seek medical attention if irritation or redness develops and persists.

Inhalation: If breathing difficulties develop, remove affected person away from source of exposure into fresh air. Seek medical attention.

Ingestion: Ingestion is an unlikely route of exposure under normal industrial conditions. However, if appreciable quantities of this product are accidentally swallowed, seek immediate medical attention.

5. FIRE FIGHTING MEASURES

Flash Point (Degree F)	Equal or greater than 200° F (Closed Cup)
Flash Point Category (OSHA/NFPA)	IIIB
Lower Flammability Limit In Air (% by Vol)	2B

NOTE: flash point value/category has been derived from testing of products of similar composition.

Extinguishing Media

This material is a water-based product as supplied is not expected to burn. The residual material and/or product container may support combustion. If this should occur, use water, multipurpose foam, dry chemical or carbon dioxide.

Fire Fighting Instructions

The use of self-contained breathing apparatus is recommended for firefighters. Water spray may be used to cool containers to heat near flame.

Fires and Explosion Hazards

No unusual fire or explosion hazards are anticipated.

6. FIRE FIGHTING MEASURES

Keep unnecessarly personnel away from spill area. Ventilate area of spill; use appropriate personal protective equipment.

For large spills, contain the spill by diking with sand or other inert material: Keep out of drains, sewers or waterways. Transfer product to suitable containers for recovery or disposal. If necessary, follow emergency response procedures.

For small spills, use inert absorbent material. Water may be used to clean the area of the spill.

7. HANDLING AND STORAGE

Keep containers tightly closed. Keep containers cool and dry. Protect from freezing. Use and store this product with adequate ventilation. Use appropriate equipment when handling this product and maintain good personal hygiene practices.

8. EXPOSURE CONTROLS/PERSONAL PROTECTION

Keep containers tightly closed. Keep containers cool and dry. Protect from freezing. Use and store this product with adequate ventilation. Use appropriate equipment when handling this product and maintain good personal hygiene practices.

Emergency Overview

Provide adequate general (dilution) and/or local exhaust ventilation. It is suggested that a source of clean water be made available in work area for flushing eyes and skin.

— continued on next page —

Personal Protective Equipment

Eye/Face Protection: The use of chemical splash goggles or safety glasses is recommended to prevent eye contact.

Skin Protection: The use of impermeable, solvent-resistant gloves is advised to prevent skin contact. Use chemical-resistant apron if splash hazard exists.

Respiratory Protection: Respiratory protection is typically not required under conditions of normal use.

However, usually high concentrations of vapor may require respiratory protection.

Established Exposure Guidelines

No ACGIH or OSHA exposure guidelines have been established for any of the components in this product.

9. PHYSICAL AND CHEMICAL PROPERTIES

Boiling Point/Range (degree F)	212° F – 370° F
Typical Density (lbs/gal)	9.00
Vapor Density (excluding water) vs. Air	Heavier
Evaporation Rate (vs. Butyl Acetate)	Slower
Appearance	Blue Liquid
Volatile Organic Compounds (wt %)	5.38

10. STABILITY AND REACTIVITY

Stability: Stable. Hazardous polymerization will not occur.

Conditions to Avoid: Keep product away from heat, sparks and open flames.

Incompatibility: This product is incompatible with strong acids or bases and oxidizing agents.

Hazardous Decomposition Products: By high heat and fire: carbon dioxide, carbon monoxide and/or oxides and sulfur.

11. TOXICOLOGY OF COMPONENTS

Information pertaining to the health effects and toxicity of the “pure” form of hazardous components identified in Section 2 is presented below. This information reflects the known hazards associated with the component and may not reflect that of the purchased material due to concentration (dilution) effects. Review and interpretation by your Hazard Communication Department is recommended.

Diethylene Glycol Monobutyl Ether (1.71%)

May cause severe eye irritation. Eye contact may cause stinging, watering, redness and possible corneal damage. Repeated or prolonged exposure may cause skin irritation. Other effects of overexposure may include irritation of the nose and throat, irritation of the digestive tract and vomiting. Ingestion of excessive amounts may cause nervous system depression. (e.g., headache, drowsiness, dizziness, loss of coordination and fatigue). Repeated, intentional mis-use or ingestion can cause kidney and blood disorders.

12. DISPOSAL CONSIDERATIONS

Dispose of this product in accordance with local, county, state and federal environmental regulations. Do not introduce this product directly into public sewer systems. The introduction of product waste and/or water used for cleaning purposes into public sewer systems without pretreatment may violate your discharge permits. Containers of this product may be hazardous when emptied. Since emptied containers may retain product residues, all hazard precautions given in this data sheet should be observed.

13. REGULARTORY INFORMATION

Toxic Substances Control Act (TSCA)

The chemical components of this product are listed or have been registered for inclusion on the Section 8(B) Chemical Substance Inventory list (40 CFR 710).

EPCRA Section 313 Supplier Notification

This product contains the following substance(s) which are subject to the supplier notification requirements of Section 313 of the Emergency Planning and Community Right-To-Know Act of 1986 (40 CFR 372).

— continued on next page —

Chemical / Category	CAS #	Concentration (wt.%)
Glycol Ethers	Not Applicable	1.71

California Air Act Amendment (HAPs)

This product contains the following substance(s) which are defined as Hazardous Air Pollutants under Title III of the Clean Air Act Amendment of 1990.

Chemical / Category	CAS #	Concentration (wt.%)
Glycol Ethers	Not Applicable	1.71

California Proposition 65

This product does not contain any chemicals which are defined by the state of California to cause cancer and/or reproductive toxicity.

OSHA Hazard Communication Label for Product

CAUTION!
UPON LOSS OF WATER, PRODUCT RESIDUE MAY SUPPORT COMBUSTION
MAY CAUSE SKIN AND EYE IRRITATION.
Please refer to the MSDS for more details.
Keep away from heat or flame.
Keep container closed.
Use with adequate ventilation.
Avoid contact with eyes, skin and clothing
Use appropriate personal protective equipment.
Wash thoroughly after handling.
FIRST AID: In cases of contact, flush eyes or skin with plenty of water.
Remove contaminated clothing. Seek medical attention if irritation
develops or persists. If inhaled, remove to fresh air. Seek medical
attention if breathing difficulties develop.
IN CASE OF FIRE, use water, multipurpose foam, dry chemical or carbon dioxide.
Empty containers may retain product residues, all hazard precautions given
on this label should be observed.
DO NOT REMOVE THIS LABEL.

14. ADDITIONAL COMMENTS

Hazardous Materials Information System (HM IS)

Health 1	Flammability 1	Reactivity 0

NOTICE: These ratings are intended only for the immediate and general identification of acute hazards. Sun Chemical is providing this information on a voluntary basis as a guide for our customers. The use and interpretation of this information may vary from company to company. All information contained in this data sheet should be considered in order to adequately deal with the safe handling of this material.

Revision Date

06/12/98

The information presented in this data sheet represents a compilation of information generated from our suppliers and other recognized sources of scientific evidence and chemical information. To the best of our knowledge and belief, it is accurate and reliable as of the date of issue. However, no warranty, express or implied, including any warranty of merchantability, fitness for any use, or any other guarantee if offered or implied regarding the accuracy of such data, the results to be obtained from the use thereof, the safety of this product, or hazards connected with the use of this material. Since the conditions of handling and the use of this material are beyond our control, Sun Chemical shall assume no liability for damages incurred, and that the person receiving them shall make his own determination as to the suitability and completeness of this information, the safety measures necessary to handle this product, and the actions needed to comply with all applicable Federal, State and Legal Legislation.

000000342504/TXG53346F /001/002/00TXG53346F / 0.00000/ 9.01/2.01.0/ 5.38/1/1/0

— continued on next page —

VOLATILE COMPONENT INFORMATION

EPA
Designate

A. Product Density
   1.) 9.00 LBProduct/Gal Product = (Dc)3

B. Nonvolatile Content:
   1.) 43.82 Weight percent of nonvolatiles in product = (Wn)s
   2.) 39.32 Volume percent nonvolatiles in product = (Vn)s
   3.) 10.04 Density, lb. nonvolatiles /gal nonvolatiles = (DN)S

C. Volatiles
   1.) 56.18 Weight percent of total volatiles in this product = (Wv)s
   2.) 8.33 Density, lb. volatiles /gal. volatiles = (Vw)s

D. Water Content:
   1.) 50.46 Weight percent of water in product = (Ww)s
   2.) 8.33 Density, lb. volatiles /gal. volatiles = (Dw)s

E. Organic Volatiles, (VOCs):
   1.) 5.38 Weight percent of organic volatiles ion product = (Wo)s
   2.) 5.76 Weight percent of organic volatiles ion product = (Vo)s
   3.) 8.41 Density, lb. organic volatiles /gal. organic volatiles = (Do)s
   4.) 9.58 Weight percent of VOCs in total volatiles = (Wo)v
   5.) 9.49 Weight percent of VOCs in total volatiles = (Vo)v

F. VOC COntent in Product Expressed in Other Terms:
   1.) a.)0.48 lb. VOC / gal. Product
   1.) b.)58.03 grams VOC / liter Product
   2.) a.)1.06 lb. VOC / gal. Product less water & exempt solvent
   2.) b.)127.32 grams VOC / liter Product less water & exempt solvent
   3.) 1.23 lb. VOC / gal. total nonvolatiles

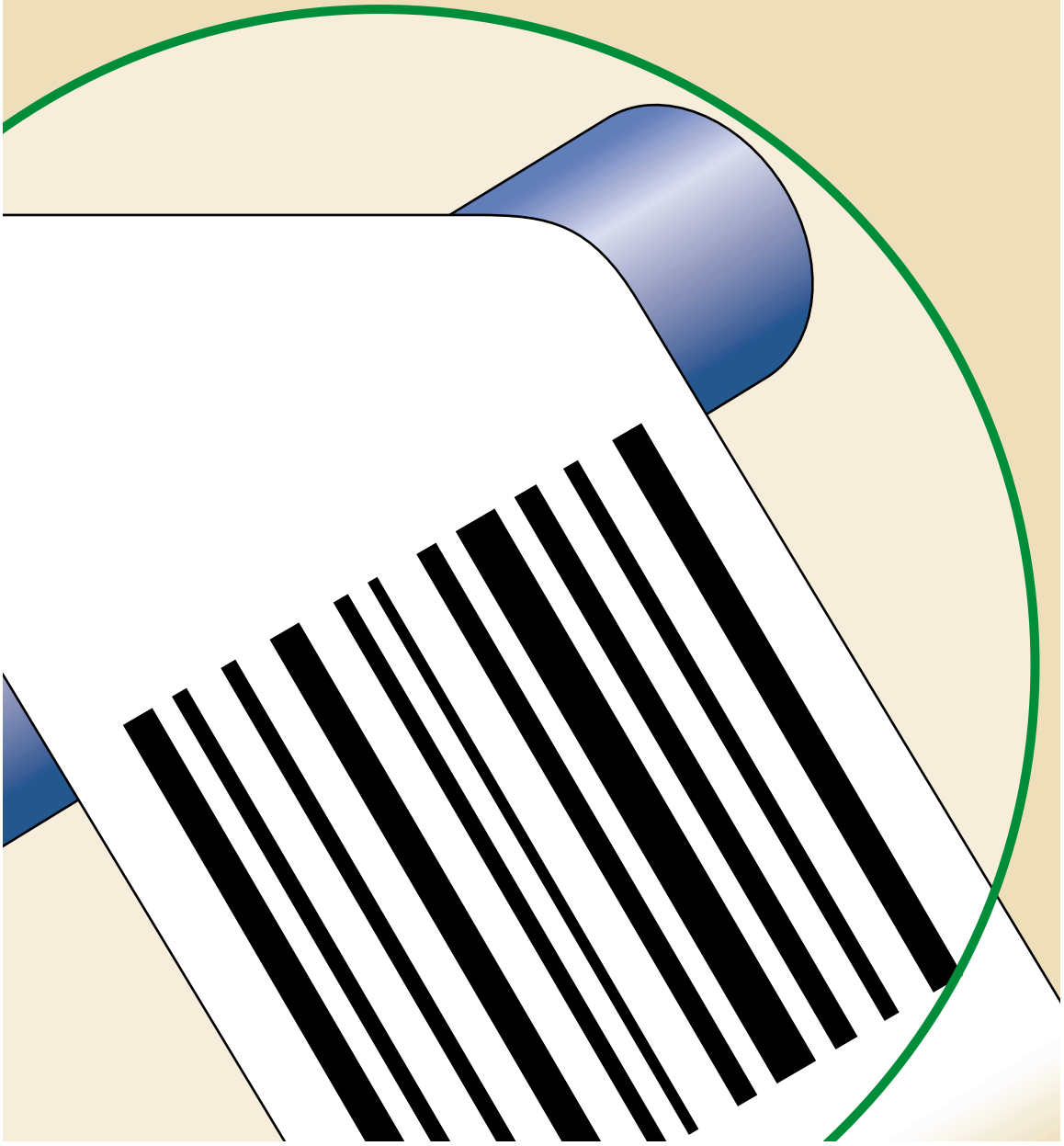
G. Volatiles: (all VOCs, HAPs, water & ammonia)

NUMBER	CAS PERCENT	WEIGHT (LB./GAL.)	DENSITY	INGREDIENT
Propylene Glycol	57-55-6	3.50	8.67	
Diethylene Glycol Monobutyl Ether	112-34-5	1.71	7.96	
Ammonia	7664-41-7	0.34	5.99	
Non HAP/SARA Organic Volatiles		0.17	7.75	
Water	7732-18-5	50.46	8.34	

NOTE: The term Volatile Organic Compounds (VOC) refers only to volatile organic materials as defined by the US EPA and does not include water, ammonia, acetone or other exempt solvents. Unless otherwise stated, the VOC values reported above are based on materials of construction.
See Section 13 of the MSDS for identification of the HAPs ingredients.

CHAPTER 2

Bar Codes



ACKNOWLEDGEMENTS

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Introduction

Beauty may be in the eye of the beholder, but bar code accuracy is another matter entirely. In some circles, you may hear sad tales about how an otherwise good-looking print job was rejected by the customer only because of "tiny" bar code inaccuracies. When you hear this story, do not lend a sympathetic ear. The fact of the matter is, there are no such things as "tiny" bar code inaccuracies. A bar code either scans correctly or it doesn't. There is no middle ground; no room for "beauty in the eye of the beholder" unless the beholder is the scanner.

Before listening to the tales about what a harsh, cold-hearted judge of print quality a scanner is, consider this. There are clear-cut guidelines and procedures that have been developed for flexographic printing of bar codes. When adhered to, they produce accurate, scannable bar codes in virtually every circumstance, on every substrate imaginable. When a client's bar code is produced correctly, everyone benefits. And we do mean everyone.

Note: *The bar codes reproduced in this volume are intended for illustration purposes only and are not meant to represent scannable bar codes.*

Understanding Bar Codes, the Lifeblood of the Supply Chain

Have you ever jumped into the express lane at the store only to be stopped in your tracks by a product that won't scan? First the clerk runs the product past the scanner a few times, turning it slightly for each pass. Then, if it's a product in flexible packaging, there follows a "smoothing" routine – pulling and twisting the packaging material until the bar code is completely flat. Finally, if that doesn't produce an accurate scan, a now-exasperated clerk holds up the package, squints and begins to manually enter the code into the terminal.

This wanton waste of your time is only the tip of the iceberg when a bar code isn't printed correctly. Consider that every checker in every store in the chain may encounter similar problems with that product. Very soon you can see why the retailer will complain to the manufacturer who supplied the product in the first place. Back charges will be levied. Then the "multiple" effect kicks in. Multiply the damage by the number of retailers across the country or around the world who are customers of the manufacturer, and you can see a potentially catastrophic situation looming for the entire product line. And that can translate into a dire situation for the designer or printer who created the error in the first place.

There is an important supply chain lesson here. Simply put, in today's globally integrated marketing environment, scannability equals salability. Those little black bars and spaces, when printed accurately as a bar code symbol, not only prevent serious problems for trading partners, but they become the key to unlocking a wealth of time – and cost-saving benefits that drive the efficiency of the entire supply chain.

Bar codes convey unique product identification for manufacturers and their products virtually everywhere in the world. They provide rapid, error-free data entry at the retail point-of-sale. They accelerate shipping and receiving, improve warehouse efficiency, aid logistics and transportation, and otherwise drive unnecessary costs out of the supply chain for industries as diverse as healthcare, automotive, foodservice and electronics. Their numbering structures even provide companies with the ability to closely track assets, monitor work-in-progress, and control the flow of internal and external routing systems and other identification applications.

In other words, bar codes mean business for you and your clients. With a little supply chain understanding, some fundamental knowledge of the most common symbologies used, and a close attention to established production guidelines, flexographic printing of bar codes can generate its own rewards in supply chain efficiencies across industry channels.

A Quick Course on Common Bar Code Symbologies

According to AIM International, Inc., the worldwide trade association for the automatic identification and data capture industry (see *Resources*), there are approximately 225 bar code symbologies that have been published around the world. However, only a small fraction of these are being used in any significant way, and fewer still have the widespread acceptance of the familiar EAN/UPC "product code" symbology.

Considered by many to be the genesis of the modern bar code era, the EAN/UPC symbol was formally introduced as a 12-digit code in the United States by the Uniform Code Council, Inc. (UCC) in 1973. In 1977, the European Article Number Association (EAN) adopted the U.P.C. product identification system. The 12-digit code was expanded to a 13-digit data structure to allow for its use internationally. Today, the UCC and EAN International manage the product identification system together. There are over 820,000 member companies in 90 countries using UCC/EAN identification numbering rules and bar codes on countless products worldwide. In fact, it is estimated that the EAN/UPC symbology alone is involved in more than 5 billion product transactions a day on a global scale. The numbering rules and bar code specifications for the primary business applications (product identification, shipment identification and coupon structures) encountered in the North American supply chain are described today in a UCC document called "Guidelines for Supply Chain Identification'. *Figure* ❽ shows the EAN/UPC symbol family.

❽ The EAN/UPC symbol family of bar codes.

The EAN/UPC symbol belongs to the linear family of symbologies, meaning it encodes its data in a simple arrangement of bars and spaces on a horizontal axis. Linear symbols can then be scanned directionally and decoded. This differs from the more advanced two-dimensional bar codes which stack information in multiple rows or in a matrix pattern with both horizontal and vertical axes contributing significant meaning. This type of symbol requires more advanced scanning techniques, but also delivers a large increase in the capacity of information it is able to encode.

The EAN/UPC is also considered to be a continuous bar code symbology. Continuous symbologies encode symbol characters without any inter-character space between them. In other words, as one symbol character ends with a space, the next begins with a bar. Compare this to discrete bar code symbologies, which treat each character independently, separating them with loosely toleranced spaces (*Table 11)*.

As manufacturers, distributors and other supply chain members sought to identify product configurations, shipments, company assets, physical locations and product attributes, new symbologies were introduced. It is impossible to cover all the events between the advent of EAN/UPC and today regarding symbology development, but a review of the major milestones can be covered fairly quickly.

❾

❾ A typical Code 3-of-9 (Code 39) symbol. This system uses a proportionally large amount of space to convey its information.

In the late 1970s, the Committee to the Department of Defense and the General Services Administration recommended Code 39 (also known as Code 3-of-9) for general use (*Figure* ❾). Many commercial and industrial businesses also picked up the symbology for their applications. Named for its distinctive encoding structure, Code 39 always features nine elements (five bars and four spaces) with three of the nine elements always being wide for each character encoded. The symbology features a full alphanumeric character set and the ability to be variable in length as required. It does, however, use a significant amount of label space, making it less desirable in certain applications.

Another popular symbology introduced in the 1970s is ITF (Interleaved 2-of-5). ITF *(Figure* ❿) is commonly encountered as

CHARACTERISTICS OF SOME COMMON BAR CODES

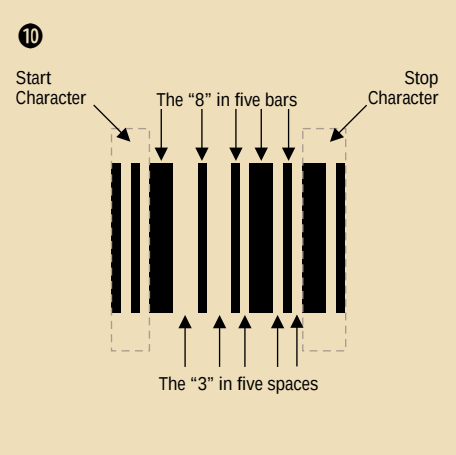
SYMBOLOGY TYPE	ENDOCATION DATA CONTENT	METHOD	LENGTH ENCODING	RESTRICTION
EAN/UPC FAMILY	Numeric only	Complex	Continuous	Fixed
CODE 39 (Code 3-of-9)	Alpha-numeric	Simple	Discrete	Variable
ITF (Interleaved)	Numeric only	Simple	Continuous	Fixed
Code 128	Alpha-numeric	Complex	Continuous	Variable

Table 11

❿ The ITF system codes characters in sets of five spaces and bars, thus the moniker "2-of-5" symbol.

⓫ By encoding two digits per symbol character, Code 128 is able to communicate its data in a relatively small space.

⓬ The UCC/EAN-128 symbology with a special double character start pattern consisting of either a start code A, B, or C character as the first symbol character, and an FNC1 as the second symbol character.



the bar code specified for UCC/EAN products when they are packaged above the unit level in corrugated cases *(see ANSI/UCC6 – Application Standard for Shipping Container Codes)*. It is also used widely by the airlines industry. As with Code 39, ITF received its name from the way it encodes its numeric-only character set. Each symbol character contains five data elements (bars or spaces), two of which are wide (2-of-5). The "interleaved" reference comes from the way the symbology takes digit pairs and interleaves them into its symbol characters, one in the bars and one in the spaces. This simple structure dictates that an even number of characters must always be encoded.

Code 128 was developed in 1981, and its name encompasses one of its primary assets – the ability to encode the full 128-character ASCII set (*Figure* ⓫). Code 128 offers a number of robust features that provide its users with many options. It can encode variable-length data and permits numeric data to be encoded as two digits per symbol character. This "double density" mode makes it one of the most efficient symbols in widespread use from the standpoint of the area it requires for encoding numeric data. Code 128 is widely used by a host of industries including healthcare, retail, food and grocery, and transportation.

The UCC, in conjunction with EAN International, licensed a unique subset of Code 128, called UCC/EAN-128, for the exclusive use of encoding UCC/EAN-defined data. The subset can be reserved because Code 128 encodes four special symbol characters referred to as function characters (FNC1, FNC2, FNC3 and FNC4). The UCC/EAN-128 symbology has a special double-character start pattern consisting of either a start code A, B, or C character as the first symbol character, and an FNC1 as the second symbol character as shown in (*Figure* ⓬). This unique start code pattern tells the scanning and decoding system that a UCC/EAN-128 has been scanned and the data should be processed according to the UCC/EAN-128 "data dictionary" defined by UCC/EAN.

Note: *Some of the bars in Figure ⓬ are shown in different colors for illustration purposes only. Multiple colors or red colors should NEVER be used in a UCC/EAN symbol intended for actual use.*

The UCC/EAN-128 "data dictionary" (formally called ANSI/UCC4-UCC/EAN-128 Application Identifier Standard) is based on using a series of two, three or four digit prefixes in front of the actual data to be encoded. These prefixes are called Application Identifiers, or AI for short. For example, the UCC/EAN specifies that the 14-digit product identification number called UCC/EAN-14 (or SCC-14) has the AI prefix of 01 in front of it to tell the scanning and decoding system that the UCC/EAN-14 follows. This is very much like the area code assigned to a telephone exchange. Application Identifiers are even put into parenthesis, like an area code, when printed in the human readable text associated with the UCC/EAN-128 symbol. There are about 100 AI definitions and each describe what type of data is encoded, how long the data content is (fixed or variable length fields), and what kind of data it can contain (numeric versus alphanumeric). By using AI prefixes, multiple identification numbers can be concatenated (combined) into one UCC/EAN-128 symbol. The scanner/decoder system uses the AIs to determine the meaning and length of the data behind each AI (by following the AI definitions). Then the decoder strips the AIs out of the data before it is sent to the business application software. There is another method of defining data called Data Identifiers (DI) which is often used within Code 39 bar codes.

Symbol Structure, an Overview

The EAN/UPC and other symbologies are each considered to be their own unique language, with their own individual rules for character encoding, decoding, checking and other features. But there are common features across the spectrum of many bar code symbols that illustrate a fundamental structure.

In their most common form, linear bar codes are a series of alternating dark bars and light bars (called spaces), in various widths, which reflect light within an acceptable reflectance tolerance as prescribed by specifications. Most linear symbols are bidirectional. That means the symbol may be scanned left-to-right or right-to-left with the same results. EAN/UPC symbols are unique in that they can also be scanned omni-directionally.

When scanned by an omni-directional scanner, the EAN/UPC symbol can be read by the reader at any orientation in which its bars are presented to the scanner's pattern of scanning beams. The symbol design requires that the height of the bars be somewhat greater than the width of any decodable segment of a symbol. This "over-square" geometry guarantees that a scanner's beams will intersect all the required bars and spaces to decode a symbol on a single pass across the scanner. EAN/UPC symbols consist of one or two decodable segments, depending on the version. The most common versions of the EAN/UPC symbols consist of two decodable segments that are read as a single symbol. This symbol design feature, when combined with special scanning patterns used in checkout scanners, speeds the checkout process in high volume applications.

The key measurement in bar code symbology is called the "X" dimension. Quite simply, X is the width of the narrowest bar or space element in the symbol, and it sets the parameters for the corresponding bar widths, symbol length and sometimes height of the printed bar code. Bar code application standards (standard based on where the bar code will be used) typically specify an acceptable range for the X-dimension and may also specify a nominal (or target) value. The range specified correlates to the scanners typically used in the application and the type of scanning conditions that are encountered. For instance, some scanners scan very small X-dimensions and require the symbol to be in near-contact with the scanner, while other scanners can scan symbols with large X-dimensions from across a room. Some scanners are operated by humans who can find the symbol and adjust scanning angle/distance while other scanners are mounted to a conveyor and expect to see symbols in a predictable location with a predictable X-dimension.

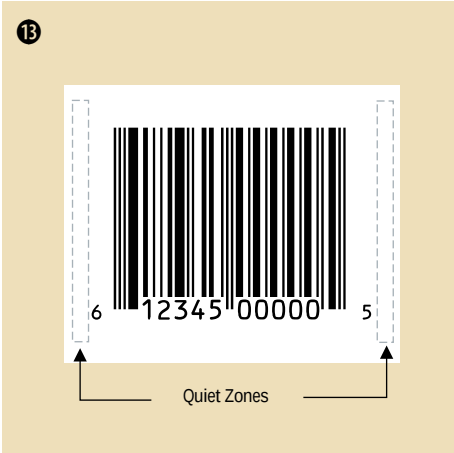
Another factor to consider for "two-width symbologies" (symbols with only two element widths[17]) is bar-width ratio. Bar-width ratio is the relationship of wide-to-narrow

17 ITF and Code 39 are two width symbols. EAN/UPC, UCC/EAN-128 and Code 128 are not.

elements, such as 3:1 or 2:1, where 1 is the X-dimension (narrow element width). For two width symbologies, the width of the wide element grows in a fixed proportion to the size set for the X-dimension (narrow element width). The application standard (based on where the bar code will be used) must take the X-dimension and the bar width ratio into account for two-width symbols. The bar-width ratio may be specified as a nominal value accompanied by an allowable range. For instance, when the ITF symbol is specified by the UCC for use on shipping containers, it has a nominal bar width ratio of 2.5:1 and an allowable range of 2.25:1 to 3:1. These application specifications for the minimum X-dimension and bar-width ratio provide the bar code designer and printer with the range of bar code sizes that must be used.

Quiet zones are another common element shared by most bar code symbologies (*Figure* ⓭). Quiet zones are print-free zones, frequently measuring 9 or 10 times the X dimension, that are used to separate the bars and spaces from any surrounding graphics or text. They are used to help the scanner locate the symbol. These zones normally precede and follow start and stop patterns that enable the scanner to decode the symbol. These bar and space patterns, which are unique to each symbology, identify the beginning and end of a decodable segment of the symbol, as well as the direction of reading.

In the EAN/UPC symbology, the start and stop patterns are referred to as guard bars. For UPC-A, EAN-13, and EAN-8 versions of the EAN/UPC symbol family, the guard bars are formed by twin narrow elements at the beginning, center, and end of the symbol as shown in (*Figure* ⓮). They divide the symbol into left and right decodable segments that are then combined by the scanner into a single symbol. For the UPC-E version of the EAN/UPC symbol family, the guard bars are formed by twin narrow elements only at the beginning and end of the symbol and create



⓭ Quiet Zones are print-free areas that help the scanner locate the bar code symbol.

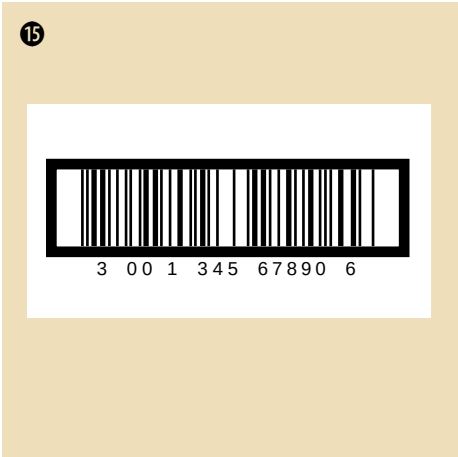
⓮ Guard bars (the twin narrow lines shown in red), divide the bar code into left and right segments.

only one decodable segment. More details can be found at the UCC web site in the document ANSI/UCC5 – Quality Specification for the U.P.C. Printed Symbol.

Note: Some of the bars in Figure ⓮ *are shown in different colors for illustration purposes only. Multiple colors or red colors should never be used in a UCC/EAN symbol intended for actual use.*

Beneath the black and white lines, many bar codes maintain an acknowledgement to those of us who are not machines. The "human-readable text" as it is often called, contains text characters that, when entered manually into a system, can also unlock the same encoded data referenced in the symbol. The symbology specifications or application standards set out how many text characters

⓯ A bearer bar (the bar encasing the bar code symbol) reduces the probability of scanner error.



are associated with the encoded data, the spacing between text characters, and even where the text should be located. There are often text characters that are not encoded in the bars and spaces, such as the parenthesis around UCC/EAN Application Identifiers. There are also symbol characters that may not be included in the human-readable text, such as symbol start/stop patterns and internal symbology check characters (module 103 for Code 128 and UCC/EAN-128).

Another major feature shared among most bar codes is a method of error checking built into the code. There are actually two ways a bar code data carrier may be checked. The first method, called self-checking or parity checking, uses the graphic design of the symbology itself to verify if a character is encoded properly. One example of this would be a symbology which requires that there be an odd number of narrow bars in every properly-encoded character; another example would be a symbology which must always have an even number of dark modules for each character. These symbol-checking arrangements are joined by a second method of checking called check digits. Based on algorithms, check digits are calculated based on strings of numbers encoded within the symbol, then the check digit is encoded as part of the symbol as well. When scanned, they allow the code inside the symbol to be verified as a valid combination of characters. This adds greatly to the high confidence factor enjoyed by bar code users.

A final feature that is found on bar codes such as the ITF symbol is bearer bars. The UCC specifies bearer bars surround the ITF symbol to reduce the probability of misreads when the scanning beam is skewed in relation to the symbol. The bearer bars also provide printing plate support when the symbol is printed directly on packaging materials such as corrugated. When the symbol is printed directly on the packaging material, the UCC specifies the bearer bar completely surround the symbol as shown in Figure ⓯.

Bar Code Design Considerations and Flexographic Printing

Preparation for bar code design and production begins with the selection of the proper symbol. Each symbology is clearly identified with its own applications. The bar code used depends on where and how the code it carries will be scanned. Scanners used at the retail POS (point of sale) checkout counter often differ dramatically from scanners used in large distribution centers. There are even significant differences among family members within the same symbology. For instance, EAN symbols used outside North America cannot yet be scanned at many retail locations in North America, but UPC symbols used in North America can be read anywhere in the world.

Symbologies, including the EAN/UPC, ITF, Code 39, and Code 128 are specified by symbology specifications. The symbology specifications for all major symbologies (other than EAN/UPC) are available from AIM USA[19]. The EAN/UPC specifications are available from UCC[20] (ANSI/UCC5 – Quality Specification for the UPC Printed Symbol). Beyond the raw specifications for the bar and space dimensions and encodation patterns, standards bodies closely regulate application standards that govern where and how bar codes are used to meet a business requirement. These application standards may even specify a symbology subset such as UCC/EAN-128 (ANSI/UCC4 – UCC/EAN-128 Application Identifier Standard). Designers and printers should obtain the symbology specifications and application standards governing the bar codes they create directly from the source. The printer's customer may also be required to apply for a part of the identification number itself. For example, the Uniform Code Council and EAN Inter-national are the two coequal standards bodies which oversee the global UCC/EAN system. Anyone wishing to employ any symbols in this worldwide network must first receive a company prefix by making application to the UCC, the EAN or one of their 90 affiliated numbering organizations worldwide. The UCC publishes a collection of symbology specifications and application standards within the Art of Producing Bar Codes Tool Kit for UCC members and their suppliers. The Tool Kit navigation system is based on the UCC/EAN flagship document for the design, preparation and production of its symbologies called Guidelines for Producing Quality Symbols. By following the membership application process and adhering to the symbology production procedures outlined by the UCC, the integrity of the system as a worldwide enabler of commerce is assured.

[19, 20] See *Appendix* at the end of this chapter for contact information.

Bar Codes in the Design Stage

Almost all packages require either a barcode or UPC symbol for pricing, identification and inventory information. FIRST and ANSI have specifications that should be followed. The difficulty for a designer who has to use the UPC code in package design is that the specifications for creating these symbols are very strict and UPC codes rarely, if ever, add to the appeal of an overall design. So, not only do bar codes become a necessary evil, but they also have a very strict set of tolerances that must adhered to by the designer and separator.

SIZE MATTERS

Some symbols are constrained by permissible aspect ratios, especially those intended for use with omni-directional scanners. Due to the nature of this type of scan, these symbols have a fixed relationship between their height and width. When one dimension is modified, the other dimension should be altered by a proportional amount.

The EAN/UPC symbols are one such example. Because of this relationship, EAN/UPC symbols have a nominal height and width specification. There is also a range of allowable sizes for the symbol, in this case from 80% to 200%. When specifying on purchase orders, indication of size is generally referred to as the symbol's "magnification factor."

Note: *Temptation is everywhere. In order to decrease the amount of space some symbols take up on a design; designers may be tempted to specify a decreased symbol height without a corresponding reduction in width. This process, called truncation, is not permitted within the EAN/UPC symbologies, as well as many others, and it should be avoided.*

It should also be noted that the allowable magnification range can depend on how the bar code will be used. For example, when EAN/UPC symbols are used in conveyorized, fixed-mount scanning environments (e.g., shipping and distribution) as well as at the retail point-of-sale, the minimum magnification allowed is increased from 80% to 160%. An example of a point-of-sale product that might also be used as a shipping container would be a carton used for a large appliance, (e.g., a television or microwave oven).

Finally, before the first ink is applied in the pressroom, every press that will run bar codes should be characterized. Press characterization (or fingerprinting) is a prerequisite for producing quality bar code symbols. Printers need to determine the minimum size bar code a particular press can produce with repeatable quality. They should ascertain the correct bar-width reduction (BWR) for bar codes in order to account for the normal ink spread encountered during the printing process. Once established, a printer should not attempt to print bar codes outside these specified ranges.

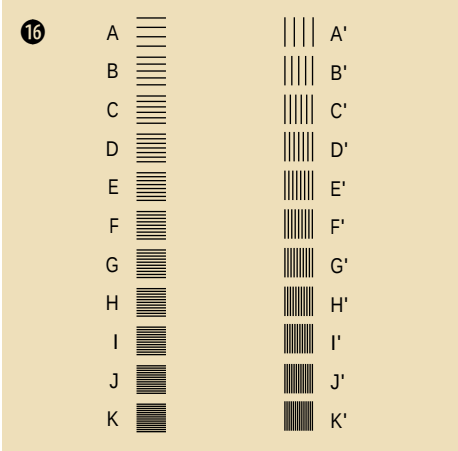
For many years, printers used the Printability Gauge illustrated in the UPC Film Master Verification Manual, repro-

duced in *Figure* ⓰. The Printability Gauge is a series of dark bars arranged in a specific pattern and is used to determine the range of print gain. The range of press variance is used to determine the minimum bar code size (magnification) and the midpoint in the range is used to establish the amount of BWR (bar width reduction) that should be made to the EAN/UPC symbol in prepress. Both factors are determined based on a set of tables that exist in ANSI/UCC1-1995: U.P.C. Symbol Specification Manual.

Today, many companies have established guidelines based on the process characterization studies they have conducted with the assistance of a film master manufacturer. However the process of press characterization may still be necessary in some cases. For instance, a company may begin printing bar code symbols for the first time or they may begin utilizing new technology in design, film-making, platemaking or printing. In cases like these, they may choose to use the traditional Printability Gauge method or a proprietary method, but the basics remain the same. If the printer chooses the print gauge method, the printer needs to establish a range for bar-width growth (press variance) and relate this range to the bar-width tolerances specified in the symbol specification. This will establish the minimum size symbol they can produce. They should then use the midpoint of the range they encounter to make bar-width reductions in the design stage.

COLOR IT BLACK

Color choice can be crucial. The optimum color combination for bar codes is carbon black bars with a white background. This provides the highest degree of reflective difference between the bars and spaces, producing an optimum read rate. Other colors may be used but, in general, red is the color of the scanner beam or light source most often used to illuminate a symbol's bars and spaces, that in turn facilitates the decoding or reading of a bar code. Whenever a scanning beam reads a bar code symbol, it determines the presence of a bar or a space by detecting whether or not the red light from the scanning beam is being reflected from the surface being illuminated by the beam. If the beam illuminates a light color such as white, or a color near the visible red spectrum such as orange and red, the area illuminated will reflect most of the red light and will be decoded as a space. If the beam illuminates a dark-colored surface such as black, dark blue, dark brown or dark green, very little of the red beam will be reflected, and this area will be decoded as a bar. That is, there must be a sufficient contrast between the reflected light from the dark bars and light spaces.



⓰ The Printability Gauge contained in the UPC Film Master Verification Manual. The dark bars are arranged in a specific pattern, and are used to determine the range of print gain.

The following guidance is provided for use on opaque substrates:

- Bar code symbols require dark colors for bars (e.g., black, dark blue, dark brown or dark green). Red is an unacceptable color for bars.
- The bars should always consist of a single line color and should never be printed by multiple imaging tools such as a combination of process colors.
- Bar code symbols require light backgrounds for the quiet zones and spaces

(e.g., white or yellow). In addition to light backgrounds, "reddish" colors may also be used.

4. In many cases the symbol background is not printed. It is the color of the substrate being printed (see Substrate Significance below). If the symbol background is printed beneath the bars, the background should be printed as a solid color or in multiple layers of solid color coverage to increase the background opacity.

In many cases the designer can be involved in the specification of the printing material characteristics such as matte, gloss, color or texture. The printer may submit sample materials for evaluation and/or approval. Whenever these decisions are made, it is important to consider the effect on the scannability of the bar codes. Such considerations as how an overprinted varnish or laminate will affect the symbol, as well as how the use of fluorescent, metallic, transparent or translucent materials might reduce the symbol contrast of the bar code, should be a priority.

SUBSTRATE SIGNIFICANCE

Some bar code symbols, such as Interleaved 2-of-5 (ITF), are typically printed directly on linerboard. Because of a lack of contrast, symbols printed on substrates such as natural kraft linerboard are more difficult to scan than symbols printed on mottled white linerboard, full bleached linerboard or white paper labels. For this reason, the best scanning results are often achieved by printing bars with opaque black, dark blue or dark green inks with uniform coverage. *Table 12* lists the Fibre Box Association's recommended Edition VIII GCMI colors for ITF symbols on natural kraft substrates.[21]

[21] From Fibre Box Association (FBA) Guideline for Direct Contact Printing of Bar Code Symbols on Corrugated. Reprinted here with permission from the FBA.

FBA EDITION VIII GCMI* COLORS

Recommended GCMI colors for natural kraft substrate.

CODE	COLOR	CODE	COLOR
3213	Aqua	3086	Blue
90	Black	52	Brown**
30	Blue	523	Brown
31	Blue	20	Green
32	Blue	21	Green
33	Blue	22	Green**
38	Blue	24	Green
39	Blue	25	Green
300	Blue	29	Green
387	Blue	2008	Green
394	Blue	2014	Green**

* Now GPI (Glass Packaging Institute)

** Least desirable of the recommended colors

Table 12

LOCATION, LOCATION, LOCATION

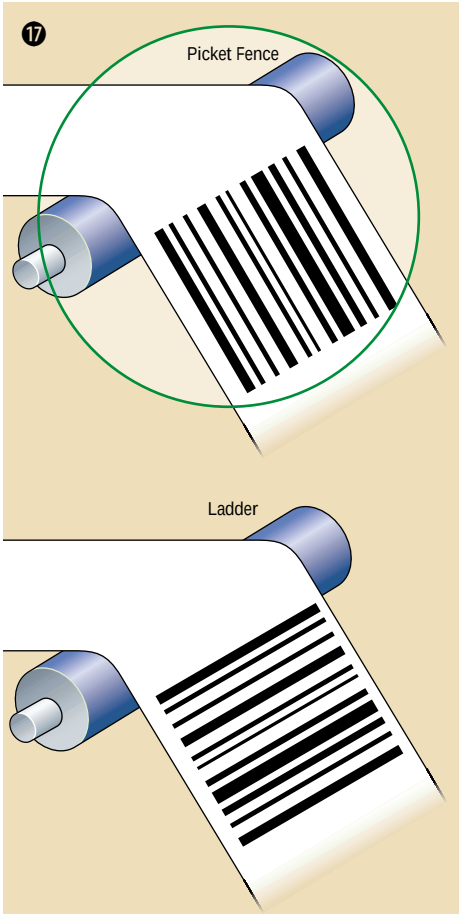
There are actually two primary considerations when determining symbol location. The first is the symbol placement on the design and the second is the symbol orientation (rotation) relative to the press-web direction.

When assigning the placement for the symbol, a designer should consult the appropriate application standards governing its use. Among the typical concerns are repeatable placement guidelines for specific packaging types (for human-factor considerations), adequate space for quiet zones, specific government labeling requirements, and the physical layout of the package itself. A packaging engineer should be consulted to make sure the symbol will not be obscured or damaged during production, (e.g., over a carton edge, beneath a carton fold, beneath a package flap, or covered by another packaging layer).

Once the proper placement is determined, the printing company should be consulted

before assigning the symbol rotation. When using flexographic printing, the bars should run parallel to the press web direction, whenever possible. This is shown as a picket-fence orientation (Figure ⓱). If the bars are required to run perpendicular to the press direction (ladder orientation), distortion of the symbol to account for the plate-roll circumference should be avoided. This lack of distortion will alter the overall width of the symbol, but will provide dimensional integrity by avoiding rounding errors. The bar code design software may account for the "distortion" input variable in the design stage, (refer to UCC Guidelines for Providers of EAN/UPC Symbol Design Software, Section 1.8.4). If it does, the procedures given by the software provider should be followed. If the software does not account for distortion when the symbol is created and distortion is unavoidable, outputting the film at higher resolutions (e.g., 4000 dpi) is advised to avoid reintroducing rounding errors.

To specify the proper placement and orientation of the bar code on the design, an FPO (For Position Only) symbol should be used (Figure ⓲). This symbol should be clearly labeled "FPO" so that it is understood to indicate size, color, orientation and placement only, and that it may not be encoded properly or produced at the specified resolution.



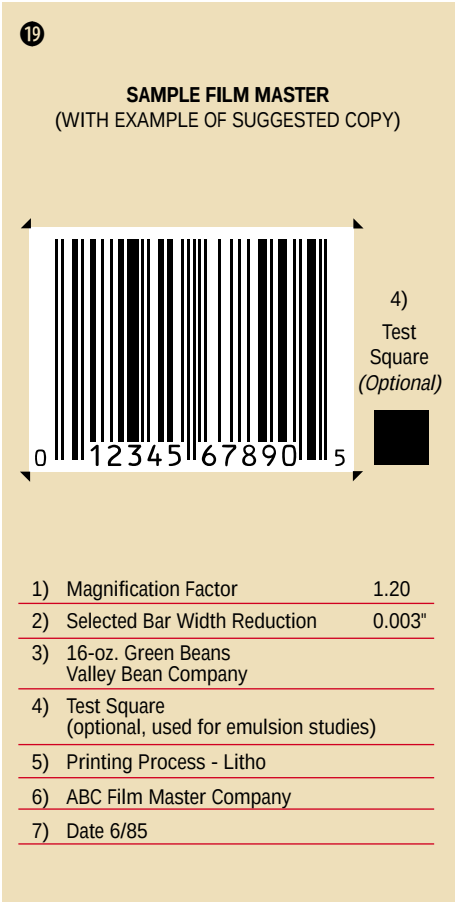
⓱ Whenever possible, flexographers should opt for the picket-fence placement, which means the bars are running parallel to the web direction.

⓲ An FPO label denotes that the bar code shown is only intended to indicate orientation, size, color, etc.; it is not to be printed.

FILM MASTERS

Many flexographic printers require precise bar code film artwork, called a film master, to manufacture printing plates for bar codes (Figure ⓳). Essentially a film master is an extremely accurate photo-representation of a bar code, in either positive or negative film. The super-accuracy of film masters cannot be duplicated by the typical photo processes available to most printers, so a reliable film master producer must be used. This is perhaps the most essential step a printer can take. Film master tolerances are strictly controlled and, in the case of most UCC/EAN symbols, are often less than ± 0.0002" (0.0051 mm) for bar and space widths. Tolerances for these symbols are set by the UCC in the U.P.C.

⓳ A bar code film master is a precise photo-representation of a bar code in film. Its use ensures accurate reproduction of the bar code.



Film Master Verification Manual (for U.P.C. symbols) and the ANSI/UCC6 – Application Standard for Shipping Container Codes (for ITF symbols and UCC/EAN-128 symbols used as shipping container codes).

Certain parameters are vital in the projection and use of Film Masters. Designers and printers should note that the following items should appear on the Film Master:

- magnification factor;
- selected bar-width reduction;
- product identification, including company name, in English language;
- an optional test square (outside the symbol area) for emulsion studies (this should be incorporated in the film, not affixed on a separate label);
- printing process for which the film master is intended (i.e., flexo);
- identification of Film Master supplier; and
- date of film master manufacture.

DIGITAL BAR CODE CAUTIONS

Today it is becoming more common for bar code designers to design and store their bar codes in a digitized format. Many good bar code design software packages exist for this purpose. However, there is an important word of caution. If the digital bar code is used in replacement of a film master, great care must be taken to insure that all final specifications will be met in the printing process. This includes sufficient room for the established quiet zones around the symbol, an accurate bar-width reduction (BWR), a correctly calculated check digit, the proper magnification within symbol tolerance, and the corrected imaging resolution.

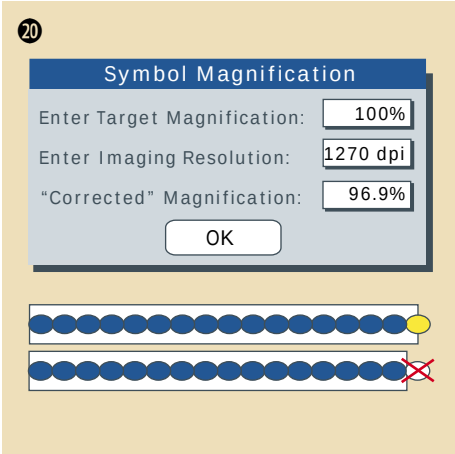
Specifying the addressable imaging resolution for bar code symbol output is critical to providing proper dimensions for the bars and spaces. This is because a bar code, unlike typical graphic images, is machine-readable based on predictable decoding formulas. If it is not designed (encoded) with corrections to the target size based on the addressable imaging resolution, rounding errors will occur in most cases.

When the print buyer provides a target size (magnification or X-dimension) for the symbol to the design or printer, a new size should be provided by the bar code design software to “correct symbol dimensions” for the imagesetter resolution specified. This process is called “corrected magnification” or “corrected size” when applied to the original bar and space widths and “corrected BWR” when applied to the amount of target BWR.

For example, if an EAN/UPC bar code with a target X-dimension of 0.0130" measures 16.5 dots wide based on a 1270 dpi imagesetter resolution, the symbol size is

corrected by truncating the 16.5 dot symbol module to 16 dots wide (an integer number) consistently across all symbol modules. The width of the dot (0.000787") multiplied by 16, gives the "corrected" symbol module width of 0.0126" (96.9% of 0.0130"), instead of the target width of 0.0130" (*Figure* ⓴). Correcting symbol dimensions slightly to accommodate the addressable output resolution of the imagesetter is far more important to bar code scanning performance than creating a symbol with any specific size.

Because of this, production-ready symbols should be designed only when output resolution is known, and digital bar code files should only be resized using the bar code design software package that originated them. Another designer should not alter these specifications at any later stage within another illustration or page-layout software program. The digital bar code file should also be linked to the output resolution attribute in some way to assure the symbol is output at the resolution specified when it was created. And finally, using the resizing tool on bar codes within an illustration or page layout software package is strongly discouraged, as the resulting symbol may not scan.



⓴ Correcting bar code dimensions for output resolution through a bar code design software program.

Bar Codes in the Pressroom

The production process begins with the receipt of a work order that includes a bar code. The first thing that must be done is to compare the bar code numbers on the work order against the numbers beneath every symbol on the plate. It should never be assumed that every number on the plate will be the same. Also, the plate should be checked for defects such as nicks, plugs, buckles or tears. If an error or defect is discovered in the plate, it should be quarantined or destroyed according to company procedures. The numbers beneath a bar code symbol should never be revised by cutting or otherwise altering the plate.

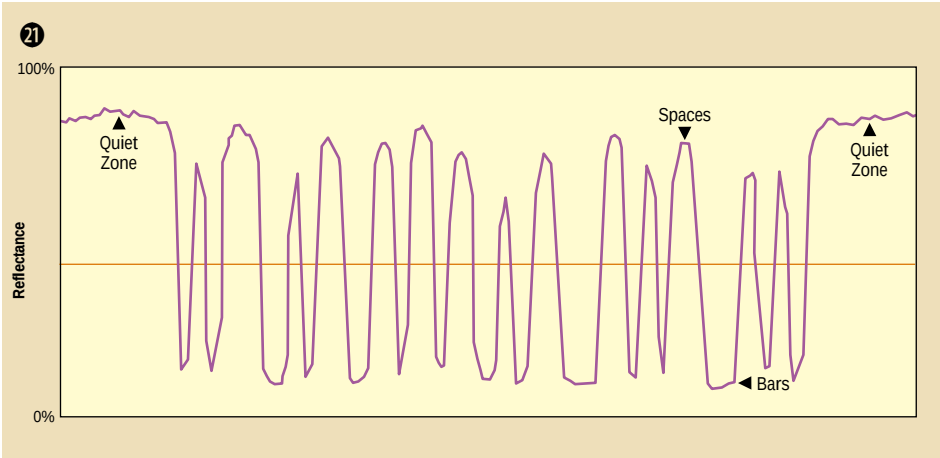
A CORRUGATED TIP

When printing directly on a corrugated substrate, an excellent resource is the Guideline for Direct Contact Printing Bar Code Symbols on Corrugated, available from the Fibre Box Association.[22] In general, the guideline provides recommendation for the purchase of bar code printing plates, a brief discussion and recommendation of inks in GCMI colors, and a section on production practices.

VERIFICATION AND MAKING THE GRADE

It can't be stated any clearer: bar codes either scan within tolerance or they don't. That means it is worth the investment in time and resources to insure that the quality goes in before the bar code goes on. And that, in turn, means that every flexographic printer printing bar codes should consider migrating to a properly calibrated ANSI/UCC5-based verifier

22 See *Resources* at the end of this chapter for contact information.



21 Scan Reflectance Profile (SRP) is generated by a single scan by a verifier.

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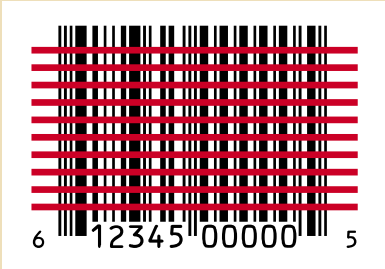
Edge Determination	Pass = A
Minimum Reflectance	3% = A
Symbol Contrast	70% = A
Edge Contrast	47% = A
Modulation	55% = C
Defects	17% = B
Decode	Pass = A
Decodability	60% = B
Quiet Zones	Pass = A

㉓



Scan Grade 1	B = 3.0
Scan Grade 2	C = 2.0
Scan Grade 3	C = 2.0
Scan Grade 4	B = 3.0
Scan Grade 5	B = 3.0
Scan Grade 6	B = 3.0
Scan Grade 7	C = 2.0
Scan Grade 8	B = 3.0
Scan Grade 9	A = 4.0
Scan Grade 10	B = 3.0
Average Grade	**2.8 or B**

㉒ The scan profile grade is determined by selecting the lowest of the parameter scores generated in the SRP. In this case, the scan profile grade is a C.

㉓ By averaging 10 scan profile grades, an ANSI symbol grade can be calculated.

to bring their quality assurance program into alignment with the direction of the future.

Following the direct visual inspection of the plate, it is recommended that the printer test for an acceptable ANSI symbol grade in the first piece approval process. There are two types of ANSI grades. A scan profile grade results from analyzing an SRP (scan reflectance profile) obtained from a single scan of a bar code by a verifier (*Figure* ㉑).

In *Figure* ㉒, each scan profile grade is established by taking the lowest of eight parameter scores (or nine if a quiet zone measurement is included as for the UCC/EAN). *Table 13* lists the details of these parameters.

An ANSI symbol grade (*Figure* ㉓) is determined by analyzing the results of 10 scan profile grades taken at equally spaced intervals down the symbol and averaging them together for one grade.

For further details on this ANSI-based verification, refer to[23]:

AIM USA: A Laymen's Guide to ANSI Print Quality.

ANSI: ANSI X3.182 Bar Code Print Quality Guideline.

UCC: Technical Bulletin #1 – Understanding UCC Specified Methods for Assessing EAN/UPC Quality, ANSI/UCC5 – Quality Specification for the U.P.C. Printed Symbol, or Guidelines for Producing Quality Symbols.

ANSI grades should always be specified by the print buyer with three key pieces of information – the minimum ANSI grade

23 See *Resources* at the end of this chapter for contact information.

ANSI SCAN-REFLECTIVE PROFILE PARAMETERS

1. **EDGE DETERMINATION**
   Counts the number of crossings over the global threshold of the scan-reflective profile to verify whether the number obtained conforms to a legitimate bar code symbology.

2. **MINIMUM REFLECTANCE**
   Measures whether the reflectance value of at least one bar is, at most, equal to or less then half of the highest reflectance value for a space.

3. **SYMBOL CONTRAST**
   Measures the difference between the largest and smallest reflectance values in a scan.

4. **MINIMUM EDGE CONTRAST**
   Measures the smallest value for edge contrast in a scan reflectance profile between a bar and adjoining space.

5. **MODULATION**
   Measures the way a scanner sees narrow spaces or bars in relation to wider spaces or bars.

6. **DEFECTS**
   Measures the voids present within the bars and the spots present within the spaces or bars.

7. **DECODE**
   Applies specific rules to the bars and spaces of EAN/UPC symbols to decode them into a series of digits and guard bars. The ANSI/UCC5 based verifier passes the symbol for decode when it is able to decode the EAN/UPC symbol including its guard patterns, and the check digit is consistent with the other digits.

8. **DECODABILITY**
   Measures how close the scan reflectance profile of the printed symbol is to approaching decode failure.

9. **QUIET ZONES**
   An area of free printing which precedes the leftmost bar and follows the rightmost bar in a UCC/EAN symbol.

Table 13

(specified as a grade point average), the verifier aperture to be used, and the verifier wavelength to be used. For example, all EAN/UPC symbols should receive a passing ANSI symbol grade of “1.5” (C grade) or better when using a verifier with the 0.006" aperture and a wavelength of 670 nanometers ±10. This would be specified as 1.5/06/670 on a purchase order.

It should be noted that the UCC makes one exception for its symbols in regard to the minimum “C” grade. This exception is for ITF symbols directly printed on corrugated. For the ITF symbol (which is never expected to be scanned in a retail checkout lane), a minimum grade of “D” is permitted due to the capabilities of industrial scanners which are used in a distribution or logistics scanning environment and ITF’s simple encodation characteristics. Flexo printers will find an excellent document on quality control for printing ITF symbols on corrugated in the previously mentioned Guideline for Direct Contact Printing of Bar Code Symbols on Corrugated.

Although it may not be possible for all packaging materials or printing processes, the ANSI grade minimum specified by the application standard should be exceeded by one letter grade at the end of the printing process wherever possible. Bettering the grade at the time of printing can be helpful in overcoming any symbol quality lost due to the packaging, labeling or distribution process of the final, filled product.

When analyzing symbol quality on transparent or translucent substrates, the final product should be simulated as clearly as possible. For example, when printing a

white EAN/UPC symbol background on a clear plastic bag, try to find out what the bag will be filled with in the packaging process. If it is white notebook paper this could actually boost the white background, but if it is black jellybeans the white may appear gray to a scanner. If simulating the package is impractical, the printed symbol should be verified twice, once by laying the symbol over a black background and next over a white background. The worst of the two ANSI symbol grades should simulate the worst case scenario.

VERIFYING THE VERIFIER

It is important to emphasize the importance of working with a properly calibrated verifier. ANSI-based verification instruments are an important tool in the assessment of quality symbols, but their performance is only beneficial when they are calibrated and used according to manufacturer's recommendations. Before the UCC released the new specification for assessing printed UPC bar code quality (ANSI/UCC5 – Quality Specification for the UPC Printed Symbol), they developed a mechanism for everyone in the supply chain to use to "verify their verifier." The Calibrated Conformance Standard Test Card for EAN/UPC Symbol Verifiers is a physical set of EAN/UPC symbols designed to test particular characteristics of ANSI/ UCC5 based verification equipment (Figure ㉔).

The standards are manufactured on special materials and are made traceable to NIST (National Institute of Standards and Technology). This traceability is facilitated through a custom-designed piece of hardware (nicknamed "the Judge") and has been engineered to measure the various attributes outlined in ANSI X3.182, published in 1990, and ANSI/UCC5, published in 1994. The Judge has also been made traceable to NIST.

The idea behind the standard is to test, on a regular basis, if the verification equipment is operating within the range of tolerance for ANSI measurements as published by the verifier manufacturer. The test cards are especially important in heavy use applications, where various operators may be involved, or where a new user is learning to use the verifier properly and needs a control target. Verifier operators, on a routine basis set by company procedures, should scan each of the symbols on the standard to determine if the verifier device is providing the values listed on the test card. If it is not, they should work with the verifier manufacturer to determine if they are using the equipment properly or if the unit is not calibrated.

ROLL WITH THE FLOW

During the production run, maintaining a clean transfer of ink, proper bar widths and consistent symbol colors are critical to

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㉔ The Calibrated Conformance Standard for EAN/UPC symbol verifiers is designed to test particular characteristics of ANSI/UCC5-based verification equipment.

repeatable symbol quality. Flexographic printers should consider these factors when making press adjustments and follow company procedures on production sampling.

Even if the plate passes inspection, production defects are common during the press run. These would be categorized as voids in bars, spots in the bar code spaces or quiet zones. Defects can be caused by factors such as cleaning the plate during the run, debris being caught in an ink cell or under a doctor blade, or the plate being damaged. If the defect is temporary and correctable it may be decided to flag the affected portion and continue production. If the defect cannot be corrected, the company's procedures to make a go or no-go decision should be used.

If prepress has made the proper BWR based on a contemporary press characterization, the symbol bars should remain within the specified width throughout the run. This relationship between the BWR in prepress is critical to quality symbol production. If the press characterization analysis is correct, a symbol of adequate size and bar width reduction is made ready for the range of print gain experienced on the press. If the BWR and minimum size are correct based on prior experience and there is still poor symbol quality, there may be a problem with press factors such as press settings, ink metering, mounting material thickness for the plate, cylinder tolerance or press maintenance. The substrate may also be evaluated if it differs fundamentally from the one used in the characterization process. Whenever a significant variable from the original characterization is introduced, a new characterization may be warranted.

When it comes to symbol color, it is understood that colors will vary somewhat throughout the run. This is due to changes in ink viscosity, press speed, drying temperature, ink chemistry and other factors. However, significant color changes should be controlled and avoided throughout the run. It is wise to develop an acceptable range for the bar color and space (background) colors for major substrates. This will avoid beginning the production process with a symbol of marginal contrast (which will produce material outside of specification with any process variation).

Finally, bar code symbols with different numbers should not be mixed on a roll or in a box unless specified by the customer or company procedures. When bar code symbols are produced via a flexographic plate, they will almost never be printed sequentially. If batches of symbols become mixed on a printed roll they might be used on the wrong product, package or coupon when automatically packaged or applied downstream. Unless otherwise specified, it is wise to separate symbols with different numbers into batches as they are produced and later when they are packaged and shipped. If the batches are of a size that prohibits separating them, company procedures should be followed to carefully identify each batch.

RAISING THE BAR

Flexographic printers have consistently "raised the bar" in the production of quality bar codes. From the very beginnings over 25 years ago, bar code users have looked to flexography for solutions that provide the essential identification and tracking aspects of bar code symbols on large volumes of products, packages and containers. Today, backed by an arsenal of new tools and technologies, flexographic printers are producing the highest quality bar codes in their history. Organizations such as the Uniform Code Council, the Fibre Box Association, AIM USA and the FTA are dedicated to raising these quality achievements to an even higher level. With a sense of partnership and a fundamental understanding of the underlying technology, flexography and bar codes will continue to improve their symbiotic relationship for decades to come.

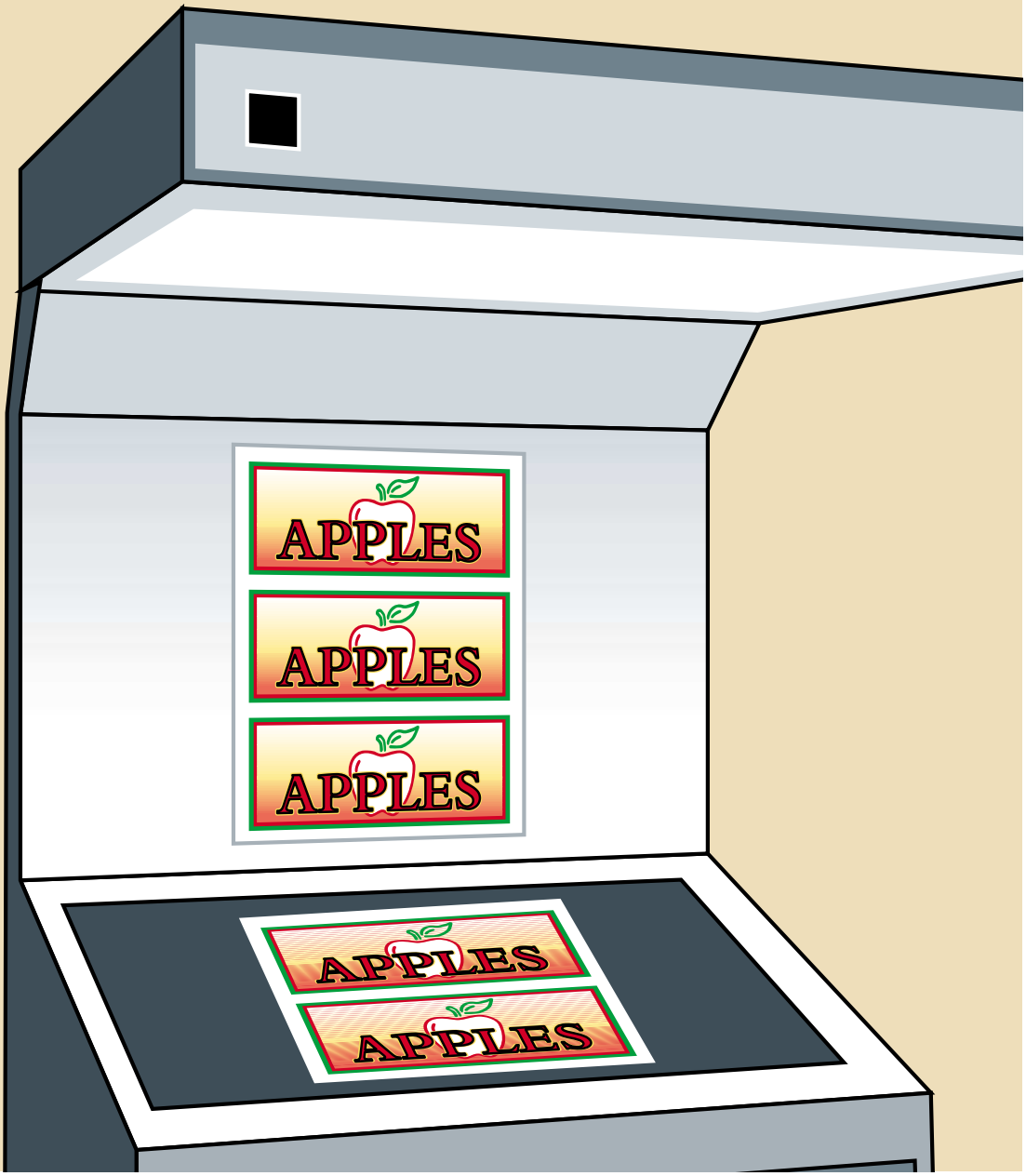
Resources

ADDRESSES OF ORGANIZATIONS MENTIONED IN THIS CHAPTER
(Valid as of Publication Date)

ORGANIZATION	TELEPHONE	FAX	WEBSITE
AIM-USA (Automatic Identification Manufacturers) 634 Alpha Drive Pittsburgh, PA 15238	(412) 963-8588	(412) 963-8753	www.aimusa.org
ANSI (American National Standards Institute) 11 West 42nd Street New York, NY 10036	(212) 642-4900	(212) 302-1286	www.ansi.org
EAN International Rue Royal, 145, B-1000 Brussels, Belgium	32-2-227-1020	32-2-227-1021	www.ean.be
ECCC (Electronic Commerce Council of Canada) 885 Don Mills Road, Suite 301, Don Mills, Ontario Canada M3C 1V9	(416) 510-8039	(416) 510-8043	www.eeec.org
FBA (Fibre Box Association) 2850 Golf Road, Suite 412, Rolling Meadows, IL 60008	(847) 364-9600	(847) 364-9639	
UCC (Uniform Code Council) 7887 Washington Village Drive, Suite 300 Dayton, OH 45459	(937) 435-3870	(937) 435-7317	www.uc-council.org

CHAPTER 3

Quality Control



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Introduction

The American Society for Quality Control defines quality as "the characteristics of a product or service that bear on its ability to satisfy stated or implied needs or a product or service free of deficiencies." Other definitions of quality may include meeting customer expectations or even exceeding customer expectations. First and foremost, the supplier must understand the customer and what he or she will be doing with the product after delivery. This can be done in many ways, depending on what the customer most values and what the supplier is capable of delivering. In the flexographic industry, meeting customer expectations might require that the price be consistent or lower than the competition or that the service received by the customer includes expert advice on the type of substrate to use or design elements that will work effectively in flexography. This implies that the flexographic printer must understand which characteristics are necessary to satisfy the customer as well as what defects must be avoided in the printed product. These defects might include more than misregistration or poor color consistency or die cut. They might include such items as late delivery and improper product count.

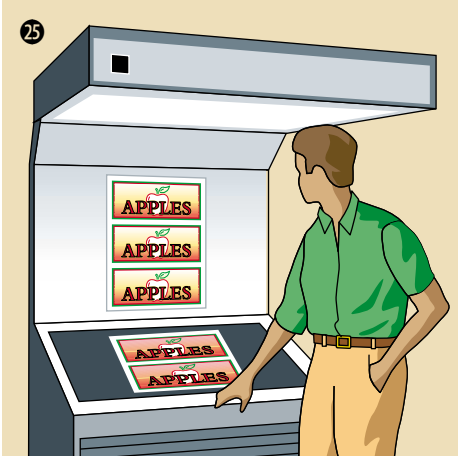
There is much confusion between features and quality. Features are those characteristics that describe a product. Quality is the continual meeting of whatever specifications have been agreed upon to achieve a satisfactory end result, and requires that you, the supplier, have an understanding of what the customer wants, a knowledge of what you are capable of delivering and the agreement in place between you and the customer on the specifications of the product or service provided. Saying that four-color process is of higher quality than spot colors and line art is not an adequate definition of quality. Because one printed product may be harder to produce or have some attribute such as an over-varnish does not make it more of a quality product than one that is easy to produce and has few attributes. Quality is, first and foremost, meeting customer expectations on a continuous basis no matter what the desired feature may be.

For flexographic printers to consider themselves quality manufacturers they need to look at their entire system. The questions that they must answer are:

- Do they know what they are capable of doing?
- Do they know the customer's expectations?
- Do they have the critical variables adequately defined?
- Do they have specifications that they and the customer have agreed upon?
- Can they consistently meet these specifications and customer expectations?
- Do they have a system in place that will answer the above questions?

QUALITY CONTROL VS. QUALITY ASSURANCE

Quality control encompasses those operational techniques and activities used to fulfill the requirements for quality. Armand Feigenbaum expands on this statement in his book "Total Quality Control" where he states that quality control is "an effective



㉕ The indiviual doing the work is ultimately responsible for its quality, but the quality control department is there to act as an extra set of eyes.

system for integrating the quality-development, quality-maintenance, and quality-improvement efforts of the various groups in an organization so as to enable marketing, engineering, production, and services at the most economical levels which allow for full customer satisfaction." Quality in this definition does not mean best overall, but best for this particular customer for a specific set of conditions and at a given price. Control means maintaining a given set of specifications and reacting when the standards are not met. Generally, the person, persons or department doing the specific work are given the responsibility for maintaining the quality outcome of their efforts.

Quality assurance refers to all these planning and systematic actions which will provide confidence that a product or service is free of deficiencies. This includes assisting in developing workable specifications, methods for evaluating conformance to these specifications, monitoring methods, an evaluation process of overall quality, working with suppliers in determining specifications and working on the procedures to improve the overall quality of the organization. The quality control department should be involved with the following:

- planning the quality system;
- determining the company's capabilities;
- coordinating the qualifications of suppliers on quality issues;
- assisting in the development of product specifications;
- developing test and inspection equipment;
- planning inspection and test procedures;
- performing in-process quality measurements;
- performing in-process quality audits;
- analyzing and sharing quality costs;
- analyzing complaint data;
- facilitating corrective action;
- feedback quality information; and
- facilitating strategies for process improvement .

WHO IS RESPONSIBLE FOR QUALITY?

There can be only one answer to that: Everyone in the organization is responsible for quality. Traditionally, when a quality control department is in place in a flexo printing company, then the responsibility for quality seems to rest with that group. However, no quality control department can be responsible for quality. The best that can be done by this department is to monitor and reinforce the quality effort. Quality must be maintained by the people doing the actual work. If the ink department makes up a specific spot-color ink, then it becomes their responsibility to match that ink to customer and press specifications. The quality department may be able to monitor the end results, but this would be after the fact. If the ink department has made a mistake in the ink color a major portion of a job could be run before the quality department could catch it. The quality control department is there to act as an extra set of eyes, not to be the first line of defense against quality mistakes (*Figure* ㉕). The individual or individuals doing the actual work are the ones who must be held accountable for their work.

Characteristics of Quality

The printed packaging product acts as a communication vehicle to give information on what the product is and how to use it, and acts as a silent salesperson in encouraging the customer to purchase the product. If the flexo product is a directory or a flexible package it is conveying information and must be printed accurately and give a realistic portrayal of what needs to be conveyed be it words or pictorials. The result of a quality effort is to satisfy the needs of the end user. If there is an error, it really doesn't matter to the end user where in the production cycle a quality error is made. All the end user cares about is "does the product work satisfactorily." When buying a bottle of wine, the label (*Figure* 26) serves the purpose of identifying the product and influencing the customer to buy and is part of the presentation of a quality product. The best wine with a poorly designed and printed label can leave an excellent wine sitting on the shelf without a purchaser. If the label falls off the bottle or is applied in a crooked manner or the colors bleed when refrigerated, the end result is that the customer may not purchase that wine again.

CUSTOMER

The purchaser of converting and printing products generally uses the printing to enhance the product. The manufacturer of the product (*Figure* 27) may wish to have a corrugated container with a point of purchase graphic printed directly on the package. What are the concerns? Do the graphics and words accurately portray the product? Will the ink rub off when shipped or handled? Are the colors consistent from one package to another? How consistent does the color have to be so it is not being noticed by the end user? Are the die cuts and scores accu-

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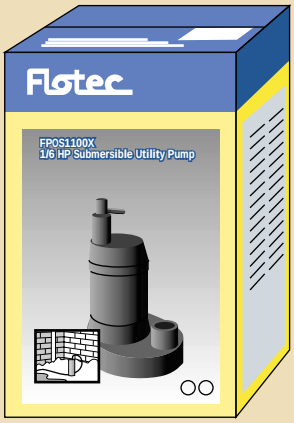


26 A label not only identifies a product, but also influences the purchasing decision.

27 In an effort to influence sales, a manufacturer may choose to print graphics right on the package.

rate so that they work well in the converting process? Is the register accurate from color to color and from the print to the die cut and scores? Will the printing and converting process crush the flutes and cause damage to the product? Will the packages be delivered on time and in the right quantity? And, lastly is the price within the area that is affordable for the product that it will contain? These quality issues must be addressed and handled between the converter and the customer to fully accomplish what is required for the particular package.

PRINTER

One of the biggest problems faced by the flexo printer is that sometimes customers and end users have not thought out what they really need and only recognize these needs when they see them pop up as quality defects. The flexographic printer needs to understand what the requirements of the end user and the customer are in order to fully satisfy the demands necessary to meet the quality requirements. This can be addressed by sales and customer service. Exceeding customer expectations means being able to ask questions that the customer and end user may not have thought about. This is truly a value-added activity on the part of the flexo printer. Developing and working with a checklist is an excellent way of heading off a problem before it becomes one. *Table 13* is a sample of a checklist that can be used for determining customer and end user needs.

SUPPLIER

In the printing industry, the supplier is sometimes expected to do too much. More and more, the supplier is expected to offer the training, research and technical assistance that goes along with the product. The printer also expects that the supplier will provide the specifications necessary for the product. This can create a problem as the supplier may not know the printer's capability or the many uses that the material will go through. It is therefore incumbent upon the printer to make the supplier understand what the specification needs are. This requires that a partnership be initiated between the supplier and printer to facilitate product specifications. Price alone will not satisfy this need. Price is very important, but the specifications must also include such items as on-time delivery, service, training and technical support.

CHECKLIST FOR SALES AND/OR CUSTOMER SERVICE

1. Who will use the printed product?
2. What are the product needs for protection?
3. Will the product be adversely affected by the ink or substrate?
4. What is the shelf life of the package before use?
5. How many times will the product be used before graphics are no longer important?
6. How will the product be placed into the package?
7. How will the graphic be applied to the package or product?
8. What type of climatic changes will the package or product undergo?
9. Where will the flexo printed product be used?

Table 13

Commitment To Quality

Commitment to quality needs to be present at all levels of the organization. It is particularly important to have management committed to quality throughout the organization. This commitment includes all products and services provided by the organization. In addition to management, each and every individual in the organization must share this commitment to quality.

TOP MANAGEMENT

Quality starts at the top. In W. Edwards Deming's book "Out of the Crises" (p. 248) he states, "The aim of leadership should be to improve the performance of man and machine, to improve quality, to increase output, and simultaneously to bring pride of workmanship to people. The aim of leadership is not merely to find and record failures of people, but to remove the causes of failure: to help people to do a better job with less effort." This has to be the mission of top management. Without a clearly defined and understood quality effort from top management, it is very unlikely that the organization can be a quality organization. Top management must balance quality, productivity and price, not choose one or two of these.

Top management must set the quality goals and provide time, money and effort to back up their words. Some managers feel that if people are honest and hard working they will, by these attributes, produce quality work. This is, of course, not true. Quality needs to be planned and cannot be left to subjective forces. Planning has to go into the materials used, the equipment chosen and the training given to employees.

MIDDLE MANAGEMENT

Middle management is generally assigned the task of implementing the quality commitment of the company. In this regard they are given the responsibility for implementing, training and monitoring the effort, but they may not be given the time or money to do the job adequately. The first objective should be to train middle managers in what they need to know and how to go about implementing a quality process.

One area in which middle managers frequently need training is the development of the team process. This means that middle managers must be taught how to delegate and work with project-oriented teams to improve the process or resolve problems. This is a new concept, as middle managers have usually been trained to do this work themselves. However, if the company has decided to empower its employees it is important that this be done (*Table 14*).

Middle managers need to be trained in how to be coaches and facilitators and a central resource of information, rather than direct supervisors of the quality process. Quality is maintained by those actually doing the job and the supervisor must make this possible by offering methods, supplies and

MIDDLE MANAGER TEAM TRAINING
How to delegate the responsibility to the team.
How to choose team members.
How to develop a team problem statement.
How to develop a team mission statement.
How to train a team to work effectively and efficiently.

Table 14

equipment that will enable the operating personnel to perform in a quality manner.

OPERATING PERSONNEL

The responsibility for first-line quality is always that of the person doing the job. While it is important to have checkpoints so that the quality of the end product is not jeopardized, this occurs only after the fact. It takes time and effort and does not add value to the process. The more that individuals are allowed to take responsibility for their own work, the less expensive it is to produce a quality flexo job.

For operating personnel to produce a quality job, it is important that they be given adequate tools, training and reinforcement so that they understand thoroughly what has to be accomplished *(Table 15)*. Understanding the specifications of the work they do in relationship to the various steps in the process and end-use requirements is paramount to the quality process.

For lack of the right tool, many operations are done poorly and end up causing quality defects in the finished work. Inadequate, inappropriate or improperly maintained tools can lead to downtime and frustrations – all which could have been avoided. It is up to management to work with and craft people to ensure that the appropriate tools are chosen, maintained and used.

ENABLING OPERATING PERSONNEL TO PERFORM QUALITY WORK		
Methods	Skills	Tools
Materials	Equipment	

Table 15

The materials used by operating personnel must be within specification to what is needed to do a quality job. Operating personnel must not be put in a situation in which they have to make do in order to get their job done. This will impede their efforts toward doing quality work. Middle and upper management must understand the capability of the materials in relationship to the equipment and customer needs, and supply operating personnel with materials that meet these needs.

The equipment must be maintained and optimized to perform at or above the original manufacturer's specifications. Optimizing is accomplished by matching the original manufacturer's specifications to the way a machine is presently functioning and repairing or replacing any component which does not conform. Some of the items one would look at in the case of a press would include gear wear, repeatability of printing units, runout and parallelism of the anilox print-impression cylinder, dryer capacity and tension variations. After optimization the press can be characterized (fingerprinted). This fingerprint would include such characteristics as registration, slur, dot gain and trap of inks. This needs to be done for each set of conditions, including anilox rollers, ink types and substrates.

Operating personnel cannot be held responsible for anything more than how they use the equipment, methods and materials given to them by middle and upper management. It has been claimed that operating personnel have control of only 15% of the output, while middle and upper management have control of 85%.

Responsibilities of a Quality Control Department

Traditionally, quality control departments were set up to inspect work in progress and do laboratory testing to ensure that the end product met customer specifications. Quality control department members were also used to collect samples that were given to customers to verify that the product was within specification. As a general rule, quality control had little to do with training operating personnel on how to evaluate the quality of their work and record these procedures. Quality control departments were not used to assist in optimizing, characterizing or developing strategies for implementing capability studies. Very little emphasis was placed upon the use of statistical process control.

The quality control function was only for the production process with little to no interaction or responsibility for working with customers, marketing, sales or customer service. Most significantly, the quality function did not include reviewing the product before manufacturing to be sure that the specifications could be met. Two attitudes were prevalent concerning quality control departments and their people. The first was that they were a form of police unit, functioning to catch people doing things wrong and were dreaded when seen heading for your department. Second was that you as an operator were not responsible for your quality because the quality department was there to catch all your mistakes. Operating personnel were not responsible for quality, that was the responsibility of quality inspectors and the quality department.

There are a number of things wrong with this traditional approach to a quality control department. The first is that if operating personnel feel the quality department is a police unit they will try and hide mistakes and the quality inspector will not get cooperation from operating personnel to review quality from an objective posture. The other major problem is that if the quality department is seen as the only group responsible for quality the end result might very well be out of specification for flexo products, thus becoming waste in the inspection process or, worse, ending up as unsatisfactory product in the customers' hands. Either of these scenarios is very expensive to the flexo printing company.

BASIC GOALS

The modern quality department needs to focus upon the needs of the customer and translate these into operational specifications and procedures that will satisfy these needs. To accomplish these goals the quality department and its manager must be involved in new design control, capability analysis, incoming raw material control, printing process control and process improvement strategies *(Table 16)*.

This does not mean that the modern quality department does not do inspections and quality testing or take samples for customers. This remains a part of their job, but the job of quality control is expanded to become more

THE MODERN QUALITY CONTROL DEPARTMENT
New Design Control
Capability Analysis
Incoming Raw Material Control
Process Improvement Strategies

Table 16

proactive rather than reactive in assisting the entire organization in its quality effort.

NEW DESIGN CONTROL

The quality department must be involved in reviewing printing job specifications including type families and sizes, trap considerations, type of inks, number of colors, die cut and scoring feasibility, substrates and shipping parameters. The development of workable specifications is the first step in being able to produce a flexo product that meets customers' needs and expectations. Some of the quality measures of the output are shown in *Figure* ㉘. It is important that all specification reviews involve the quality department as it is their function to assist in evaluating the quality output. In order to do so they need to be involved with the quality input.

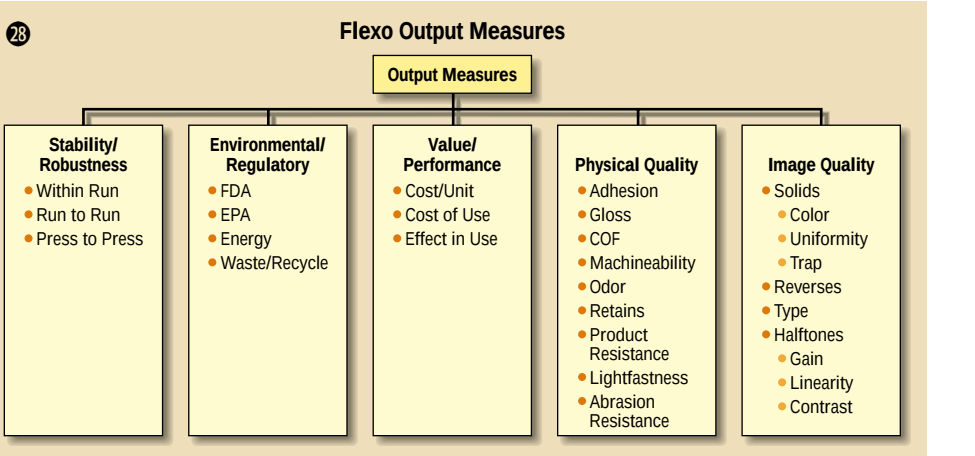
CAPABILITY ANALYSIS

It is extremely important for the printer to understand the capabilities of the manufacturing process in order to assure that the process is capable of producing the work that the sales department has sold and that the package and graphic designers have developed. A capable process is a process that will produce virtually all of its product within designated specifications.

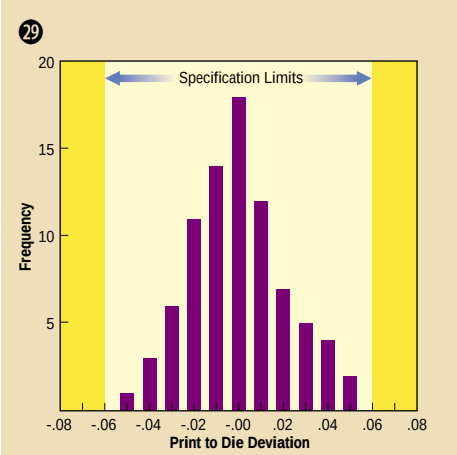
The capability of the process can be discovered using a statistical technique such as a simple histogram (*Figure* ㉙). A minimum of 30 samples needs to be taken to be statistically sound. In the figure, the deviations from the print to die are measured and the frequency of each deviation is plotted. Putting in the acceptable limits (customer specifications) shows whether the process is capable of producing product within those limits.

INCOMING RAW MATERIAL CONTROL

It is important that all supplies that are used in each and every process be within the specifications designated by agreement with the customer, whether they are internal (produced in-house), or external (purchased from an outside supplier). The quality con-



㉘ Flexo output measures.



29 A histogram can be used to determine the capability of a process. This histogram depicts print-to-die deviations.

trol department should have responsibility for random sampling of these supplies. They should be involved in verifying that external suppliers understand the importance of agreed upon specifications and can meet these specifications on a continual basis.

All supplies should have specifications. The quality department should have the responsibility for making sure that there are specifications and follow-up to be sure that suppliers can meet these demands. Sometimes this is impractical as department managers or purchasing departments control these items. In that case the quality department should at least be involved in developing specifications and verifying that they are met. In this way the quality department can work toward reducing inspection cycles.

Too often individual departments and operators assume that the supplies they will work with are within specification and only find out that this is not true when they get to use them. Some departments and individual operators can be delegated to inspect the incoming materials. This is a good practice if they understand what to inspect, how often to inspect and what to do when the material is out of specification. Quality departments should assist in the training of all employees involved in these functions.

CALIBRATION PROGRAM
Identify what needs to be calibrated
Establish the tolerance
Establish the frequency of calibration
Designate who does the calibration

Table 17

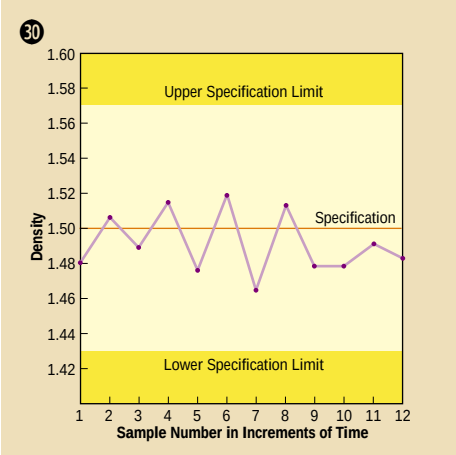
PRINTING AND CONVERTING PROCESS CONTROL

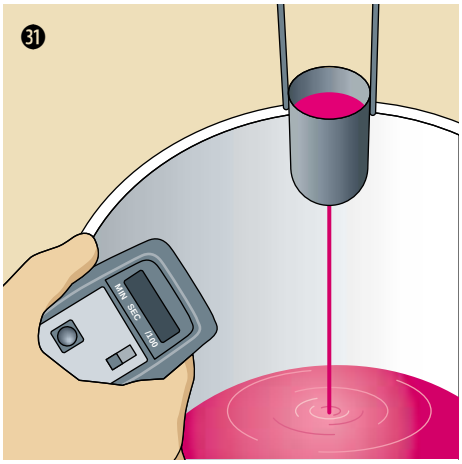
Setting up procedures and even doing calibration of inspection and quality devices is a value-added activity for quality departments. Most manufacturing departments are too busy producing the product and even though they may value the results of calibrated instruments they rate it low on the priority list of things to do. It then falls to the quality department to make sure that the devices used to measure the accuracy of the product, as it is manufactured, are within proper tolerances. This can be done through an investigation of what each instrument's calibration tolerance is and how often it needs to be checked for accuracy and then developing a strategy to accomplish this calibration and holding an individual in the quality department responsible for it *(Table 17)*.

The development of a plan of when to sample, how to measure and the use of statistical process control are part of the quality department's responsibility. Developing a program that will sample frequently enough to ensure that the product is within tolerance and yet not too often so that it gets in the way of manufacturing is an important part of the quality strategy. A part of statistical process control is to record and analyze the results. Written records of inspections are critical, even if the inspection is visual and subjective. A simple run chart *(Figure 30)* is a good way to record and display the results of a measurement or inspection.

30 The results of a set of measurements can be plotted in a run chart. This chart shows density measurements.

31 Ink viscosity can be measured by timing its flow through a Zahn cup.





CHECKLIST
Documenting the Design

1. List and include key files, FPO (for position only) files placed in key file
2. List fonts used (include if necessary)
3. List correct names of fonts
5. List software names and versions
6. Name final file that prepress is to open, all other support files listed
7. When including more than one design, put one design file and all support files in one folder
8. Annotate any layers that are common
9. List layers to be used with base design
10. Include hard copy of disk directory
11. Include hard copy of final art files, same size or 100%
12. List all file names
13. List all colors – process, special
14. Include instructions for blends
15. Include instructions for special effects
16. List all FPOs
17. List of all items provided (transparency, disk, color proofs, etc.)

Adapted from p. 24 of FIRST, 1997.

Table 18

PROCESS-IMPROVEMENT STRATEGIES

Assisting all departments of the organization with process-improvement strategies is a major function of a modern quality department. It is their responsibility to observe methods, materials, skills and equipment and then evaluate the outcomes. Better, simpler and less expensive systems can then be developed. These can range from major process changes to simply reviewing how sales uses effective forms to gather information that will be used to develop the specifications for a corrugated, paperboard or flexible package, label or publication.

Listening to and observing what operating personnel do and say about the quality methods and tools they use for inspection is an important function that can be used to start the process-improvement cycle. Here are some sample questions that might be explored: How often should a Zahn cup *(Figure 31)* be used to check viscosity of an ink or a pH meter be used to check water-based inks? How often should these instruments be calibrated? Are there more efficient procedures that can be used instead? Should measurements be recorded? Why are the measurements recorded? Is it to see whether the process is in control or how far it varies

over time or, when to make corrections to the process? It is the quality department's obligation to review these elements and assist in offering improvements to satisfy customer expectations while developing more efficient and economical quality processes.

Organizing process-improvement teams into departments and interdepartmental groups is an effective manner of gathering information on what may be needed to do an effective job of maintaining and improving quality. Industry standards or guidelines can provide valuable assistance to this process. For example, FIRST provides a checklist to document the design in prepress which will help assure a quality product and smooth workflow *(Table 18)*.

The research and development of quality devices is a significant part of what a modern quality department can and should do. Reviewing the literature, and attending printing and converting conferences and exhibitions where suppliers present their equipment is an important part of the job. Some of the other research methods can include contacting suppliers and having them supply literature, quotes and demonstrations.

The Economics of Quality Improvement

Quality costs are the sum total of all of the costs involved in making a product correctly. In flexo printing and converting there are two choices: either the job is printed and converted correctly the first time or it must be redone until it is correct. Quality costs are one of the best means for quantifying the overall level of quality, since they take into account the entire impact of both problems and improvements. Quality theorists and practitioners have broken down quality costs into four general categories:

- prevention;
- inspection and appraisal;
- internal failure; and
- external failure.

PREVENTION COSTS

Prevention costs represent, in large part, the investment that the flexo printing and converting company will make in quality improvement. Traditionally, prevention has had a very low priority in the United States. These costs represent the up-front time and effort required to do the job correctly the first time. Typical prevention costs include training, preventive maintenance, vendor certification, ISO certification, planning and quality team meetings. Prevention costs are unavoidable if the flexo printing company is to reduce its overall cost of quality. In other words, prevention costs are the price a printing company has to pay for real quality improvement.

INSPECTION AND APPRAISAL COSTS

Inspection and appraisal costs represent all of the various ways in which we look at the product to ensure its conformance to requirements. This process starts and ends at the receiving and shipping dock and takes place at various checkpoints throughout the process. Instead of preventing problems from occurring in the first place, many flexo printers will inspect the product and weed the substandard pieces out. Inspection and appraisal costs are partly avoidable and partly unavoidable. As internal quality levels increase, the need to inspect finished products will be reduced. However, true quality improvement involves allowing employees such as platemakers and press operators to appraise their products in order to control their processes. These costs are unavoidable, but they will also be diminished as processes come into a more stable, controlled state. An excellent example of an appraisal cost in the printing industry is color proofing. It is generally considered a necessary process, although by standardizing the reproduction process from computer monitors to imagesetters and consistently optimizing and characterizing the process, it is possible to minimize the use of color proofs for monitoring purposes.

INTERNAL FAILURE COSTS

Internal failure costs represent what happens when the job hasn't been done right the first time. Some of the printed matter will be

thrown away and some will be reprinted. Either way, valuable prepress and press time will be used for reprinting the job and additional inspectors will be required to make sure that the defective product doesn't reach the customer. Internal failure costs are wholly avoidable when the proper preventive measures have taken place and in-process inspections have ensured product conformity. The potential savings that can be realized by focusing on internal failure costs, and reducing waste and rework, is enormous.

EXTERNAL FAILURE COSTS

External failure costs are those that occur when the customer gets defective products. These costs include liability costs, claims and discounts, and high customer turnover. It has been estimated that an unhappy customer will typically tell five to seven friends about the problems associated with the flexo printer involved. Think about how you react in your personal life when you go to a restaurant and receive inferior service. If you are anything like a print buyer, you will tell your friends about the experience and never go back. What's worse, customers don't usually complain, they just leave. If quality improvement is to be effective, printers must ask customers not only what they liked about the job, but what they didn't like as well. External failure costs are also wholly avoidable. When the printed product is delivered on-time and defect-free, the customer will react favorably and be retained. The sales effort can then focus on truly new customers, not just replacing those that have left because they were dissatisfied.

Unfortunately, traditional methods of accounting and control have failed to look at these categories as separate elements on the income statement. Instead, quality costs have been lumped together with such general items as labor, materials, overhead and selling expense. Recent findings in companies like Motorola and TRW have shown that, when separately accounted for, quality costs can be as high as 20% to 30% of sales revenues for manufacturing organizations. *Table 19* lists some of the reasons to measure quality costs.

In the words of Dr. Joseph Juran, quality costs represent "gold in the mine." This is money that the printer is already spending. As companies invest resources in their quality improvement processes, the managers of those companies will want to see the return on that investment.

QUALITY COST STRATEGIES

The levels of prevention, inspection and appraisal, internal failure and external failure should represent strategic choices made by the flexo printing company's top management. It is too important just to let various quality costs happen by chance. A company can choose to try and "inspect quality in" by putting their quality resources into inspectors or a company can choose to focus its efforts on improving quality and preventing problems. In the long run it is more cost effective to focus on prevention rather than inspection. Every flexo printer needs some inspection; however, they should work toward minimizing inspection and maximizing prevention.

REASONS TO MEASURE QUALITY COSTS

- Determine the return on investment
- Justify individual quality improvement projects
- Benchmark the overall impact of the quality effort
- Get top-management attention
- Give direction to your improvement efforts

Table 19

The Principles of Total Quality Management

The Total Quality Management Process or TQM involves the entire organization. It affects the way of doing business in all aspects of the operation. The Total Quality Management Process can be defined as combining the nine elements listed in *Table 20*.

THE PRINCIPLES OF TOTAL QUALITY MANAGEMENT
1. Focus on the CUSTOMER – both internal and external
2. Involve the ENTIRE flexo organization
3. Develop a TEAM effort
4. EMPOWER the employees of the flexo company
5. Work toward PROCESS IMPROVEMENT of the entire organization
6. BENCHMARK activities of the organization
7. PARTNER with suppliers and customers
8. REENGINEER where needed
9. MEASURE quality so that it can be managed

Table 20

CUSTOMER FOCUS: INTERNAL AND EXTERNAL

The success of a flexo printer is driven by the understanding of what the customer wants and needs and by meeting those needs. The external customer is the one who pays the bills and purchases the flexible package, corrugated container, label or any other flexo printed product. In order to fully understand the needs of this customer it is necessary to also understand the end use of the product. Some considerations may include the type of material to be used, UPC and color tolerances and ink rub and durability needs. These issues can only be addressed by doing a thorough investigation of customer expectations before the job is specified.

The internal customers are those individuals or departments that are part of the sequence that goes into the manufacturing process. This might include sales, estimating, planning, customer service, design, electronic prepress, press, finishing and shipping. The concept implies that every department and individual has responsibility for understanding what the next person, department or operation needs in order to fulfill quality obligations. Each sequential operation has to have specifications and it is up to the person and department of each preceding operation to understand these demands and meet them every time. If the specification requires that a highlight dot of two percent be maintained on the photopolymer plate then it is the responsibility of the plate maker to have a system in place that verifies this to the press department. It is also advisable that internal suppliers and customers work together so that they understand what each needs to supply the appropriate product to the next operation.

INVOLVE THE ENTIRE FLEXO ORGANIZATION

A quality flexo product is the sum total of the efforts of all those involved in the process from sales to production to delivery and billing. It is a serious mistake not to understand the relationship of all the elements that go into the execution of a flexo job. Understanding the customer's needs and converting these to acceptable and workable specifications, that can be maintained, is a critical part of each step in the operation. Customer satisfaction is the sum total of the individual parts. If the janitorial staff leaves dust and dirt around which contaminates the plate-making process, or the inks or substrate, the end result could be work rejected by the customer. If the sales department does not get the proper information from the customer and manufacturing does not know of this, then the end result could be an unacceptable job. Quality is the sum total of doing many small and large things correctly.

DEVELOP A TEAM EFFORT

The success of a quality flexo organization depends upon each individual and department working well with other individuals and groups within the organization. This requires that employees view themselves as team members and part of an organization that pulls together for the benefit of the customer. The organization needs to foster and reward team behavior. This can be done by including team effort as part of each job description. This then can become part of the evaluation process which in turn can be rewarded in the normal appraisal process.

There are a number of ways formal teams can be implemented into an organization. The first way is to establish an executive team which comprises top management. Usually, the chief executive officer or a designee is on the team along with a financial officer, someone from marketing and sales as well as manufacturing. Their purpose is to act as a steering arm of the team effort. They give approval to the operations of a team and make decisions on team suggestions. It is suggested that for teams to be really successful the organization needs to develop a budget that will sustain team efforts.

Teams can be set up a number of ways. The functional team is set up to operate within a department. If customer service procedures are to be analyzed for improvement purposes then the customer service department would set up a team of individuals to review the process and make suggestions for changes. The cross functional team is similar to the functional team, however they also have members that are internal suppliers and customers as team members. The purpose of the internal supplier and customer team members is to assist in developing solutions that positively affect both of these groups. Self-directed work teams are the fourth type of team. In the self-directed team approach the employees are trained to take responsibility for managing, coordinating, scheduling, quality control, working with suppliers and evaluating team members. This team approach requires that supervisors relinquish their traditional roles and work as trainers, coaches and facilitators.

EMPOWER THE EMPLOYEES OF THE FLEXO COMPANY

The employee-empowering process requires that management relinquish control of individual efforts and that employees take responsibility for their work. The job of the supervisor becomes one of a mentor, trainer and facilitator of employee efforts. He or she acts in the capacity of a staff person in offering advice and working toward satisfying the needs that employees have in relation to performing their job in a quality manner. Employees are trained and encouraged to

make decisions as it concerns their work. The end result is that work should be done better, faster and more easily.

WORK TOWARD PROCESS IMPROVEMENT OF THE ENTIRE ORGANIZATION

Flexography is a printing process that has seen monumental strides in process improvement. Ink systems are better understood, and with understanding of the relationships between ink viscosity, pigmentation level and the proper choice of anilox roll, the flexo printer can predict density and dot gain more effectively. The use of doctored anilox rollers and chambered print units have dramatically increased the fidelity of print and reduced environmental issues. Various teams of the Flexographic Quality Consortium have undertaken studies in wide web, narrow web and corrugated to determine how to maximize the most important characteristics of the flexo printing process. Some of the studies undertaken have included the relationship of substrate, ink system, plate characteristics and anilox roll configurations. Studies have also been done to judge the value of flexo printers using a Pantone®[24] guide to color match flexo colors. These and other studies are available through the Flexographic Technical Association.

Most of these studies have been accomplished through the efforts of a few companies and individuals and coordinated by the Flexographic Technical Association. More involvement is necessary in order to remain competitive with other printing processes and other methods of communication. Each company must encourage the flexo work force to maintain a mind-set for process improvement. This means questioning the methods, materials and their combinations to determine the best procedures for quality flexo reproduction.

BENCHMARK ACTIVITIES OF THE ORGANIZATION

Benchmarking is the process of measuring a flexo company's level of performance in its various functions and comparing this level of performance to the level of performance achieved by successful leaders in their similar functions.

Internal, competitive and generic benchmarking are the three common methods of benchmarking. The constant review of internal processes, including how people interact, choice of materials, methods practiced and the quality procedures used to ensure the accuracy of the work need to be studied. Competitive benchmarking looks at what the competition is doing to produce a quality flexo product and be profitable and productive. Generic benchmarking reviews "best in class." This may be a review of any company, not necessarily a flexo organization. The review would include specific similarities to the flexo company. If a company is known to have a superb customer service process then the review would include how they accomplish this in order to be able to develop similar strategies for customer service. Benchmarking is a powerful tool because it enables the flexo printer to analyze its strengths and weaknesses against the best in class. In turn, the gap between what exists and what can exist can be narrowed by initiating similar actions to the benchmark that has been studied.

PARTNER WITH SUPPLIERS AND CUSTOMERS

Partnering is a method of working with suppliers and customers for the common good. When dealing with key materials, purchasing by price alone without considera-

24 Pantone, PMS and Pantone Matching System are trademarks of Pantone, Inc.

tion of long-term relationships can be devastating to long term needs. Knowing what the supplier can do concerning price, on time delivery, consistency of meeting specifications and assistance with training and technical information will make the printer/converter a more competitive company. Price needs to be considered in relationship to the total cost of the product over the long run. If materials are out of specification or their delivery is late or incomplete the long-term effect upon the operation could be very expensive and therefore not very cost effective.

Studying and understanding the needs of your customers and being able to advise them on their printing needs makes your organization truly value-added. This means having intimate knowledge of what your customers are doing in the marketplace and what the needs of their customers are. If the corrugated package must withstand a certain crush force and the fluting required may prohibit the fidelity of print, it is your responsibility to offer advice as to whether to direct print, or use preprint or printed labels as the decorative medium. The true flexo partner studies what the customer's competition does and offers suggestions as to how the customer can compete more favorably with better printed products.

The nurturing of partnerships between suppliers and customers allows a flexo company to spend more time on process-improvement activities rather than having to look for new suppliers and customers.

REENGINEER WHERE NEEDED

In their book "Reengineering the Corporation" Michael Hammer and James Champy define reengineering as "the fundamental rethinking and radical redesign of business processes to achieve dramatic improvements in critical, contemporary measures of performance, such as cost, quality, service, and speed." This includes all aspects of the organization from management issues, equipment, materials, new technologies and methods of operation.

The objective is to satisfy customer needs and look for ways to delight the customer with possible new processes, procedures and services. Reengineering means starting over. What would you do if you were starting a flexo company? What would you do differently? Reengineering does not mean tinkering with the old, but doing something entirely different. Reengineering means getting rid of old systems and starting over again.

Reengineering can be a very difficult process. It is much easier to say "let's reengineer" than to actually do it. Reengineering means change and change can be very expensive in the short run. Also, people will resist change because it is not comfortable for people to change their habits. If reengineering is seen as a process that may cause job loss then people will resist. However, will the company be in business and for how long if changes are not made? The most expedient procedure for reengineering is to observe, through the benchmark process, what other organizations are doing and then evaluate whether it is in the company's best interest to reengineer processes, equipment and methods. Participating in management and technical organizations as well as reading available literature and working with suppliers and customers will assist in developing procedures for reengineering within the flexo company. Think of a flexo company as a packaging and communication organization and not just a label, corrugated or flexible packager. In this way it is easier to see opportunities to reengineer and remain profitable, productive and competitive.

MEASURING QUALITY SO THAT IT CAN BE MANAGED

It has been said that "what you do not measure you cannot control." One of the most

important reasons for measuring quality is so that it can be controlled. Color variation, registration and other important aspects of quality flexo reproduction must be measured on an ongoing basis. This data needs to be recorded and evaluated to determine if the process is stable and in control. It is impossible to evaluate trends without measuring and recording the flexo process.

How can one take corrective action if one does not measure what is taking place? If the specification for the density of the black ink is 1.50 ±0.07 then measurements with a densitometer must be taken at statistically sound intervals to determine whether black is remaining within its range of 1.43–1.57. The measurements can be plotted on a run chart as shown previously in *Figure* 30. The operating staff can visually determine, from the chart, if there is a need for corrective action.

Records should be kept of all measurements made so that a flexo company can prove to a customer how quality was monitored and maintained during a given production run. These records may include color, trap, dot gain, register, number of products run and waste.

Quality records will also show the source of variation. If flexo plates are continually monitored for overall height it is then easy to offer constructive feedback to the supplier by sharing this information. This will assist in the quality effort because plates that are not within specification can be rejected before they are mounted and run on the press.

The measuring and recording of quality data will help characterize the process capability. If, for example, images are trapped to one-sixteenth of an inch, but after monitoring the press it is shown to hold register to one-sixty fourth of an inch, the trapping specification could be decreased to one-thirty second of an inch or twice the register tolerance. This might allow sales to develop new markets that require closer tolerances.

Statistical Process Control

Statistical process control (SPC) represents a "tool box" from which the printer can draw in order to define the printing process, measure and control its key parameters, and improve upon its ability to deliver a satisfying product to the customer. Measuring, collecting and using critical data is a cornerstone of a quality program.

100% INSPECTION AND SAMPLING

The use of 100% percent inspection is not a statistical tool; however, in the flexo industry it is sometimes necessary to inspect every item in the process. This is true in areas such as artwork and designs, computer disk files, printing plates, cost estimates and billing. Items in these areas are one of a kind and irreparable damage can be caused if they are not caught and corrected. In this type of inspection, it is very important that the inspector be knowledgeable and alert and have the appropriate time to accomplish the inspection process. Sometimes it is necessary to have more than one person inspect the process because of the criticality of the object being inspected. It is helpful to have an inspection form (checklist) so that the inspector does not forget items. A record can be kept of the item checked and noted as approved, or flagged for correction. *Table 18,* is an example of a checklist.

STATISTICAL SAMPLING PLAN

RUN LENGTH	SAMPLE SIZE
1–5,000	2 samples per 100
5,001 – 100,000	1 sample per 100
100,000 up	1 sample per 200

Table 21

STATISTICAL INSPECTION AND SAMPLING

In contrast to 100% inspection, statistical sampling means inspecting a limited number of samples. Statistical sampling offers economy of scale while remaining a very effective quality tool. In a 30,000 run of flexible packages it would be prohibitive in time and cost to inspect each bag. Therefore a more effective procedure is to develop a statistically valid sampling plan to validate the quality of the product being produced. A minimum of 30 samples is needed to adequately develop an SPC charting system. *Table 21* shows the numbers for a statistically sound sampling plan.

ATTRIBUTES AND VARIABLES

An attribute is defined as a characteristic that is either present or absent. Some examples of attributes include whether the die is cutting or not, whether the seal holds or not, whether the typography is present or not. An attribute can be classified as yes or no, 0 or 1, present or absent.

A variable is the result of a measurement and has a tolerance or ± associated with it. During a flexo production run variables will never be constant but always have some variation. Some common variables are ink viscosity and pH, solid ink density, dot gain, color value, plate, stickyback and substrate thickness, and registration.

MILITARY STANDARD (MIL-STD-105E)

Military Standard (MIL-STD-105E)[25] is a method of attribute-acceptance-sampling that has been developed by the United States Department of Defense and is widely accepted by industry as an effective procedure for attribute sampling. This standard includes a sampling plan, which is the acceptable quality level (AQL), run-length size and corresponding sample size, and acceptance and rejection numbers. A sample is shown (*Figure* 32).

To review how to use MIL-STD 105E use *Figure* 32. The figure has two charts, "Sample Size Code Letters Chart" and "Acceptable Quality Level Chart." The first lists code letters for inspection levels for a given lot or batch size. The inspection levels allow for more or less sampling depending on the history or established quality level of a given supplier. For example, if the flexo run length is 100,000 and there is no history, the normal or default level II (letter N) would be used. With a quality supplier with a history of quality success, column I, (letter L) could be used. On the other hand, with a poorer quality supplier, column III (letter P) might be appropriate.

Next, the Acceptable Quality Level Chart is used. Using the above example of a run length of 100,000 and the letter N, the second column of the chart shows the sample size needed. In this case the number is 500 samples, which need to be taken in a random manner. Finally, the number of samples allowed to be out of specification to achieve an Acceptable Quality Level (AQL) is given in the right hand side of the chart. Most companies in the U.S.A. choose an AQL of 1.5 or 2.5. Basically, the 1.5 and 2.5 mean there is a 98.5% and 97.5% confidence, respectively, in the sample plan. This is the customer's choice and is dependent upon the chances one is willing to take that the sample plan may fail. Using an AQL of 1.5 for this example, two numbers, Ac and Rc, are listed in the column under 1.5. Their values are 14 and 15. This means that the product is within the acceptable tolerance level chosen if 14 or less out of the total sample of 500 are out of specification. If 15 or more are out of specification, the product is out of the acceptable tolerance level and may be rejectable. One could go to a higher level of sampling (such as from N to P) or, if feasible, one could go to 100% inspection to get rid of all out-of-specification product. Strictly speaking, even when 100% inspection is done, this does not guarantee 100% acceptable product. Letter P with an AQL of 2.5 doesn't have an entry in the chart. Instead, the arrow means to use the numbers to which it points, in this case, 21 and 22.

[25] Military Standard Sampling Procedures and Tables for Insertion by Attributes (MIL-STD-105E) and Military Standard Sampling Procedures and Tables for Insertion by Variables (MIL-STD-114) can be obtained from Naval Publications and Forms Center, 5801 Tabor Avenue, Philadelphia, PA 19120.

32

Sample Size Code Letters Chart

Lot or Batch Size	General Inspection Levels I	II	III
2–8	A	A	B
9–15	A	B	C
16–25	B	C	D
26–50	C	D	E
51–90	C	E	F
91–150	D	F	G
151–280	E	G	H
281–500	F	H	J
501–1,200	G	J	K
1,201–3,200	H	K	L
3,201–10,000	J	L	M
10,001–35,000	K	M	N
35,001–150,000	L	N	P
150,001–500,000	M	P	Q
500,001 and over	N	Q	R

Acceptable Quality Level Chart

Sample Size Code Letter	Sample Size	Acceptable Quality Levels (Normal Inspection)																
		0.010	0.015	0.025	0.040	0.065	0.10	0.15	0.25	0.40	0.65	1.0	1.5	2.5	4.0	6.5	10	15
		Ac Rc	Ac Rc	Ac Rc	Ac Rc	Ac Rc	Ac Rc	Ac Rc	Ac Rc	Ac Rc	Ac Rc	Ac Rc	Ac Rc	Ac Rc	Ac Rc	Ac Rc	Ac Rc	Ac Rc
A	2															0 1		
B	3														0 1			1 2
C	5													0 1			1 2	2 3
D	8												0 1			1 2	2 3	3 4
E	13											0 1			1 2	2 3	3 4	5 6
F	20										0 1			1 2	2 3	3 4	5 6	7 8
G	32									0 1			1 2	2 3	3 4	5 6	7 8	10 11
H	50								0 1			1 2	2 3	3 4	5 6	7 8	10 11	14 15
J	80							0 1			1 2	2 3	3 4	5 6	7 8	10 11	14 15	21 22
K	125						0 1			1 2	2 3	3 4	5 6	7 8	10 11	14 15	21 22	
L	200					0 1			1 2	2 3	3 4	5 6	7 8	10 11	14 15	21 22		
M	315				0 1			1 2	2 3	3 4	5 6	7 8	10 11	14 15	21 22			
N	500			0 1			1 2	2 3	3 4	5 6	7 8	10 11	14 15	21 22				
P	800		0 1			1 2	2 3	3 4	5 6	7 8	10 11	14 15	21 22					
Q	1,250	0 1			1 2	2 3	3 4	5 6	7 8	10 11	14 15	21 22						
R	2,000			1 2	2 3	3 4	5 6	7 8	10 11	14 15	21 22							

32 MIL-STD-105E is a method of attribute-acceptance-sampling. In the top chart, a letter is assigned based on run length. This letter is used in the bottom chart to determine an appropriate sample size and (reading across) the "accept" and "reject" levels, based on the number of errors found.

Tools of Statistical Process Control

Statistical process control (SPC) involves not only measurements and tracking those measurements, but also charting and other tools to quantify and describe the process. The seven tools of statistical process control are listed in *Table 22*.

FLOW CHARTS, OR PROCESS MAPPING

Flow charts, which are also known as process maps, are used to define the key steps in the flexographic reproduction process. They help in determining the correct and necessary ways to perform a given operation and give direction to the development of standard operating procedures (SOP's). By following the standard operating procedures established by the flow chart, a printer can be assured of "doing things right the first time." This results in less waste, a more consistent product, higher productivity and reduction in the cost of producing the product. *Table 23* shows the symbols used in flow charts and *Figure* 33 shows an example of a flow chart for creating a color target to be used for customer approval of a spot color.

THE SEVEN TOOLS OF STATISTICAL PROCESS CONTROL

1. Flow Charts or Process Mapping
2. Cause & Effect Analysis
3. Checksheets and Checklists
4. Pareto Analysis
5. Run and Control Charts
6. Histograms
7. Scatter Diagrams

Table 23

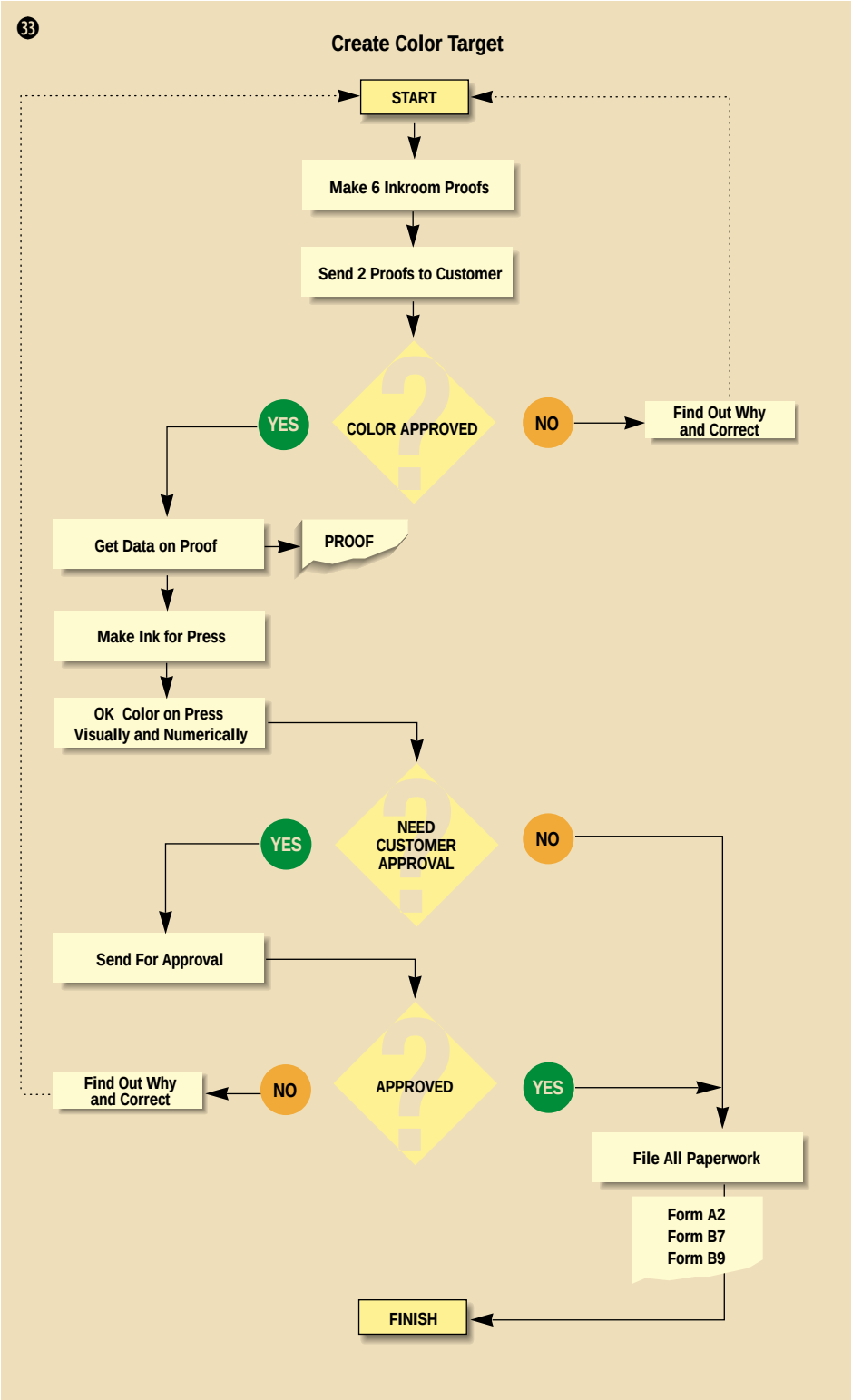
CAUSE AND EFFECT ANALYSIS

Cause and Effect Analysis is used to identify the many causes of quality-related problems. For example, if the printer wanted to know the causes of dirty print, cause & effect analysis using what is called a Fishbone diagram (*Figure* 34) would be a useful tool which could quickly and efficiently define a list of probable causes. Most often, this tool is used by a small group of people utilizing the brainstorming methodology. This allows

FLOW CHART SYMBOLS

- **Oval** Begin or End
- **Rectangle** Activity
- **Document** Linked to Activity
- **Diamond** Decision
- **Arrows** Flow of Process

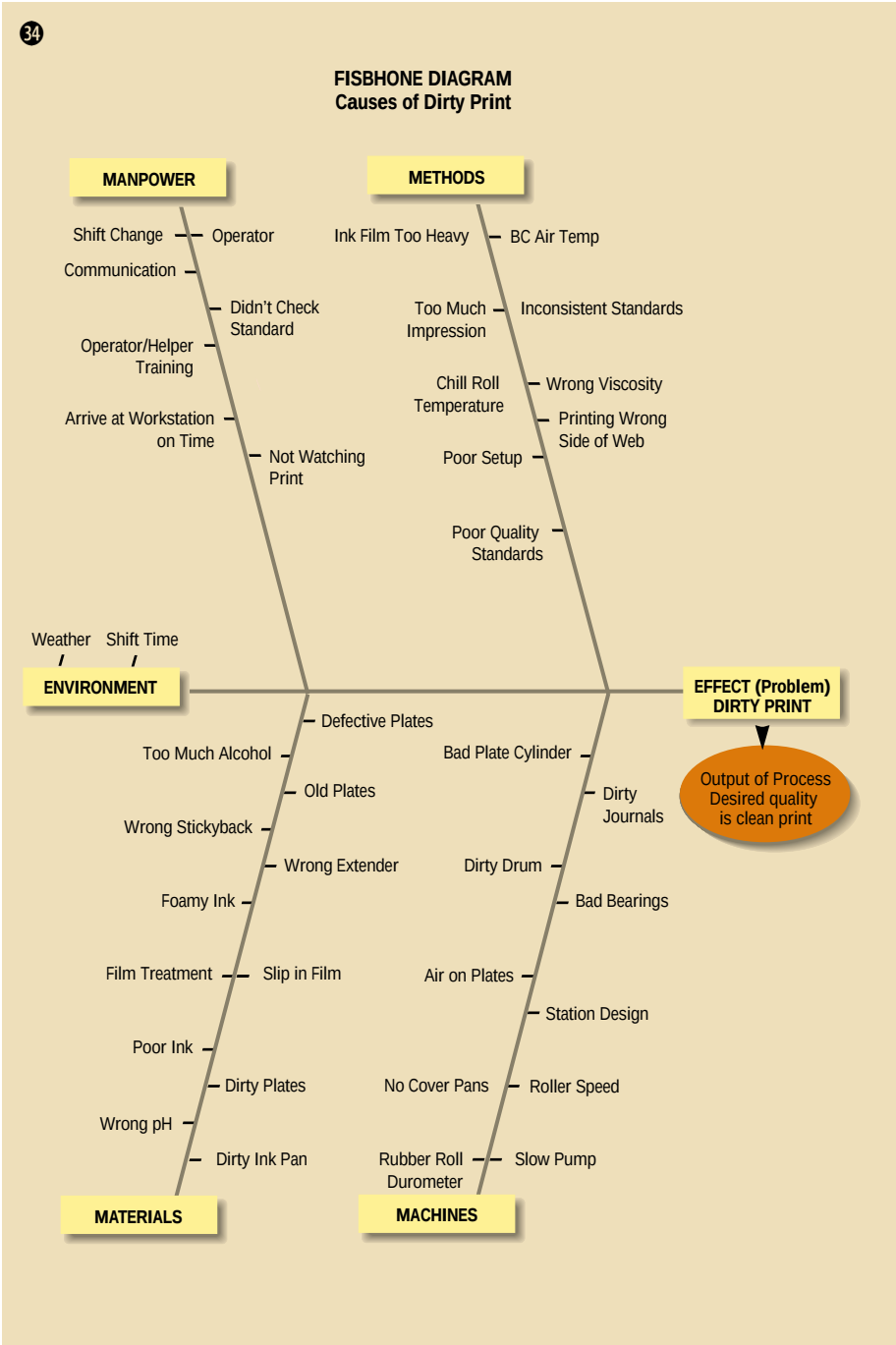
Table 24



Adapted from Progressive Inks.

33 Flow charts should be used to define key steps in a given process. This chart shown might be used in creating a color target.

34 A fishbone diagram is helpful in defining the cause and effect of a problem. The chart to the right shows possible causes of a dirty print.

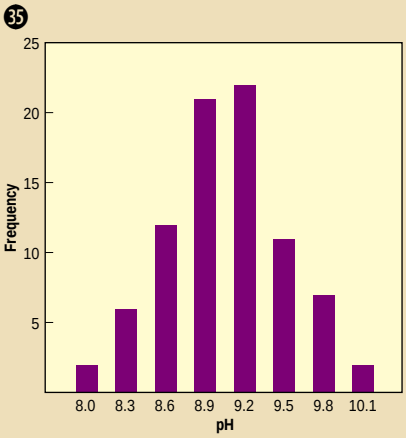


Adapted from Progressive Inks.

CHECKSHEET FOR pH

READING	FREQUENCY	TOTAL
8.0	✓✓	2
8.3	✓✓✓✓ ✓	6
8.6	✓✓✓✓ ✓✓✓✓ ✓✓	12
8.9	✓✓✓✓ ✓✓✓✓ ✓✓✓✓ ✓✓✓✓ ✓	21
9.2	✓✓✓✓ ✓✓✓✓ ✓✓✓✓ ✓✓✓✓ ✓✓	22
9.5	✓✓✓✓ ✓✓✓✓ ✓	11
9.8	✓✓✓✓ ✓✓	7
10.1	✓✓	2

Table 24



PROOF OF APPROVAL CHECKLIST

Check against customer original art, board or a proof of electronic file.

- Color Breaks.
- Copy: Location and verbiage.
- Bleed off panels (0.375" min.)
- Special instructions on Mylar.
- Printability of small copy © ®
- Ensure verbiage is not less than 0.25" to score
- Check process work against customer target.
- Affix sign off label, sign and date.

Adapted from Checklist developed by Schiffenhaus Packaging Corp.

Table 25

the printer to draw upon the collective expertise of process "experts" (electronic prepress, press operators, supervisory personnel, helpers, strippers and others directly working in the system).

CHECKSHEETS AND CHECKLISTS

Checksheets are tools which allow for the easy collection and analysis of data (*Table 25*). They are simple, systematic ways to collect and organize data. Checksheets can be used to determine where, when and why problems such as hickies, wrinkles, marking, and other printing defects occur. The data collected can easily be turned into a histogram (*Figure* 35).

Checklists are familiar to most people from ordinary experience. An example is using a shopping list when going to the store. The benefits of doing so far outweigh the costs of trying to remember. In the printing environment checklists can be used in the same way to consistently check items against a list and not leave anything to memory. *Table 18* already showed such a list. *Table 25* shows a checklist for proof approval.

PARETO ANALYSIS

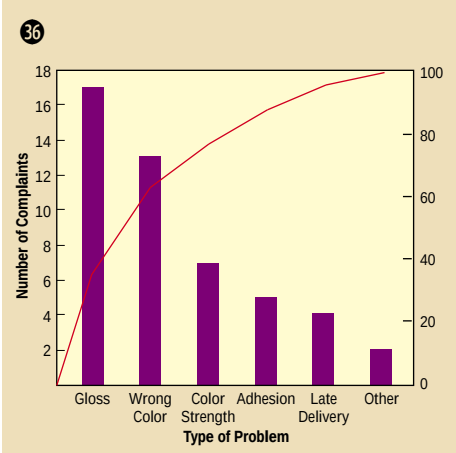
Pareto Analysis is a tool for identifying cost-effective solutions for quality improvement. The principle of Pareto Analysis is the familiar 80/20 rule: the bulk of printing problems (80%) are due to only a small minority of the related causes (20%). Most customer complaints can be tied to a few systemic problems such as late delivery or printing defects (*Figure* 36). Most printing defects are caused by a few items such as a specific stock, press or ingredient. The key is to collect data on the relative frequency of each of the causes and then find solutions to the largest of these. Most importantly, do not make assumptions about how important an item may be – collect the data first.

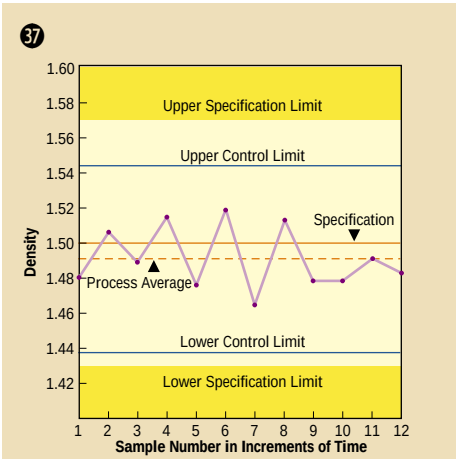
35 This histogram, based on data collected in Table 24, plots pH readings in an easy-to-reference format.

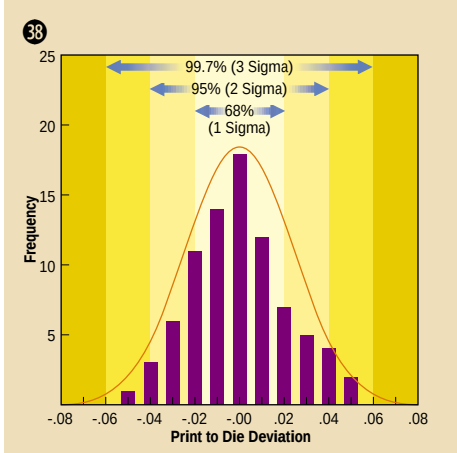
36 A Pareto chart can be used to plot the different types of customer complaints.

37 A control chart shows the upper and lower limits for your process. If the plotted values fall outside of these limits, corrective action must be taken.

38 A histogram shows whether the variation or tolerance for a variable is within desired limits.







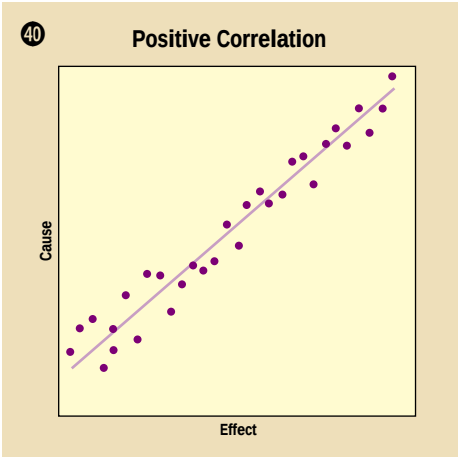
RUN AND CONTROL CHARTS

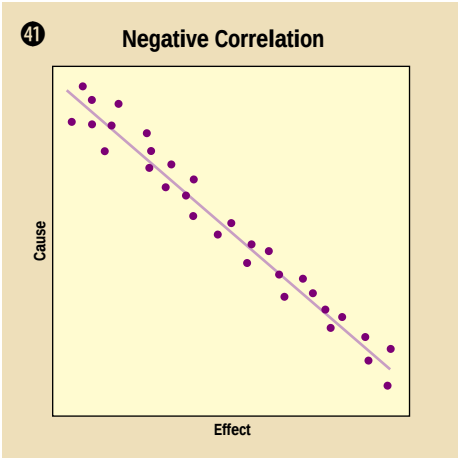
Run and control charts are tools used by operators for monitoring the printing process on an ongoing basis and making adjustments as necessary. Instead of waiting for things to go wrong, the control chart serves as an early warning device for the operator who can then take the appropriate action long before the occurrence of substandard production. The cost of using control charts is the time and training required so that operators have the knowledge and resources necessary to use them properly. The benefits are reduced spoilage and much more consistent results. *Figure* 30 showed a run chart. With the addition of upper and lower control limits, this chart becomes a control chart as shown (*Figure* 37). If the measured values fall outside these control limits, some corrective action needs to be taken, since out of specification product can be produced. A control chart is used in conjunction with a range chart so that a whole picture can be seen of the process. It is important to note that the control limits must be well within the specifcation limits. Control charts should be used to determine whether the process is in control before using a histogram to determine process capability. It is advisable to use spreadsheets or specific statistical computer programs when working with control charts.

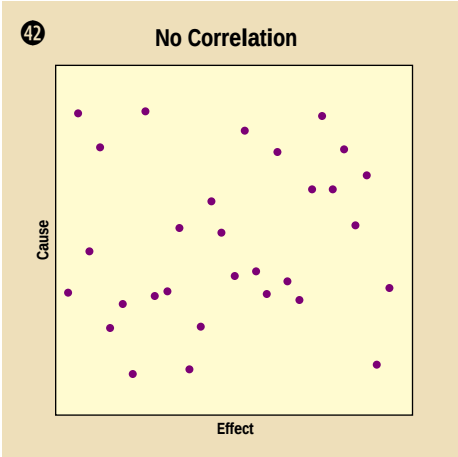
Refer to *Appendix C* for additional details.

HISTOGRAMS

Histograms are used for comparing the flexo product to its specifications and to assist in the determination of press capability. Histograms do not show variation over time, but the overall variation of the process being statistically monitored. For a particular variable, measurements are taken and the frequency of the results are graphed as was shown in *Figure* 29. The histogram will show if the natural variation in the variable is larger or smaller than the desired variation. *Figure* 38 is shown again in *Figure* 29 with the natural variation shown as a bell-shaped curve (normal distribution). An important sta-







39 Scatter diagram of dot gain vs. film thickness.

40 Scatter diagram showing positive correlation.

41 Scatter diagram showing negative correlation.

42 Scatter diagram showing no correlation.

tistical measure associated with this curve is the standard deviation called sigma (σ or Σ). In *Figure* 38 the sigma value is 0.02. This means that 68% of the values will have a deviation of ±0.02, 95% a deviation of ±0.04 (2 σ), and 99.7% a deviation of ±0.06 (3 σ). Control limits should be 3 σ or larger in order for the process to consistently and reliably produce the target value.

In the example shown in *Figure* 38, the histogram shows that for a specification or tolerance of 0.06 or greater, the process would be capable of producing acceptable product. For a tighter tolerance, the process is not capable of reliably producing acceptable results.

For more information on histograms, refer to *Appendix B*.

SCATTER DIAGRAMS

Scatter diagrams are tools used for determining how important the cause and effect relationship is between two variables. This method could be used for testing out such hypotheses as "Running the press faster causes more spoilage," "Customer turnover is lower when jobs are delivered on time," or "Thicker ink films cause higher dot gain" (*Figure* 39). While these statements may be intuitively appealing, it is hard to know how important press speed, on-time delivery or ink film thickness are without collecting data. A scatter diagram can be used for showing the correlation (*Figures* 40, 41 *and* 42).

Elements of Process Control in Flexography

The pursuit of quality is an ongoing process. Using SPC tools the process should be monitored and corrected as required. A good way to do this is to include a control target, as shown in *Figure* 43, on every job. If the job precludes this target, at the very minimum a run target should be included in the live area of the job (*Figure* 44).

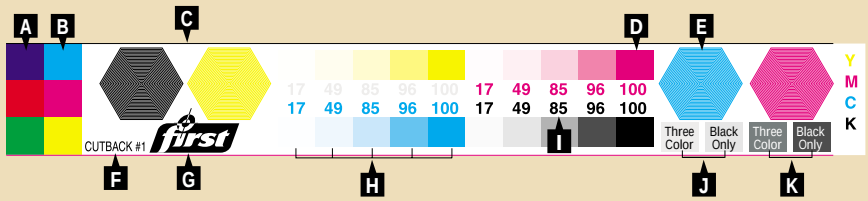
The control target allows continual inspection and measurement of key quality parameters of the process. These parameters can then be charted to make sure the process stays in control. The flexo printer should have in house standards which are used to control the process. These standards may be industry guidelines, such as FIRST, or standards specific to the printer. The standards need to be understood and communicated to the entire organization, including suppliers and customers.

VISUAL INSPECTION

A number of quality characteristics can be checked visually. These include slur, registration, trap, gray balance and color. Some of these characteristics can also be measured and quantified, but a visual check is a quick verification that the process is still under control.

- Registration can easily be measured through visual inspection. Accuracy for this measurement can be greatly increased with the use of a magnifying glass. A 12x or greater power device is very effective. Register marks can be designed that visually assist in determining how far out of register the colors are from each other.
- Slur targets will assist the press operator in visually determining the accuracy of the impression and anilox pressure settings. These targets can also assist in determining worn gears, out of round

43



A Ink Trap Patch
B Solid Process Patches
C Exposure Guide
D Solid Density Patches
E Slur Patch
F Reference Code
G First Logo
H Tonal Scale
I Dot Gain Values
J Highlight Grey Balance
K Shadow Grey Balance

43 A control target is an excellent means of monitoring a process. A simple control target is shown here. This is the FTA control target, adapted from the 1997 FIRST Standards.

anilox, plate or impression cylinders, or caliper variations of the substrate.

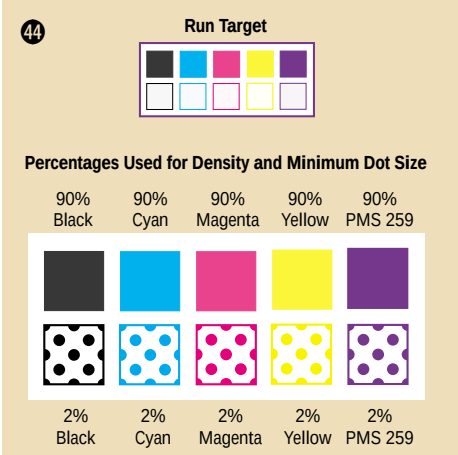
- Trap targets will show visually if the inks are trapping properly.
- Color can and must be visually checked. When evaluating the color match of a press sheet to a contract proof, the evaluation should be done in a viewing booth using a 5,000° K light source. Densitometers or spectrophotometers can be used to quantify color and are essential to chart the process quantitatively. However, in the last analysis, the visual comparison must be acceptable for the job to be acceptable.

DENSITOMETRY

Densitometers are used to assist in quantifying and controlling quality in flexo printing. The measurements are mainly concerned with the primary printing colors of cyan, magenta, yellow and black. Key measurements to control the process are solid ink density and dot gain. A densitometer can also be used to monitor trap, gray balance and spot colors quantitatively.

SPECTROPHOTOMETRY

Spectrophotometers are instruments designed to see light in much the same way the human eye does. As such, they are the preferred instrument to control spot colors as well as the printing colors. Unlike the human eye, the instrument can quantify a color in terms of the three visual attributes of hue, saturation and lightness. Once quantified, color differences can be calculated and color tolerances can be established, charted and maintained in the production process. Densitometry and spectrophotometry are covered in more detail in the process color printing volume.



44 A run target should be included in the live area of the job. This run target is adapted from the 1997 FIRST Standards.

UPC VERIFIERS

A bar code scanner is not adequate for the task of quality control of UPC bar codes. UPC verifiers are used to monitor if the bar code is printed within specification. A verifier will:

- measure bars and spaces;
- print out contrast ratio;
- check spaces for ink and specks;
- check bar edge roughness;
- check quiet zones; and
- print out all data for documentation.

ISO 9000

The ISO 9000 system is not specific to flexo printing, instead it specifies in very broad terms the necessary components of a quality system. It details a list of standards that encompass the quality function for all industries. ISO 9000 was originally published in 1987 by the International Organization for Standardization in Geneva, Switzerland and updated in 1994. It is scheduled for review every five years. The standards were written by an international group of quality experts and practitioners including those from the United States.

The registration function is performed by an organization known as a registrar. These are mostly private companies whose purpose is to perform third-party audits and verify that a company is in compliance with ISO 9000. These groups are registered with a group known as the Registrar Accreditation Board (RAB) in the U.S.A.

THE ISO 9000 SYSTEM

Actually, ISO 9000 is a series of five documents working together as a complete quality system. The documents and their content are as follows:

ISO 9000. This is the basic set of guidelines for the selection and use of management and quality assurance standards. It is a statement of purpose and a set of definitions that serves as an advisory function. It suggests whether to pursue ISO 9001, 9002, or 9003 registration.

ISO 9001, 9002 and 9003. These are the actual standards to which a company becomes registered. Each of the three differs in scope and represents a different model quality system depending on the type of business involved. The most comprehensive is ISO 9001, covering 20 different components of a quality system. These range from the responsibility of management in setting quality policy and defining quality responsibilities to such areas as purchasing processes, training procedures, and corrective action methodologies. ISO 9002 is less comprehensive, omitting the necessity of looking at design control (research and development). ISO 9003 is primarily for service type businesses. *Table 26* shows the requirements of each of three standards and which items are not required as you move from ISO 9001 to ISO 9003.

ISO 9004. This is a generic template of the various elements of a quality management and assurance system. It covers such items as economics, quality in procurement, quality in marketing, and the use of statistical methods. Essentially, ISO 9004 is a guideline for implementing and auditing the total quality process.

The key to selecting the appropriate standard is to look at the type of business involved. If it is a manufacturing-intensive firm without extensive research and development (design of the product), as are most flexo printers, ISO 9002 is the appropriate standard.

In order to become ISO 9000 certified, a flexo company must do the following three things:

1. Document what you do, especially if there is an effect on product quality –

REQUIREMENTS OF ISO STANDARDS

Clause/Title		ISO 9001	ISO 9002	ISO 9003
0.0	**INTRODUCTION**			
1.0	**SCOPE**	◆	◆	◆
2.0	**NORMATIVE REFERENCES**	◆	◆	◆
3.0	**DEFINITIONS**	◆	◆	◆
4.0	**QUALITY SYSTEM REQUIREMENTS**			
4.1	Management responsibility	◆	◆	□
4.2	Quality system	◆	◆	□
4.3	Contract review	◆	◆	◆
4.4	Design control	◆	–	–
4.5	Document and data control	◆	◆	◆
4.6	Purchasing	◆	◆	◆
4.7	Control of customer-supplied product	◆	◆	◆
4.8	Product identification and traceability	◆	◆	□
4.9	Process control	◆	◆	–
4.10	Inspection and testing	◆	◆	□
4.11	Control of inspection, measuring and test equipment	◆	◆	◆
4.12	Inspection and test status	◆	◆	◆
4.13	Control of non-conforming product	◆	◆	□
4.14	Corrective and prevention action	◆	◆	□
4.15	Handling, storage, packaging, preservation and delivery	◆	◆	◆
4.16	Control of quality records	◆	◆	□
4.17	Internal quality audits	◆	◆	□
4.18	Training	◆	◆	□
4.19	Servicing	◆	◆	–
4.20	Statistical techniques	◆	◆	□

Key:

◆ Full requirement

□ Less stringent requirement than in 9001 or 9002

– Not applicable

Table 26

ISO PHILOSOPHY
Say what you do
Do what you say
Document what you do in required form
Check the results
Correct the difference

Table 27

this means that you must write down exactly how you take an order, make a plate, or run a press as it relates to the quality aspect of the process.

2. Do what you document – you must do your work the way you have said you will do it in the documentation.
3. Give the customer what you promised – you must have procedures for testing, inspecting and controlling your printing processes.

These three points illustrate the philosophy behind ISO as shown *Table 27*.

This is not to say that implementing ISO 9000 is easy; it isn't. However, many printing organizations are already doing many of the things necessary for certification. They must take the next step, which is to codify the tasks being performed in the form of agreed-upon standard operating procedures.

IMPLEMENTATION OF ISO 9000

Implementing ISO 9000 is primarily a process of organizing, training and documenting. Depending on the present level of the company's procedures and documentation and the system's complexity, the process can take from several months to several years. A typical registration cycle takes from 12 to 18 months. Some flexo printing organizations have been documenting their procedures and policies for years. For them, it should be very easy to get ISO 9000 certification. Others flexo printers have done a very poor job of writing down what they do. For them, it will take longer to become certified. A basic plan of attack for getting certified would consist of four phases *(Table 28)*.

STANDARD OPERATING PROCEDURES

When writing standard operating procedures for ISO 9000, it is very important that certain items be given consideration. In particular, it is critical to identify who will perform the procedure, who is responsible for enforcing the procedure, what the actual procedure is, how people get trained in the procedure, how frequently the procedure is to be performed, and what types of records are associated with the procedure. A typical ISO 9000 procedure format would have the components shown in *Table 29*.

BENEFITS OF ISO 9000

Some of the benefits of the ISO process include:

- Jump starting and managing the quality improvement process
- Breaking down organizational boundaries
- Improving the training process
- Marketing rewards

FOUR PHASES OF ISO REGISTRATION
1. Management commitment
2. Training and organization
3. Documentation
4. Third-party audit (Registrar)

Table 28

SPC PROCEDURE PROCESS CONTROL

1.0 PURPOSE:

To identify and control the key elements of the manufacturing process in order to ensure to a higher degree of certainty that products conform to agreed upon specifications. By verifying these controls we can deliver consistent and acceptable quality levels to our customers.

2.0 SCOPE:

2.1 To identify all processes within the manufacturing operation of SPC that have a direct effect on the final product quality, see Macro Flow Chart describing the process.

2.2 The ultimate responsibility belongs to the V.P. of Manufacturing. The daily responsibility belongs to the supervisors and team leaders.

2.3 The responsibility for maintaining all equipment belongs to the Maintenance Manager.

3.0 ASSOCIATED DOCUMENTS AND RECORDS:

3.1 ANSI/ASQC Q 9001 1994 sec. 4,09 Process Control

3.2 SPC Quality Manual

3.3 Applicable Work Instructions

3.4 Macro Flow Chart

4.0 DEFINITIONS:

4.1 CC1 – Preprint department computerized scanner.

4.2 Scores – Creases in corrugated board enabling the board to fold per specification.

5.0 PROCEDURE:

Responsibility	Step	Action
Customer Service	5.1	Releases Hard Card to planning and scheduling. The Hard Card contains all information and specifications necessary to manufacture the product.
Preprint Group Leader		Runs job according to schedule and appropriate work instructions.

6.0 DOCUMENT REVISION HISTORY:

Revision:	Date of Last Revision:	Last Approval Date:
3	6/7/99	6/7/99

7.0 APPROVALS:

Abbbreviated procedure adapted from Schiffenhaus Packaging Corp.

Table 29

- Reduced manufacturing costs
- Supplier evaluation
- Consistency of operations
- Potential for improved quality
- Potential new customers
- Lower costs leading to higher profits
- Improved market share
- Less rework
- Lower waste and spoilage
- Reduced inspection costs

GETTING STARTED

It should be kept in mind that ISO 9000 is not the "ultimate quality process" as much as it is the "minimal requirements of a quality system." What this means is that ISO is a good way to get started in the quality improvement journey. Even for a company that is well into its quality journey, ISO is a good way to institutionalize improved processes in order to minimize the risk of going back to the old ways of doing things. A flexo company interested in pursuing ISO 9000 should contact the Registrar Accreditation Board (RAB) through ASQC. The RAB and ASQC can provide information about the standard and its application as well as pertinent books and a copy of the standard itself.

For further information concerning the ISO 9000 series contact:

American Society for Quality
611 East Wisconsin Avenue
P.O. Box 3005
Milwaukee, WI 53201-3005
Phone: (800) 248-1946
Fax: (414) 272-1734
E-mail: asqc@asqc.org

Malcolm Baldrige National Quality Awards

Work done by many experts involved in government, business and education has led to the development of a quality strategy known as the Malcolm Baldrige National Quality Award (MBNQA). It is suggested that most flexo printers should use the methodology to analyze their strengths and weaknesses, but not necessarily apply to win this award. Some companies use the MBNQA application process as a means of getting expert feedback. Others take a long-range view and apply with the thought that they will utilize the feedback to improve their quality process each year until they can win.

The MBNQA criteria is a method of benchmarking a flexo printing company's quality progress in relationship to what is considered an outstanding American company. The use of the MBNQA is an all-inclusive benchmark focusing on the customer and how customer satisfaction is achieved. This benchmark can then be used as a means of process improvement for the company.

HISTORICAL BACKGROUND AND PURPOSE

The Malcolm Baldrige National Quality Award was signed into law on August 20, 1987. The award is intended to encourage improved quality, productivity and service. Poor quality can cost companies as much as 30% of sales revenue while improvement in quality and services can lead to improved productivity, lower costs and increased profits. Management must understand and lead the work force in a personal commitment to quality and the use of quantitative analysis tools such as statistical process control. Successful quality improvement programs must be management-led and customer-focused.

HOW THE AWARD IS SET UP

The Foundation of the MBNQA was created with its main objective being to raise funds to permanently endow the mission of the award. The Department of Commerce is assigned the responsibility of the award, which it has assigned to the National Institute of Standards and Technology (NIST) to manage. In turn, the American Society for Quality Control (ASQC) has a contract to assist in the administration of the award program. ASQC has the mission of identifying, communicating and promoting the use of quality principles to facilitate customer satisfaction through continuous improvement.

A maximum of six awards is given annually, with a maximum of two each in the categories of manufacturing, service and small business (less then 500 employees) companies. The process is set up in four stages.

1. A review of the application by at least five examiners.
2. A consensus review of how well the company scored.
3. A site visit, if warranted.
4. The final review.

Each applicant receives a feedback report at the end of the process. The cost of the application process includes a $100 non-refundable eligibility fee, for manufacturing or service companies a $4,500 fee, for small businesses a $1,500 fee, and if more than one type of business (e.g., printing and publishing or broadcasting), an extra $1,500 for a supplemental form. All award winners must share information on their success. However, proprietary information does not have to be shared. This is generally done at the annual Quest for Excellence Conference.

THE MBNQA EVALUATION CATEGORIES, ITEMS AND POINTS

The examination criteria for the Malcolm Baldrige National Quality Award has seven categories that are broken into 24 items with a total value of 1,000 points. Details are listed in *Table 30*.

EVALUATION BY APPROACH, DEPLOYMENT AND RESULTS

The 20 items which comprise the examination criteria are evaluated in respect to approach, deployment and results for each item. Approach is how appropriate are the methods, tools and techniques being used and whether these are systematic and consistent in the entire organization. The company must use information that is objective and quantifiable. Deployment is how a flexo printing company applies the approaches of the items being evaluated throughout all relevant areas in the company. Results include present performance levels and quantitative proof that positive changes are taking place. Also analyzed, under the results category, would be the flexo printing company's rate of improvement and whether this improvement is being sustained throughout the organization.

STATE AND LOCAL QUALITY AWARD PROGRAMS

Many states and local communities have undertaken the role of promoting quality through the establishment of quality programs. Most of these programs are very similar to the Malcolm Baldrige National Quality Award. States and local communities use the system set up by the MBNQA to encourage organizations to focus on meeting customer expectations through management commitment to quality and productivity.

For further information concerning state and national awards contact:

The Malcolm Baldrige
National Quality Award
United States Department of Commerce
National Institute of Standards
and Technology
Route 270 and Quince Orchard Road
Administration Building, Room A537
Gaithersburg, MD 20899-0001
Phone: (301) 975-2036
Fax: (301) 948-3716
E-mail oqp@nist.gov
Web Address: http://www.quality.nist.gov/

MALCOM-BALDRIGE NATIONAL QUALITY AWARDS
1999 CRITERIA FOR PERFORMANCE EXCELLENCE

1999 Categories/Items		Point Values	
1.	**LEADERSHIP**		**125**
1.1	Organizational Leadership	85	
1.2	Public Responsibility and Citizenship	40	
2.	**STRATEGIC PLANNING**		**85**
2.1	Strategy Development	40	
2.2	Strategy Deployment	45	
3.	**CUSTOMER AND MARKET FOCUS**		**85**
3.1	Customer and Market Knowledge	40	
3.2	Customer Satisfaction and Relationships	45	
4.	**INFORMATION AND ANALYSIS**		**85**
4.1	Measurement of Organizational Performance	40	
4.2	Analysis of Organizational Performance	45	
5.	**HUMAN RESOURCE FOCUS**		**85**
5.1	Work Systems	35	
5.2	Employee Education, Training and Development	25	
5.3	Employee Well-being and Satisfaction	25	
6.	**PROCESS MANAGEMENT**		**85**
6.1	Product and Service Processes	55	
6.2	Support Processes	15	
6.3	Supplier and Partnering Processes	15	
7.	**BUSINESS RESULTS**		**450**
7.1	Customer-focused Results	115	
7.2	Financial and Market Results	115	
7.3	Human Resource Results	80	
7.4	Supplier and Partner Results	25	
7.5	Organizational Effectiveness Results	115	
	TOTAL POINTS		**1000**

Table 30

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Resources

ADDRESSES OF ORGANIZATIONS MENTIONED IN THIS CHAPTER
(Valid as of Publication Date)

American Management Association (AMA)
9 Galen Street
Watertown, MA 02172

American National Standards Institute (ANSI)
1430 Broadway
New York, NY 10018

American Society for Quality (ASQ)
P.O. Box 3066
Milwaukee, WI 53201-3066

American Society for Testing and Materials (ASTM)
1916 Race Street
Philadelphia, PA 19103

Association for Graphic Arts Training (AGAT)
c/o RIT/T&E Center, PO Box 9887
Rochester, NY 14623

Association for Quality and Participation (AQP)
801-B W. 8th Street, Suite 501
Cincinnati, OH 45203

The Association for Suppliers of Printing and Publishing Technologies (NPES)
1899 Preston White Drive
Reston, VA 22091

CEEM Information Services
10521 Braddock Road
Fairfax, VA

Flexographic Technical Association (FTA)
900 Marconi Avenue
Ronkonkoma, NY 11779

Graphic Arts Technical Foundation (GATF)
200 Deer Run Road
Sewickley PA 15143-2600

Graphic Communications Association (GCA)
100 Daingerfield Road
Alexandria, VA 22314-2888

Gravure Association of America (GAA)
1200-A Scottsville Road
Rochester, NY 14624

GOAL/QPC
13 Branch Street
Methuen, MA 01844

INFO
PO Box 606
Ayer, MA 01432

International Organization for Standards (ISO)
1, Rue D Varembe, ch-1211
Geneva 20, Switzerland

International Prepress Association (IPA)
7200 France Avenue South, Suite 327
Edina, MN 55435

Japan Printing Academy (JPA)
Koishikawa 4-13-2, Bunkyo-ku
Tokyo, Japan

Joiner Associates Inc.
3800 Regent Street, PO Box 5445
Madison, WI 53705-0445

Juran Institute
11 River Road, Box 811
Wilton, CT 06897-0811

Kaizen Institute
701 Dragon
Austin, TX 78734

Malcolm Baldrige National Quality Award (MBNQA)
U.S. Dept. of Commerce,
Technology Administration,
National Institute of Standards and Technology,
Route 270 and Quince Orchard Road
Administration Building, Room A537
Gaithersburg, MD 20899

National Association of Printing Ink Manufacturers (NAPIM)
777 Terrace Avenue
Hasbrouck, NJ 07606

National Printing Ink Research Institute (NPIRI)
Lehigh University
Bethlehem, PA 18015

Naval Publications and Forms Center
5801 Tabor Avenue
Philadelphia, PA 19120

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Resources cont'd from previous page

Philip B. Crosby Associates, Inc.
3260 University Blvd., Suite 175,
Winter Park, FL 32792

Printing Industries of America (PIA)
100 Daingerfield Road,
Alexandria, VA 22314-2888

Quality Circle Institute
PO Box Q
Red Bluff, CA 96080

Quality Digest
PO Box 882
Red Bluff, CA 96080

Quality Progress
American Society for Quality
P.O. Box 3005
Milwaukee, WI 53201-3005

Registration and Accreditation Board (RAB), American Society for Quality Control
P.O. Box 3066
Milwaukee, WI 53201-3066

Research and Engineering Council of the Graphic Arts Industry (R&E Council)
PO Box 639
Chadds Ford, PA 19317

Research Association for the Paper and Board, Printing and Packaging Industries (PIRA)
Randalls Road, Leatherhead,
Surrey, KTSS 7RU, England

Technical and Education Center of the Graphic Arts (T&E Center)
Rochester Institute of Technology
One Lomb Memorial Drive
Rochester, NY 14623

Technical Association of Pulp and Paper Institute (TAPPI)
PO Box 105113
Atlanta, GA 30348-5113

Technical Association of the Graphic Arts (TAGA)
RIT/T&E Center
One Lomb Memorial Drive, PO Box 9887
Rochester, NY 14623

WEBSITES (Valid as of Publication Date)

American National Standards Institute
www.ansi.org

American Productivity & Quality Center
www.apqc.org

American Society for Nondestructive Testing
www.asnt.org

ASQC Headquarters
www.asq.org

ASQC Quality Audit Division
www.asq.org/about/divtech/qad/qad.html

ASQC Quality Management Division
www.asq-qmd.org

International Organization for Standardization
www.iso.ch

Los Alamos National Laboratory Quality and Planning Program Office
iosun.lanl.gov:2001/qp/qp.html

NASA Quality Pages
akao.larc.nasa.gov/dfc/qtec.html

National Quality Award Homepage
www.quality.nist.gov

National Standards System Network
www.nssn.org

Quality Progress Magazine
qualityprogress.asq.org

Quality Resources Online
www.quality.org

Registration Accreditation Board
www.asq.org/rab/index.html

Standards Resources on the Internet
www.library.ucsb.edu/subj/standard.html

The Deming Home Page
www-caes.mit.edu/products/deming/home.html

The Quality Management Principle Site
www.wineasy.se/qmp

The W. Edwards Deming Institute
www.deming.org

Appendix A - Central Tendency

Measures of central tendency are averages that give definite characteristics about the data. The examples below indicate how the various measures are computed.

A ARITHMETIC MEAN, M_X

$$M_X = \frac{\sum fx \text{ (sum of all values)}}{N \text{ (number of observations)}}$$

B MEDIAN, M_D

The midpoint value of all data, above and below which 50% of the values lie.

C MODE, M_O

The most prevalent value observed.

D EXAMPLE

The distribution of weights of rolls in inventory.

	WEIGHT (X)	NUMBER OF ROLLS (F)	TOTAL WEIGHT (FX)
	120	1	120
	130	2	390
	140	17	2,380
	150	24	3,600
	160	32	5,120
	170	14	2,380
	180	6	1,080
	190	2	380
	200	1	200
TOTALS	N=100		fx=15,560

MEAN: $M_X = \frac{15{,}650}{100}$

$M_X = 156.5$ **lbs./roll**

MEDIAN: $M_D = 160$ **lbs.**

MODE: $M_O = 160$ **lbs.**

Table A-1

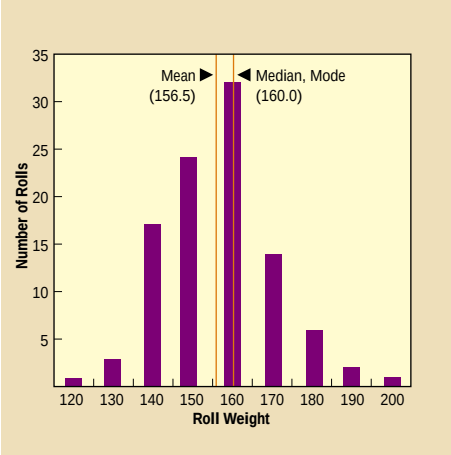

Figure A-1

There are three mathematical models that describe the average. These three models are the arithmetic mean, median and mode. Generally, the "average" refers to the arithmetic mean. *Table A-1* defines mean, median and mode and shows how to calculate these three averages. For a normal distribution of values these three averages are the same, hence the term "Central Tendency".

Normal distribution implies that the values refer to one variable and the variations in that variable are random.

Figure A-1 shows a bar graph of the data in *Table A-1*. The distribution is not quite normal. However, the results are probably satisfactory for acceptance from a supplier or sale to a customer depending upon customer agreed specifications. The data indicates a kurtosis greater than 1 and a negative skew (refer to *Appendix B* for skew and kurtosis).

Appendix B - Histograms

Most flexo processes will not have the perfect bell shape that is traditionally associated with a histogram. These distributions are natural and when charted on a bar graph can be analyzed to determine how normal they are and how much they may vary from the perfect bell shape curve. As is shown in the *Figure B-1*, when the process is perfectly normal, 68.27% of the values fall within 1 standard deviation; 95.45% fall within 2 standard deviations; and 99.73% fall within 3 standard deviations. The standard deviation is simply how the process varies around a central tendency called the process mean (arithmetic average).

Figure B-1 also illustrates a skew to the left of the process mean. This indicates a positive skew. If the skew is to the right of the process mean the process would have a negative skew. Either of these skews need to be analyzed to determine whether the product or service being charted is within acceptable tolerances. In a normal distribution the mean and median are both in the center of the distribution. When there is skew, they are different.

An abnormal amount of data around the mean is called kurtosis. A normal curve will demonstrate 68.27% of the data within 1 standard deviation of the arithmetic mean. When this occurs the kurtosis is 0. If there is a greater amount of data around the mean with long tails on either side of the mean then the kurtosis is greater then 1. If the graph looks square with little shoulders and slope to the curve then the kurtosis is less than 1.

Finally, *Figure B-1* illustrates a bimodal distribution. This indicates that there are two sets of data represented in one bar graph; that is, two variables. It is necessary to determine which elements exist that create this situation and only collect and chart histogram data for one variable at a time. To illustrate, when charting pH of a water based ink it may be determined that a bimodal distribution indicates two different shifts charted together or it may indicate a change in ink. There may be more than two bell shape curves in a bar graph. Each of these differences must be identified and graphed separately to truly determine the variation of each of these variables.

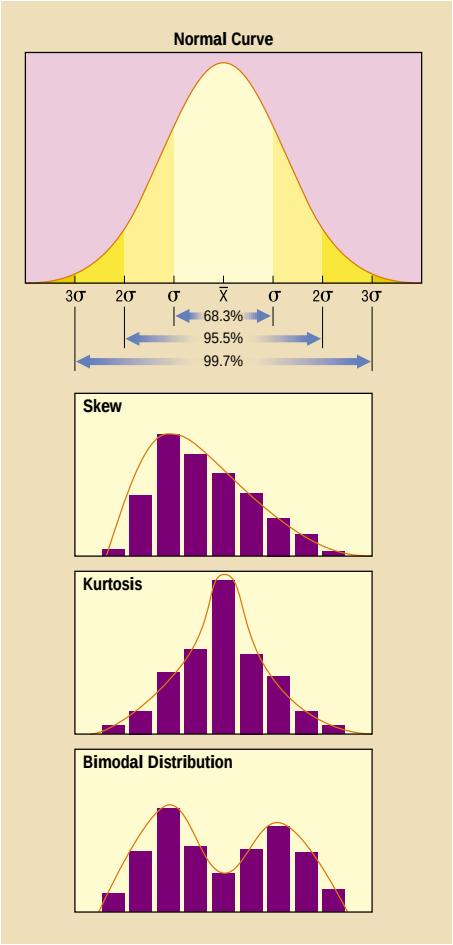

Figure B-1

Appendix C - Control Charts

This appendix shows an example of how to collect, organize and chart data for control and process improvement purposes. The objective of this data collection exercise is to find out if the density of black ink is in control. The agreed upon specifications between the printer and customer are 1.50 ±0.07. This is illustrated in *Figure C-1* where these lines are drawn in.

The following statistical data manipulation was done on a personal computer using a popular spreadsheet program. It was decided to sample one press sheet every one-half hour and take 5 densitometric readings on each sheet (table in *Figure C-1*). These 5 measurements are the subgroup sample size. The 5 measurements were then added together and divided by 5 to determine the average of each subgroup. This can be seen in the table below where press sheet 1 shows the average of the 5 readings as 1.48. All the averages are then added together and divided by 12 (total number of press sheets). This is the grand average of 1.49. The standard deviation of the grand average is calculated and multiplied by 3 (three standard deviations). This value is 0.05 and is added and subtracted from the

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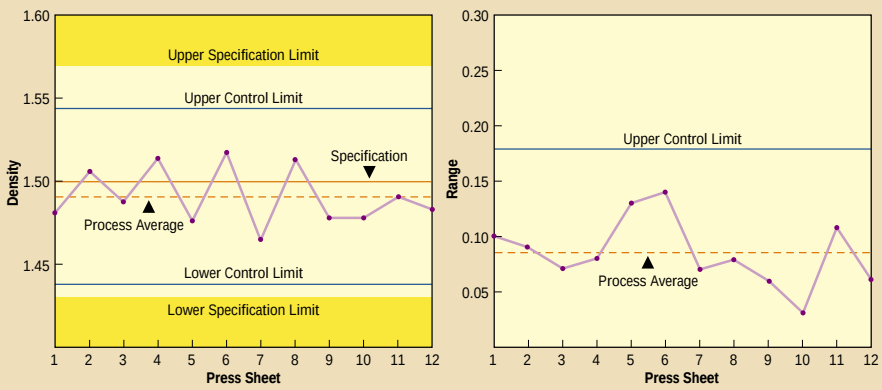

Press Sheet	1	2	3	4	5	6	7	8	9	10	11	12
Density1	1.53	1.48	1.51	1.56	1.45	1.57	1.43	1.48	1.52	1.47	1.43	1.48
Density2	1.46	1.56	1.52	1.52	1.48	1.56	1.49	1.50	1.48	1.48	1.44	1.46
Density3	1.48	1.50	1.47	1.48	1.53	1.56	1.46	1.56	1.46	1.50	1.54	1.52
Density4	1.50	1.52	1.49	1.50	1.40	1.47	1.50	1.50	1.47	1.47	1.50	1.48
Density5	1.43	1.47	1.45	1.51	1.52	1.43	1.44	1.52	1.46	1.47	1.54	1.47
Average	1.48	1.51	1.49	1.51	1.48	1.52	1.46	1.51	1.48	1.48	1.49	1.48
Range	0.10	0.09	0.07	0.08	0.13	0.14	0.07	0.08	0.06	0.03	0.11	0.06
Upper spec limit	1.57	1.57	1.57	1.57	1.57	1.57	1.57	1.57	1.57	1.57	1.57	1.57
Lower spec limit	1.43	1.43	1.43	1.43	1.43	1.43	1.43	1.43	1.43	1.43	1.43	1.43
Spec	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50

Figure C-1

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grand average of 1.49. These two values become the upper and lower control limits of 1.54 and 1.44.

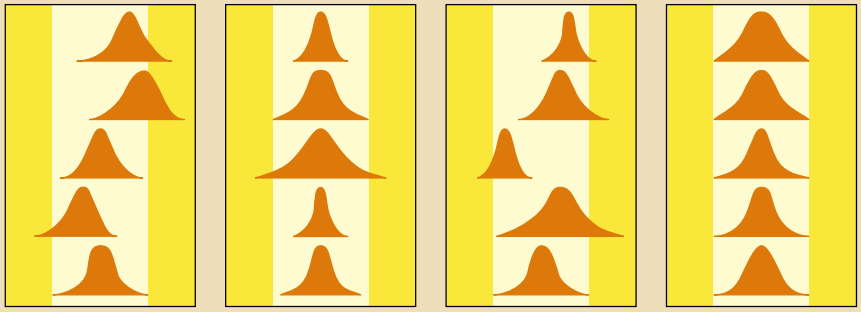
The range is determined for each subgroup of five readings by subtracting the lowest reading from the highest reading within the subgroup. As can be seen for press sheet 1 its range is 1.53 to 1.43, or 0.10. This is done for all 12 press sheets. The average range is calculated by adding up all the ranges and dividing by 12 and its value is 0.09. The standard deviation of the average range is calculated and multiplied by 3. This value is 0.09, which is added to the average range. The result, 0.18, becomes the upper control limit for the range as shown in *Figure C-1*.

In order to understand fully what is happening when using a control chart it is important to also use a range chart. When viewing any given subgroup data point on the control chart one must also review that same point on the range chart. Add and subtract half the corresponding range number from the control chart number to determine the variation at that point on the control chart.

A review of *Figure C-1* indicates that the last 4 sheets were, on average, under the process average line. If there are 4 consecutive subgroup data points on one side of the process average, this indicates that there may be a process shift. Similarly, 4 or more points heading in the direction of the upper or lower control limit may indicate a trend in the process away from the process average. The subgroup average data points should fall fairly evenly on either side of the process average.

As can be noted in *Figure C-1*, the upper and lower control limits are well within the agreed upon specifications for the black ink densities. There should never be a process in which the average data point is not well within the upper and lower specifications. It is assumed that whenever a data point is close to the specification limits there is a tendency for the process to vary enough to produce out of specification work. One must look at the specifications in terms of process average, control limits, range, skewness and kurtosis (*Figure C-2*).

Process Variations as Seen in the Use of Control Charts



A. Lack of control due to a shifting quality level.

B. Lack of control due to changes in inherent variability.

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FLEXOGRAPHY:
Principles & Practices

5th Edition

VOLUME

4

CHAPTER 1
Printing Plates

CHAPTER 2
Mounting And Proofing

Flexography: Principles And Practices

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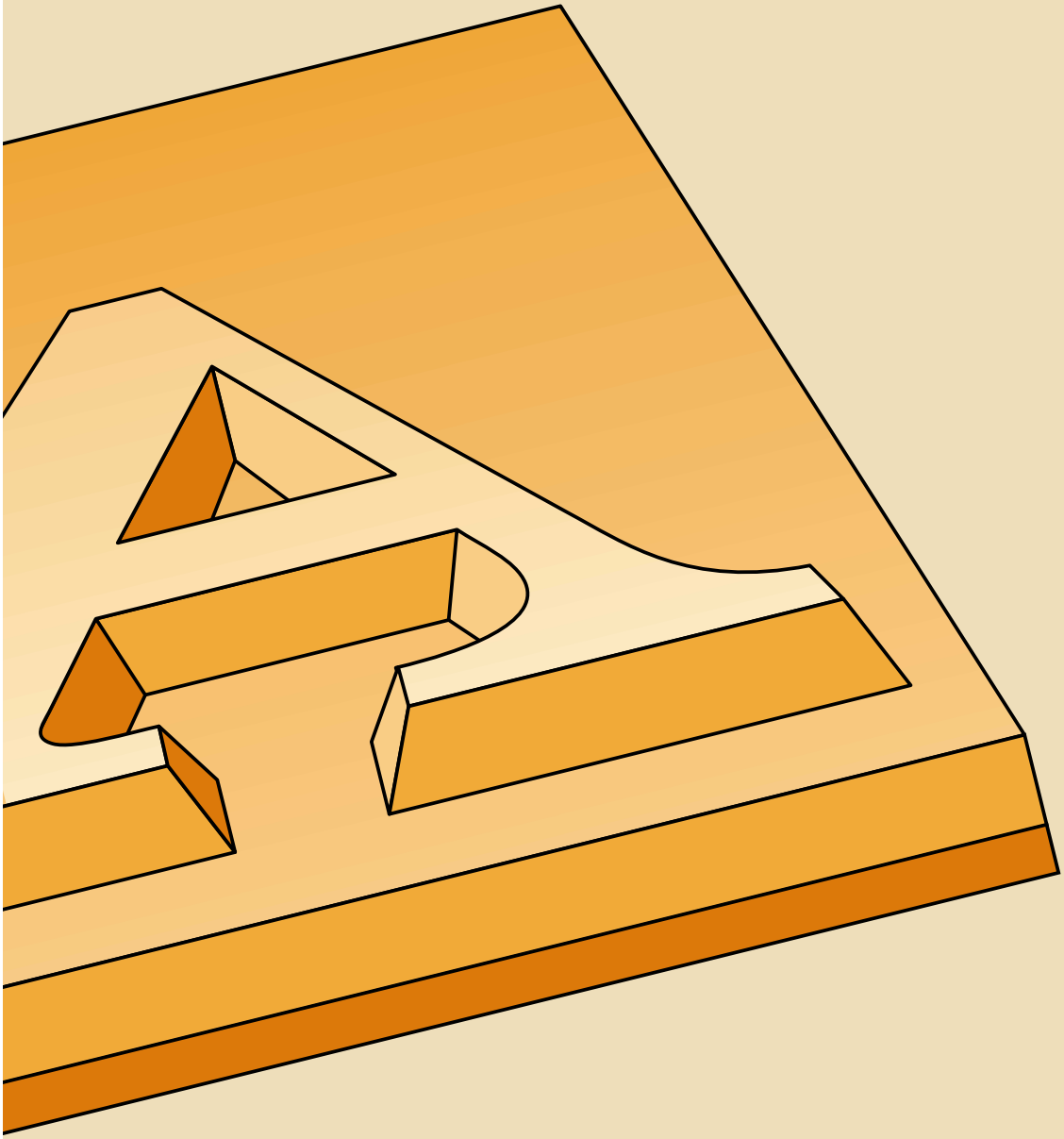
CHAPTER 1

Flexographic Printing Plates



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Introduction

The manufacture of flexographic printing plates has been revolutionized in recent years. In the past, hand-cut and molded rubber was the only choice for flexo printers. These plates were labor intensive, operator-skill-dependent, imprecise and time consuming to manufacture. Mounting was also imperfect. Often, plates had to be repositioned on the press because of inaccuracies in the mounting devices or methods. With rubber plates, this could be a problem because they were not dimensionally stable and could stretch unevenly if pulled off a mount.

Today, technology has been adopted from the offset and gravure industries. Images are stepped and repeated multiple times on one plate. These plates may be positioned mechanically onto a printing cylinder by a variety of techniques: pins, micro dot and microvideo registration systems. Plate mounting now takes minutes, not hours, produces accurately mounted plates and eliminates the need for special skills.

With the advent of dimensionally stable rubber compounds and polyester-backed photopolymer, images on the printing plate are now of predictable size with no distortion across the cylinder. These plates last longer and can be registered accurately. They are also more environmentally safe to manufacture, and can be made in larger sizes with multiple images on one plate. Chemical changes in ink formulation have resulted in photopolymer printing plates gaining wide popularity, becoming the standard quality plate of choice.

Rubber plates are still used in some market segments of flexo, but their stronghold on the industry has been relinquished to photopolymer. Many printers have typically chosen rubber because of its ink-transfer characteristics. With new photopolymer technologies that emulate these properties, this point is moot.

Large-format platemaking systems have also become popular. One-piece photopolymer plates are now being manufactured in sizes up to 52" x 110". Images that are stepped and repeated multiple times on one plate are larger than ever before. This stepping of multiple images, combined with the need for large, one-piece, corrugated plates and pin register, has led to rapid acceptance of these large-format platemaking systems. Large platemaking systems are computer-controlled, ensuring predictable and consistent plate quality.

Halftone process-printing plates are made from electronically imaged films, computer-compensated for dot gain and other printing characteristics. These films are output for each individual press, based on press characterization data. In an effort to further enhance quality, modern suppliers produce all their printing plates using statistical process control.

Artwork for the manufacture of flexographic printing plates is also computer-generated, with all copyart and masks output to exact specifications, including print-length distortion. Artwork is designed by using electronic design software that is accurate, quick and capable. Logos, bar codes, register marks, tone reproduction targets and other frequently used items can be stored electronically and called up for any job required.

There are not many general manufacturing areas that have seen as many changes in the past few years as the techniques for making quality-controlled flexographic printing plates. This chapter will cover these new techniques, as well as the traditional ones, used for the manufacture of the many types of flexographic plates.

Plate Classes

Flexographic printing plates are divided into two broad classes: rubber and photopolymer. The oldest technology is that of hand-engraved rubber plates, followed by molded-rubber plates. The photopolymer plate, in its sheet and liquid forms, represents a major step forward in the industry and is the dominant technology in use today.

HAND-ENGRAVED RUBBER PLATES

Long before the introduction of molded-rubber and photopolymer plates, there were hand-engraved rubber plates. These plates have limited use today in printing large, point-of-purchase displays, in applications requiring very large printing blankets for solid-color printing, or in the application of coatings. The material is supplied as a cured-rubber sheet, either natural or synthetic. It is usually of a soft durometer and comes in large rolls roughly 4' wide by 10' long.

Instead of using a film negative for plate-making, a full-size mechanical tracing is made for each of the colors to be printed. Each tracing is then "rubbed off" or transferred to the rubber-engraving material by using a transfer solution, allowing the pencil tracing lines on the layout to be tattooed on the surface of the rubber. If compensation for plate stretch is required, the rubber material is secured to the appropriately sized curved cylinder and the tracing is transferred in the curve.

When the tracing has been transferred, a skilled engraver cuts the traced image by hand-ensuring an accurate depth of cut, as well as the proper shoulders and bevels. The finished product is a printing plate that is ready to be mounted and go onto the press. In some applications, hand-engraved plates are the quickest, most economical method of producing flexographic printing plates. *Table 1* summarizes the advantages and disadvantages of hand-engraved plates.

HAND-ENGRAVED PLATES

ADVANTAGES	DISADVANTAGES
Plates can be used for very large areas of print	Layout and cutting are hard work
Plates do not require metal or photopolymer engraving	Size and intricacy of the characters cut are limited
Plates are ready to use after being cut	Plate life is not as long as with molded or photopolymer plates
	The engraved image may not have the same accuracy as that of a molded or photopolymer plate

Table 1

BASICS OF MOLDED-RUBBER PLATEMAKING

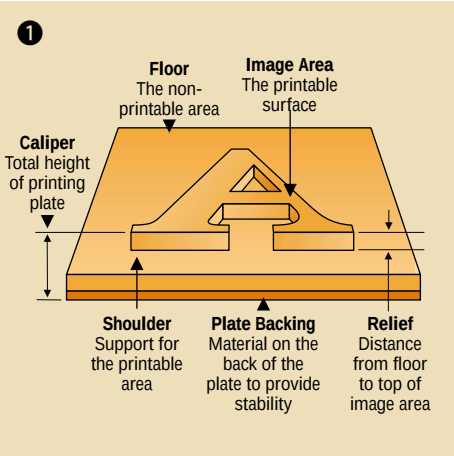
1. Create a master pattern by exposure through a photographic negative, either acid etching a metal engraving, or processing a hard-durometer photopolymer plate by water wash
2. Mold a cavity in a phenolic matrix board from the master pattern plate
3. Produce the rubber plate by molding from the cavity in the matrix board

Table 2

MOLDED-RUBBER PLATES

Molded-rubber printing plates are flexible, resilient and have the printing image in relief. They are duplicated from a mold, or matrix and made from an original or master pattern plate carrying the image. The master pattern may be made of metal, either magnesium or copper, and is produced from the artwork through a photographic and etching process. Any number of printing plates may be made from this mold. The printing plate is pliable because it is made from a flexible material, either rubber or a combination of rubber and plastic. These materials have excellent ink-transfer characteristics, possessing both an excellent affinity for a wide variety of inks and the ability to release the ink onto many different substrates. The basic production steps for molded-rubber plates are listed in *Table 2*.

Most suppliers of liquid photopolymers provide materials ranging in durometer from 40 to 60 Shore D, designed to manufacture masters for molding matrix boards, from which rubber printing plates are made. These photopolymer masters are manufactured in the same way as direct-printing plates. The plate masters for compression molding, as well as deep-relief powder molding, can be made from these materials. Most molding techniques dictate that the photopolymer master be sprayed with a release agent to prevent sticking to the matrix. Most standard matrix boards can be used for face molding or powder molding. Molding procedures are comparable to rubber, except for the need to minimize pressure to prevent plate distortion.



1 The various components which make up a photopolymer plate.

PHOTOPOLYMER PLATES

The direct photopolymer plate is one of the major innovations in modern flexographic printing. It affords the ability to transfer an image from a photographic negative directly onto the surface of the printing plate, thereby giving excellent image fidelity.

Photopolymers are ultraviolet light-sensitive materials and are used to prepare printing plates for flexography, letterpress and offset, as well as printing resists and proofing films. Flexographic photopolymer printing plates are similar to molded-rubber plates in that both are flexible, resilient and have excellent ink transfer. There are many systems available for producing photopolymer flexo plates.

Raw materials are available as either viscous liquids, ready to be cast to a desired thickness, or as preformed solid sheets of an appropriate thickness. Photopolymer materials, whether liquid or sheet, are converted

BASICS OF PHOTOPOLYMER PLATEMAKING
1. Back-exposure of base to ultraviolet light to harden (cure) floor and establish relief depth
2. Face exposure of surface to ultraviolet light through the negative to harden (cure) the relief printing image
3. Wash out in appropriate solvent or water to remove unexposed polymer and leave printing image in relief
4. Post-exposure to finally cure floor and character shoulders
5. Drying of the plate either to remove absorbed solvent and restore gauge thickness, or remove surface water and render plate pressready

Table 3

to flexographic printing plates when exposed to ultraviolet light passed through a photographic negative image of the artwork to be reproduced. The photopolymer is then processed to develop the relief image (*Figure* ❶). *Table 3* outlines the process.

The negative is the single most important element in photopolymer plate preparation. It is a selective, light-blocking stencil that controls image formation during exposure of the photopolymer plate. In general, the guidelines are discussed in the film-negative section of the Photopolymer Plate chapter apply to all photopolymers. It is important to check with your plate-material supplier to determine the correct negative preparation for your particular platemaking process.

Liquid and Sheet Photopolymers Compared

The liquid-photopolymer system uses detergent and water to process the plate. The solid-plate process generally uses organic solvents. Some water-wash sheet photopolymer systems use a mild acid or caustic solution, depending on material type. Drying time of a water-wash plate is five to 10 minutes because only water needs to be removed from the plate surface. Sheet-plate systems using solvent wash require additional drying time to remove solvents that have been absorbed by the photopolymer material. In liquid-photopolymer platemaking systems, the exposure unit includes the setting of plate thickness.

Customized platemaking techniques can cast and expose varying plate thicknesses. Sheet photopolymers are available in a range of predetermined thicknesses. The overall platemaking time for liquid photopolymer plates is generally shorter than that for sheet plates.

Plates for Process Printing

Much has been said about relative differences between rubber and photopolymer, in terms of molecular structure, porosity and ink-transfer capabilities. Either can achieve outstanding print results. The inherent dimensional stability of photopolymer and direct reproduction capabilities have made photopolymer more popular for printing sophisticated designs, halftone screens and process-color images. Tone-reproduction curves that accurately compensate for image gain, can be established for each type of plate, either through characterizing (fingerprinting) the press or other controlled methods. Different image-compensation requirements for rubber- and photopolymer-plate systems tend to rule out using the same screened, color-separated negatives for both processes.

All steps of the “rubber” production process for making plates (i.e., acid etching, matrix molding, subsequent rubber-plate molding operations) contribute to dot-percentage change and affect printed tonal values.

FILM NEGATIVE REQUIREMENTS

Preparation of the film negatives is one of

the most crucial operations in the manufacture of relief-image photo engravings and photopolymer printing plates. Prior to the introduction of computer graphics, the finished black-and-white mechanical artwork was photographed using an engraving camera to produce the platemaking negatives. In the engraving camera, special lenses were used to pick up the finest detail, but any imperfections in the artwork were also transferred to the negative. Therefore, in camera-art systems, the artwork was carefully inspected to make sure that the image elements were clean and had sharp line definition before the art reached the camera.

With the advent of computer graphics, laser-imaged film and automatic film processing equipment, reflection-copy imperfections have been eliminated. This does not imply that laser-imaged platemaking films are perfect. Poorly maintained imagesetters can produce minute imperfections in the platemaking films that may escape the notice of both the artist and platemaker. This is especially true of films containing halftone process screens.

After photography or imagesetting, the film is developed to conform to density specifications and should be inspected for defects. Inspection is carried out on a light table. The light beneath the negative makes any tiny transparent spots ("pinholes") or other imperfections easily detectable. These faults in the negatives may be corrected by painting over them with a commercial opaquing solution. Opaquing should be applied carefully and with the platemaking process in mind as each image transfer system may have different requirements.

In single-color jobs, only one negative is produced. For multicolor jobs, a negative for each color must be made. If preseparated art is used, each overlay is imaged and a negative made. With "composite" or "key-line" artwork, it is necessary to make a composite negative for each color to be printed. The color-separation artist then paints out all the colors but one on each negative, leaving all details of that one color on its own film. For example: On a two-color job, say red and blue, two negatives are made. All the blue copy is opaqued out of the negative, producing the red-plate film. On the second negative, all the red copy is removed, producing the blue-plate film.

Great care is required to ensure that all copy is clean and sharp. In addition, imperfections such as pinholes, broken letters or other flaws should be carefully retouched. Center lines and registration marks should appear on the negatives and be reproduced on the printing plates. Small designs (under 24 square inches) can be photographed on 0.004" film, while larger designs should use 0.007" film.

A good film negative is critical to all the plate-imaging processes with the exception of laser-engraving and other direct computer-to-plate processes. *Table 4* briefly lists the considerations when producing film for flexo platemaking

Note: *If the film is imaged with poor or veiled dots, higher-than-normal exposure times will be needed. Over-exposure causes reverses to fill in and results in tone compression on the finished plate.*

DIRECT-IMAGED PLATES

Direct-imaged plates refer to plates made directly from digital data output from a computer and usually, but not always, involves a laser to write the image to be printed.

Laser-engraved Plates

Laser-engraved rubber plates are produced by engraving rubber with a laser unit similar to that used when producing ceramic anilox rolls. The high-energy laser vaporizes (ablates) the unwanted rubber in the relief area of the plate, leaving the raised image. Laser-engraved rubber plates combine the

excellent printing characteristics of rubber and direct imaging from the computer-generated artwork, thereby eliminating the need for negative films. The engraving process is, however, time consuming, especially in the deep-relief printing plates used for direct-corrugated postprint applications.

KEYS TO A GOOD FILM NEGATIVE FOR FLEXO PLATEMAKING

- High-contrast film free of dirt, kinks, nicks and pinholes
- For process, halftone or screened plates, the film must be imaged with hard, fringe-free, round dots
- The density of the film:
  - in the nonimage area (black area) should be 4.0 or greater
  - in the image area (clear area) should be 0.05 or less
- Nonmatte film should be used for liquid photopolymer and metal master patterns
- Matte film is mandatory for sheet photopolymer
- Image orientation must provide for emulsion to plate contact
- The negative must be:
  - emulsion side, right reading for surface printing
  - emulsion side, wrong reading for reverse printing
- Image correction for distortion of the plate material being used
- Film thickness is either 0.004" or 0 .007", however, 0.007" film is desirable, as it is easier to handle and store without kinking
- Opaquing:
  - liquid photopolymer systems: on the emulsion side only
  - sheet photopolymer and metal masters: on the base of the film

Table 4

Molded-Rubber Plates

Molded-rubber plates are flexible, resilient and have excellent ink-transfer characteristics. They are manufactured by duplicating an image from a mold, or matrix, that was generated from an original pattern plate. The mold can be used repeatedly to make duplicate plates carrying the same image. The plates are made from a flexible material, either natural rubber or a combination of natural and synthetic rubber compounds, giving the plate its flexibility. The basic production steps in making molded-rubber plates can be seen in *Table 5*.

BASIC PRODUCTION STEPS FOR MOLDED-RUBBER PLATES

1. Make the master pattern by exposure through a photographic negative and either acid-etching a metal engraving or processing a hard-durometer photopolymer pattern material
2. Make a phenolic matrix mold of the master pattern plate
3. Mold the rubber plate from the matrix

Table 5

THE MASTER PATTERN

The first step in the molded-rubber plate-production cycle is making a master pattern. These could be either metal masters or photopolymer masters.

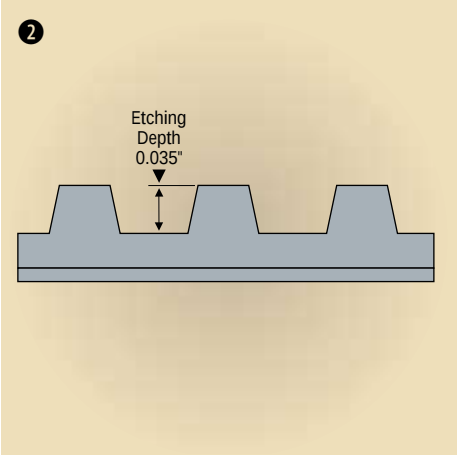
Metal Masters

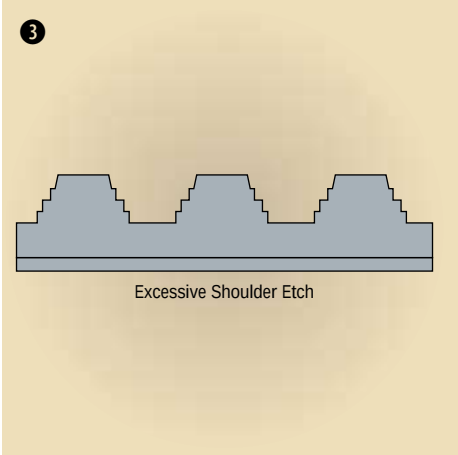
Metal masters are produced from the original art using a photographic process. The image on the negative is first transferred photographically to a photosensitive coating on the face of a sheet of metal. The plate is then etched in an acid bath, leaving the relief image. The etched metal becomes the master pattern from which a matrix mold is made. For standard-web flexo applications, the metal sheet is usually 0.064" overall in thickness, with an etched-relief depth between 0.030" to 0 .035". Deep-relief plates used in the corrugated industry are made using 0.250" or 0.187" metal originals with an etched relief between 0.140" to 0.150".

Types of Metal Originals. Photo engravings can be made from magnesium or copper. Magnesium is an excellent engraving metal for producing high quality line originals. Magnesium is sometimes used for coarse-to-medium (up to 100-line screen) process color work but magnesium undergoes unpredictable lateral copy loss in the etching process, making it unsuitable for very fine work. Copper is used mainly for fine detail and halftone screen reproduction where fine tone or process color jobs are involved.

Preparation of Metal and Image Exposure, The metal for the photo-etching process is precoated with a photosensitive material, ready for transfer of an image from the negative film. The photo-resistant coating has a polyethylene protective sheet that adheres lightly to the surface. After removal of this protective sheet, the emulsion side of the image-carrying negative is placed in direct contact with the photo-sensitive coated surface. The two are locked tightly together in a vacuum frame and exposed to a light source.

When transferring the image to the photo-





❷ Ideally, the proper etching should be almost vertical, with a uniform, smooth taper.

❸ An improper etching with excessive shoulders will tend to cause ink build up on the finished plate resulting in a smeared and dirty print.

resist, it is recommended that a step exposure (Stouffer) gauge be used to ensure sufficient light exposure. For surface printing, the negative should be wrong reading, with the emulsion down to make plates; for reverse-printing applications, the negative should be right-reading emulsion down.

The procedure is similar to printing photographs, except that the platemaker is working with metal, instead of photographic print paper. The vacuum locked assembly is exposed to an intense light source, rendering the exposed areas of the photo-resist insoluble when contacted by acid. Developing the image removes the still-soluble coating from the unexposed, nonprinting areas, leaving the acid-resistant coating on the image areas of the metal.

The Etching Process. The metal, with the exposed and developed photo-resist, is placed in a stainless-steel etching machine where it is splashed with a mixture of nitric acid, oil, etching additives and water until the proper etching depth is reached. The hardened coating, which carries the image of the design to be printed, resists the action of the acid, while the unprotected areas are dissolved by the acid. In this way, the acid bath creates a relief image on the surface of the metal against a background that has been etched away.

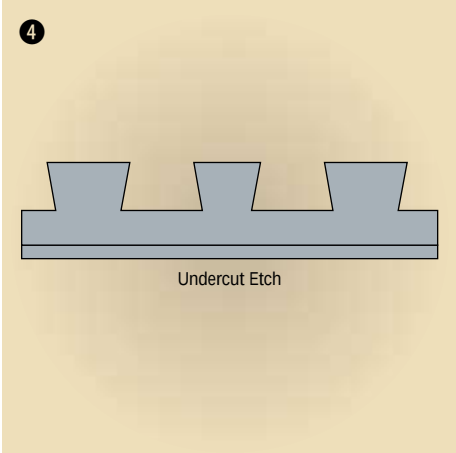
A concern in the etching operation is to control the acid action to prevent undercutting the metal from beneath the image. This would destroy the usefulness of the engraving as a pattern for molded-plate production. In the mid-1950s, a chemical process called "powderless etching" was developed. The process involved a special filming agent mixed in the nitric acid bath that acted to protect the side-wall or shoulder formation of the image, preventing undercutting during the etching cycle. The entire etching procedure requires very precise control of the chemical solution, machine speed, bath temperature and timing. The powderless etching method is universally used and produces high quality flexo engravings.

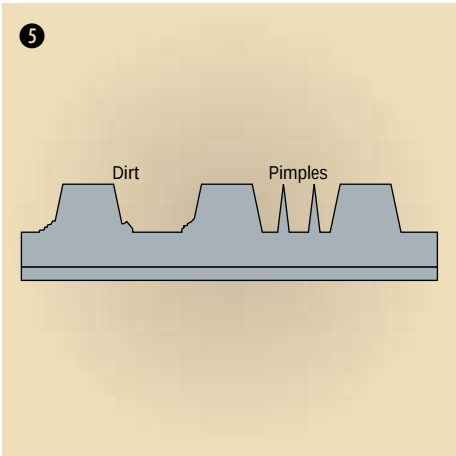
The ideal profile of the supporting sides or shoulder formation of the engraving should be almost vertical, with a uniform, smooth taper (*Figure* ❷). Excessive shoulders and broad, stepped shoulders (*Figure* ❸), will tend to cause ink buildup on the finished plate, resulting in a smeared and dirty print. At the other extreme, undercut conditions (*Figure* ❹) would tend to lock the engraving into the mold and make separation of the two impossible without irreversible damage to the mold and possibly the master.

Finishing. After etching, the finished engraving is cut from the large metal flat and carefully finished to remove any imperfections.

❹ Undercut conditions in the plate tend to lock the engraving into the mold and make separating the two impossible without damaging the mold and/or master.

❺ Dirty etching can be caused by pinholes, impurities and/or lack of proper control of the ethcing bath operation.





Ideally, there should be little tooling, routing or other handiwork necessary with a good quality etching. Pinholes in the photographic negative, impurities in the metal or a lack of proper control during the etching bath operation often cause pimples or tick marks (*Figure* ❺). If the condition is not too severe, the marks can be removed by tooling or routing the finished engraving.

Extra centerlines are sometimes provided for convenience in locating slug sections such as price changes, nutritional clauses, weight or other changes to any part of the plate. Some printers and converters use scribe lines to indicate folds, panels, repeat marks or other data, especially on carton work. Identification for the job should be carefully stamped into the background area of the engraving. Other useful information, such as curve direction, print position, location on bag, color and any identifying data the platemaker or customer requires would also be added to the background area.

The photo-resist is removed and cleaned from the face of the engraving for subsequent production of the mold. If all of the photo-resist is not removed, it can cause a blistered, uneven print surface and flaws in the finished plate. After the finished engraving is proofed and checked for quality, size and accuracy of color separation, it is ready to serve as a master pattern for molding the matrix.

Photopolymer Masters

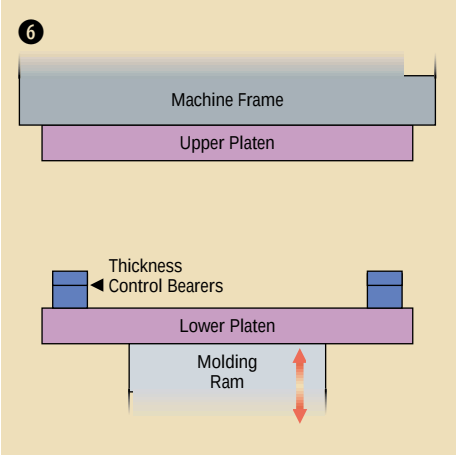
In the production of metal masters, the metal-etching acid is dangerous and difficult to dispose. Therefore, for both environmental and health reasons, masters made from very hard-durometer photopolymer material have become the standard in molded-rubber plate production.

There are many types of photopolymer masters for shallow-relief printing including, photosensitive nylon and metal-backed thin photopolymer. These masters come in a variety of thicknesses and with different backings, usually either stainless steel or aluminum. Deep relief photopolymer masters for corrugated plates are usually made using the liquid platemaking technique and a special high durometer master pattern photopolymer.

The masters are produced in the same way as regular photopolymer flexo plates. Once the photopolymer master has been made, it is handled in the same molding procedure as a metal master.

THE MOLDING PRESS

The molding press, or vulcanizer as shown in *Figure* ❻, is used to make both the



6 The matrix molding process uses a heat-set material. The plate-molding process vulcanizes the rubber-plate material. Both require high temperature and pressure.

matrix and, in turn, the printing plate. The matrix molding process uses a heat-set material and the plate-molding process vulcanizes the rubber-plate material; both require high temperature and pressure.

The matrix and printing plates are produced between two, accurately ground, parallel surfaces. A press with accurately ground platens and precise temperature control is necessary to produce properly cured flat molds and rubber plates. Normal press tolerances are ±0.0015", while critical accuracies of ±0.0005" are needed for process printing plates.

The molding press may be heated by either steam, electricity or hot oil. The ideal temperature for matrix and rubber molding is 308° F to 310° F. It is important that platen temperatures are maintained above 200° F. Constantly cooling and reheating the press can eventually cause the shims (accurately ground thickness-control bearers that give the press its accuracy) and platens to become uneven and put the press out of tolerance.

Molding pressure is generated by hydraulic pressure applied to the bottom table or platen (sometimes referred to as the ram), which travels up or down as required. The top platen is stationary in the press. Molding presses are equipped with a serving tray to allow the work to be brought into and out of the open press. An accurate timer is provided to time preheat and molding cycles, together with accurate temperature and pressure controls. The thickness of the matrix and rubber plates is determined in the molding press through use of steel shims (accurately ground steel strips), sometimes referred to as molding bearer bars.

Auxiliary Equipment

A matrix preheat oven can be used, instead of preheating the matrix in the molding press, before applying pressure during the molding cycle. A matrix preconditioning cabinet can also be used to keep moisture out of the uncured matrix sheet before molding. This will help achieve a full cure of the matrix sheet and maximize stability, eliminating excessive shrinkage and blistering.

THE MATRIX MOLD

Three components make up modern matrix materials: phenolic resin (Bakelite), cellulose fibers and mineral fillers. A phenolic, thermosetting resin first melts, then cures when exposed to heat and pressure. The fibers consist of cellulose derived either from cotton or wood pulp. Fillers typically are finely ground, high-temperature minerals that give the matrix resistance to the conditions of plate-molding. Matrix mold is produced from the metal or photopolymer master. The two main types of plates produced are thin-plate/shallow-relief and thick-plate/deep-relief, each using a slightly different matrix-molding technique.

Thin-plate/Shallow-relief Molding. Matrix-molding materials for producing thin plates with shallow relief come in fibrous sheets, coated-one side with the phenolic resin. The wide- and narrow-web fields traditionally work with shallow-relief/thin masters and use this sheet form of matrix. Sheet-matrix materials come in various thicknesses, sizes, durometers, coating thicknesses and floor

specifications, depending on the application and printing plate requirements. Relief potential in sheet matrixes ranges from 0.020" to 0.125".

Thick-plate, Deep-relief Molding. When a finished plate with reliefs over 0.125" is required, phenolic or Bakelite fill-in powder is used in conjunction with the sheet matrix to achieve the extra relief depth. The sheet matrix is used as a backing sheet, which provides support and added mechanical strength. Powdered Bakelite is used mostly in platemaking for corrugated postprint because of the greater etching depth required. The powder is contained in the mold by providing a frame around the image in the master. This process is called deep-relief powder molding or DRPM.

Making the Thermosetting Mold or Matrix

Matrix Floor. The matrix floor is the point of measurement from the back of the matrix to the lowest point of impression. The recommended floor measurement furnished by suppliers of matrix material is the safe limit of compressibility for a given original sheet thickness. As a general rule, the matrix floor thickness represents 50% to 60% of the original thickness, when molded at pressures ranging from 200 to 1,000 lbs. per square inch. Over-impressing and reducing the floor of the matrix may cause cupping in the print surface, especially when photopolymer masters are used.

Determining Thickness-control Bearers. Various thickness bearers, or accurately ground steel shims, are used to stop the movement of the molding press ram and control the final thickness of the molded product. To compute the thickness of the bearer required for molding the matrix, the total thickness of the master is added to the desired matrix floor thickness. The thickness of a cover sheet, starched linen (Holland cloth), release paper, metal panel or other sheet is also added if it does not cover the bearers. If the cover sheet extends over the bearers, then the thickness of the cover sheet is not included in the calculation.

For example, to calculate bearer height:

	Engraving Thickness	0.064"
	Desired Floor Thickness	0.080"
+	Cover Sheet Thickness*	0.005"
=	Bearer Thickness	0.149"

*There is no need to add the thickness of the cover sheet if it extends over the bearers on both sides. If it does, overall bearer height would be 0.144" instead. In either case, it is important to verify that both sets of bearers are exactly the same height on each side of the press.

Note: *Unequal bearer height can destroy originals and damage the molding press. Making an accurate thickness matrix is the key to successful plate molding.*

Occasionally, the calculation used to deteremine bearer height, does not give the exact matrix floor, due to the characteristics peculiar to the molding press, the materials used and the nature of the graphics. Some experimentation may be needed to arrive at the correct bearer thickness for a particular press and floor thickness, but once the floor is established, it rarely changes. Forming the matrix in the same press, and in roughly the same position every time, also produces consistent results.

Preheat Function. The type form or metal photoengraving must be preheated in the molding press for roughly five to seven minutes to allow for the expansion of the original. This helps prevent the pattern from “locking-up” in the mold as expansion takes place. Preheating the matrix is perhaps the single most important step in producing a good mold. It softens the phenolic resin and prepares it for molding. Preheating involves heating the uncured matrix material and pattern plate (original) without applying pressure before molding. An accurate timer, or clock with a sweep-second hand; should be used to time the preheat cycle.

Preheating can be done with the serving tray either barely touching the upper platen of the press or with a “daylight” gap of up to 0.125". No pressure should be applied in either case. Usually, the matrix manufacturer will specify the length of the preheat cycle. The duration of the preheat should not vary by more than 15 seconds to account for normal changes. During the preheat cycle the molding press must maintain a temperature between 3,000° F and 3,100° F.

Closing Rate. At the end of the preheat period, the thermosetting phenolic resin of the matrix will soften to a working viscosity and allow entry of the master into the board with minimum pressure. The closing rate of the press is critical and should be slow, about 0.10" every five seconds. Pressure can then be applied, maintaining a steady closing rate until the bearers are tight. It is important to time the close rate accurately and it should generally take about 30 seconds to completely close onto tight bearers. Closing too fast will cause a “splashing” or “ridging” of the viscous phenolic resin. Closing too slowly can result in precuring of the phenolic resin, causing a high matrix floor and poor shoulder formation. Ram movement may be indicated by a commercially available depth gauge that amplifies the slow vertical closing movement of the upper and lower platens.

The fibrous material of the matrix is hygroscopic (attracting moisture from the atmosphere) and may require a "breathe" cycle to eliminate potential problems, such as blistering. The breathing procedure involves applying a small amount of pressure and then quickly opening and closing the press to allow the steam and volatiles to escape. Using a matrix conditioning unit will dehumidify the board and help eliminate this type of problem.

Pressure and Curing Requirements. The amount of pressure required for any particular mold will vary, depending on the nature and total print area of the copy matter in the master. If the master is plain type form, no more than 300 lbs. per square inch should be necessary. If, however, a halftone engraving is used, pressures up to 1,000 lbs. per square inch may be necessary. The amount of pressure required to mold an engraving varies in direct proportion to the amount of solid area to be molded. The pressure required to mold a particular image can be calculated using the following formula:

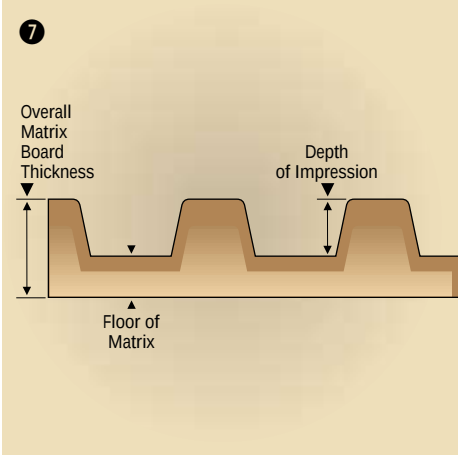
$$\text{RAM FORCE (LBS)} = \text{PRESSURE (LBS/IN}^2\text{)} \times \text{PRINT AREA}$$

The phenolic resin materials of the matrix require a curing (vulcanization) time of 8 to 10 minutes at a temperature of 3,000° F to 3,100° F to ensure a complete cure. In some molding operations, where production speed is desired, the matrix material can be partially cured for 5 minutes in the molding press, separated from the original and oven cured at 3,000° F to 3,100° F for the remaining five minutes, producing a total cure.

Cooling. When the molding cycle is over and before removing the mold from the press, the position on the serving tray should be noted to ensure repeatable accuracy during the plate-molding procedure. The cured mold is removed from the original and allowed to cool to room temperature. Once cooled, the mold should be checked for accuracy by measuring the matrix floor thickness (*Figure* ❼). To determine the thickness of the molded floor, a micrometer or depth gauge with a needle point or tip should be used to allow precise measurement in the finer areas compressed into the matrix. If there are inaccuracies in the floor readings, these should be noted on the back of the matrix and makeready (doctoring) of the mold may be required.

Position Molding. Molding presses vary slightly and the molding surfaces may not be perfectly parallel. It is therefore desirable to mold the rubber plates in the same position on the serving tray in which the matrix was

❼ After the molding cycle, the mold is allowed to cool. Cure before being checked for accuracy. Using a micrometer or depth gauge, the matrix floor thickness is measured.



originally made. To achieve this, the exact location of the matrix on the serving tray should be noted by marking the front portion of the mold with a wax pencil. The matrix should be placed in the same press and in roughly the same position every time a plate is made.

Matrix Mold Makeready. Inaccuracies in a matrix mold can be corrected (doctored) without remaking the mold. Makeready is accomplished by a combination of building up thin areas of the mold with thin paper or foil and by sanding down the thick areas of the mold with a fine-grain sandpaper.

The sections to be corrected can be identified from the back of the matrix by noticing the color difference between the high and low areas. The ultimate goal is to produce an accurate printing plate; therefore, plates made from doctored molds should be checked carefully.

Shrinkage. Progressive mold shrinkage was a major problem at one time, but is no longer a concern. Modern materials and techniques assure that the molds experience almost no progressive shrinkage when used again and again in the vulcanizing process. Although low-shrink matrix materials have excellent dimensional stability in both directions, it is still recommended that the matrix material be cut in the same direction for each color of a multiple color job containing fine screens or exceptionally tight registration to eliminate any dimensional differences.

Molding a Matrix

The following is a general summary of steps and procedures in molding a matrix:

Temperature. Molding press temperature should be between 300° F and 310° F (60 lbs. steam pressure at sea level if press is steam-heated).

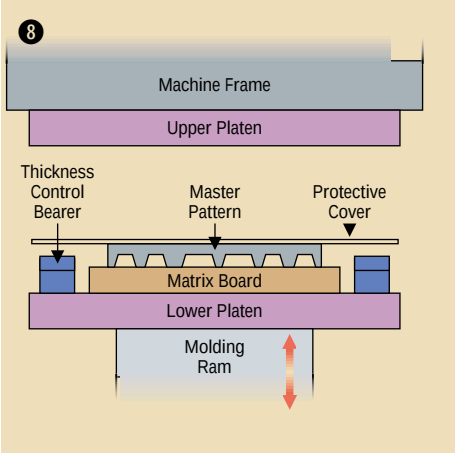
Preheating. Master type form or metal photoengraving should be preheated in the molding press for roughly five to seven minutes to allow for the expansion of the metal. This helps prevent the pattern from "locking-up" in the mold as expansion takes place.

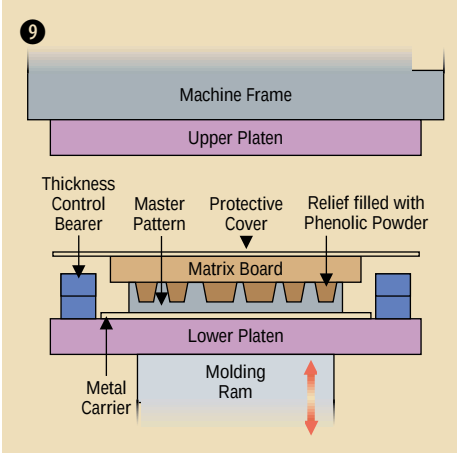
Preconditioning. Matrix material in a heated oven will prevent the hygroscopic matrix board from taking on moisture and reduce the need to "bump" the mold to release gasses. Preconditioning will also soften the phenolic resin in preparation for molding.

Preparation. Matrix material to be vulcanized is cut approximately l" to 2" larger than the master on each side. The border should be fairly uniform to restrict the flow of rubber evenly on all four sides during the subsequent plate-molding process. Spraying the metal original or the uncured matrix board with a commercial release agent before molding the matrix, is a common practice.

Thin-plate/Low-relief. The matrix material is placed coated-side-up on the serving tray with the metal engraving face down on the board (*Figure* ❽). Bearer bars of the correct thickness are placed either side of the assembly.

Thick-plate/Deep-relief. The type form is placed face-up on a carrier. The relief cavity of the master is filled with phenolic powder, lightly tamped and carefully leveled. The carrier and master is positioned on the serving tray and the matrix board placed coating-side down over the powder filled master (*Figure* ❾). Bearer bars of the correct





8 In molding a matrix for thin-plate/low-relief, the matrix material is placed coated-side up on the serving tray, with the metal engraving face down on the board.

9 In matrix molding for deep/relief plates, the type form is placed face-up on a carrier. The relief cavity of the master is filled with phenolic powder, lightly tamped and carefully leveled. The carrier and master is positioned on the serving tray and the matrix board placed coating-side down over the powder filled master.

thickness are placed on either side of the assembly.

Protective Cover. Whether a photoengraving or type form original is used, the entire assembly is covered with a protective cover panel or sheet. The sheet can either be Holland cloth (starched linen), release paper, a sheet of graphite-coated steel or an epoxy-fiberglass laminate.

Preheating. The serving tray is positioned between the platens and the molding press closed to a gap of about 9". The entire assembly is preheated according to the thickness of the matrix material. (The supplier will generally furnish the recommended preheat time for a given board.)

Closing. After the initial preheat interval, the molding press is slowly closed, until the bearers are tight. This is best determined by tapping the bearers as pressure is applied until they are immovable. The amount of pressure varies with the image area in the original, but will rarely exceed 1,000 lbs. per square inch.

Curing. The entire assembly is cured from eight to ten minutes at 3,000° F to 3,100° F.

Marking. Before removing the cured mold from the press, identify its position on the serving tray.

Cooling. Allow the mold to cool to room temperature before inspecting it carefully for defects and measuring the floor height. It is recommended that the floor measurement appear on the back of the mold for future reference.

Brushing. Brush the inside of the mold with a soft-bristled brush to remove any foreign particles while polishing the surface at the same time. The mold is now ready for rubber plate molding.

Appendix A covers some common matrix-molding problems and offers suggested remedies.

MOLDING THE PRINTING PLATE

Before molding the rubber plate, it is necessary to know the final thickness of the printing plate in order for the molding press to be properly set up. The final plate thickness is determined by the control bearers used to set the molding platens parallel.

There are also many other considerations in rubber molding, including molding-press pressure requirements, correct load of rubber, flow characteristics of the rubber, repetition in loading, proper use of release agents, the preheat cycle, the curing cycle and the closing speed of the press.

Once the rubber plate has been cured and cooled to room temperature, the plate must be inspected, trimmed down and checked for

plate thickness and defects, such as voids or bubbles.

If it is determined that there is too much variation in the plate thickness, either the back of the rubber plate may be ground in an attempt to bring the plate into acceptable tolerance, or the mold may be doctored and the plate remade. Plate grinding calls for caution. Too much abrasion of the back of the plate can cause distortion of fine type or cupping (dishing) of solids and, in some cases, the plate can be totally destroyed.

Determining Molded Plate Thickness

The final rubber printing plate will be mounted on a bare cylinder that will be driven by a gear attached at the end of its shaft. The combination of the bare cylinder diameter plus the thickness of both stickyback and printing plate, must build up to the pitch diameter of the gear driving the cylinder. The pitch diameter of a gear can be determined from any standard gear publication. The bare-cylinder diameter can be determined by measuring its surface. The difference between the pitch diameter of the gear and the bare cylinder diameter must be offset by the combined thickness of the printing plates and mounting material. The combined thickness of rubber plate and mounting material will be half the difference between the pitch diameter of the gear and the bare cylinder diameter.

In wide- and narrow-web applications, the usual practice is to add 0.002" to the plate thickness to allow for impression squeeze and to prevent the cylinder drive gears from "bottoming" during the pressrun. The corrugated industry usually adds 0.005" to the plate thickness.

Determining Bearers. It is necessary to calculate the thickness of the control bearers for the finished rubber plate to be at its proper thickness. This calculation is made by adding the floor thickness of the mold to the desired plate thickness, including that of the cover sheet (i.e., Holland cloth, release paper). As an example, consider the following hypothetical situation:

Floor of Mold	0.080"
Cover Sheet*	0.005"
Shrinkage & Deflection	0.005"
Desired Plate Thickness	0.107"
Impression Squeeze	0.002"
Overall Height of Bearers:	0.199"

* There is no need to add the thickness of the cover sheet if it extends over the bearers on both sides. If it does, overall bearer height would instead be 0.194".

A shrinkage allowance, plus press deflection caused by molding pressures, must be taken into account when computing the thickness of bearers required to produce the plate. These factors are constant for each press and generally do not change unless the press is re-shimmed or there is a change in the rubber compound or desired plate thickness. Typically, an allowance of 0.005" for shrinkage and deflection is added.

The bearers are placed on both sides of the serving tray to limit the ram movement. The bearers must be free of dust and foreign matter and be well maintained to consistently produce accurate plates. To avoid substantial press temperature loss, the serving tray should be kept in the press whenever it is not in use for any prolonged period.

Pressure Requirements, Pressure requirements for molding rubber printing plates vary according to the compound thickness and the plate construction. Pressures necessary to mold rubber plates can run as high as 600 to 1,000 lbs. per square inch. In some instances, thinner and shrink-controlled plates need even higher molding pressures. For the highest degree of plate accuracy it is important to mold all plates with just enough pressure to produce tight bearers.

Compound Loading Procedures. It is important to ensure that the mold is always cold

before charging it with raw plate gum to avoid partial curing of the raw compound. Operator experience plays an important part when laying down plate gum in the correct proportion to produce the desired plate thickness. For example, where solid areas occupy a large portion of the mold, more plate compound is needed to fill out these areas compared to areas containing fine type or small-print areas.

Compound Thickness. As a rule, type areas should be covered with a thickness of rubber 10% to 20% less than the desired plate thickness, whereas solid or tint areas require at least 20% more than the final plate thickness. For example, for a finished 0.110" plate thickness, type areas must be loaded with approximately 0.090" thickness material and solid areas would need 0.130" material. There must be enough plate gum to properly fill out the entire plate area with sufficient rubber density, leaving no porosity or voids.

Compound Flow. As the rubber begins to flow around the sides of the mold, it hinders the natural flow of the material in the center. For best thickness accuracy, the “flow” of the rubber must be assisted in the center portion of the plate. If this is not done, the solids and tints will be thicker in the center compared with the edges, and will generally require plate-grinding and/or makeready in order to print well. The problem can be solved by carefully loading and doctoring the mold or by using a fast-flowing rubber.

Repetition in Loading. When molding multiple plates of the same or similar design, the operating steps must be duplicated in order to reproduce identical-thickness plates with the same accuracy. Loading the mold must be done carefully, using pieces of plate gum cut exactly the same size and positioned in the same way for each repeat plate. This will eliminate any major pressure adjustments on the molding press for each new plate.

Release Agents. Rubber compounds may stick to nonprinting areas, especially on the borders of the mold. The problem can be minimized by ensuring the smoothness of the matrix coating and using release solutions applied to the surface of the matrix prior to loading. Plate compounds may be dusted on one side with special talcum powder to improve rubber flow and molding fill-in.

The face of the rubber is checked for cleanliness and placed dusted-side down on the mold. The talc on the surface of the rubber acts as a lubricant and assists the escape of air as the plate gum flows into the crevices of the mold. The talc will also absorb any moisture present.

Accurate Plate Molding

General guidelines for accurate plate molding follow.

Release Sheet. The back of the plate can be prevented from sticking to the upper platen of the press by the addition of a cover sheet, such as Holland cloth, or any number of appropriate silicone-treated kraft papers. If Holland cloth is used, it should be free of pinched folds that may tend to form when rubber flows during the molding cycle. Any fabric pleats present will be duplicated on the back of the plate.

Position on the Serving Tray. To minimize plate-thickness variations, the assembly (charged mold) should be placed on the serving tray in the same position as when the mold was made, as indicated by the “front mark” put on the mold .

Preheat. Preheating softens the compound to enable proper flow to be maintained as molding pressure is applied. The preheat cycle is accomplished by contacting the molding assembly with the upper platen (at 307° F) for a prescribed length of time. Preheat time can vary, depending on the rubber compound.

Closing. Closing speed can vary according to the rubber compound being used. Closing pressure should be applied at the same rate until the bearers become tight. The depth

gauge should be used as a reference to determine speed of closing and degree of tightness. It may be necessary to “bump” the plate as pressure is being applied in order to fill an intricate design, or compensate for batch differences among rubber compounds.

Bumping is accomplished by first applying a small amount of pressure and then quickly opening and closing the press (similar to matrix breathing). This bumping should be repeated several times. The final pressure is then applied until the bearers are tight.

Vulcanizing. Vulcanization of the rubber compound takes about 10 minutes at 3,070° F, depending on the total thickness of the finished plate. Once the rubber plate has been completely cured, the assembly is removed from the press. The plate is stripped from the mold while still hot, taking care not to tear the still delicate plate. The recommended procedure is to gently remove the plate from the sides and carefully work toward the center. This will help prevent possible stretching and plate distortion. The plate can then be brought down to room temperature or cooled in a chiller.

Inspection and Finishing

As the molded plate cools, it contracts or shrinks in all directions, including the cross section or thickness. The plate must therefore be gauged with a micrometer after it reaches room temperature. The printing plate is inspected for complete fill-out, skips, blisters or foreign matter and absolute fidelity with the mold. The plate is then gauged for accuracy using a plate micrometer. A standard hand-held micrometer should never be used to gauge the flexible printing plates, because there is no control over the amount of pressure applied.

When gauging a rubber plate, it is essential that the foot of the indicator rest squarely on the plate surface. Gauging for accuracy and consistent plate thickness in the larger-type and solid-printing areas usually is satisfactory. Readings of plate gauge should be taken every 2" or so throughout a plate to determine uniformity. Even with a special gauge, it is very difficult to get an accurate reading on small isolated areas or small type within a line of copy, as any pressure applied will cause deflection of the print surface. Special attention should be given to the corners and the center of the plate; if there were variations in the molding process, this is where they will show.

Plate Gauge. A thickness range of ±0.001" is generally accepted for line work and solids. Plates with halftone process screens should have a thickness range of less than 0.0005". Fine type or delicate copy matter, positioned alongside heavier type or solid areas, should be lower than the heavy areas by 0.001" to 0.002". This means that the total variation from the heaviest point of a solid area to the lightest point of a fine-type section could be as much as 0.004".

Out-of-Gauge Plates. If it is determined that there is too much variation in the plate thickness, two options exist: Doctor the mold to eliminate the variation or ground the back of the rubber plate in an attempt to bring the plate into acceptable tolerance.

Remolding with Makeready. If the plate is not of uniform thickness, it may be remolded using makeready on the mold. Makeready is the method of fine tuning the matrix board before molding the rubber plates. If the plate is too thin in one area, the back of the matrix board may be sanded in the offending area to raise the plate height. Conversely, if the plate is too thick, makeready tape, foil or tissue paper may be used under the matrix board in the offending area to lower a section of the finished plate.

Plate Grinding. If the plate is only slightly over caliper it may be recovered by grinding the back of the plate. Care must be taken when plate grinding, as too much abrasion of the back of the plate can cause distortion of fine type and cupping (dishing) of solids and, in

some cases, can totally destroy the plate.

Plate Cupping. Plate cupping is the result of taking the rubber plate and arcing it in the opposite direction to normal, then removing rubber by grinding. On a drum-type grinder, this is necessary because the backside of the plate is being finished, and the printing face is against the drum of the plate finisher. When the rubber is removed, the backside has a greater circumference than the print side. When the plate is arced back for mounting on the print cylinder, the print side is stretched slightly to conform to a greater circumference than the backside. On large solids, the edges will tend to print harder than the center.

TROUBLESHOOTING RUBBER-PLATE MOLDING PROBLEMS

Rubber-plate molding requires attention to the process and the materials being used, since they are perishable and can change with age. The troubleshooting guide in *Appendix B* lists some common plate-molding problems and remedies.

RUBBER PLATE COMPOUNDS AND PROPERTIES

There are many different rubber compounds used in the molding of flexographic plates. Among these are: natural rubber, Buna N (nitrile), butyl, styrene, ethylene, propylene, neoprene and a combination of Buna N/vinyl elastomers.

Properties such as modulus, ozone resistance, durometer, abrasion resistance, storage stability, cure rate, molding shrinkage, resilience and solvent resistance are all important factors in plate gums formulated for molded-rubber flexo printing plates. All these properties have a direct bearing on the molding and printing characteristics of the rubber.

Rubber printing-plate compounds are marketed in many colors. The amount of coloring matter is sufficient, seldom, if ever, to affect the service characteristics of a compound and usually is just a matter of choice. The black compounds are the only plate gums that are both colored and reinforced by the fillers. All other colored compounds are simply reinforced with white fillers and tinted by the addition of a colorant.

Material properties are obtained by modifying the rubber with various compounding ingredients, such as carbon black, zinc oxide, barytes clay, plasticizing oils and others. Unmodified compounds generally are unsuited for printing plate use. Most compounds used for flexo plates require relatively high proportions of reinforcing fillers to increase hardness and resistance to tear, abrasion and solvent attack. There are also fillers that are nonreinforcing agents, added to act as processing aids, or to obtain specific physical traits, such as shrinkage control.

Thickness

Compounds used for molded printing plates must be smooth, of uniform gauge, properly dusted with talc and free of entrapped air. The thickness of uncured rubber compounds normally used in the fabrication of printing plates are: 0.040", 0.060", 0.090", 0.110", 0.125" and 0.187".

Storage

All rubber printing-plate compounds are perishable and should be refrigerated by the distributor and platemaker to ensure ultimate molding performance. Flow characteristics of the compound decrease with aging, making it difficult to mold large plates of uniform thickness. As a general rule, fresh rubber compounds will completely cure in 90 days at 700° F. Storage temperatures lower than room temperature (below 55° F) retard the action of the curatives in the compounds, thus making it easier to maintain the stock in prime molding condition. Shelf life of a plate

compound is effectively doubled for every 15° F reduction in storage temperature. It is imperative, however, to bring rubber to room temperature before molding. The plate molder must exercise sound judgment.

TYPES OF MOLDED PLATES

The choice of compound for the printing plate depends on the type of ink and solvent being used. There are various constructions available: plain-backed plates, shrink-controlled plates, metal-backed plates.

Plain-backed Plate. This is the most widely used type of flexographic printing plate. It is supplied without any special inserts or backing and usually is molded between 0.105" and 0.112" for wide web and 0.067" for narrow web. Plate height usually depends on press specifications and thickness of the mounting material. The corrugated postprint industry generally uses 0.25" molded plates with a fabric insert sandwiched between two layers of rubber to maintain dimensional stability.

Shrink-controlled Plate. Shrink-controlled plates are typically used in applications where accuracy of print size and color-to-color register is critical, or subsequent die-cutting or other in-line operations require accurate print register. The shrink-controlled plate is made by sandwiching a piece of fabric between two layers of rubber during the molding procedure. The fabric minimizes shrinkage during molding and gives the plate its shrink-control characteristics. Thickness normally ranges between 0.135" and 0.165" for this type of plate.

Camera-ready art should allow for elongation around the cylinder for shrink-controlled plates. This type of plate exhibits negligible shrinkage across the cylinder.

The shrink-controlled plate can be handled and ground in the same way as a plain-backed plate, as long as it is done before the plate is precurved. This type of plate is usually permanently curved to hug the cylinder by rolling, placing into a cylindrical fiber tube and post-heating the plate to 250° F for about one hour.

Metal-backed plates. The metal-backed plate is molded and permanently vulcanized to a metal sheet. The metal backing is usually a thin (0.008" to 0.012") sheet of mild steel or half-hard brass. Because this plate is metal-backed, it cannot be ground on a plate grinder. Therefore, whenever necessary, molds should be prepared using makeready techniques. The inherent dimensional stability of this type of plate makes it ideal for close registration requirements of milk cartons, paper cups, boxes, egg cartons and tissue paper.

Metal-backed plates may be integrated to the plate cylinder either by a mechanical lock-up system, or, when steel-backed, using magnetic plate cylinders. The plates may be secured to conventional cylinders with tension hold-down bands that fit over exposed metal edges on either side of the plate.

Metal-backed plates can be provided with prepunched holes that fit over accurately positioned pins located in the face of the plate cylinder. They may also have a bent lead edge for plate cylinder groove type lock-up systems. The punched hole or lead-edge slot systems enable rapid plate changes and accurate registration of multicolored jobs.

Special Considerations for Process Plates

Molding procedures used to produce both line plates or plates containing halftone screen are basically the same. With plates containing process screens, special care must be taken to ensure that the mold releases fully from the engraving, without tearing isolated highlight dots or plugging small reverse dots located in the shadow areas. The mold should faithfully reproduce every detail in the engraving.

The most critical element in the production

of a molded-rubber plate with process screens is the engraving. This has to be proofed and carefully examined to make sure it retains all the finest details in a form that is reproducible during the molding operation.

The molding compound most widely used for process printing plates is a blend of Buna-N and polyvinyl. This compound can release ink from the plate and run cleaner, with less tendency to fill in. It has good abrasion resistance, which helps prolong plate life and reduces changes in tonal values due to wear.

The most important consideration for any molded plate containing halftone process screens is gauge accuracy. It must be produced to extremely close thickness tolerances by applying local makeready on the back of the original, or mold, if necessary. Grinding process plates is not recommended; however, if plate grinding is unavoidable, only a very light “polish” or “dressing” is acceptable. The amount of plate grinding should not exceed 0.001". Grinding should never be used to salvage a bad plate.

Photopolymer Plates

The direct photopolymer plate is one of the major innovations in modern flexographic printing. It affords the ability to image the printing plate directly from a photographic negative, thereby proving excellent image fidelity. Photopolymers are ultraviolet, light-sensitive materials used to prepare letterpress plates, offset plates, printing resists, proofing films, pattern masters for molded rubber flexographic printing plates and direct flexographic printing plates. Photopolymer printing plates are similar to molded-rubber plates in that they are flexible, resilient and have excellent ink transfer.

There are many systems available for producing photopolymer flexo plates. The photopolymer materials used to make the plates are either viscous liquids ready to be cast to the required plate thickness, or solid sheets of appropriate thickness. Photopolymer materials, whether liquid or sheet, are converted to flexographic printing plates when exposed to ultraviolet light through a photographic negative of the artwork to be reproduced.

The film negative is the single most important element in photopolymer-plate preparation. It is a light stencil that controls image formation during exposure of the photopolymer plate. In general, the guidelines discussed in the film negative portion of this section apply to all photopolymers. It is important to check with the plate supplier to determine the correct negative preparation for the particular plate material and printing application.

CHARACTERISTICS

There are a number of manufacturers who supply various types and constructions of material used to produce photopolymer printing plates. Each material is designed to meet the requirements of a specific flexo market segment. Two basic categories of photopolymer printing-plate materials are liquid and sheet. While finished plates in both categories are very similar, the plate-making processes are very different and may create different physical properties.

When selecting a photopolymer material for a particular application, it is important to know the printing system. Not all photopolymers are compatible with all inks. Different materials from the same supplier may have different applications and chemical compatibility characteristics. Each manufacturer has specific recommendations with regard to ink and solvent compatibility. Those recommendations should be followed, assuming that a photopolymer is compatible with a particular ink or solvent.

Durometer

Hardness or durometer of the printing plate has a large effect on the printing characteristics. Durometer is measured by using a Shore gauge and measurements are reported as either Shore A or D – depending on hardness.

Photopolymer-plate materials are available in a range of cured-plate durometer reading from 25 to 70 Shore A. Most plate materials for general film and paper converting have a cured plate durometer hardness of 45 to 60 Shore A. Rough and uneven substrates, such as corrugated board, require lower-durometer materials of 25 to 40 Shore A.

Plate Construction

In most common applications, photopolymer material is supported by a transparent and dimensionally stable polyester backing sheet. The polyester sheet is generally between 0.004" to 0.010" thick. In some special applications, the polyester sheet may be removable. Some manufacturers of sheet photopolymer offer a metal backing for use on magnetic or mechanical lock-up printing cylinders. These metal-backing materials are not transparent to ultraviolet light and are supplied with a preset relief depth. These materials have a limited shelf life and should be used soon after receipt.

Special Plate Construction

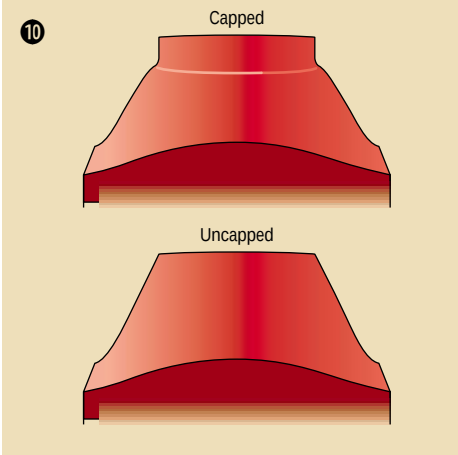
Both liquid and sheet photopolymer manufacturers offer materials with special constructions. The following paragraphs describe several examples of special-construction plates.

Image Contrast. In this construction, the top, or imaging layer, is of a different color than the base photopolymer. Consequently, once the plate is processed, the image surface is of a different and contrasting color from the base of the plate. This aids in aligning the plates when mounting on the plate cylinder.

Dual Durometer (Capped Plate). In dual durometer plates, a thin (0.004" to 0.010"), harder image surface lies atop a lower-durometer polymer base. The image surface may also produce a steeper character shoulder. *Figure* ❿ shows a photomicrograph of a capped and uncapped plate.

Strippable. This construction allows removal of the polyester base following plate production. These plates are generally used when the plate is laminated to sheet steel for mounting on magnetic cylinders and in non-critical register applications.

Compressible Construction. Compressible plate construction is available in both sheet (as supplied) and liquid (as produced) photopolymer systems. These plates have a compressible foam layer within the plate – between the photopolymer image layer and the dimensionally stable polyester backing – that control image gain with printing impression.



❿ A capped and uncapped plate. In durometer plates, a thin (0.004" to 0.010"), harder image surface lies atop a lower-durometer polymer base. The image surface may also produce a steeper character shoulder during plate development.

Aqueous Processing. Liquid photopolymer systems utilize water and detergent solutions for plate processing. Most sheet photopolymers are processed in an organic solvent that require special processing equipment with aqueous chemistry.

Jumbo Plate Sizes. The most common platemaking equipment size, liquid or sheet, is 30" x 40". Recent demands on manufacturers have extended these capabilities to sheet sizes of 52" x 110" and even larger for special applications. Special processing equipment and handling techniques are required for plate production of these extraordinary sizes. Demand for these sizes is driven by corrugated linerboard, large point-of-purchase displays, and stepping of multiple repeating images on plates for general flexo converting.

PHOTOPOLYMER PLATES: AN OVERVIEW

The following is a brief overview of generally accepted benefits of using photopolymer plates.

General Factors:

- **Better Print Quality.** Produces sharp line

images, excellent ink transfer and predictable halftone results.

- **Large Plates**. Sizes up to 52" x 110" are possible.
- **Plate Mounting.** Efficient process to mount plates, especially when pin or microdot registration systems are employed.
- **Allows Step and Repeat**. Plates can carry multiple images.
- **Filing Space**. Film requires less space than metal and rubber molds. Negatives will not deteriorate like metal or rubber molds and can be easily duplicated.

Accuracy Factors:

- **Predictable Plate Gain.** Plate gain can accurately be determined and compensated for in art.
- **Better Registration.** Because of stable backing, a 90% coverage plate will now register with a 10% coverage plate.
- **Accurate Prepress Proofing.** Off-press proofs are accurate reproductions from the film used for plates. Photopolymer prepress proofs provide accurate rendition of specified job.

Time-saving Factors:

- **Time Trimmer.** A 6-color, 4-up job can be mounted with pin registered photopolymer plates in about 30 minutes as opposed to 8 hours or more for rubber.
- **More Efficient.** Eliminates the mounter-proofer operation.
- **Economical.** Downtime is minimized to reregister plates.
- **Fewer Steps.** Process work can be done in half the time (or less) than it takes to make copper engravings, molds and rubber-plates, and can be stepped and repeated in multiple images, so there are fewer plates to register.
- **Easier.** When rubber plates are mounted on a mounter-proofer, they may not register on press.
- **Faster**. Plate production is faster than for metal, molds and rubber.

Cost-saving factors:

- **Longer Plate Life.** Lasts about twice that of rubber plates.
- **Eliminates Need for Engraving or Mold**.
- **Allows Reuse.** Plates are more reusable due to less distortion.
- **Better Production Capability.** More photopolymer can be made per man-hour using relatively unskilled labor. Process work will cost about half as much as molded rubber for initial printing plates to press.

HOUSEKEEPING

Maintaining a clean, dust-free environment in the platemaking area cannot be overstated. Photopolymer materials in the uncured state are susceptible to contamination and damage by dirt and other foreign particles.

Materials and solvents used in photopolymer platemaking should be handled carefully.

Physical Hazard of UV Radiation

The photopolymer platemaking sequence uses several sources of high-energy ultraviolet (UV) radiation that may present a hazard to the platemaker. The exposure equipment supplied provides sufficient protection to the operator during normal platemaking. Safety interlocks should be maintained at all times.

Ultraviolet Light. The high-energy lamps used in the exposure, post-exposure and light finishing units of the platemaking system emit ultraviolet energy, as well as visible-light energy. The proportion of ultraviolet light energy is far higher than the visible light, therefore, the human eye is a bad judge of how bright the light is. Special UV-blocking glasses are needed to provide adequate eye protection and the protective quality of these lenses need to match the wavelength of the UV light source. Platemakers taking certain prescription medications should avoid UV light as those medications can amplify skin photosensitivity.

Short-wavelength Ultraviolet (UV-C). UV-C has a wavelength bandwidth of 180 to 280 nanometers. This light is used in the light-finishing process of photopolymer platemaking. UV-C lamps, generally referred to as germicidal lamps, emit very little visible light, but can cause severe burns to both skin and eyes from very short exposures.

Medium-wavelength Ultraviolet (UV-B). UV-B has a wavelength bandwidth of 280 to 320 nanometers and is not normally found in platemaking equipment.

Long-wavelength Ultraviolet (UV-A). UV-A has a wavelength bandwidth of 320 to 400 nanometers – visible light starts at about 380 to 400 nanometers. This light is used in the back-, main- and post-exposure processes of photopolymer platemaking. UV-A lamps, typically found in commercial sun beds, emit a fairly large amount of visible light. Prolonged exposure can cause severe sunburn and eye damage.

FILM NEGATIVE PREPARATION AND HANDLING

The film negative is the single most important element in photopolymer plate preparation. Necessity for the care in preparation, handling and storage of these critical imaging tools cannot be overstated. Negatives used in photopolymer platemaking should meet the following requirements as summarized in *Table 6*.

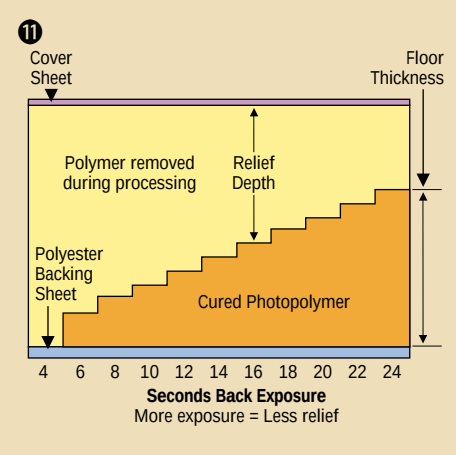
PRINCIPLES OF PHOTOPOLYMER PLATE EXPOSURES

The basic process of making a printing plate is similar for liquid and sheet photopolymer. In both cases, the back is exposed to UV light to establish the floor. The face is then exposed through the film negative, which sets the printing surface. As a final step in the platemaking process, the plate is "light finished" to cure all remaining photopolymer.

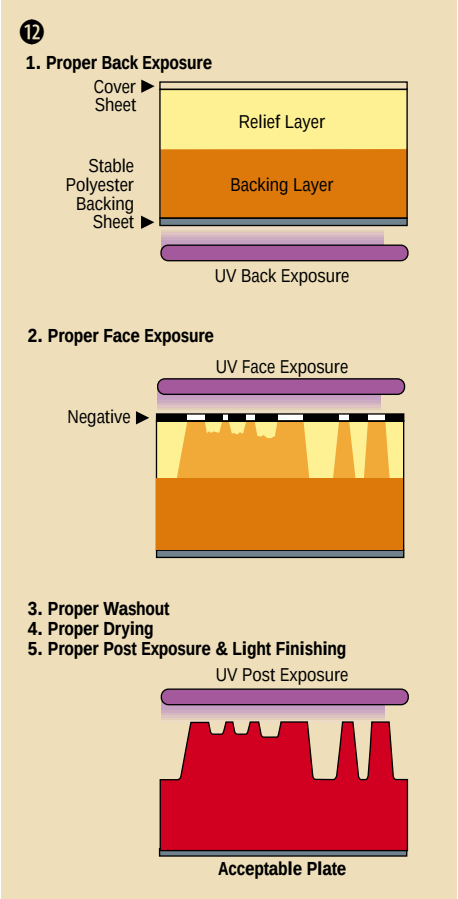
MAKING NEGATIVES FOR PHOTOPOLYMER PLATEMAKING

- Negatives must be high contrast film, free of dirt, kinks, nicks and pin holes
- Matte-surface films are mandatory for sheet photopolymers to ensure good contact between negatives and plate during exposure.
- Nonmatte films should be used for liquid photopolymer platemaking
- Optical density of the film should be
  - 4.0 or greater in the nonimage (opaque) areas
  - 0.05 or less in the image (clear) areas
- Image orientation must be correct and provide for emulsion-to-plate contact
- Images must be
  - right-reading, emulsion side for face printing
  - wrong-reading, emulsion side for back or reverse printing
- Images should be clean, fringe-free and sharply defined with no broken letters or lines
- Colloidal black opaques are recommended. Avoid red opaques which have a tendency to flake.
- Opaque on the
  - emulsion side of negatives only for liquid polymer platemaking
  - back side of negatives only for sheet polymer platemaking
- Opaque only in the nonimage areas no closer than 0.1" to an image area
- Prevent kinks from developing in the image areas. Film thickness of 0.007" is preferred
- Prevent scratches in image areas. Scribing or scraping of the emulsion must not roughen the surface

Table 6



11 During back exposure, polymer is cured to form a solid. The plate floor is thickened via absorption of UV-light energy. Relief depth is charted to measure curing rate. Data collected in this process form as a back-exposure guide for the material and machine. Depth of the photopolymer cured in the face-exposure test depends on plate thickness and results of the back-exposure test.



12 Capped plates are relief printing plates composed of two levels of photopolymer. The cap layer may be of harder durometer and different photosensitivity than the base layer. Advantages include wider exposure latitude and less distortion.

Back Exposure

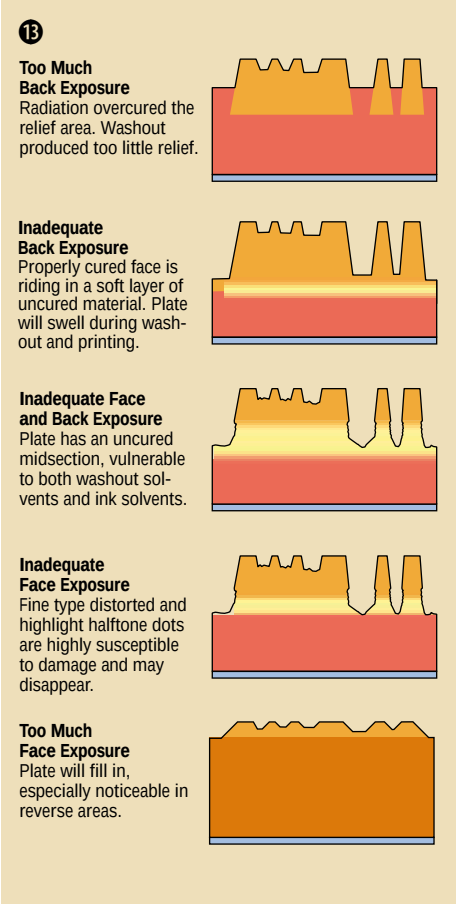
This simple step is necessary to fully attach the floor layer of the plate to the polyester backing and establish the relief depth. No negative is used during back exposure and the photopolymer is cured (cross-linked) by exposure to high intensity ultraviolet light through the polyester backing sheet. During the back exposure, the polymer is cured to form a solid in a progressive migratory manner. The longer the exposure or more UV-A energy absorbed, the thicker the floor becomes. Variables that can effect proper exposure include differences in UV sensitivity for the photopolymer, and UV energy output, especially as the UV lamps age. Back-exposure tests should be conducted regularly to establish the rate of cure for particular combinations of photopolymer materials and exposure equipment.

Back-exposure Test

This simple test exposes a sample of the plate material through the polyester backing sheet on the exposure equipment. The exposure times are stepped according to the plate material and the equipment manufacturer's recommendations (*Figure* 11). The resulting thickness steps produced in the plate material are recorded and charted to form a back-exposure guide for the particular material and machine.

Face or Image Exposure

This exposure transfers the image from the photographic negative to the printing face of the photopolymer. This is done by selectively curing the photopolymer with UV light through the clear areas of the negative. As with the back exposure, the curing is progressive and the rate of cure is dependent on many factors: clear area in the film, transparency of the film, sensitivity of the photopolymer, image detail and ultraviolet energy output of the exposure unit. The depth of photopolymer to be cured during the face exposure is dependent on the overall plate thickness and the amount of floor that was cured during the back exposure (*Figure* 12).



⓭ Exposure problems caused by incorrect face and back exposures.

These complex relationships can only be resolved by conducting a face exposure test. *Figure* ⓭ illustrates some of the problems with incorrect face and back exposures.

Face- or Image-exposure Test

Image-stepped test negatives containing a variety of copy detail and tonal values are available from the various plate material suppliers. Once the desired back-exposure is established, these images are face-exposed for various periods to establish the times necessary for plate production.

Post-exposure or Light Finishing

During the plate processing, areas of partially cured photopolymer are exposed on the floor and flanks of the relief image. These tacky areas are rendered tack-free by further exposure to high energy ultraviolet light. In most photopolymers, the presence of oxygen inhibits the curing action from the standard exposure lamps. Therefore, special short-wave UV-C lamps are used to "light finish" the plate's surface. The combination of light finishing, and/or post-exposure, ensures the entire plate is fully cured and has the optimum physical properties for printing.

Light Intensity

Exposure times effected by light intensity. Light intensity falls as lamps age and consequently, exposure times must be increased to achieve the correct amount of energy. Exposure lamps should be checked at 20-hour intervals and replaced when the intensity falls below the recommended level, usually about 75% to 80% of peak emission.

Main- and back-exposure lamps should be replaced as a set to maintain uniform light intensity over the exposure area. New lamps require a burning-in period of 15 to 20 minutes to stabilize output before plate exposures are made.

LIQUID PHOTOPOLYMER PLATEMAKING

The liquid photopolymer platemaking system is versatile, reliable and efficient for plate manufacturing. Liquid photopolymers are washed out with a water and detergent solution, which makes them environmentally safe and user-friendly. Most liquid photpolymers are designed for use with water-based ink systems, but there are liquid systems that can be used in solvent-printing applications.

Systems are available to manufacture plates in sizes from 18" x 26" up to 52" x 110". They can be used to produce direct-printing plates for flexographic, as well as letterpress and molding applications. The platemaking system uses a viscous liquid photopolymer resin, which is cast in the imaging unit by the plate operator and then processed into a fin-

ished plate. Under ordinary lighting conditions, liquid photopolymer is stable and safe to handle at room temperature

The plate-backing material is a manufactured polyester sheet, specially coated on one side for bonding to the photopolymer. This provides a dimensionally stable base for the finished printing plate. No solvents are used in the process, so plates can be manufactured and press-ready in under one hour.

Equipment

The standard system includes four or five pieces of equipment, described below, that is used with some types of liquid polymers.

The Exposure Unit. Casts the polymer in a precise thickness over the protected film negative and exposes the photopolymer material. The exposure unit consists of a pair of precision-ground glasses which are responsible for the accurate plate tolerance. Exposure units are available in both state-of-the-art computer-controlled and manual models.

The Reclaim Unit. An automated device which removes the unexposed (still liquid) photopolymer and collects it for reuse during another platemaking cycle.

The Washout Unit. Cleans the plate and removes the residual unexposed polymer from between the image elements.

The Post Exposure/Dryer Unit. Finishes the plate with ultraviolet light to cure the floor of the plate, and the dryer evaporates the water from the plate.

The Light Finishing Unit. Provides a final cure to the plate, leaving a tack-free, press-ready printing surface.

THE LIQUID PLATEMAKING SEQUENCE

The section on principles of photopolymer plate exposures covered the basic theory and steps involved in exposing any photopolymer plate. This section will detail the steps for the liquid plate.

Casting the Plate

With the liquid photopolymer system, the plate operator casts the raw photopolymer material to form the finished plate thickness. The equipment supplier sets the exposure unit during installation and provides the necessary information to manufacture the range of desired plate thickness. The following are steps necessary in casting a plate:

- Enter the desired plate thickness into the system and set the machine to specification.
- Place the film negative emulsion-side up on the bottom glass and cover with a thin protective cover-film (*Figure* ⓮).
- Turn the vacuum on to draw the air out from between the lower glass, negative film and cover-film.
- Cast the photopolymer over the protected film negative to the appropriate thickness.
- Laminate the dimensionally stable backing sheet to the upper surface of the liquid polymer. Doctor the cast polymer to a controlled thickness (*Figure* ⓯).
- Lower the upper glass until it makes contact with the backing sheet and the thickness gauging system.
- To ensure good tolerance at the thickness required, apply the vacuum to the upper glass and backing sheet.

Back Exposure

The back, or T1, exposure is responsible for establishing the relief depth and floor thickness of the finished plate, increasing adherence to the polyester backing sheet, and presensitizing the material for shorter main-exposure times. A negative is not used during back exposure. The exact back-exposure time needed to obtain the desired floor thickness in the plate is determined by using a back-exposure step-test procedure. The longer the T1 time, the thicker the floor of the plate and consequently the shallower the relief (*Figure* ⓰).

Face Exposure

The face, or T2, exposure is responsible for the imaging characteristics of the plate. The length of the T2 exposure is determined by the type of copy on the negative. Fine lines and screens require more exposure than do solids and fine reverses.

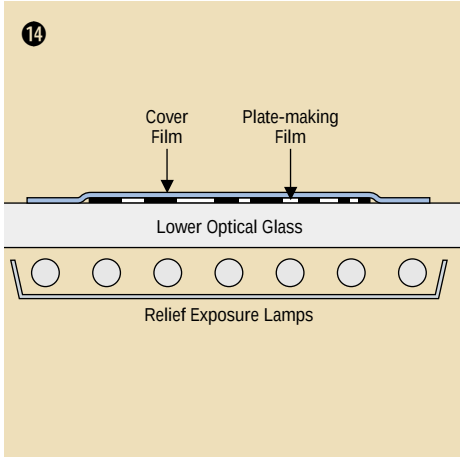
When the plate material is exposed through the negative with UV light, the areas corresponding to clear areas on the photographic negative are hardened. The areas, corresponding to the black areas in the negative, are not exposed and remain in a liquid state (*Figure* ⓱).

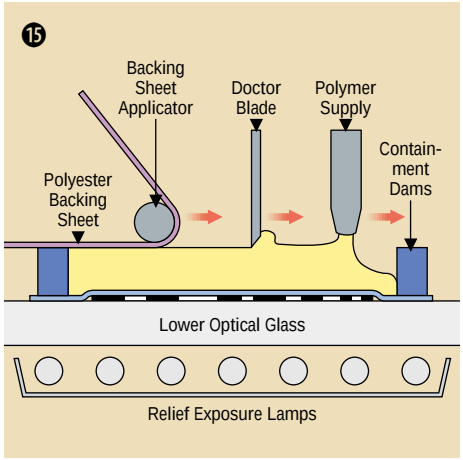
Exposure-control Guides

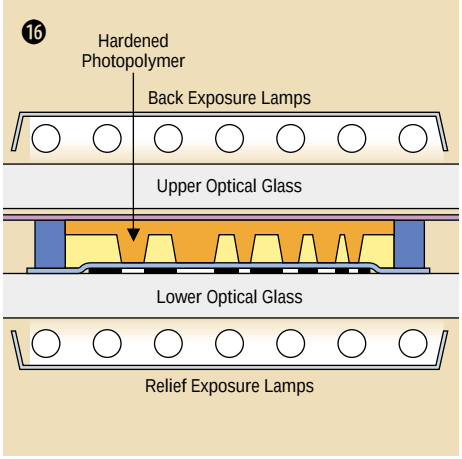
It is essential to use exposure-control guides to determine the proper amount of face exposure, especially when making process-color plates. These guides, supplied by the material manufacturer, are small-test negatives available in different line screens. They are imaged using a calibrated glass screening process for accuracy. The guide incorporates highlights and reverses, as well as lines and reverse lines. To use the control guide, the plate is exposed only until the smallest desired image on the control guide is held. Exposure times and data from the test is recorded for future reference. Since the output of lamps in the exposure unit will decline with age, exposure control guides assist in ensuring consistent imaging.

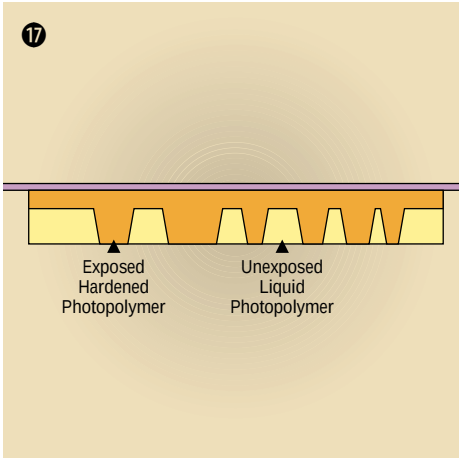
Reclaim

After exposure, the plate is removed from









⓮ Casting the plate. the film negative is placed emulsion-side up on the bottom glass and covered with a thin protective cover-film.

⓯ The dimensionally stable backing sheet is laminated to the upper surface of the liquid polymer. The cast polymer is doctored to a controlled thickness.

⓰ The exact back-exposure or T1 time needed to obtain the desired floor thickness in the plate is determined by using a back-exposure step-test procedure. The longer the T1 time, the thicker the floor of the plate and consequently the shallower the relief.

⓱ When the plate material is exposed through the negative with UV light, the areas corresponding to clear areas on the photographic negative are hardened. The areas, corresponding to the black areas in the negative, are not exposed and remain in a liquid state.

the exposure unit and placed on the reclaim unit. The cover-film, which protected the negative, is removed at this point. The reclaim unit collects the unexposed liquid material for reuse, which offers substantial cost savings, and minimizes the amount of waste going into the environment.

After reclaim, the plate is ready for further processing in the washout unit.

Plate Washout

This unit washes the plate with a warm, mild detergent-and-water solution to remove any remaining unexposed resin.

Post-exposure/Plate Drying

After washout, a post-exposure step using UV light hardens the floor of the finished plate. At this point, the plate is placed in the dryer to remove rinse water from its surface.

Light Finishing

After the plate is dry, it is moved to the light-finishing unit, where it is exposed to shortwave UV (germicidal) light. This step gives the plate a final, tack-free surface.

SPECIAL LIQUID PLATE-MAKING TECHNIQUES

Special techniques for liquid photopolymers include makeready, capping and image-positioned plates.

Prepress Makeready

Prepress makeready is a technique that allows the platemaker to selectively reduce the thickness in isolated areas within a single plate. Using this technique, press impression can be optimized when printing fine type adjacent to large solids by reducing the plate caliper of the fine images. It can also be used to compensate for thickness loss distortion, which occurs when the plate made in the flat is wrapped around a cylinder.

In the liquid platemaking system, the thickness of the film negative directly affects the plate thickness. If the film negative thickness is increased in certain areas by transparent shimming, the additional thickness will displace liquid resin and cause the finished plate to be thinner in those areas by a like amount. Any transparent shim material may be used as long as the optical density is satisfactory for UV-light transmission. Shim material should be placed on the back (nonemulsion) side of the negative, so that the emulsion remains as close as possible to the photopolymer (separated only by the protective cover-film over the negative). *Figure* ⓲ shows an enlarged area of *Figure* ⓮ with the makeready in place and *Figure* ⓳ shows the final plate with typical dimensions.

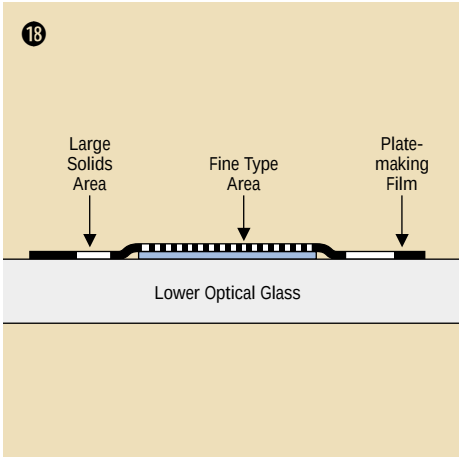
Capping

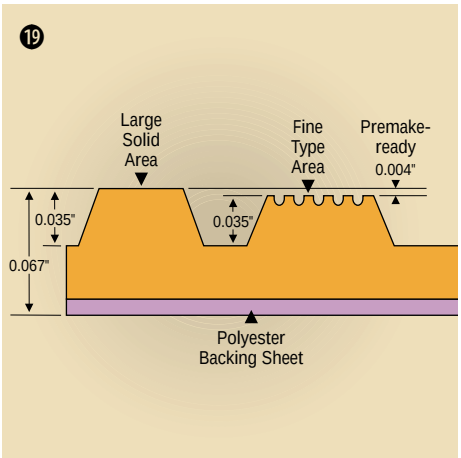
Capped plates are relief-printing plates composed of two layers of photopolymer. The cap layer may be of a harder durometer and different photosensitivity than the base layer. As plates are made, two layers of different liquid photopolymers are either manually or automatically cast – one on top of the other. Advantages of the capped plate include wider exposure latitude, less distortion on the printing surface, deep reverse-etch depth and lower press-gain from plate to printed product.

Image-positioned Plates

Image-positioned plates are large, one-piece plates with all images in register. The plates are assembled directly on a 10-mil carrier sheet. This eliminates later mounting of several smaller plate pieces on 30-mil PVC or similar carrier sheet that is typically used in corrugated printing.

A full-size, one-piece negative is made for each color to be printed. Each color is prepared in register to the others, and the negatives are produced with register marks that are in perfect parallel with the required plate-trimming line.





A back-mask negative may also be used to prevent background buildup in nonimage areas of the plate, thus increasing the amount of polymer reclaim. Using the prepress software, a "white plate" or trap is easily created around each image area. The back mask can then be made in any conventional film imagesetter, or cut on a sample die table from any opaque film or paper. The back mask is placed between the plate substrate and the background exposure source during plate exposure, thus preventing polymer cure and background buildup except in the image area. Plate exposure and processing is the same as for conventional plates.

After platemaking, each one-piece printing plate is registered and trimmed in position. Lock-up strips are attached, and the plates are ready for press. Advantages of image-positioned plates are excellent registration, reduced time to press, elimination of plate-mounting materials, and light, flexible plates that allow easy handling and storage. While image-positioned plates can be made with sheet photopolymer, the ability to reclaim and reuse uncured polymer makes their manufacture more conducive to liquid-photopolymer systems.

SHEET PHOTOPOLYMER PLATEMAKING

The sheet photopolymer system offers high quality plates for direct flexographic printing applications. Many sheet photopolymers are washed out with a solvent system. Water washout sheet systems are available, offering environmental and operator benefits.

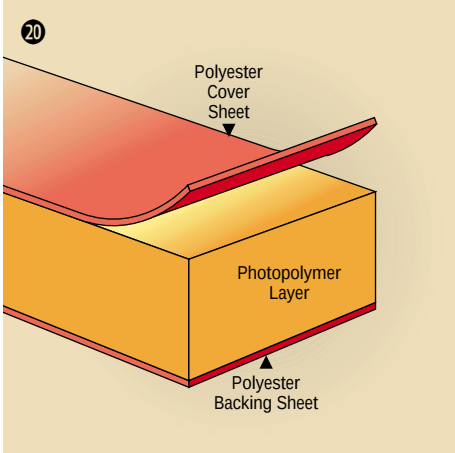
Platemaking systems can be purchased to manufacture plate sizes up to 52" x 80" of specific thicknesses for each application. They can be used to produce direct-printing plates for both flexography and letterpress.

The plate material (*Figure* 20) consists of three layers: a polyester backing sheet, a photopolymer layer, to which the backing sheet is bonded, and a cover sheet to protect the printing and image face.

The polyester backing sheet provides a dimensionally stable base for the finished printing plate. The photopolymer layer is a super-viscous liquid which, under normal conditions, is dimensionally stable. Under either heat or pressure, the polymer may be permanently deformed producing low spots in the finished plate.

Unexposed plate material should be stored and handled with care. Boxes of material and individual plates should be stored absolutely flat – never on end. Smaller sheets or boxes should not be stacked on larger sizes. All platemaking materials must be stored away from sources of heat

The cover sheet provides protection to the



20 Plate material consists of three layers: a polyester backing sheet, a photopolymer layer to which the backing sheet is bonded, and a cover sheet to protect the printing and image face.

image surface of the plate material. When the cover sheet is removed prior to placing the negative in position, a thin "slip film" remains to ensure that the negative does not bond to the polymer during exposure. Large sheets and narrow strips of plate material should be handled with care to prevent premature delamination of the cover sheet.

The sheet photopolymer is stable and safe to handle at room temperature in a safe-light (UV-screened) environment. The precast sheet is exposed and developed by the platemaker into a finished plate. Because solvents are used in the development of these plates, they may take a few hours to manufacture, due to the long drying times.

Equipment

The standard system includes four pieces of equipment: an exposure unit, a processing or washout unit, a dryer unit and a light-finishing unit. The exposure unit exposes the photopolymer sheet and transfers the image from the negative or exposure mask. Exposure units are available in both manual and state-of-the-art, computer-controlled models. The processing or washout unit cleans the plate and removes the residual unexposed polymer between image elements. The dryer unit removes the solvent, which has absorbed into the surface of the plate during washout, and dries the plate. The light-finishing unit eliminates the surface tack, and then post-exposes the finished plate with UV light to cure the floor of the plate. On newer machinery these two steps can be performed simultaneously.

SHEET PLATEMAKING SEQUENCE

Steps for making sheet photopolymer plates follows.

Material Preparation

Unexposed plate material should be cut carefully to minimize waste. Typically, on a sheet of raw photopolymer, there is a small border of cured material around the edges of the sheet.

The film negative size is transferred to the plate material, which is then placed face-up on the sheet-cutter board. Smooth, clean cuts should be made either with a sharp knife or a "hot knife", allowing a 1" border around the copy to provide a clamping edge.

It is more practical if several negatives can be grouped together to form a single sheet exposure, thus eliminating the necessity to cut individual sheets of raw material. When grouping negatives together, it is recommended that the negatives do not overlap. UV-opaque adhesive tape should be used to eliminate gaps and to ensure that the negatives are kept flat.

Back Exposure

The back exposure is completed first. The sheet material is placed base-side up on the exposure unit and exposed to UV light. Some automated systems are equipped with dual light sources. In that case, the sheet is placed base-side-down over the bottom set of lamps. The back exposure is responsible for the relief depth and floor thickness of the finished plate, increasing adherence to the polyester backing sheet, and presensitizing the material for shorter main exposure

times. Negatives are not used during back exposure. The exact back-exposure times are determined using a back-exposure step-test procedure.

Main Exposure

The plate material is turned over and the coversheet is removed. Clean negatives are placed emulsion down on the material and the vacuum sheet is smoothed over the material. In systems equipped with dual light sources, the plate material does not need to be turned and this step is combined with the back-exposure step. The UV lights are then turned on for a specified amount of time. When the plate material is exposed through the negative with UV light, the areas corresponding to clear areas on the photographic negative are hardened. The areas, corresponding to the black areas in the negative remain unexposed (uncured).

Face-test Exposures

Face-test exposures should be conducted to determine the exposures necessary to reproduce the copy detail. Image-stepped test negatives containing a variety of copy detail and tonal values are available from various suppliers. Once the desired back exposure is established, these images are face exposed for various periods to establish the times necessary for plate production.

Plate Processing

After exposure, the plate is ready to be processed in the washout unit. This unit removes uncured photopolymer material, leaving the cured image in relief. A processing solution together with a brushing action removes the uncured material, which then dissolves in the solution. Washout conditions may vary considerably from one manufacturer's system to another. Most plate material suppliers also supply an alternative, more environmentally friendly, line of solvents than those marketed in the past. Plate-processing units come in both rotary and in-line versions. Some important considerations in processing are brush pressure and replenishment of solvent chemistry.

Typically, short washout time can cause shallow relief, tacky and uneven background (floor), and surface scum (dried polymer on image surface). Long washout time can cause damaged or missing characters, excessive swelling and uneven plates. Consult the appropriate polymer processing manuals for the best processing times.

Preliminary Inspection

After a brief time in the dryer, the plates should be inspected and wiped to remove the thin film of residue that may remain on the print surface of the plate. Failure to remove this film will result in the appearance of "orange peel" or dry-down spots, which may appear principally on solid areas and around reverses. The plate should also be checked for correct processing and floor formation. A poorly processed plate may be reclaimed by reprocessing at the correct settings.

Plate Drying

When solid-sheet plates are removed from the washout unit, they are soft, swollen and tacky. Processing solvent is absorbed into the plate during washout, causing the plate to swell. As a result, straight lines become wavy and type is distorted. Oven drying will evaporate this absorbed solvent. The plate's swelling will reduce, making the images sharp and clean. A fully dried plate will return to the original gauge of the material.

Time and temperature must be controlled for proper plate drying. Plates not dried sufficiently may be swollen and uneven in gauge. If the drying temperature exceeds 140° F (60° C), the polyester backing may shrink and cause the plate's dimension to change. Process-color plates generally take longer to dry than line plates. Follow the plate material and equipment supplier's rec-

ommendations for setting dryer temperatures and times.

Plates will still be tacky when removed from the dryer, and care must be taken not to touch the surface of the plates because fingerprints will be left on the finished plate. After drying is complete, the plate back should be wiped with clean solvent and a lint-free wipe to remove any polymer residue prior to light finishing.

MAINTAINING PLATE QUALITY Checklist

TRIMMING PLATES:

- Use a sharp blade, to avoid creating nicks or fuzzy edges
- Make cuts from the backing sheet (preferred)

INSPECT PLATES FOR:

- Thickness and levelness
- Relief
- Surface finish, free from blemishes and pits
- Reverse-image depth
- Register line rip marks
- Hardness (durometer)

PROPER PLATE HANDLING AND STORAGE:

- Avoid 180° bends
- Use a soft-bristled brush for cleaning
- Avoid kinking the backing sheet
- Use proper washup solvents
- Clean plates before storage
- Store plates in cool, dry and dark areas

Table 7

Light Finishing and Post-exposure

Light finishing and post-exposure are performed image-side-up in the unit. Light finishing eliminates surface tackiness of the dried sheet photopolymer plate. This process uses shortwave (germicidal) UV-C light to finish the plates before post-exposure. Light finishing times will vary with plate type. Prolonged exposure in the light-finishing unit can cause premature cracking of the print surface during subsequent printing and storage.

After the plates are light-finished, they must be post-exposed using UV-A light to complete the polymerization process, ensuring the whole plate is fully cured and has the optimum physical properties for printing. Light finishing and post-exposure may be run simultaneously on the appropriate equipment. *Table 7* summarizes conditions in order to maintain plate quality.

TROUBLESHOOTING

Problems in plate performance can usually be traced to changes in platemaking conditions or press techniques. *Appendix C* covers some common photopolymer plate problems and offers suggested remedies. Note that a problem may be caused by a combination of factors (for example a “wavy line” can be caused by a combination of inadequate exposure time and long washout time).

Direct-Imaged Plates

Plates, particularly the laser-engraved variety, have been directly imaged for a number of years. Direct-imaging technology is now being applied to sheet photopolymers, as well as rubber, but in the case of sheet photopolymers, conventional processing is still required after the direct-imaging setup.

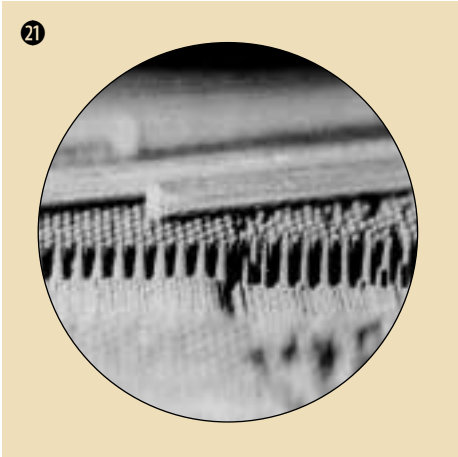
LASER-ENGRAVED PLATES

Laser-engraved rubber plates are produced by engraving the rubber compound with a high energy laser unit similar to that used when producing ceramic anilox rolls. The high energy laser ablates the unwanted rubber in the relief area of the plate, leaving the raised image. Laser-engraved rubber plates combine the excellent printing characteristics of rubber and direct imaging from computer-generated artwork, thereby eliminating the need for negative films. Most images for laser-engraved plates are produced from computer-generated artwork.

The engraving process is, however, time consuming, especially with thicker plates like those used for direct corrugated printing. Laser technology is continually improving, increasing both the image fidelity and production speeds.

Rubber used for the printing plate is supplied either as prevulcanized sheets of specific thickness for the range of plate gauges used in flexography and letterpress, or raw gum compounds for design-roll applications.

The prevulcanized sheet material may be imaged on a flatbed machine or on a rotary drum laser-imaging machine. Both types of machines are directly linked to a raster image processor (RIP) which drives the laser. *Figure* ㉑ shows the dot structure of the finished plate.



㉑ This laser-engraved image profile reveals dot structure of the finished rubber plate.

LASER ABLATION OF LIQUID PHOTOPOLYMERS

Laser ablation works very well with liquid photopolymers. The photopolymer is cast on a standard exposure unit and a large, solid plate is made. This plate is produced in the normal fashion, and then imaged using a laser unit similar to laser engraving a rubber plate. Ablation time is typically shorter than ablation of rubber. Dual-durometer capped plates have shown excellent imaging and printing results when laser ablated. *Table 8* summarizes the advantages and disadvantages of laser ablation.

DESIGN ROLLS

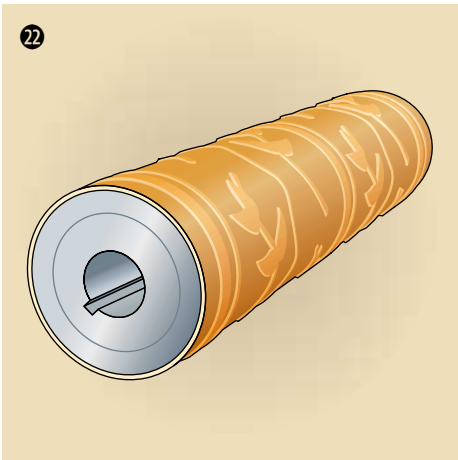
Many designs for floor coverings, wallpa-

LASER ABLATION OF LIQUID PHOTOPOLYMERS	
ADVANTAGES	**DISADVANTAGES**
No film production	Increased plate costs (due to no liquid polymer reclaim in nonimage areas)
No light scatter during exposure	Slower plate turnaround
Excellent tone reproduction	High cost of the laser-imaging units

Table 8

pers and flexible packaging have continuous patterns or solid-color backgrounds whose appearance is improved by eliminating seams. For good decorative printing, the absence of "plate breaks" is virtually mandatory. Seamless pattern printing is the most obvious feature and is the main reason for using laser-engraved design-roll cylinders (*Figure* ㉒). *Table 9* summarizes the conditions to consider for design roll use.

In flexible packaging and some other flexographic applications, it is not unusual for the printer to use a laser-engraved design roll, together with one or more conventional plate-mounted rolls, when printing a multicolor design. Laser-engraved design rolls are often used for multicolor images being mated to cutting dies or patterned embossing rolls, requiring a degree of registration accuracy difficult to achieve with conventional plate-mounting techniques.



㉒ For good decorative printing, the absence of "plate breaks" is mandatory. Seamless pattern printing is the most obvious feature and is the principle reason for using laser-engraved design-roll cylinders.

Various rubber compounds, polyurethane materials or photopolymers may be applied to the surface of a standard press cylinder and cured in place to form a continuous sleeve of flexible plate material. The print surface of the design roll is preground, before laser-engraving, producing a high level of concentricity. This concentricity, together with a sharp, clean laser-engraved relief, give design rolls a very long press life – several times that of most individually mounted printing plates.

PREPARING THE ROLL

Laser-engraved design rolls can be created on practically any print-cylinder base – integral-shaft cylinders, de-mountable metal cylinders or rigid metal sleeves – on which

CONSIDERATIONS FOR DESIGN ROLL USE
Seams between plate units would show objectionable breaks in a continuous pattern design
The nature of the design demands intricate plate mounting with a large number of small repeats
Close register is required.
Plates will be used over a long period and be subject to numerous washups
Repeat orders necessitate plates be on and off the press over a period of time

Table 9

conventional flexographic printing plates might be mounted. Design rolls can be manufactured for most cylinder sizes, from small narrow-web cylinders to the very large wide-web types.

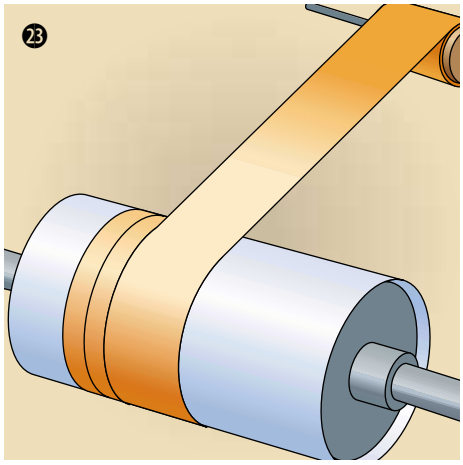
The thickness of rubber or photopolymer plate compound, applied during manufacture of the design roll, is typically 0.125" or greater. This makes a standard plate-mount cylinder, undercut from the gear pitch diameter to allow 0.125" or more of combined plate and stickyback, ideal for laser-engraved design roll application.

Vulcanized Rubber Compound Selection

For vulcanized laser-engraved design rolls, a range of natural rubber, synthetic rubber and polymer compounds are available. Some of these, however, are not usable for the molded-plate applications. The printer may specify a rubber compound for mounted-plate operations, or depend upon the expertise of the laser engraver to recommend the best compound for the environment in which the roll will be used. Characteristics to consider when choosing the best rubber covering for the printing process include ink and solvent exposure, press speed, ambient temperature, substrate to be printed and run lengths.

Compound Application

Before the application of the compound, the surface of the cylinder is coated with a suitable adhesive to ensure bonding during vulcanization. Usually, thin, latex-like, sheets of the chosen compound are wrapped around the cylinder or sleeve under tension and pressure to ensure that no air is trapped between the successive layers (*Figure* ㉓). Excess compound is applied to allow for shrinkage during the subsequent vulcanization process and to allow for grinding to size. The wrapped compound is then tightly wound with wet shrink tape, and end plates are applied to prevent the compound from escaping during the vulcanizing process.



㉓ Thin, latex-like sheet of rubber or photopolymer is wrapped around the cylinder or sleeve. Tension, or pressure, is applied to ensure that no air is trapped between the layers.

Vulcanizing

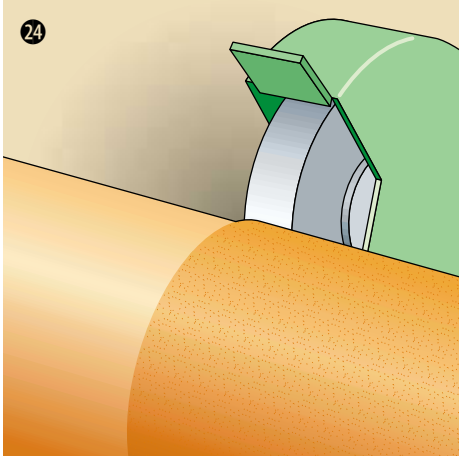
The wrapped roll is placed in an autoclave, where, under elevated temperature and pressure, it is “cooked” until the compound is vulcanized (fused) to form a solid sleeve that is firmly bonded to the cylinder base. Vulcanizing time will vary relative to roll size and compound thickness.

Photopolymer Application

Strippable sheet photopolymer may also be used to coat the print cylinder to form a print surface for a laser-engraved design roll. Raw (uncured) sheet photopolymer is first stripped from the polyester backing material and applied to the surface of the print cylinder. When sufficient photopolymer has been applied to the surface of the cylinder, it is fully cured using high energy ultraviolet light before grinding and polishing.

Grinding and Polishing

A vulcanized roll must be allowed to “cook” for up to 24 hours to stabilize the compound before it can be cooled and rough-ground to remove excess rubber (*Figure* ㉔). Up to four more days must elapse before final grinding and polishing



24 Excess rubber from the vulcanized roll is rough-grounded to produce a dimensionally stable, concentric and smooth roll.

can take place. The objective is to produce a stress-free roll that is dimensionally stable, concentric and smooth within a dimensional tolerance of 0.001".

One advantage of using photopolymer is that cured photopolymer is more dimensionally stable and may be ground to the final diameter without the aging or seasoning delay. This also applies to polyurethane coverings.

Polyurethane Covering

In certain flexographic applications, particularly those requiring a high order of resistance to wear and damage, cylinders are covered with cast polyurethane, selected for laser compatibility, ink transfer and toughness. These cylinders are finished and sized in the same way as rubber.

PREPARING ARTWORK FOR DESIGN ROLLS

The cylinder surface of a design roll is dimensionally stable and seamless; therefore, the stretching and shrinkage factors associated with conventionally produced plates, need not be considered when providing artwork for laser engraving. The ideal input for laser-engraved rolls is one-up, uncompensated digital graphics. Hard-copy art, or undistorted positive or negative films, may be used, but then need to be scanned and digitized before they can be utilized for laser engraving.

Digital artwork can be modified, stepped-and-repeated, or otherwise layed out to meet the requirements of repeat length (cylinder circumference) and print width for the particular job. Digital artwork can also offer specified trap between colors, provide bleed and precisely place registration marks, eye spots or other devices as part of the design. Digital-proof prints may be produced directly from the electronic file or color keys and glossy proofs can be made from conventional image-set films for review and approval of the design before actual engraving is undertaken. The final digital graphic files will then be used to drive the laser output. Refer to *Table 9* for a summary on the use of design rolls.

Engraving the Cylinder

While there are at least two different laser-engraving technologies in use, each differing in the way the laser beam is guided, both achieve the desired result by using the concentrated high energy of the laser to remove the plate material from the nonprinting areas. The plate material, whether rubber, polyurethane or cured photopolymer, is vaporized by the laser, leaving a clearly defined image. Depending on the technology used and the requirements of the specific application, engraving depth can be varied from cylinder to cylinder and the image shoulder profile may be vertical, sloped or stepped.

Proofing and Inspection

The laser-engraved design roll can be proofed on any one of several proofing machines to check print uniformity with minimum pressure. Proofs can also be made to assist in mounting plates on other rolls to be used in conjunction with the laser-imaged design roll. The cylinder print surface and

images, as well as its mechanical components, are inspected using special lighting and magnification.

SPECIAL CARE CONSIDERATIONS

Unlike mountable printing plates, design rolls are solid integral units, which cannot easily be repaired or replaced if damaged. With proper use and care, they are suitable for long, or repeated, pressruns.

On press, cylinders should be exposed to the minimum pressure consistent with quality printing. As the cylinders warm up on the press, they may expand and print pressure should be further reduced. As soon as a run is completed, the cylinders should immediately be removed from the press and cleaned. A cylinder can be cleaned quickly and without damage using ample quantities of cleaning agents designed for that purpose, together with a soft-bristle brush.

All polymers and rubber compounds tend to age and suffer changes in their physical properties over time, especially if exposed to elevated temperature, ozone or fluorescent light. If the cylinder is to be used again, it should be stored in a cool area, suspended by its journals, or by a rod through the bore. It should be loosely wrapped to allow any cleaning solutions it may contain to evaporate, while protecting it from direct fluorescent light or sunlight.

Most electrical equipment, especially electric motors, produce ozone that may attack rubber compounds and photopolymers. Therefore, cylinders should not be stored near such equipment. These precautions also apply to standard plate-mounted cylinders or plates being saved for future use.

DIRECT-TO-PLATE IMAGING

The newest technology to enter the flexographic printing plate market utilizes direct-to-plate (DTP) or computer-to-plate (CTP) imaging. These technologies are following the trend in the general printing industry toward film-less platemaking. *Table 10* summarizes some of the advantages and disadvantages of the direct-to-plate process.

In a conventional platemaking process, the digital images in the graphics computer are raster image processed or RIPped to the emulsion of a photographic film to form a negative image. The negative film is then placed on the photopolymer with the emulsion in contact with the print surface of the plate to be imaged. In all cases, there is a thin “slip-film” on the surface of the photopolymer to prevent the negative film from sticking to the polymer during the exposure. This slip-film proves detrimental and contributes to image spread during plate exposure, creating the shoulder on the relief characters that is typical of a flexographic printing plate. The supporting shoulders evident in the relieved areas of a photopolymer plate, are the result of light scattering within the photopolymer. A conventionally imaged (with film) plate is exposed in a contact frame, where atmospheric gases, including oxygen, are evacuated from the area immediately surrounding the plate. This oxygen-deprived environment contributes to the development of the sharp transition from printing surface to shoulder. As the plate is impressed onto the substrate during printing, the shoulder on the image causes the print element to gain in size, creating the “halo” that typifies flexographic printing.

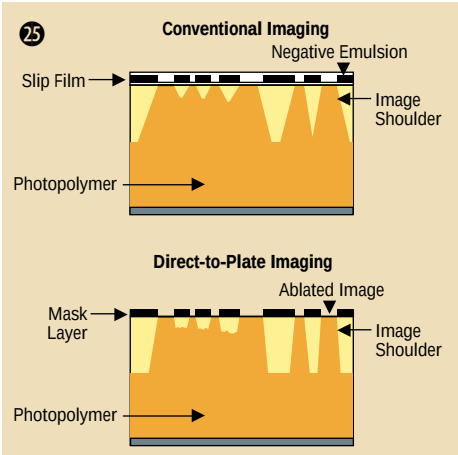
With direct-imaged printing plates, the digital image in the graphics computer is RIPped directly to a masking material that is an integral part of the print surface on the photopolymer (*Figure* ❷❺). The masking material is burned away or ablated by a focused laser beam. Once the mask is ablated with eth RIPped date and a negative image crated, the plate is handled as a conventional photopolymer plate. The one exception is that during the exposure step, no vacuum is

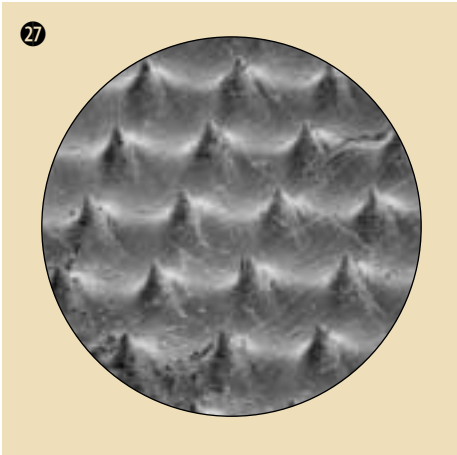
25 Cross-sections of a conventional and direct-imaged plate reveals the steeper shoulders of the digital process.

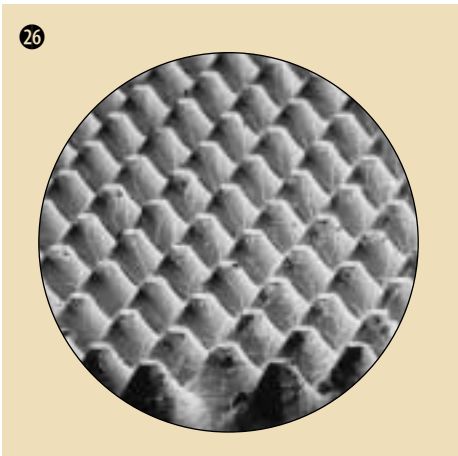
26 An enlarged detail of a hightlight dot on a conventional photopolymer plate.

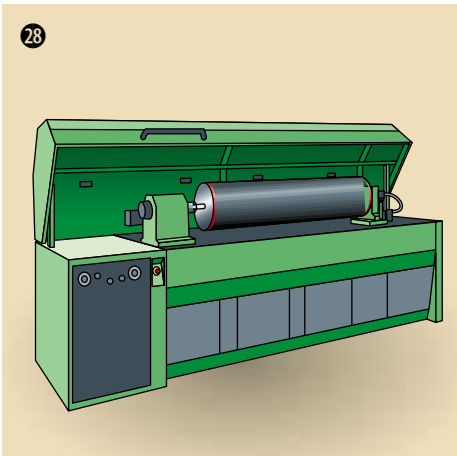
27 An enlargement showing a highlight dot on a digitally imaged photopolymer plate.

28 The direct-to-plate imager uses a laser beam to ablate or vaporize masking material on the photopolymer plate that is mounted on the drum.









required, as the image-carrying mask is alrady in intimate contact with the polymer surface. There are, therefore, no materials to interfere with the imaging light as it impacts the plate surface. More importantly, exposure and polymerization take place in the presence of oxygen, which inhibits polymerization at the plate surface. As a result, the images that form in the plate are actually smaller than the image that was written into the integral mask; the shoulder is not as sharp when compared to a conventionally made plate imaged from the same electronic file. This is an important factor when printing highlight dots in halftone process screens and stochastic images. *Figure* 26 and 27 show the enlarged dot structure of the same highlight dot exposed conventionally and digitally. While the digital difference is most apparent in highlights, the full tonal range or an image is affected.

The use of direct-to-plate imaging affects more than just the platemaking step of the flexo process. No film negative is generated to make the plate, and consequently, no film negative is available to make a proof. The entire workflow right up to the press is now digital. Color management and digital proofing become essential elements of the process. Some of these required technologies, in turn, will continue to improve, as more of the process becomes digital. Digital proofing, for example, has been available for some time, yet, there is still reluctance to accept these proofs as contract proofs. Doubtless, continued progress will be made

in this area so that a completely digital workflow is possible. Process control and consistency have always been required for quality printing. New methods, tools, skills and training are required for successful implementation of direct-to-plate.

Integral Mask Technology

This technology utilizes sheet photopolymer, as well as in-the-round photopolymer, bonded to sleeve, sized to fit typical plate cylinders. The basic concept of this CTP technology is to build a "mask" onto the image surface of the raw plate material during manufacture of the sheet or after surface preparation of sleeved photopolymer. The mask is a thin layer of material that blocks ultraviolet light. The integrated mask material on the plate is imaged by a laser that ablates only the masking material in the image areas of the plate. The laser imaging equipment (*Figure* ❷❽) is similar, in concept, to that used to image offset printing plates, laser imaged films, laser engraved rubber cylinders and some rotogravure cylinders.

Note: *In most equipment, the sheet photopolymer is mounted on a drum for laser ablation. If the exposure drum is of a different diameter than the print cylinder, care must be taken to correctly calculate the distortion compensation required. Also, the exposure system may impose on the drum in order to use all of the plate material. If any images are rotated in order to fit efficiently, compensation will need to be made on a per-image basis, not globally. If done globally, the compensation on the rotated images would be incorrect. The supplier of the imaging equipment should be consulted for proper handling of the issue.*

Ink-jet Mask Technology

The ultraviolet-blocking mask is generated on the surface the photopolymer of the sheet photopolymer using ink-jet technology (*Figure* ❷❾). This DTP system is especially advantageous in the corrugated post print sector, where many small pieces of plate are generally mounted flat on a large single carrier sheet. In this application, individual pieces of sheet photopolymer are cut roughly to the size of the image elements in

DIRECT-TO-PLATE (CTP)

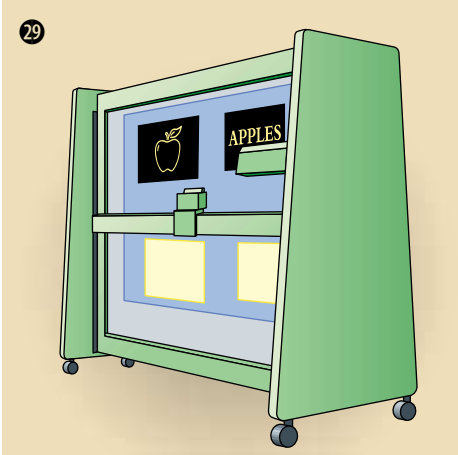
ADVANTAGES

- All digital workflow eases implementation of color management and aids in consistent, predictable image and copy reproduction
- Superior color registration is attained
- No film is needed, resulting in saving of the cost of film as well as the film production, handling and storage costs
- Step and repeat can be incorporated into the RIP, reducing file sizes and speeding up output time
- Vacuum is not needed during plate exposure. Imaging faults caused by air and dust trapped between the negative and plate are reduced
- Intimate contact of mask on the plate during exposure produces a sharper, high definition plate image and improves retained tone values, particularly in the highlights. Dot gain is minimiezed throughout the entire tonal range

DISADVANTAGES

- Higher plate costs during initial adoption of this technology
- Learning curve of a new process requires training on new equipment and processes
- High costs of the imaging units

Table 10



29 The ink-jet mask imager uses an ink-jet to create a UV-blocking mask on the surface of the photopolymer.

the design. The pieces of plate are mounted in position on the large carrier sheet that will be used on the press. The ultraviolet blocking mask is then printed on the surface of the individual plate pieces.

The fully computerized system reduces overall plate production and mounting times by as much as 30%, while dramatically reducing plate material waste. The inherent positional accuracy obtained when producing multicolor images, without the time-consuming mounting process, combined with the material cost saving, more than offsets the imaging cost.

The fully computerized system reduces overall plate production and mounting times by as much as 30%, while dramatically reducing plate-material waste. The inherent positional accuracy, obtained when producing multicolor images without the time consuming mounting process, together with the material cost saving, more than offsets the imaging cost.

Exposure and Processing of Direct-imaged Plates

In both direct-imaging processes (integral mask technology, ink-jet mask technology), the plate is exposed on a standard platemaking exposure unit, and processed in the normal fashion.

Plate Considerations

Plate quality should be assessed before beginning any printing job. This section presents a review of tools and tests developed to accurately determine whether or not a plate is press-ready. Hardness must be determined. Excess material may need to be trimmed. Mounting marks might have to be etched, adhesives may require preparation and ink formulations may need to be analyzed for compatiblility. Here is an outline of what must transpire.

MEASURING PLATE THICKNESS

Plate thickness, or caliper, accuracy is the most important factor when controlling the print impression on press. Any low caliper spots in the plate will either not print or will cause over-impression of the remainder of the printing plate. The more accurate the plate caliper, the longer the plate will last on press. Plate thickness tolerances of 0.0005" (12 microns) or better should be expected on high quality plates.

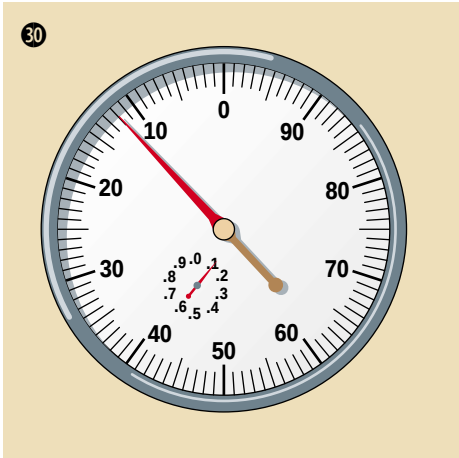
Plate thickness is measured using specially designed thickness micrometers with either digital or analog readouts. Standard thickness micrometers, like those used in textile and metal fabrication industries, are unsuitable for measuring flexographic printing plates due to the excessive foot pressure employed. Flexo plate thickness micrometers employ large diameter anvils with very light application pressure to ensure minimum deflection of the plate material during measurement.

Bench Micrometers. It is important that the foot of the micrometer is in full contact with the section of the plate being measured. The micrometer must be mounted on a stable base such as wood, stone or metal to provide strong support. The base should also be large enough for the plate to lie completely flat, allowing the foot of the micrometer to be in full contact with the plate, thus ensuring more readings.

Since the introduction of large photopolymer plates – sizes from 30" x 80" to 52" x 110" – bench micrometers are being designed with bases as large as 54" x 90". It takes practice to develop proficiency, especially when using analog micrometers. Only light finger pressure should be used once the foot is in contact with the plate.

Analog Indicators. Analog gauges are recognized by the familiar dial indicator face (*Figure* 30). A revolving pointer rotates inside a circular scale that represents the least significant value, for example 0.001". Each rotation of the pointer represents an anvil movement of 0.1". A smaller-scaled

30



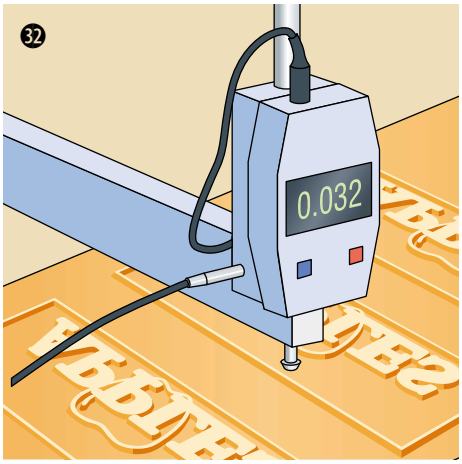
30 A typical analog gauge used to measure plate thickness.

31 Parallax error occurs when the dial is not viewed straight on, thus giving a false reading.

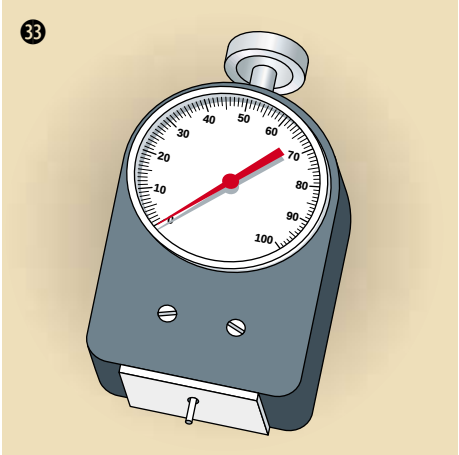
32 Digital readings avoid human error such as parallax error, and is the most accurate.

33 Durometer gauges measures the indentation of a frustum cone into the resilient surface under spring load. The 2" round style "A" model durometer gauge is used for measuring soft, resilient compounds.

31



32



33

pointer on the face reads the most significant value 0.1" increments to 1.000" to keep track of each revolution.

The term analog, refers to the measuring scale and how it is presented. Indicated values are continuously changing and the slightest change could be significant. When using an analog dial micrometer it is important to be cognizant of, and avoid, parallax error. This occurs when the dial is not viewed straight on (*Figure* 31) and can lead to different interpretations of the same reading. Measurements can also vary from one person to another if the dial is not perfectly aligned and the least significant digit needs to be estimated.

Digital Indicators. When the value can be represented in digital display, it leaves no room for interpretation (*Figure* 32), such as the inherent possibility of parallax error from an analog gauge. Digital flexo plate micrometers may be as accurate as 0.0002" or 5 microns, over its range.

Another feature of digital indicators is the ability to provide a hard-copy readout in millimeters or inches. A mini-processor and printer can be attached to record readings and variances while measuring the plate. After all the readings are recorded, the processor can print out the statistical information for the particular plate or set of plates. This information would typically include the maximum and minimum readings, total variation, average thickness and average variation. A histogram based on upper and lower limits set by the user is also possible. Along with this information, the job name, date and other data can be printed and sent to the customer with the plates. Special interfaces are also available to transmit this information directly to a host computer for maintaining departmental quality-control statistics and eliminate errors in reading or incorrectly recorded data.

CHECKING PLATE HARDNESS

The most common instrument for measuring rubber hardness is the Shore durometer gauge. The hardness gauge measures the

indentation of a frustum cone into the resilient surface under spring load. The durometer hardness scale runs from zero (softest) to 100 (hardest).

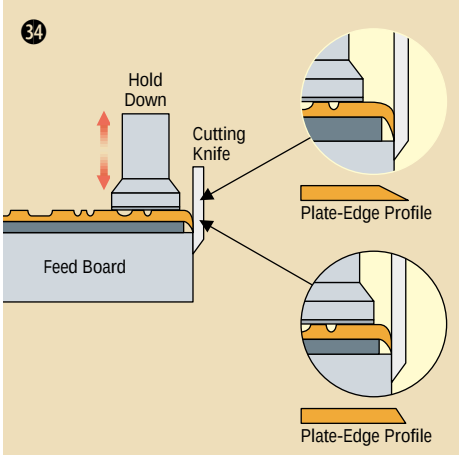
The most widely used Shore durometer gauge for measuring soft, resilient compounds is the “A” type gauge. The Shore “D” durometer gauge is used for harder products. The gauges are available in either the quadrant or round style (*Figure* 33). The round-style, “A” model, 2" durometer gauge produces the same readings as the quadrant type and satisfies the need for an instrument calibrated in single units rather than in increments of five units.

For example: For a Shore hardness of 45A, the stylus would penetrate the surface by 0.055" (0.100"–0.045"). For a proper durometer reading, it is essential that at least a 0.25" thick sample block of material be used. Checking a 0.107" thick 50A durometer flexo printing plate, supported on a hard surface, would tend to transmit some of the hardness of the support surface and the polyester backing sheet, registering a false reading. Temperature is also a critical factor when measuring hardness, especially of photopolymers. Hot material will produce a softer reading.

Time is another factor to be considered with most plate materials. As the stylus penetrates the surface of the plate material, the hardness reading will drift downwards. Both instantaneous readings and readings taken after five seconds of gauge application, should be compared. Hardness readings must not be taken on the face of the printing plate because this may cause irreparable damage. The durometer gauge should be handled with care, and checked and recalibrated if necessary.

CARE AND HANDLING OF PLATES

Whether rubber or photopolymer, finished plates must be trimmed accurately. The preferred method of trimming a printing plate is to do so using a plate cutter or foot shear. If a knife is used to trim photopolymer plates, the cut should be made from the polyester backing side of the plate. Edges must be smooth and free of nicks and burrs.

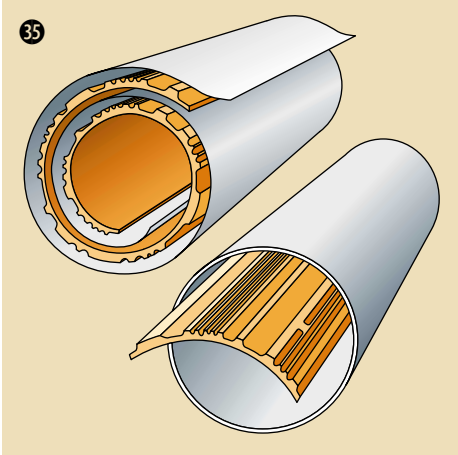


30 When trimming plates, beveling the plate edges is desirable. It helps keep the plate from lifting during the pressrun.

Beveling all sides of the plate is desirable and may be done by securing a rigid material on the bed of the paper cutter or foot shear (*Figure* 34). Place the finished plate on top of the rigid material and press firmly to trim. This flexes the edge of the plate and cuts a neatly beveled edge. The position and height of the rigid material determines the bevel angle. The beveled plate edges help keep the plate from lifting during the pressrun.

PLATE MOUNTING

Centerlines may be drawn on the floor of plates with a ballpoint pen or lightly inscribed on the reverse side of the polyester backing of photopolymer plates with a film cutter. With the center lines permanently marked on the plate, white or orange mounting chalk rubbed over the lines make them more visible during mounting on an optical mounting machine. Register marks imaged on the plate are usually left in place during mounting and throughout press makeready. They can be removed before the production



35 Precurving plates relaxes the plate and increases conformity to the curvature of the plate cylinder, thereby preventing plate lift during the pressrun.

run using any sharp cutting instrument. Care should be taken to avoid damaging any image area during this process.

Precurving Plates. When plates are to be mounted on small diameter cylinders, it is recommended that the plate be precurved. This is done to prevent lifting during the pressrun. The precurving procedure relaxes the plate and increases conformity to the curvature of the plate cylinder. Plates are precurved by heating the plate in a temperature-controlled oven (plate dryer) to 140° F (60° C) for 10 to 15 minutes. The warm plate is then covered with a piece of polyester slip sheet and rolled in the print direction with the print face outward to approximately the print cylinder size (*Figure* 35). The rolled plate is then allowed to cool to room temperature for at least four hours.

Mounting Tapes (Stickyback). Plates may be mounted with any commercially available double-sided tape called stickyback. High-tack tapes are recommended for mounting photopolymer plates, especially on small diameter cylinders. Tapes should be of uniform thickness to get the most out of gauge-controlled platemaking. Often, "highs and lows" in printing are mistakenly blamed on the plate, when they are really caused by uneven mounting tape or air entrapment. There are many types of tapes available and tape should be chosen based on its tack and cushion properties for the job being printed.

Edge Sealing. Plate-edge sealant will prevent ink and solvents from attacking the adhesive tape during printing and plate washup. After the plates have been set onto the adhesive tape, the edge seal should be applied in a fine bead around the plate border. The sealant must be allowed to dry thoroughly before wrapping cylinders to continue setting of plates onto the adhesive.

Demounting Plates. If plates are to be stored and reused, care should be taken when demounting from the double-sided mounting tape. Rubber plates can be stretched or torn, and photopolymer plates may be susceptible to delamination from their polyester backing or kinking of the polyester backing. Special medium-tack double-sided mounting tape is available for de-mountable applications.

PLATE WASHUP

Proper plate washup on press can lengthen plate life. Plates should be washed immediately after printing with the correct platewash solution before the ink has time to set. Plate manufacturers' suggestions should be followed when determining which plate wash to use. Plates should never be scrubbed using a wire- or stiff-bristled brush. Ample quantities of the correct solvent, or prepared plate wash, should be used in conjunction with a lint-free cloth that will cut the ink without hurting the plate material. The plate should be swabbed gently until the ink loosens and can be sponged off with a second cloth. Final drying may be achieved using a soft, absorbent paper. Forced air may also be used to blow away the residual solvent and lint.

Note: *When cleaning plates on the cylinders, care should be taken not to let the solvent or cleaning agent get under the stickyback. That can cause the plate to lift from*

the cylinder or off the stickyback itself.

Once the plates are clean and dry, they should be dusted with talc or fine corn starch and placed in a proper storage area.

PLATE STORAGE

The temperature in plate storage areas should not exceed 100° F (38° C). The plate storage area should also be located away from ozone sources such as power stations, press-motor drives and corona-discharge film-treating units. Plates should be kept in a cool, dry, dust-free environment, away from direct exposure to light sources.

Plates stored on cylinders are more susceptible to deterioration from ozone attack. If plates must be stored in this way, they should be thoroughly cleaned and dried, then tightly wrapped in black polyethylene to protect against ozone exposure.

When high ozone levels cannot be avoided, applying ozone-resistant finishes to the cleaned and dried plates may provide some protection. Consult your materials supplier for recommended materials.

RUBBER PLATE AND SOLVENT COMPATIBILITY

SOLVENT	NATURAL RUBBER	BUNA "N"	ETHYLENE PROPYLENE (EP)
Acetone	F	NR	S
Benzene	NR	NR	NR
Carbon Tetrachloride	NR	NR	NR
Cellosolve	S	F	S
Cellosolve Acetate	F	NR	S
Ethyl Acetate	NR	NR	F
Ethyl Alcohol	S	S	S
Isopropyl Acetate	NR	NR	F
Isopropyl Alcohol	S	F	S
Kerosene	NR	S	NR
Lactol Spirits	NR	S	NR
Methyl Alcohol	S	S	S
Methyl Ethyl Ketone	NR	NR	S
Methyl Isobutyl Ketone	NR	NR	S
Mineral Spirits	NR	S	NR
Naptha VMP	NR	S	S
Normal Butyl Acetate	NR	NR	F
Normal Propy Alcohol	S	S	S
Toluene	NR	NR	NR
Xylene	NR	NR	NR

S Satisfactory
F Fair
NR Not Recommended

Note: Guidelines only; to ensure compatibilty, contact supplier or conduct swell test.

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PHOTOPOLYMER PLATE AND SOLVENT COMPATIBILITY

	PURE SOLVENT	MAXIMUM % IN NORMAL PROPYL ALCOHOL COSOLVENT	MAXIMUM % IN WATER COSOLVENT
KETONES[1]			
Acetone	N	5	5
Methyl Ethyl Ketone	N	5	5
Methyl Isobutyl Ketone	N	5	5
ALIPHATIC/AROMATIC HYDROCARBONS[1,2]			
Heptane	N	5	n/a
Hexane	N	5	n/a
Cyclohexane	N	—	n/a
VM&P Naptha (3% aromatic)	N	5	n/a
Lactol Spirits 9300 (9% aromatic)	N	5	n/a
Lactol Spirits 9500 (14% aromatic)	N	3	n/a
Lactol Spirits 45 (19% aromatic)	N	3	n/a
Lactol Spirits 50 (32% aromatic)	N	3	n/a
Benzene	N	1	n/a
Toluene	N	1	n/a
Xylene	N	1	n/a
Ethyl Benzene	N	1	n/a
GLYCOL ETHERS			
Butyl Cellosolve	N	3	3
Ethyl Cellosolve	N	30	30
Proposal P	N	30	30
Carbitol	N	30	30

cont'd on the following page

1 *For extended run lengths, lower maximum percentages are recommended for best results.*

2 *This category includes petroleum/paraffinic distillates.*

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INK AND SOLVENT COMPATIBILITY

A simple test for swelling can be used to determine the relative compatibility between the plate material and printing solution. Take a small section of a fully cured plate material, measure the thickness, and immerse it for 24 hours in the solution to be tested. Remove the sample from the solution and, after blotting the sample dry, again measure the thickness. If the material has gained more than 5% in gauge, then the two materials may be considered incompatible. For thinner plates (0.045" or 0.067"), this means a value of 2 to 3 mils and for a thick plate (0.25") a value of 10 to 12 mils.

A more complete test is to leave the sample out of the solvent for 24 hours and then re-immerse it for an additional 24 hours. In most cases, the abbreviated single 24-hour test will indicate if the plate and solvent are compatible. A longer test may be warranted on a plate which will be used for a long run or for repeated runs.

Table 11 lists the solvent compatibility for rubber plates. *Table 12* lists the compatibility for photopolymer plates.

PHOTOPOLYMER PLATE AND SOLVENT COMPATIBILITY *CONT'D*

	PURE SOLVENT	MAXIMUM % IN NORMAL PROPYL ALCOHOL COSOLVENT	MAXIMUM % IN WATER COSOLVENT
Water	Y	100	—
AMINES (PH ADJUST)			
28% Ammonium Hydroxide	Y	n/a	—
2-Amino-2-Methyl-1-Propanol	Y	n/a	—
Morpholine	N	n/a	—
Monoethanol Amine	Y	n/a	—
Triethanol Amine	Y	n/a	—
ALCOHOL/GLYCOLS			
Methyl Alcohol	N	50	50
Ethyl Alcohol	Y	100	—
Isopropyl Alcohol	Y	100	100
Normal Propyl Alcohol	Y	—	100
Normal Butyl Alcohol	Y	100	100
Octyl Alcohol	N	5	5
Benzyl Alcohol	N	5	5
Ethylene Glycol	Y	100	100
Propylene Glycol	Y	100	100
Diethylene Glycol	Y	100	100
Dipropylene Glycol	Y	100	100
Triethylene Glycol	Y	100	100
Glycerine	Y	100	100
ESTERS[1]			
Ethyl Acetate	N	20	n/a
Isopropyl Acetate	N	20	n/a
Normal Propyl Acetate	N	20	n/a

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WRAP DISTORTION

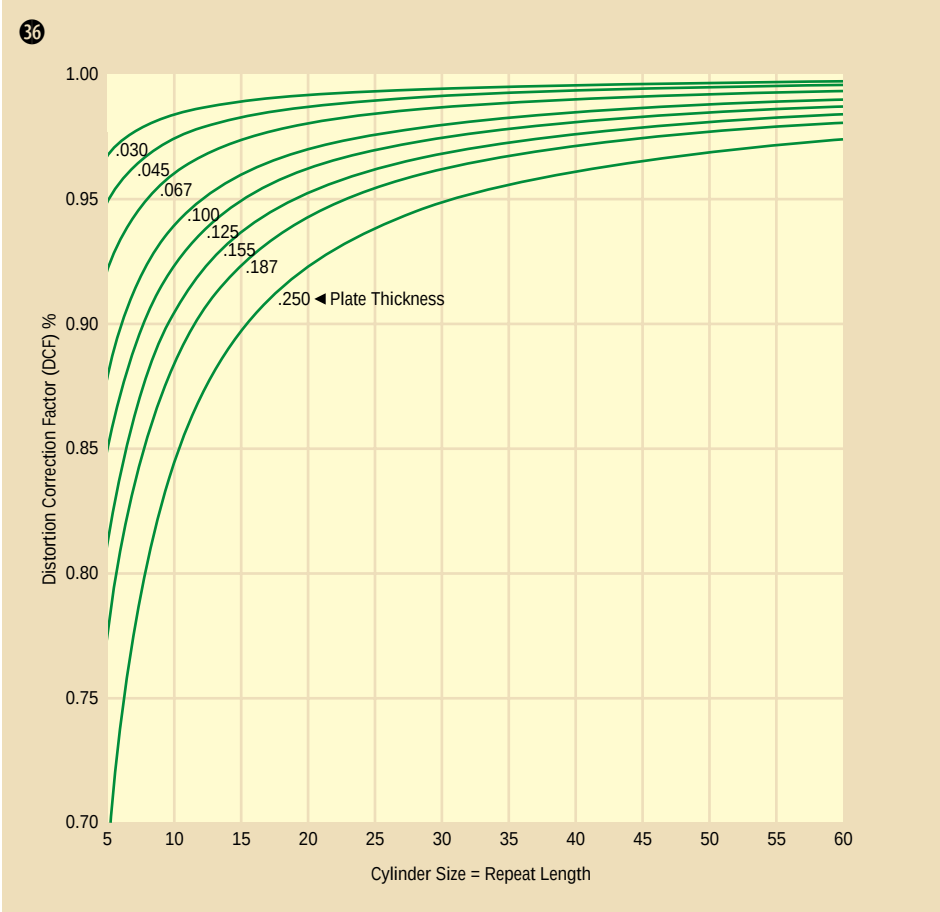
Elastomeric printing plates that are made in the flat and then wrapped around a printing cylinder experience distortion (elongation) in print length. The amount of distortion depends on the dimensions of the plate and the cylinder, as well as plate construction. Photopolymer plates tend to have greater, but more constant distortion factors than their rubber counterparts. This is due to the dimensionally stable polyester backing sheet.

Two factors determine image elongation in printing plates:

1. The thickness of the elastomeric layer above the neutral plane. The neutral plane on polyester-backed plates is displaced to a point just above the polyester carrier. In nonbacked rubber plates, the neutral plane runs through the center of the plate thickness.
2. The diameter of the printing cylinder.

Distortion-correction factors for polyester-backed photopolymer plates up to 250 mils thick and for cylinder sizes up to 60" repeat length are shown in *Figures* 36.

36 The graph at right plots the alculated distortion-correction factors for polyester-backed photopolymer plates up to 0.25" thock and repeat lengths up to 60".



The calculations are based on the formula for distortion:

$$\text{DCF} = \frac{1 - 2(Tp - Tb)}{R}$$

Where:

DCF = Distortion correction factor

R = Printing circumference (repeat length) of cylinder

Tp = Plate thickness (inches)

Tb = Thickness of the polyester backing sheet

***Note**: Figure 36 is calculated with a Tb value of 0.007". On the scale of the figure, using a different Tb value, such as 0.004", would show no significant difference.*

A second formula commonly used to determine the percent a film negative must be reduced in order to compensate for image distortion is:

$$\text{\% reduction} = \frac{K}{R} \times 100$$

Where:

K = a constant supplied by the plate material manufacturer

R = Printing circumference (repeat length) of cylinder (inches)

Notice that K is equal to 2 (Tp−Tb) in the DCF calculation. *Table 13* lists calculated K factors for common plate thicknesses with 0.004" and 0.007" backing. The K factor depends on the measurement system used. The table lists the value for repeat lengths in inches and centimeters.

Example: *What is the distortion needed in*

K FACTORS

INCHES			CENTIMETERS		
PLATE THICKNESS	K FACTOR 0.004 BACKING	K FACTOR 0.007 BACKING	PLATE THICKNESS	K FACTOR 0.004 BACKING	K FACTOR 0.007 BACKING
0.030	0.163	0.145	0.076	0.415	0.367
0.045	0.258	0.239	0.114	0.654	0.606
0.067	0.396	0.377	0.170	1.005	0.958
0.080	0.478	0.459	0.203	1.213	1.165
0.090	0.540	0.522	0.229	1.372	1.325
0.100	0.603	0.584	0.254	1.532	1.484
0.107	0.647	0.628	0.272	1.644	1.596
0.112	0.679	0.660	0.284	1.724	1.676
0.125	0.760	0.741	0.318	1.931	1.883
0.155	0.949	0.930	0.394	2.410	2.362
0.187	1.150	1.131	0.475	2.921	2.873
0.250	1.546	1.527	0.635	3.926	3.878

Table 13

film negatives for a 0.067" plate with a 0.004" backing sheet and a repeat length of 8"?

From *Figure* 36, the distortion factor is about 0.95. Using the K-value calculation, the percent reduction is 0.396 (from *Table 13*) divided by 8, times 100. This gives a value of 4.95%. The distortion factor would be 95.05%. This is the same as the 0.95 (95%) from *Figure* 36. Clearly, *Figure* 36 only indicates a rough value for the distortion factor. For precise values, the percent reduction or DCF formula should be used.

In principle, distortion factors could be calculated for rubber plates also. Since rubber plates have the shrink as well as wrap distortion and are unbacked, the distortion is usually determined empirically.

Surface Tension

Surface tension is a condition existing at the free surface of a liquid, resembling the properties of an elastic skin under tension. Dynes per centimeter is the unit that is generally used to measure surface tension. One dyne is the force one milligram exerts under the influence of gravity. Printing plates, substrates, and inks have a dyne value. A practical example of what dyne and surface tension is all about can be seen in the reaction of water on a waxed surface. Plain water will bead up on a waxed surface because the surface tension of the water is greater than that of the wax. If a surfactant, such as detergent or alcohol, is added to the water to lower the surface tension, it will spread and wet the wax surface. This is known as wetting out.

Surface energy and its relation to ink transfer and printability is not understood well enough to allow exact use of surface-energy specifications for plates, inks, transfer rollers or anilox rollers.

The surface energy values for water-based inks are between 34 to 38 dynes/cm, while the values of resins used in solvent-based inks are 28 to 32 dynes/ cm.

Most photopolymer plate materials have lower, but more consistent, surface energy than natural rubber. Materials with higher

surface energy have a greater affinity for fluids with lower surface energy. Consequently, natural rubber plates, with higher surface energy, accept ink more readily from the anilox roll than photopolymer plates.

Photopolymers exhibit high critical surface tension values. Ink wetting and transfer properties increase as plate wettability increases. Plate wettability increases as the critical surface tension of the plate exceeds that of the ink. Surface energy of ink, rollers and substrates can sometimes be altered within narrow limits to affect the amount of ink film transferred by the printing plates. All these factors have a direct bearing on the final ink transfer. See also the section pertaining to the dyne level of substrates in the ink volume.

Appendix A

MATRIX MOLDING PROBLEMS AND CORRECTIVE ACTIONS

PROBLEM/PROBABLE CAUSE	CORRECTIVE ACTION
CRUSHED TYPE FORM	
1. Improper heat	1. Heat upper and lower platens to 300° F to 310° F
2. Excessive pressure	2. Reduce molding pressure; apply only the amount of pressure to keep the bearers tight
3. Improper preheat	3. Check for optimum preheat time to ensure easy press closing and material displacement
4. Too fast a close on the work	4. Slow down initial approach to work and application of molding pressure
5. Too deep a molded floor and/or wrong bearers	5. Mold a shallower floor; recalculate the bearer height so the mold is deep enough for matrix thickness
CRACKS I N THE COATING SURFACE AFTER BEING MOLDED	
1. Improper cutting or damage to matrix material	1. Cut the matrix cleanly; use a sharp cutter, which will not drag along the edges. Avoid shattering or breaking the coating surface
2. Too long a preheat	2. The matrix board's elastic coating may be partially set-up before being displaced. Reduce preheat cycle time. Close platens slowly on the work
BLISTERING	
1. Excessive moisture in matrix material	1. Store raw stock properly; keep it away from moisture exposure and high humidity. Precondition (dry out) matrix board before using
2. Too high press temperature	2. Check molding press temperature
COATING OF MATRIX MATERIAL PULLS OFF AND STICKS TO MASTERS OR TYPE FORMS	
1. Insufficient cure	1. Cure matrix at prescribed time (at least 10 minutes)
2. Press temperature too low	2. Check molding press temperature.
3. Undercut originals	3. Check shoulders of master; reject very badly undercut originals, otherwise use graphite on master and matrix board to make a release liner
RIDGING OR PILING-UP OF COATING SURFACES AROUND TYPE CHARACTER EDGES	
1. Excessive temperature	1. Check for correct press temperature
2. Excessive preheat	2. Reduce preheat time
3. Too fast a press close	3. Close mold slowly on the work and allow material to flow and displace gradually
4. Mold cavity too deep	4. Raise bearer height and mold to a thicker floor depth

Appendix B

TROUBLESHOOTING GUIDE FOR RUBBER PLATES

PROBLEM	CORRECTIVE ACTION
RUBBER STICKS TO MOLD: PLATE IS SOFT AND GUMMY ON REMOVAL	
Uncured compound	Check platen temperature. If too low, raise to 307° F, or increase cure time
RUBBER STICKS TO MOLD: PLATE IS BRITTLE AND TEARS ON REMOVAL	
Overcured compound	Check platen temperature, if too high, reduce to 307° F, or reduce cure time
RUBBER STICKS TO MOLD: TEMPERATURE AND CURE TIME OK	
Poor release	Check board coating. Use a spray release agent on matrix. Dust rubber and matrix with talc and place talc-side of rubber to mold
RUBBER TEARS ON REMOVAL FROM MOLD	
1. Improper removal	1. Do not tug at stuck rubber. Start separation in one corner and pull slowly from mold with an even pull
2. Mold too deep	2. Allow a least 0.030" for background rubber (more for thick plates). Use correct matrix board. Reduce depth of magnesium original
3. Undercut engraving	3. Check etching for undercut condition. Remake master engraving, if necessary
4. Press closing too far	4. Check bearer height and raise, if needed. Reduce molding pressure
5. Powder density in mold	5. Make new powder mold using enough power and pressure to increase density
6. Wrong type of rubber for mold format	6. Consult manufacturer for plate gum with high, hot tear strength
PLATES CURL – WILL NOT LAY FLAT	
1. Rubber compound is old and set-up	1. Check age of rubber and storage conditions; temperature should be 45° F to 55° F. Rotate stock to turn over inventory
2. Excessive preheat	2. Reduce preheat cycle, especially for older stock
3. Excessive pressure	3. Apply only enough pressure to bring platens tight to bearers. Reduce rubber charge
4. Press temperature too high	4. Check platen tempratures for even heat distribution or set to 307° F
5. Press closure too slow	5. Sets up rubber, increase rate of close
6. Nonuniform heat distribution	6. Check both plates for even heat distribution. Preheat molds before laoding with rubber
7. Undercured	7. Fully cure rubber for prescribed time at 307° F

CONT'D ON FOLLOWING PAGE

B: TROUBLESHOOTING GUIDE *CONT'D*

PROBLEM/PROBABLE CAUSE	CORRECTIVE ACTION
DISTORTED LETTERS AND RULES	
1. Inadequate pressure	1. Check bearers (too thick) and or compound loading (too little). Adjust as needed
2. Slow cure	2. Use faster curing rubber. Increase preheat cycle
3. Damaged mold	3. Inspect mold; remake if necessary
PLATES HAS SKIPS AND NONFILLED AREAS	
1. Inadequate loading and pressure	1. Increase loading – should be 90% to 100% of desired plate thickness. Strip in rubber where additional fill is needed
2. Air tapped in mold cavitities	2. Check rubber or adequate dusting. Use spray release or lightly powder deep molds. "Bump" molds by releasing pressure momentarily after closing press
3. Press temperature too high	3. Check plate temperature; adjust to 307° F. Check for even heating of both platens
4. Excessive preheat time	4. Decrease or elininate preheat cycle – especially with older stock
5. Insufficient preheat	5. Increase preheat cycle – especially if stock is fresh
6. Rubber is old and set-up	6. Store rubber at 45° F– 55° F. Rotate stock to turn over inventory
PLATE BLISTERS OR BUBBLES	
1. Air is trapped in rubber	1. Slow the press closing after proper preheat
2. Too rapid a press close	2. Bump mold by quickly releasing pressure momentarily after closing press
3. Press temperature too high	3. Check platen temperature for even heating; adjust as needed
4. Insufficient talc or dusting on rubber	4. Check rubber for dust and lightly powder with talc if needed
UNEVEN PLATES	
1. High centers, too much rubber	1. Reduce rubber charge on mold, especially in middle
2. Insufficient pressure	2. Increase molding pressure. Select free-flowing gum for large molds
3. Excessive heat	3. Reduce preheat cycle, especially for old stock
4. Press platens not parallel	4. Have platens readjusted

Appendix C

C: TROUBLESHOOTING GUIDE FOR PHOTOPOLYMER PLATES

PROBLEM/PROBABLE CAUSE	CORRECTIVE ACTION
REVERSES FILL IN	
1. Too much face exposure (especially with metal-backed plates)	1. Reduce amount of time for face exposure or mask this area and make the plate again
CAN NOT WASH DOWN TO FLOOR	
1. Too much back exposure	1. Decrease back exposure
2. Negative not dense enough	2. Make another negative
LINES WAVY	
1. Not enough face exposure	1. Increase face exposure
2. Not enough back exposure	2. Increase back exposure
3. Not enough drying	3. Increase drying time –but not temperature or leave for 5 hours at room temperature
4. Saturated solvent	4. Refill reservoir with clean solvent
5. Artwork exceeds material capabilities	5. Redo artwork or compensate with more face exposure
FINE DOTS OR FINE TYPE WASHES OFF	
1. Not enough face exposure	1. Increase face exposure
2. Not enough back exposure	2. Increase back exposure
3. Over-brushing or too much brush pressure	3. Make sure time is set correctly or pull pressure drum away from brushes
4. Artwork exceeds material capabilities	4. Redo artwork or compensate by increasing face exposure
PLATE TOO HARD	
1. Over-exposed	1. Reduce face exposure and/or post exposure time
LETTERS OR SOLIDS CRACK WHEN FLEXED	
1. Too much face exposure	1. Decrease face exposure
2. Too much postexposure	2. Decrease post exposure
3. Too much chlorinating	3. Decrease amount of light finishing
4. Not enough back or face exposure	4. Check UV lamp intensity
5. Incompatible ink or wash solvents	5. Use only compatible ink or wash solvents

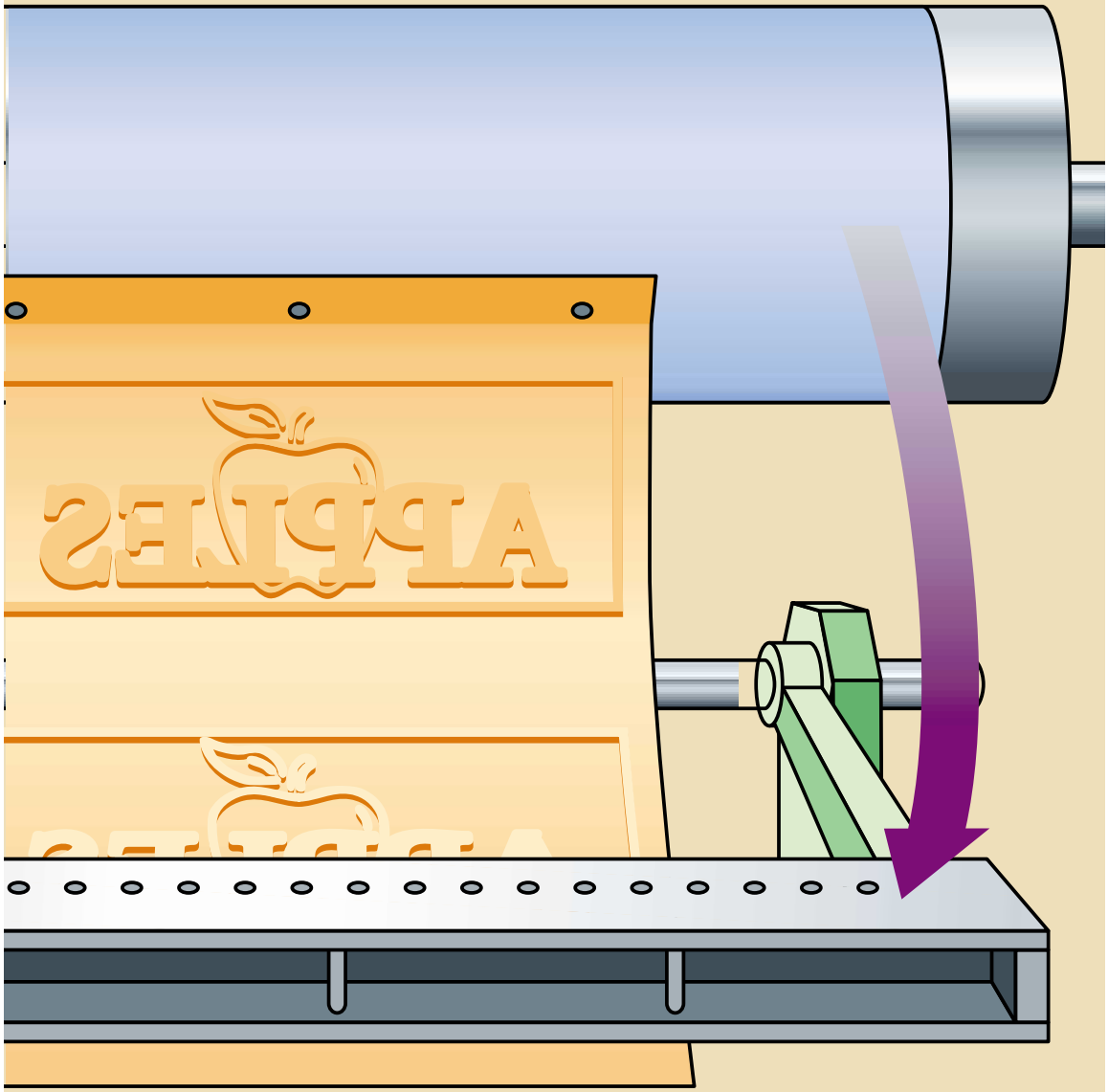
CONT'D ON FOLLOWING PAGE

C: TROUBLESHOOTING GUIDE FOR PHOTOPOLYMER PLATES *CONT'D*

PROBLEM/ PROBABLE CAUSE	CORRECTIVE ACTION
SMALL HOLES AND DEPRESSIONS IN SURFACE OF SOLIDS	
1. Poor housekeeping during platemaking	1. Provide positive room ventilation. Get rid of dirt and lint: Clean room periodically, clean exposure bed daily, change vacuum sheet
2. Improperly made negative: Over- or under-exposed film, insufficient density, pinholes or kinks in negative	2. Redo negatives that have scrapes or kinks in the printing areas; touch up pinholes
3. Low face exposure	3. Increase face exposure
4. Faulty material	4. Return sample to manufacturer for quality evaluation
KINKS IN POLYESTER CARRIER SHEET	
1. Plate curls in brush unit of falls out of drum clamp in the processor	1. Refer to the mechanical troubleshooting section
TACKY FEELING PLATES	
1. Insufficient light finishing	1. Check finishing times and lamp output

CHAPTER 2

Mounting and Proofing



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Introduction

In the early days of rubber plate printing, “aniline” presses were usually one-color, homemade, “tail-end” printers positioned on the end of bag-making machines. The hand-engraved rubber plates, which often had caliper variances of 0.063" to 0.0312", were either nailed to a wooden cylinder or, at best, glued to a steel cylinder of dubious concentricity. The accumulated variations in rippled plates and irregular cylinders were compensated for by forcing the plate cylinder and impression cylinder more tightly together, adding more impression to the plates.

Most print jobs of the day were single-color and were run with just one plate mounted on the cylinder. The major requirement was to print a reasonably aligned reproduction of the plate image somewhere on the face of the bag. When the job called for two colors, the press operator lined up the horizontal and vertical center-scribe lines on the face of the rubber plate with the horizontal and vertical grid lines engraved in the surface of the plate cylinder. Alignment was assisted by “sight-holes” punched through the rubber plate center scribe lines.

If each plate was mounted straight and was fairly well centered on the plate cylinder, the press operator could bring the two colors into register by moving the two cylinders circumferentially and sideways in the press in a sort of trial-and-error fitting exercise. This simple, on-press plate-mounting procedure sufficed, as long as jobs were run “one-up” (only one design repeat per plate cylinder), and print quality and press downtime was of no great concern or importance.

In the early 1940s, with the advent of cellophane, molded-rubber printing plates and wider multicolor presses, the nature of printing with rubber plates took a giant step forward and flexographic printing technology became more specialized. The hard, nonabsorbent surface of cellophane was almost impossible to print by conventional letterpress or gravure processes, so the lowly rubber plate, which indeed could do the job, came into its own.

Clear cellophane required white to be printed as a base or a back-up color on almost every job. This requirement resulted in a demand for presses capable of printing three and four colors and wide enough to run several design repeats across the web simultaneously. Multiple images could then be slit into separate rolls, and wound for placing on wrapping or bag-making machines.

Demand for more sophisticated printing caused presses to become more expensive. Lost press time became correspondingly a more critical concern, creating a need to reduce press downtime. A method or machine capable of accurate mounting and proofing of rubber plates off-press developed. It became an essential component of the prepress functions.

DEVELOPMENT OF MOUNTING AND PROOFING EQUIPMENT

The first commercial “machine” for accurately mounting and proofing rubber printing plates was developed by Franklin Moss, founder of the Mosstype Corporation in, what most people believe to have been, the early 1940s. The well-known letterpress “line-up table” was adapted for rotary use by mount-

ing a calibrated straightedge bar exactly over the press plate cylinder axis. The press cylinder was held in alignment by resting the shaft bearings in V-blocks.

Circumferential divisions and/or spacing of the printing plates was achieved by mounting a "dividing head" (similar to that used on a lathe) to the end of the plate cylinder shaft. Plates were aligned to the straightedge and fixed to the cylinder using a paint-on rubber adhesive. A movable impression cylinder mounted in front of the plate cylinder allowed proofing of various-sized plate cylinders and various thicknesses of printing plate.

In 1945, Earle Harley, president of E.L. Harley, Inc., then associated with the press supplier H. H. Heinrich, adapted another letterpress plate-positioning device for rotary rubber-plate mounting. He adapted the "Taylor Regiscope" principle, which uses a slanted, transparent, reflecting mirror to superimpose the image of a rubber plate to be mounted over the proofed image of a previously accurately mounted "key" plate. This resulted in his patent for mounting plates optically. In this equipment, the proofing or impression cylinder is positioned above the plate-mounting cylinder.

In Europe, during the late 1940s, Bieffebi, Inc., developed a mounting and proofing machine which also used the transparent, reflecting mirror principle. Over the years, each of these three basic machine types have been refined and improved, some with the addition of electronic devices such as digital readouts and computer aids.

The growing importance for highly accurate and more expedient "off-press" mounting and proofing, created other unique devices and approaches, which will be discussed later in this chapter. This pressroom preparatory tool is one of the most important links in the chain of improvements in the flexographic printing industry and has lead the way to the high quality, high speed flexographic printing seen today.

THE PURPOSE OF MOUNTING AND PROOFING

The purpose of mounting and proofing is to prove that the job which is to be printed is press-ready. A determination must be made that it is properly laid out and positioned to conform to end-use specifications; that it has the correct copy mounted on an approved color cylinder in appropriate register to one another; and that its plates, cylinders, gears and bearings are sufficiently mechanically accurate to perform, on the press, within acceptable standards.

To accomplish this, two things must occur:

- The mounting and proofing procedure must be performed correctly and with precision, according to clearly defined and accepted practices.
- The equipment used must be manufactured and maintained within stringent mechanical tolerances.

To be a successful printer demands a good mounting department, good mounting knowledge and techniques and good documentation procedures. If they are not in place, the same errors can be made again and again. Each time a job is run, more should be learned about it, so for the next press run, it can run more easily and efficiently. A one-page sheet of documentation should be completed by each department involved in the printing process and placed in a job ticket to be reviewed by all departments. *Table 14* details the minimum information that should be included for review.

For example, consider a print job that is mounted, with the conditions above noted, and sent to press. If there is a problem with makeready or taping, then the next time the job is mounted, the mounting technician can look at how the job was mounted before. By looking at the problem and solution section of the press condition sheet, a determination can be made if there is something else that can be done in mounting that would help the

CHECKLIST Documenting a Print Job
1. Plate type, caliper and plate condition
2. Cylinder ID and TIR (total indicated runout) of each cylinder
3. Mounting tape used for each color
5. Any makeready done for each color
6. Problems encountered and solutions

Table 14

job run better on press this time. There usually is a better way, but without the proper documentation the same erroneous mounting procedures could happen again. With the proper mounting techniques, the proper documentation and communication, print jobs will, for the most part, run with fewer problems and with better quality.

Preparing for Mounting and Proofing

The following section will outline the minimum mechanical requirements needed to achieve satisfactory results from mounting and proofing equipment. Machinery used for mounting and proofing halftone process color work requires the smallest mechanical tolerances achievable.

EQUIPMENT CALIBRATION

The following inspection checks and corrective adjustments should be carried out in the order listed to ensure proper mechanical function.

Leveling the Machine

Accurate leveling avoids proofing problems. The machine must be level along the plate cylinder pedestal-support beam and transversely across the side frames. An out-of-level machine will have a twist, causing the plate cylinder to be out of parallel with the impression cylinder. As a result, the optical mirrors will show error from left to right and the reference straightedge will not be true.

To level the equipment correctly, all foreign matter, dust and dirt must be cleaned from the machine. For side-to-side leveling, a properly calibrated and adjusted machinist's level should be placed on the top of the impression cylinder and square with the scribe line. For front-to-back leveling, the level should be placed on each of the end support frame (in many models, the level is built into these frames). The adjustable feet are raised or lowered as necessary. On older models, it is important to specifically check the level of the plate cylinder compared to the impression cylinder.

Impression Cylinder Concentricity

The impression cylinder usually cannot be adjusted within the end-support frames which hold it, and becomes the object against which all other parts must be judged. The impression cylinder must be as nearly perfect in concentricity and surface condition as possible with zero taper.

Once the impression cylinder is absolutely level, it should be checked using a dial indicator. A dial indicator, capable of showing deviations of 0.0001", mounted on a magnetic base, should be used to take concentricity readings in the middle and about 5" from each end of the cylinder.

Total concentricity run-out should not exceed 0.0005". If the excess run-out is constant, it may be possible to rotate or change impression-cylinder bearings to improve the condition.

Using an outside diameter micrometer, the cylinder is measured for taper, with readings taken every few inches along the cylinder length. Deviations should not exceed 0.0005".

Condition of Plate Cylinders

Plate-cylinder walls must be clean and free of foreign matter, including ink and grease. They should also be free of cuts, nicks, dents

or other surface damage. Plate-cylinder journals, as well, must be clean and free of surface damage. Check the concentricity of the plate cylinder using a dial indicator. The total indicated run-out (TIR) should not exceed 0.001" for line work and 0.0005" for process work. Surface nicks and scratches can be buffed out with fine 400- to 600-grit emery paper.

Note: *Each time a plate cylinder is used it should be checked for concentricity with a dial indicator before mounting. Damage which affects cylinder concentricity could have occurred since its last use.*

Check the plate-cylinder diameter and taper following the same procedure as above for checking taper of the impression cylinder. Deviation should not exceed 0.001" across the entire face of the cylinder. Normally, the diameter and taper check need only be made as new cylinders are received or as used ones are re-machined or resized to correct surface damage.

When a sleeve-cylinder system is used, the concentricity of the sleeve, the shaft and the complete assembly must be checked very closely. Each assembly and subsequent change of assembly can affect final concentricity of the plate-mounting surface.

Plate-Cylinder-to-Impression-Cylinder Relationship

The mechanical relationship between the impression cylinder and the plate cylinder must be such that repeated proofs under the same settings will yield the same results. This requires the elimination of lost motion by adjusting screws, plate cylinder and bearings, as well as any devices that hold the plate cylinders and the impression cylinder in position. Older equipment can develop excess wear and warrants being inspected for possible refurbishment.

The plate-cylinder journals and bearing supports, or pedestals, must always be parallel to the impression cylinder. Parallelism is essential to detecting nonuniform areas in the plates, such as low spots or nonprinting areas, during proofing.

A suitable method of testing parallelism on adjustable-plate cylinder models uses a mechanically correct plate cylinder, set in the normal proofing position, without a gear attached. The eccentric journal bearings on the plate cylinder pedestal are turned to the neutral position, ensuring the cylinder support pedestals are firmly locked into position and allowing no fore-and-aft play. Three 2"-wide strips of cellophane are inserted between the printing and impression cylinders, one strip at each end and one at the center. The impression cylinder is brought into contact with the printing cylinder. If plate-cylinder pedestals are motor activated, the plate and impression cylinders should be brought into contact cautiously and slowly to avoid damage.

Under these conditions, each cellophane strip should pull out with the same amount of resistance. If not, the equipment must be corrected mechanically until satisfactory parallelism is achieved.

The verticality and/or height of the plate-cylinder support pedestals may be the cause of unsatisfactory parallelism. In some rare instances, they may require shimming or re-machining. If this is the case, contact the equipment manufacturer for recommendations on remedial action.

For fixed-plate cylinder support models with adjustable impression cylinders, the test can be conducted in a similar same way, as long as the impression cylinder is in a neutrally “square and parallel” position.

Condition of Gears

Make sure the gears are clean and free of damage or missing teeth. The plate-cylinder gear must fit the cylinder journal snugly with no more than 0.002" total tolerance. The gear must not be misaligned or “cocked” when the securing set screw is tightened. It is rec-

ommended that a gear be purchased for each cylinder repeat and only used for mounting. This will help to eliminate another variable in the process.

CARE OF EQUIPMENT

The mounting equipment, impression surfaces, plate cylinders and gears are precision tools and must be handled with care and protected from abuse. It is essential that all equipment used for mounting process work is kept as clean as possible in order to maintain sharp, accurate proofs.

Daily attention should be paid to the following instructions:

- Keep all surfaces clean.
- Make sure the plate and proofing cylinder surfaces are free of any surface damage, including knife cuts. The displaced metal makes it more difficult to take sharp, accurate proofs. If an impression surface is damaged, contact the equipment manufacturer for recommendation of corrective action.
- Lubricate all metal parts that mate and move. Apply a light film of oil to all unpainted portions of the machine to prevent rust and corrosion.
- Carefully handle and clean mirrors. ***Note:*** *The semitransparent mirror coating can be destroyed by oily fingerprints and by improper cleaning. Do not use solvents that may dissolve the coating. Use only a soft, lint-free cloth lightly dampened with a mild soap and water solution or any prepared glass cleaner. Caution should be taken to avoid getting moisture between the optical bar and mirrors. Rust may develop and effect mirror accuracy. If rust is present, it must be removed.*
- Every few months, or more frequently, depending on the average hours of machine operation per day, add one or two charges of standard machine grease into the machine's grease fittings. Clean the fittings with a cloth, and remove all foreign matter before applying the grease.
- Make it a good practice to periodically wash the machine and remove all old oil, grease, ink and other substances. Any solvent that will cut the oil, grease, ink and foreign matter may be used, but take care to keep the solvents from coming into contact with the mirror viewer on the optical mounting and proofing unit.
- Check all electrical connections and wires. The frequency of these checks will depend on how often the machine is used.

UNDERSTANDING THE MOUNTING INSTRUCTIONS

A great deal of planning has gone into any job before it reaches the mounting and proofing department. It is necessary for the mounting operator to understand each step, and make certain everything is ready before mounting plates (*Table 15*). The production order must be studied carefully to ensure that the following are correct:

- The plate-cylinder repeat size is the same as the design repeat size or multiples of it.
- The reading direction of the plates (vertical, horizontal, right side up, upside down, etc.) is specified in relation to the web at the rewind. The "rewind figure" shows the possible copy positions on a given web.
- The gear-pitch diameter is the same as the plate-cylinder diameter with mounted plates in place.
- The positioning of the plates across and around the plate cylinder, i.e., the location, size and color of the eye spots, guidelines and register marks are correct.
- The side of the substrate to be printed,

PRODUCTION ORDER CHECKLIST PRIOR TO PLATE MOUNTING
Plate-cylinder repeat size
Reading direction of the plates in relation to the web at the rewind.
Gear-pitch diameter.
Positioning of the plates across and around the plate cylinder.
Side of the substrate to be printed
Number of colors, color sequence and the key color
Plate position as to bag over-wrap or other package, sealing, trimming of stock or copy bleed
Special construction specifications, special perforations and opening instructions

Table 15

either surface printing or reverse printing (i.e., printing on the underside reversed for proper reading through the film) is stated.

- The number of colors, color sequence and the key color to determine which set of plates all others will register to, and therefore, the first set of plates to be mounted is identified. The same applies to the sets of plates to be mounted second, third, etc.
- A study made of the layout, digital proof, color sketch, printed sample, blueprint, die-line layout or finished artwork to determine the positioning of plates as to bag, over-wrap or other package, sealing, trimming of stock or copy bleed.
- Special bag, carton or other package construction specifications, such as special lip, header, bag, double wall, special seams, folds, slots and special perforations and opening instructions must be noted and adhered to.

TOOLS NEEDED

The mounting and proofing department should have the following tools on hand to help in professional mounting. Of course, some tools are more essential than others, and these include but are not limited to:

- smooth-surfaced proofing paper, approximately 0.003" thick ;
- four ink braying rollers;
- sheet of Plexiglas for ink rollout;
- set of proofing inks;
- set of Allen wrenches,;
- feeler gauges;
- dial indicator and magnetic base;
- steel rule;
- ball-point pen;
- makeready tape of various thickness;
- cleaning rags;
- magnifying glass; and
- razor blade knives.

A more comprehensive list of tools appears in Appendix A.

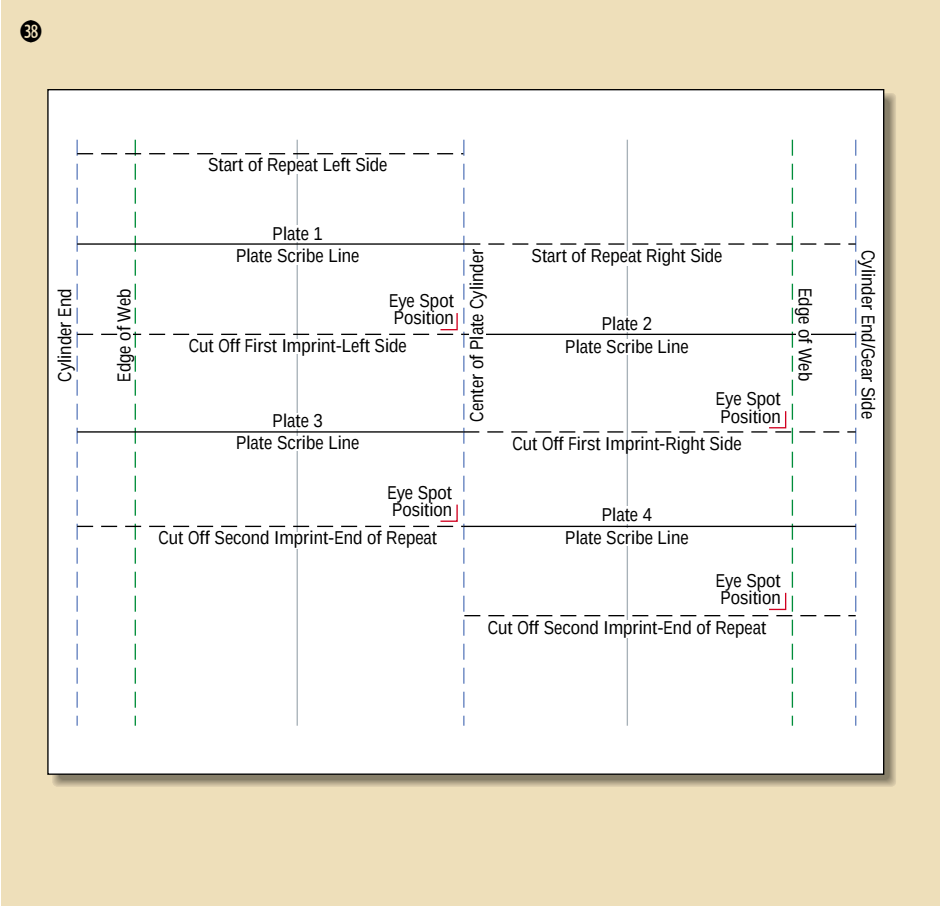
Mounting and Proofing a Complete Line Job

With clean, level, mechanically true mounting and proofing equipment that is in good repair, the specific mounting instructions of the job understood and the necessary tools on hand, the operator should be ready to begin plate mounting.

Mounting and proofing a critical process job is very similar to a critical line job. Helpful hints for accomplishing the process job will be found in appropriate steps throughout this dissertation on line work.

PLATE-MOUNTING PROCEDURES

1. Assemble all plate cylinders, gears and bearings necessary for the job and check each for correct size, mechanical fit and cleanliness.
2. Position the plate cylinder by measuring the distance between the two plate-cylinder journal bearings – center to center. Position the plate-cylinder support pedestals equidistant from the plate-cylinder bearings and far enough to the left to permit the plate-cylinder gear to align with the gear on the impression cylinder.
3. Place the plate cylinder on the cylinder supports. When possible, mount the job using the same plate-cylinder bearings to be used in the press. Move the cylinder supports inward to allow the small cylinder-support bearings to touch the plate-cylinder walls on each end. The entire assembly must allow the plate-cylinder gear and impression-cylinder gears to align. Lock the supports firmly into position. Avoid too much forward pressure as this will reduce the advantage of the anti-backlash gears of the mounting equipment.
4. When the final position of the plate cylinder is set, lock it in position allowing no free movement – either side-to-side or up-and-down. The plate-cylinder gear should now be engaged with the impression-cylinder gear; check that the plate-cylinder gear is also locked in place.
5. Clean the surface of the plate cylinder again to make sure it is free of oil, ink, grease and foreign matter.
6. Position the dividing head on the plate-cylinder journal opposite the gear end for jobs requiring multiple repeats around the cylinder
7. Apply proofing paper with the proper thickness to bring the impression cylinder on gear pitch. Most manufacturers undercut 0.003" for proofing paper. (Consult the manufacturer for the correct thickness.) The paper should be white with a machine glaze (MG) or machine finish (MF) as minimum smoothness. The surface of bleached kraft is generally too rough and irregular in caliper to disclose plate variation for high quality plate makeready. An extremely clean and unmarred surface



38 An example pf a properly drawn layout on the impression cylinder. This job calls for four design repeats.

on the impression cylinder is important to professional proofing.

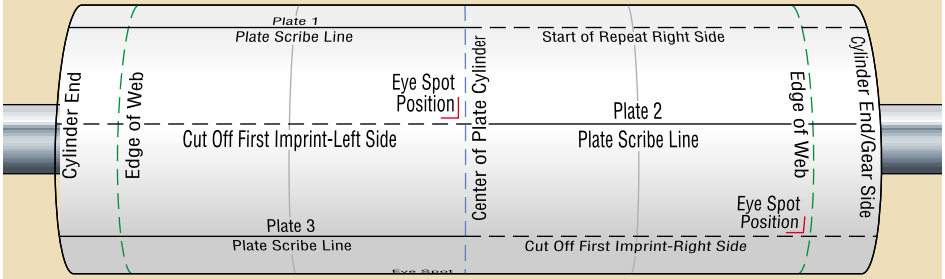
8. The sheet of proofing paper should be precut to size. Knife cuts and proofing-paper trimming must not be done on the impression cylinder.
9. Apply proofing paper to the impression cylinder with masking tape, aligning the edge of the paper with the scribe line on the impression cylinder. The paper should be pulled tight and securely taped to the impression cylinder in several places to eliminate the possibility of movement or buckling.
10. Draw a complete plate layout on an optical or mechanical mounting machine to ensure an accurate, press-ready job. Take time to mark all the information given on the job order or printing instructions. This is also another way to check plate layouts, avoiding possible mistakes. *Figure* 38 and 39, are examples of layouts, typical of a web press, properly drawn on a mounting and g machine using the built-in scriber, tape and dividing head. An example of a layout for a corrugated box is shown in *Figure* 40.

The job shown in *Figure* 38, called for four design repeats, a minimum of four plates – two across the cylinder and two around the cylinder – offset or staggered 180°. The plate-mounting operator begins the layout by setting the scribing pen to line up with the center of the plate cylinder. The scribing pen

39 A properly drawn layout on an impression cylinder.

40 A properly drawn layout for a corrugated box. All sections of the box are drawn to exact dimensions and the lead edge of the box is positioned at the top.

39



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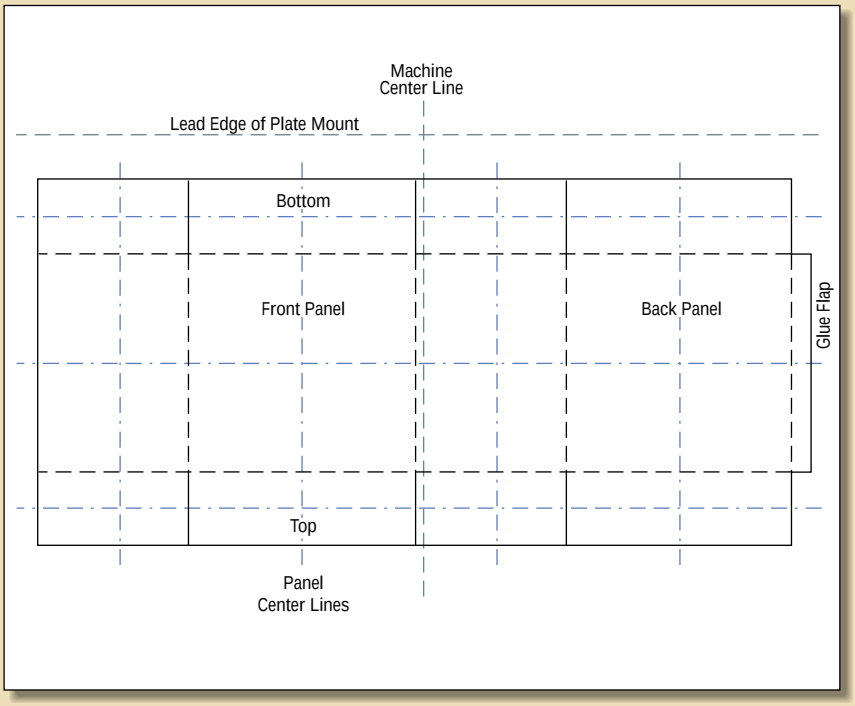


is jogged up and down to make a broken vertical line that will help to differentiate between plate centerlines and other lines drawn to complete the layout.

From the first plate-cylinder centerline drawn, the operator sets the tape measure and moves the scriber to the correct measurement to draw the rest of the vertical lines that form the layout from measurements given on the specification sheet. These lines include a line to identify the end of the cylinder, the edge of the web, the plate scribe lines and the eye-spot position.

Note: *To avoid confusion, the only solid lines are those to which the plates will be mounted.*

The horizontal lines are now drawn to complete the layout. This is done by using the dividing head mounted on the journal of the plate cylinder. No matter what the repeat of the cylinder, the dividing head will automatically space the horizontal lines on the layout to preset angular relationships around the plate cylinder. The first horizontal line represents the start of the printing repeat (broken line). This is drawn with the dividing head set at zero.

On this sample job, two plates are spaced equally around the cylinder and the second set is staggered. Therefore, the plate-cylinder repeat is divided into four intervals, 90° apart. The plate cylinder is rotated to the first number four on the dividing head and the next line is drawn representing plate 1 centerline, left side (solid) and the start of repeat right side (broken). The cylinder is rotated to the next number four on the dividing head to draw the last line or cut off the second imprint end of the repeat. Additional lines for eye-spot positions are measured and drawn, and the gear side is marked on the layout. This completes the layout. The first plate cylinder is ready for the application of stickyback.

Impression Cylinder Layout for Corrugated Postprint

Drawing the job layout for plate- (die-) mounting in the corrugated post-print industry involves drawing the layout of the actual box on paper covering the impression cylinder. (*Figure* 40)

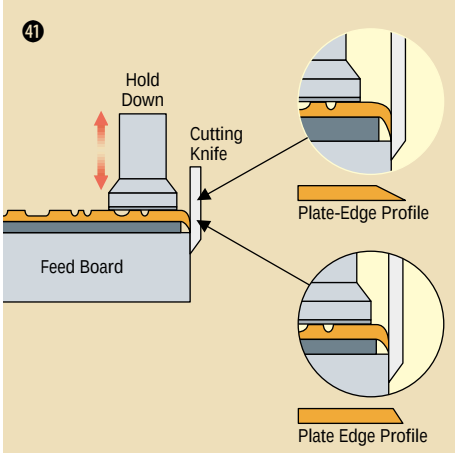
It is important to place the lead edge of the box drawing at the top. All sections of the box must be drawn with exact dimensions. On mounting and proofing machines for corrugated post-print, the plates (dies) are mounted on a plate cylinder that matches the print repeat of the press, thus eliminating the stretch compensation factor in the layout.

In some operations, when the box to be printed will be cut and creased, an acetate plot of the cutting die, or a full-size digital color proof of the images, may be simply aligned and taped to the impression cylinder. This eliminates the need to draw the layout by hand, increasing productivity and accuracy. It is important to tape the predrawn template "squarely" on the cylinder, with the lead edge of the box at the top and the emulsion-side down against the paper to minimize any effect on the cylinder's diameter.

Cleaning the Plates and Cylinders

The back of photopolymer plates should be cleaned thoroughly, removing any foreign matter or particles that, if trapped between the plate and the mounting tape, would effect adhesion or caliper. Prepare the plate cylinders and sleeves in the same fashion. When cleaning cylinders and plates, it is important to allow adequate solvent dry-time before applying the stickyback to the cylinder or plate. The same holds true for flexographic adhesives. Isopropyl alcohol works well on the cylinders or sleeve because it leaves no residue.

Use of an incompatible cleaning solvent can lead to plate-lift on press or make plate removal very difficult. If the composition of the adhesive is unknown, consult the tape



41 Using a modified sheer, beveling plate edges creates a wider surface area to apply edge sealant and also prevents the plate from lifting during a pressrun.

supplier to ensure that the cleaning solvent is compatible with the cushion adhesive.

Photopolymer plates processed in new "safe solvents" must be cleaned thoroughly before being light finished and prior to mounting on the cushion adhesive. These wash-out solvents can leave an oily residue on the back of the photopolymer plate, which will cause plate-lift on press.

Trimming and Preparing the Plate Edge

Whether rubber or photopolymer, finished plates must be trimmed accurately before mounting. The preferred method is to use a plate cutter or foot shear. If a knife, however, is used, the cut should be made from the polyester backing side of the plate. Edges must be smooth and free of nicks and burrs.

Beveling all sides of the plate is desirable because it helps keep the plate from lifting during the pressrun, in addition to providing a wider area to apply edge sealant. Beveling may be done by securing a rigid material on the bed of the plate cutter or foot shear (*Figure* 41). Place the finished plate on top of the rigid material and press firmly to trim. This flexes the edge of the plate allowing a neatly beveled cut edge. The position and height of the rigid material determines the bevel angle.

Applying the Stickyback

Double-sided adhesive film, or stickyback, is used to secure the plates in position on the plate cylinder or carrier in either of two methods. In the first, if the job calls for only a few small plates – each no longer than one-fourth the plate-cylinder circumference – the stickyback may be applied directly to the plate and then the backed plate may be applied to the bare cylinder. If compressible stickyback is used, it should be permitted to extend beyond the plate about 1" on all sides.

When multiple plates, spread over much of the cylinder are being mounted, it is expedient to cover the entire layout area of the cylinder with the stickyback and then position and apply the plates to it.

Stickyback should be applied to the cylinder first when mounting individual plates longer than one quarter of the cylinder circumference. This will prevent plate buckling caused by the stickyback bunching when the plates experience curvature growth at different rates. This is especially important in process work.

The second method is to apply the stickyback around the entire cylinder. If using double-backed stickyback (protective sheet on both faces), approximately 6" of backing along the leading edge should be removed; then, holding the entire piece with the side edge as square with the cylinder as possible, position the leading edge on the cylinder about 0.5" above the horizontal lead-edge scribe line. Gradually remove the remainder of the backing sheet from below the stickyback. While rotating the cylinder, smooth and press the stickyback firmly into position all around the cylinder. If using single-backed stickyback (protective sheet on one face only), use a clean, undamaged piece of discarded coversheet to prevent premature adhesion to the plate cylinder.

Using the grooved scribe line in the plate cylinder as a knife-blade guide, trim the leading edge of the stickyback straight. Then

press the overlapping trailing end down firmly over the leading edge groove and trim the overlap to make a perfect butt joint. The dividing head, or the impression cylinder drag brake, can be used to hold the impression cylinder in position while trimming the stickyback. At this point the protective cover should still be on the top side of the stickyback.

Stickyback and plate-trimmng devices are available which attach to the mounter and can produce accurately angled butt joints.

When a single-roll width of stickyback is not wide enough to cover the cylinder, a second or third width can be butted to the first, all along its length and completely around the plate cylinder. Working from one end of the cylinder, the first width should be laid with its side parallel to the cylinder end to avoid an increasing spiral. A circumferential scribe line, or a measured and drawn line, may be used as a guide.

The lamination of the stickyback on the plate cylinder should be thoroughly inspected to ensure foreign particles or air are not trapped between the cylinder and adhesive. Small air pockets may be pierced with a pin to release air and then smoothed out.

Zoning

When printing repeats with large coverage, “zoning” the mounting tape prior to removing the liner facilitates easy tape removal from the plate cylinder once the print is complete. Simply put, zoning involves using a precision knife to turn one large section of mounting tape into several smaller sections by following a select number of horizontal and vertical scribe lines in the plate cylinder. These recessed scribe lines facilitate accurate incisions and prevent the formation of burrs on the surface of the plate cylinder.

Framing and Priming

Framing and priming the back of the plates helps in eliminating plate lift. Framing is accomplished by masking the outer 1" border of the plate with a removable tape (prior to applying a release agent to the back of the plate). Once the release agent has been applied and sufficient dry time has been allowed, the framing tape is removed from the back of the plate to expose the uncoated section. This uncoated border section of the plate will have a higher level of adhesion to the mounting tape.

Priming consists of applying a proprietary solution to the underside lead and trailing edges of the plate. This facilitates a very high level of adhesion along the edges, greatly reducing the plate’s tendency to lift on press

Matching Plate Thickness

For jobs requiring the mounting of two or more complete design repeats across or around a cylinder, it is necessary that all plates mounted on the same cylinder be precisely the same thickness. Variations of just 0.00l" to 0.002" can make a visible difference in the final printed product, especially when printing critical line work on smooth substrates and certainly in process work. This tolerance in thickness cannot always be achieved among plates to be mounted on one cylinder, especially within economic constraints. In these cases, makeready techniques need to be used to achieve the required thickness uniformity. Thinner plates need to be built up with makeready tape to match thicker plates.

An alternative makeready technique is illustrated by the following example:

Assume the job calls for a total of six plates – three images across and two around. Each plate has less than 0.001" thickness variation. The total plate-to-plate variation is 0.002", more than the normally acceptable tolerance. The six plates should be carefully gauged. This means taking readings in many places (for process plates, perhaps every square inch). The average gauge is then calculated for each plate. The plates

can then be positioned to print acceptably with minimal makeready by grouping the two thickest plates on the right (gear) end of the plate cylinder, the two thinnest ones on the opposite end and the remaining two in the center position.

When proofing, the impression is set to print the two thickest plates with a near-skip impression. Using the parallel eccentric, the left (operator's) end is then moved in until the two thinnest plates print. With a little trial and error, acceptable results may be achieved with no additional makeready.

Note: *After mounting, the parallel eccentric must be reset to the original position.*

MOUNTING THE FIRST SET OF PLATES

The first set of plates should be mounted over the butt seam of the stickyback to prevent the horizontal ends of the seams from lifting during the run. Rotate the plate cylinder until the butt seam is positioned near the top. Remove a 1"-wide strip of protective liner from the stickyback in the area of the horizontal center of the first plate. The center lines should be extended on photopolymer plates (before register marks and center lines are cut off the plates) by aligning a straightedge with the horizontal and vertical marks and drawing an accurate extension of these across the plate in the nonimage area.

Position the plate on the plate cylinder, making sure that the horizontal and vertical scribe lines in the nonimage area of the plate correspond with the lines drawn on the proofing paper. This is done by looking through the viewer on the optical-type mounting and proofing unit. With the mechanical type unit, use the mounted straightedge and markings.

When the two scribe lines are in position, tap the plate gently onto the stickyback to set the position of the plate while avoiding excess pressure. Check the alignment of the plate to ensure that it is in perfect position. When positional accuracy is acceptable, the remainder of the stickyback protective liner may be removed on the portion nearest to the operator, allowing the plate to fall gently down. The plate should be smoothed out as it rests lightly on the stickyback. Take care not to trap air bubbles between the plate and stickyback. If air bubbles are seen or felt by hand, lift the plate free from the stickyback, wipe out the air bubbles, and smooth down the plate. Then reapply the plate to the stickyback. The same procedure is repeated to lay the opposite side of the plate nearest the impression cylinder. Before proceeding, the plate should be checked to make sure it is in perfect alignment with the layout guidelines. Repeat this operation with each of the other plates for this color.

Note: *Mounting plates from the center first, rather than the top edge, reduces by half any alignment error that may occur.*

The larger plates with a great deal of printing area, specifically solids, should be mounted first because they are generally less prone to distend or distort as they are laid. This first plate mounted becomes the key plate providing the location for all the others. For film printing, the key plates are usually the white plates; for paper printers, they are usually the black. When very tight register is required, particular care must be taken when positioning the key plate. If there is more than one color with large coverage, it becomes a matter of selecting the more important plate to become the key plate.

When mounting thin-molded rubber plates, no plate with a solid print area should be "stretched" in order to fit an image. Stretching of the rubber will create thin or low printing areas in the plate. Conversely, with rubber plates that have a scattered or sporadic image area, it is acceptable to stretch corresponding colors to fit an image in the solid plate because the stretching takes place in the nonprinting areas.

There may be times when it is necessary to cut plates apart in order to achieve accurate register. This can only be done when the copy is broken up into small sections, as with minor colors.

MOUNTING FOR CORRUGATED POSTPRINT

For flexographic corrugated postprint applications, it is common practice for several small pieces of printing plate (slugs) to be positioned on a single 0.030"-thick carrier sheet, which is then attached to the print cylinder of the press. With changing technology, some operators mounting for corrugated postprint use stickyback to hold plates to the carrier or backing sheet. Many, however, still use a brush-on adhesive. High quality printing requires careful mounting to minimize plate thickness variation on a given printing cylinder, whatever the cause. If the film thickness of a brush-on adhesive is not controlled, it will affect the overall plate height on press.

Reduce the adhesive to the recommended viscosity, so that brush marks will flow out, producing a smooth, even coat. Apply thin, smooth coats to both the backing sheet and the plate. Allow both surfaces to thoroughly dry, in order to achieve the maximum bonding strength, before mounting the plate. Remove all previously applied adhesive from the cylinder, backing sheet or used plates, before re-mounting.

When using stickyback to hold plates to the backing sheet, take care to ensure that no pieces of paper, dust or trash are trapped between either the cylinder and carrier sheet, carrier sheet and stickyback or stickyback and plate.

PROOFING THE FIRST SET OF PLATES

When proofing the first set of plates, cover the comprehensive proofing paper, showing the layout, with clear 0.004" to 0.005" acetate and tape it in position, making sure there are no wrinkles or movements. This will enable a proof to be taken over the laid out comprehensive proofing paper, to check the position and printability of the plates, without destroying the original layout.

Note: *When mounting in register and proofing, the impression cylinder should be rotated in the same direction for all colors.*

If the first plates down are not positioned correctly, they can be moved and proofed again. The first proof can be washed off the acetate with a lint-free cloth and water or solvent. If all plates print up fully with acceptable impressions, then the acetate sheet can be removed and the proof taken directly onto the comprehensive proofing paper carrying the job layout. Move the impression and plate cylinders closer together a distance equal to the acetate preproof thickness, to ensure the same impression on the comprehensive proof layout paper as was obtained on the preproof acetate.

A thin, uniform film of ink should be applied to the plates for each impression made. This is achieved by first rolling out the ink using a brayer on a sheet of Plexiglas to a minimum film of ink – just enough to fill the grain of the paper. The ink is then applied with the brayer to the surface of the plate to be proofed.

Once the first color plates are mounted and proofed and after the ink has dried, tape a sheet of acetate over the comprehensive proof. This will protect the proof during mounting of the second color plates and also provides a surface for a trial proof of the second color over the first. The first plate cylinder may now be removed.

When using an optical machine, the best register is achieved by matching the designs into each other. The scribe lines can also be used, but only as a check for the second color. With a mechanical-type machine, the

BENEFITS OF PRESS-RELATED PROOFING
Press downtime will be reduced
Waste will be reduced
Quality will improve
Production will be better

Table 16

same marks and divisions used on the first color should be followed. The plates should be inked and the second color proofed on the transparent sheet overlaying the comprehensive proof of the first color.

Next, check the register of the two colors. (Corrections may be readily made by lifting and repositioning the plates and pulling another trial proof if necessary). Re-ink the plates, remove the transparent sheet, move the impression equal to the thickness of the acetate preproof, and pull the proof of the second color directly on the proof of the first color. Repeat this procedure for the other colors.

The recommended proofing ink is a water-based paste ink that does not readily dry and harden on the brayer, but dries quickly on the paper and can easily be washed from the plates and acetate. The ink rollout slabs may be washed with water. If necessary, alcohol may be used to remove dried ink. Cleaner proofs are obtained when ink slabs and brayers are kept clean.

For a detailed procedure on a specific make and model proofing machine, consult manufacturer.

PROOFING FOR PRINTABILITY

Described here is a procedure that can best be called “proofing for printability” or “press-related proofing” (*Table 16*). Skills developed in the proper use of this technique make it possible to detect and correct potential printing problems off press, achieving a number of benefits:

- Press downtime will be reduced, since the press operator will not have to do plate makeready on the press to eliminate high and low spots.
- Waste will be reduced. Less print stock will be required for setup and less wasted during running because of unsatisfactory printing.
- Quality will improve. Where multiple plates (per color) around and across the cylinder are being printed, conditions in which some plates are producing satisfactory printing, while others on the same cylinder are printing with an insufficient or an excessive amount of squeeze or ink, will be eliminated.
- Production will be better. With fewer press stops, efficiency will increase, resulting in more production with less effort.

Steps to Proofing for Profitability

Proofing Paper. Choose a proofing paper with the smoothest surface and least thickness variation. The thickness should be sufficent to increase impression-cylinder circumference to match the gear pitch circle. Although 0.003" undercut is common for many mounter-proofer manufacturers, this dimension should be checked. Using a 50# supercalendered paper is suggested.

Securing the Paper. Make sure the proofing paper is secured to the impression cylinder very tightly and snugly.

Proofing Ink. Use a water-based, glycol or oil-based ink, compatible with the plate material. The ink should be high in color strength, of thin paste consistency, and moderately fast drying (it should be fast enough to dry on the proofing paper within half to three-quarters of an hour after the impression is made), but slow enough not to dry on the plates until the proof can be pulled.

Palette or Roll-out Surface. Spread the ink onto a sheet of 0.25" acrylic or glass as thin-

ly and as evenly possible, using the brayer roll. A sheet of white paper should be placed under the transparent roll-out surface to show the ink film applied. Keep the surface and entire area clean, allowing only a minimum of ink on the surface.

Note: *Use a brayer or roller that is concentric, with no damage or dirt on the surface. The rubber covering should be about 50 Shore "A" durometer.*

Inking the Plates. Practice is required to achieve a very thin, strong, even coat of ink on the roll-out glass, brayer roll and the mounted printing plate. The proper amount of ink applied to the plate should be sufficient to just fill the grain of the proofing paper. Too little will show the white of the paper within an area of supposed ink coverage, whether a large solid or a small halftone dot. Too much will show excess pile-up, either on the face of solids and dots, or outlining the solids and dots. Extreme excessive inking will cause bridging from dot to dot and small-type characters will fill in and not be crisp or sharp. Examine the ink coverage under a 20x magnifier to see that it is right.

After Inking. After the plates are inked, re-examine the surface for evidence of brayer marks, either of stops and starts or of brayer edges – small ridges of ink. To remove any brayer marks without adding more ink, roll a nearly dry brayer over the plates repeatedly, thereby smoothing out the ink.

Paralelling the Plate Cylinder. To ensure accurate proofing, the plate cylinder must be parallel to the impression cylinder. Using a feeler gauge equal in thickness to the total of the ideal plate and stickyback thickness, place the gauge between the bare plate cylinder and against the proofing paper that is taped to the impression cylinder. Bring the plate cylinder and impression cylinder together until the gauge can be removed with minimum drag. Gauge the opposite end and the middle to make sure that drag resistance is identical at all locations. If it is not, then the machine must be reset before mounting.

42 Establishing zero contact requires that all parts of all plates on a given cylinder print up with a thin, strong, continuous film of ink. No portions can exhibit signs of skipping or partial ink transfer, and no portions can meet so high as to over-impress and distort the image.

Establishing Zero Contact. Even the most perfect plate, stickyback and plate-cylinder combination will have some minor variations in concentricity and printing height. The goal is to have all parts of all plates on a given cylinder print up with a thin, strong, continuous film of ink, with no portions skipping or partially transferring ink, and no portions so high as to over-impress and distort the image. When the plates are properly inked, bring them into gradual contact with the paper by rotating the print cylinder with an oscillating movement. When the first visible ink is transferred (*Figure* 42), roll a complete proof. "Zero contact" is that distance between the plate cylinder and the impression cylinder that permits some small amount of the total plate area to print up on the proofing paper.

The mounting operator needs both judgment and skill to achieve viable zero contact. When proofing a cylinder mounted with multiple plates, a single spot of printing on the proofing paper must be considered a high spot and not a zero contact. On the other hand, four or five large areas beginning to print up on the proofing paper, may be considered excessive for zero contact, unless they are exactly the same area on multiple plates.

Setting the Gauges. Having established zero contact, set the impression gauges on the mounting and proofing machines to zero.

Obtaining a Complete Print. When proofing a set of mounted plates, the goal is to get all the print areas, on all the plates mounted on the cylinder, to print completely with the least possible additional impression of the plates to the impression cylinder. For process work, this should be minimal, generally within 0.001" additional impression.

Impression Tolerances. It is difficult to generalize what constitutes good and bad impression tolerance because of the diversity of plate thickness, mounting foam thickness and other materials used in the vast field of flexographic printing. Corrugated postprint presses may use printing plates with 0.280" of total mounting thickness, while small label presses may only have 0.067" total undercut. As a rough guide, a compression of the plate material and mounting foam equal to 2% of their total thickness should be sufficient to proof print the images on the plate.

On a typical press undercut for 0.125" additional impression from zero of 0.002" may be the difference between good, sharp printing and a completely unsatisfactory job. This 0.002" additional impression may produce halos and fill-in while the job is being run. The maximum allowable impression may be different from one type of plate to another or from one kind of print copy to another. All large solids and large type will permit more impression before distorting than will small type, mechanical screens or halftone process work.

Inking should always be consistent in film thickness. However, if the plates on the same cylinder contain both larger solids and type and small type or dot work, then the maximum tolerable impression is that amount just before any of the copy becomes distorted or enlarged with over-impression.

For process work, color keys made from the finished negatives can serve as a goal for ideal small-typeface appearances and ideal halftone dot sizes in highlight, midtone and shadow reverses.

Areas of poor or no ink transfer, known as skip-outs, are a possible indication of low areas that need to be built-up with make-ready to print up without additional impression squeeze. False skip-outs may be caused by incomplete plate ink-up, ink dried on the plate before transfer, or low areas in the proofing paper itself (usually not over 0.0005"). These last three possibilities should be checked before using makeready by re-inking the “skipping” area, rotating the impression cylinder to a clean area on the same paper and pulling a partial proof at the same impression reading.

PREPRESS MAKEREADY

If several portions on all plates do not print before the highest plate areas distort, two options are available: raising low areas, or lowering high areas.

Note: *The following procedure is not recommended for process work. Plate cylinders, bearings, stickyback and plate-thickness variables for process work need to be hand picked, measured and controlled so that the whole plate area will print without visible image growth or distortion.*

Lowering High Areas

When using nonfoam or noncushion stickyback, and with line work of various configurations, the impression cylinder may be utilized as an accurate smoothing and leveling device.

Remove all ink from the plates and with about 0.010" to 0.012" additional impression from zero, rotate the plate cylinder against the impression cylinder. This may “set” the plates at the high points into the stickyback and level them out.

Clean and re-ink the plates, find the new zero contact (as it will likely be farther in than the first contact because higher areas have been lowered) and reproof the plates. If the condition has improved but some areas still do not print, the procedure may be repeated with more impression, perhaps 0.0015" without damage to the plates.

If the setting of the plates into the stickyback fails to produce acceptable results, the plates must be removed from the cylinder and another makeready technique applied.

If the irregularity was not found in premounting quality control of plates and cylinders, the variation could be due to stickyback or plate-cylinder surface variations, which are not discovered until initial proofing on the mounter. The following procedure may produce acceptable results.

1. Clearly outline the area needing correction. Lift the plate from the stickyback by the end closest to the high plate area until the backing substrate behind the area is exposed. Take care not to distort or crinkle the backing or move the plate from its registered position. Isolated high spots in photopolymer plates can be successfully lowered by as much as 0.002" by manually sanding the backing substrate.
2. Best results are obtained by removing the plate from the cylinder and laying it face or image area down on a smooth, flat surface. The high spot should be clearly identified and outlined and, using a small piece of #400-grit wet or dry finishing paper, gently sand the plate backing substrate within the outlined area.
3. Finish by feathering the outer perimeter of the sanded area. Be sure not to remove too much material from the backing sheet as this will cause a low spot. Check your progress periodically with the plate micrometer.
4. To avoid removing excessive film, periodically lay the plate back down and reproof it. At best, this is trial and error, but with practice and observation, judgment and skill will improve. As a result, otherwise questionable plate/cylinder relationships may be greatly improved.

This procedure has also proven helpful in softening dots in vignetted areas of process work. Although slightly more difficult to sand, similar corrective action can be accomplished with rubber and other synthetic plate materials.

Building Up Low Areas

There are several ways of building up nonprinting areas or low spots in the plates.

Large low areas, or areas that do not print up satisfactorily, after lowering the high areas as discussed above, can be raised by partially lifting the plate from the stickyback, applying a thin coat of liquid adhesive to the back of the plate in the low areas and resetting the plate on the stickyback.

Use a liquid adhesive from the plate manufacturer or plate-making material supplier, or common rubber cement which is satisfactory for this purpose. Dilute the cement with the recommended solvent, then apply with a clean brush in several thin layers, allowing each layer to dry in turn. There is also the possible danger of swelling the plates. If the cement is applied too heavily, remove the excess adhesive. Use a flat, wide brush on larger areas and a round brush for smaller areas. Common shellac can also be used for the same purpose; the buildup of each coat of adhesive will vary with viscosity.

Another alternative to raise low areas in the plate is double-sided adhesive tape, which is available in various thicknesses, ranging from 0.0009" to 0.005". Experience with these techniques will make it possible to determine very quickly, when looking at a proof, just how much cement, shellac or tape is required to build up a low spot.

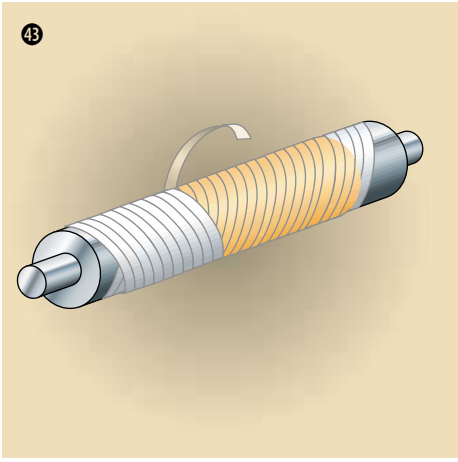
Composite Proof

After each cylinder has been proofed and made ready as outlined above, a composite proof of the entire job is made. As a guide to the press operator, the composite proof should be marked with the total amount of impression required for each cylinder to obtain a complete print up of all plates.

Any failure to get the same results on press probably means the printing equipment or the mounting and proofing machine needs maintenance. Proper interpretation of the handmade proof requires the understanding that plate flaws or printing irregularities unacceptable on the press will not be nearly as obvious. Close inspection is required. One of the most important functions of the mounting and proofing operator is to read the final proof for correctness of copy and freedom from errors. The final proof should be folded into the finished product to verify that all copy is in the right place on all panels before the job is passed to the pressroom for printing.

Edge Sealing

If the job is mounted for a long run or for repeated runs, tape down or cement all plate edges. This will prevent inks or plate-cleaning solutions from working under the plate edges and dissolving or otherwise destroying the adhesive or cushion. There are special edge-sealing cements available for this purpose. Any good plastic adhesive tape will also suffice. All edges and ends must be rubbed down thoroughly.



㊸ Low density polyethylene film is wrapped in a spiral manner around the cylinder from one end to the other. Each winding overlaps the other, and then is reversed to crisscross back over the first layer of winding. Wrapping the mounted cylinder this way eliminates captive air pockets and assures a firm complete bond between plate, stickyback and cylinder.

Cleaning

After completing the mounting and proofing, carefully wash and dry the printing plates. Wash molded plates thoroughly with alcohol and photopolymer plates with a mild solution of soap and water. Grease spots, finger marks and other foreign matter on a plate can repel ink from the print surface and make it appear that the plate is not printing properly. Proofing ink left on the plate can cause fine type and dot work to build up ink on press and cause dirty print, especially if the proofing ink is oil-based and the press ink is water-based.

Wrapping Mounted Cylinders

One way to assure a firm, complete bond between the plate, stickyback and cylinder, and to eliminate captive air pockets, is to wrap a low density polyethylene film (about 2.5" wide) around the cylinder, completely covering all plates mounted on it. Wrap the tape around the cylinder in a spiral manner from one end to the other, with each winding overlapping the other, and then reversed to crisscross back over the first layer of windings (*Figure* ㊸). Keep the tape tension tight, but not too tight to compress the plates, possibly creating highs and lows. Secure the tape end with a pressure-sensitive tape or by tucking it under one of the last turns. The wrap should remain in position at least several hours, overnight if possible, but not more than 24 hours. Mark the over-wrap with the color, press number, station or deck number, plus any other helpful information to identify the job.

ADDITIONAL OFF-LINE TIME SAVERS

To reduce downtime and waste during a job set-up on press, there are several additional steps that can be taken while the job is in the mounting and proofing machine.

Web-edge Guide Marks

To identify the precise edges of the press web, mount two small plates in the trim area. The plates have a printable line about the thickness of a pencil line (1 pt.) and about 0.125" to 0.25" long. From these printed lines, the press operator can quickly see where to establish lateral web position in relation to the copy and be assured the edge guide is holding it in place during the run.

Web-trim Mark

When a web-stock slightly wider than that required for the job is printed, and a selvage edge must be trimmed, a small plate is mounted (as above) to identify the correct location for the trim knife. This permits the press operator to set the knife quickly and accurately, and to check its position on each roll change, web break or stock-width variation.

Slitter-knife Marks

The same principle can be applied in locating multiple-up slitting-knife locations. It assures quick knife positioning at setup and is a constant reminder of any knife slippage or web deviation.

Bag-folds, Former-guide Marks

After multiwall bags are printed, the web is folded into a tube in which formers are set to create side folds and gussets. The web-marking principle can be applied to locating the formers. The small marks are located at bag cutoff and will not be visible in the finished bag. The final proof, containing all of the above information, is used to check the job thoroughly for just about every possible requirement, except the actual color.

Recent Introductions in Mounting Equipment Systems

Mounting systems designed and developed for the flexographic printing industry, have enhanced the accuracy of prepress plate positioning in registration. Press time has been diminished as a result. This section discusses the components of the different mounting systems on the market today, as well as the advantages of the process and the preparation practices necessary to the success of these latest technololgies.

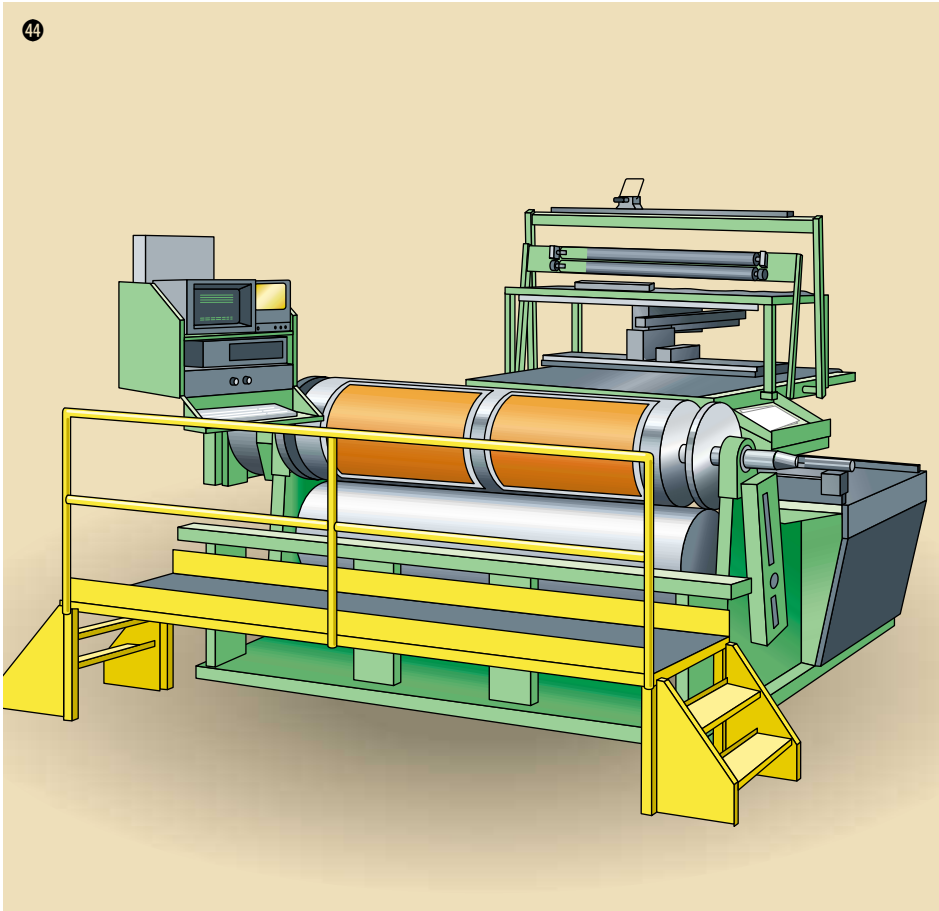
COMPUTERIZED MOUNTING AND PROOFING SYSTEM

Computerized mounting systems were introduced to the flexo industry for both wide-web substrates and corrugated preprint liner in recent years. These mounting systems are available in a range of sizes for plate cylinders, from 60" to 120" with associated cylinder-repeat sizes (*Figure* 40). The systems do not use conventional pins or punching of plates and negatives. They use conventional stickyback for holding plates to sleeves or integral printing cylinders.

Accurate registration is aided by microvideo cameras and monitors that magnify register marks 30x to 40x actual size for visual alignment, making it possible to position plates across and around a given cylinder to within a tolerance of 0.002". All preliminary functions are programmed into the machine, allowing the operator to complete the plate-mounting process rapidly.

The following is an abbreviated series of procedural steps for operating the system:

1. Select the proofing paper or other proofing material and place it on the impression cylinder. This may be done manually or automatically.
2. Bring the printing cylinder into position and lock in place. Apply stickyback to the plate cylinder, either automatically or manually.
3. Lower the plate hold-down table ito a predetermined position relative to the plate cylinder.
4. Place the plate on the hold-down table, allowing a portion of the plate to hang over the front edge of the table. Turn the vacuum on to hold the plate in position to the table.
5. Move the microvideo camera over a defined register mark on the plate and enter the position into the computer. Locate a second register point on the plate and enter this into the computer.
6. The computer determines the position of the plate on the hold-down table and moves the table to bring the plate square with the cylinder face. Position the plate relative to the centerline or any designated point on the plate cylinder.
7. Two pressure rollers contact the overhanging portion of the printing plate, attaching it to the stickyback and holding it in place while the vacuum is shut off.
8. As the computer rotates the plate cylin-



44 Computerized mounting and proofing systems were introduced to provide greater accuracy and efficiency. They use conventional stickyback for holding plates to sleeves or integral printing cylinders, instead of pins. Punching of plates and negatives is not necessary.

der, the pressure rollers gradually apply the plate to the stickyback and the plate is mounted.

9. The plate is inked and proofed. The proofing cylinder moves down and away, allowing the plate cylinder to be removed and the next cylinder brought into position.

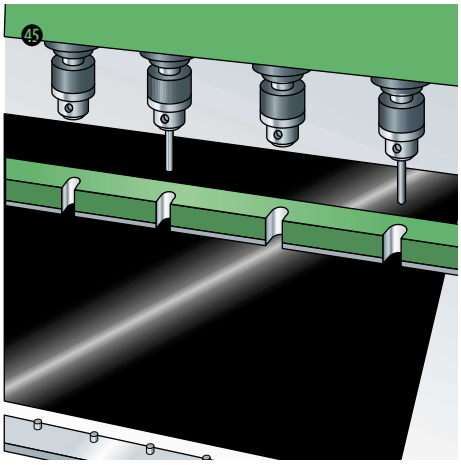
These steps are repeated with each plate to be mounted, substantially cutting mounting time, especially in three- or four-color process work.

PIN-REGISTER MOUNTING SYSTEM I

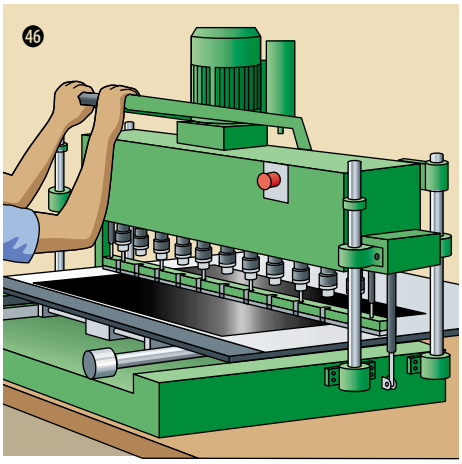
Pin-registration systems have been used for many years in letterpress and offset printing. Adaptation of these methods to flexography has not been easy in the past because of dimensionally unstable rubber plates and the large cylinder inventories used for variable repeat lengths in packaging markets. Availability of dimensionally stable photopolymer plates allowed pin registration to become a reality in flexographic printing.

Operating Principles

The pin-registration system, used in other printing technologies, consists of producing accurately sized and positioned holes for registration pins. In practice, this usually involves punching holes in the films, plates and press cylinders, and positioning these materials on register pins during all steps of



45 The initial step in pin mounting requires determining the hole locations and removing the unwanted drill bits.



46 After the hole locations are determined, the plate-making films are positioned over each other and pin-registration holes are drilled.

the film, plate- and press-mounting process. Thick, elastomeric flexographic printing plates do not punch easily – especially in the uncured state; with liquid photopolymers, it is practically impossible. As an alternative, drilling plates has been found to be a suitable method. In addition to drilling the plate material, a procedure is required to use pin registration during the mounting operation without extensive modification to the press cylinder. One solution is to mount a temporary pin-registration bar on the printing cylinder.

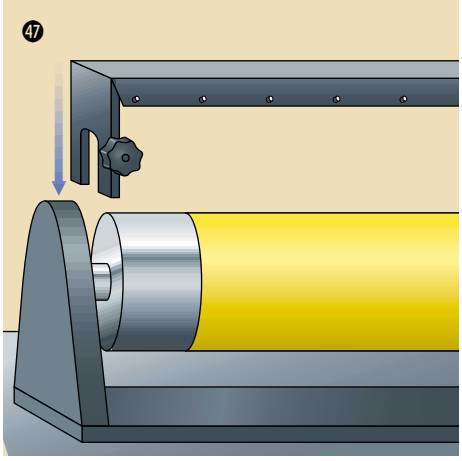
System Components

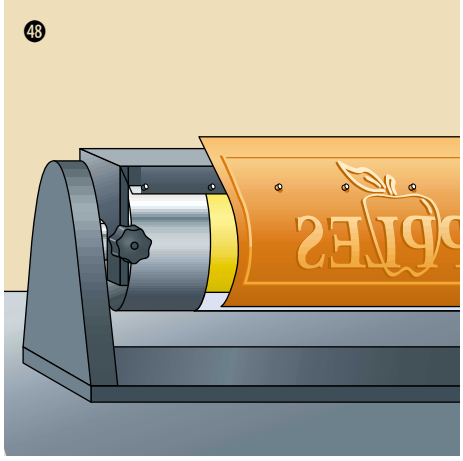
A pin-registration system for sheet photopolymer plates consists of two parts: a film and plate drill, and a registration bar. The film and plate drill (*Figure* 45) is used to place up to 11 registration holes in a line across the film and plates. The drill can be positioned to avoid drilling holes in image areas, and individual drill bits can be removed. The standard drill table accepts plates up to 41" but can be modified to accept wider plates.

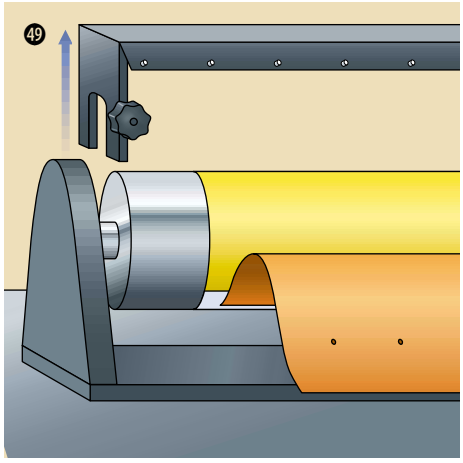
The second part of the system is the registration bar. This is a portable bar that clamps securely to the printing cylinder. Registration pins on the bar are aligned with the holes drilled in the plates. Plates mounted on these pins are in precise alignment with the cylinder. Registration bars are available up to 112" wide with either fixed or sliding pins.

Preparation for Pin Mounting

1. Select hole locations for drilling the film, avoiding any image areas. A composite proofing film that has been exposed to show all printing plates on one film helps in this step. Remove any unwanted drill bits (*Figure* 45).
2. Assemble plate-making films in position over each other. Align plates by the registration marks made during the film preparation step.
3. Drill pin-registration holes in the assembled plate films simultaneously while they are held in place by the reigstration pins in the punched holes used during the film preparation steps (*Figure* 46). During this step, a transition is made from the punched film-register system to the drilled plate-register system. This is a critical step.
4. The printing plates are prepared for drilling. Cut the individual plates to size for each color, then back expose to produce smoother drilled holes. The imaging face is not exposed.
5. Drill pin-register holes in each of the prepared plates, one at a time.
6. Position the drilled plate and negative together on the registration pins for exposure.







47 Accurately aligning the pins onto the registration bar of the plate cylinder requires the bar to be attached to the plate cylinder by clamping the bar end-plates to the bearing surface of the plate cylinder shaft.

48 The next step requires smoothing the plate down onto the sticky-back

49 In this final step, the pin registration bar is removed from the plate cylinder.

7. Use the standard plate-making procedures for sheet photopolymer plate-making to process the plates.
8. Repeat steps 6 and 7 for all plates for the job.

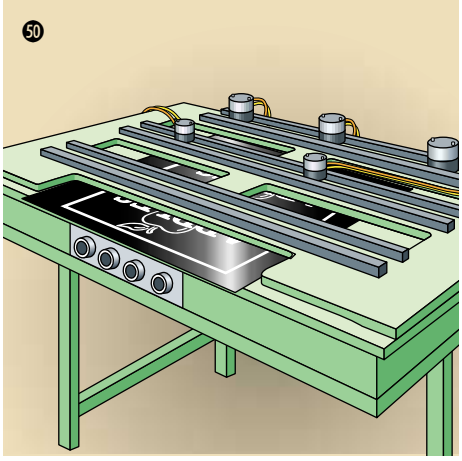
Procedure for Pin Mounting

Pin-registration bars can be used for mounting to the plate cylinder either on the mounting and proofing machine (if an inked proof is required before going to press), or on the cylinder rack (if no proofing is required). The following procedure should be used:

1. Attach the registration bar to the plate cylinder by clamping the bar end-plates to the bearing surfaces of the plate cylinder shaft (*Figure* 47). This accurately aligns the pins on the bar to the plate cylinder.
2. Select the required drill-hole locations and remove unused pins from the registration bar.
3. Apply stickyback to the plate cylinder in the conventional way, then remove a small portion of the backing paper.
4. Position the printing plate over the pins on the bar.
5. The plate should then be held tightly between the bar and the plate cylinder while contact is made with the sticky-back.
6. Smooth the first portion of the plate down onto the sticky-back (*Figure* 48). Remove the plate from the pins, then remove the pin registration bar from the plate cylinder (*Figure* 49).
7. Remove the rest of the backing sheet from the sticky-back and smooth the plate onto the plate cylinder.

Advantages of Pin Mounting

Pin mounting provides fast, easy, accurate mounting. Complex, normally time-consuming mounting jobs can be reduced to a few minutes per cylinder. It is especially advantageous in permitting accurate mounting of one large plate per color carrying many small repeats, resulting from step-and-repeat imaging techniques. This process eliminates



50 In this pin-register system, the film is held flat and immobilized on the vacuum table, while holes are punched within an accuracy 0.001" by a precision, air-actuated punch.

the time and registration difficulty of mounting many small plates per cylinder.

Pin mounting minimizes differences in labor-intensive conventional mounting methods and reduces press setup. Mounting times are multiplied as jobs are rerun.

Even when using a pin-mounting system, however, proofing for accuracy and makeready is still recommended.

PIN-REGISTER MOUNTING SYSTEM II

This registration system combines the accuracy of pin registration with the versatility of computer-controlled micro-video cameras for locating imaged register marks. The system provides for the alignment of the plate cylinder, preplate positioning, punching or drilling of negatives or photopolymer plates for accurate register and mounting.

The technology for negative and printing-plate alignment is adapted from the same registration techniques used in the electronics industry for aligning multilayer printed circuit boards. The equipment includes a planning grid sheet, target punch, optical plate punch, plate mounter and pin-bar mounter. The plate mounter is adjustable for various sized cylinders.

System Components

A planning grid sheet, which consists of a 30" x 40" polyester sheet, is laser-plotted with 37 intersecting lines spaced in 1" increments. The intersecting grid lines are identified by numbers and letters along the side and bottom margins. Along the top edge is a series of five punched slots, one vertical, flanked by two pairs of horizontal slots.

The film is then punched using a target punch, a precision, air-actuated film punch (target punch) that creates target slots in the negative at any selected grid line intersecting point with an accuracy within 0.001" (*Figure* 50). The vacuum table holds the film flat and immobilized during punching. Original art and negatives for new jobs, as well as existing negatives in inventory, are target-slotted for pin-register platemaking.

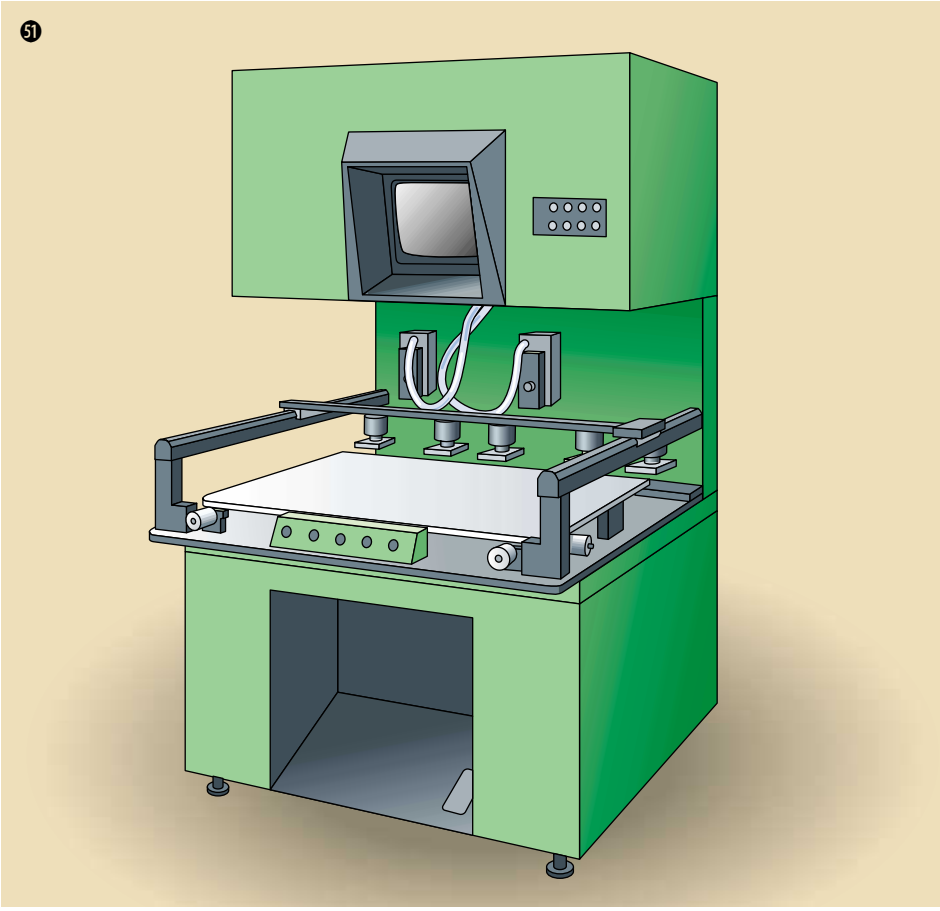
An optical plate punch punctures a series of registration slots in the fully processed printing plate, aligning with the target slots in the negative (*Figure* 51). The plate punch uses a high-resolution micro-video camera, closed-circuit, split-monitor screen at 20x magnification to facilitate operator location and alignment of register punching targets. Punching accuracy is within 0.001" punch to target, and 0.0005" repeatability plate-to-plate.

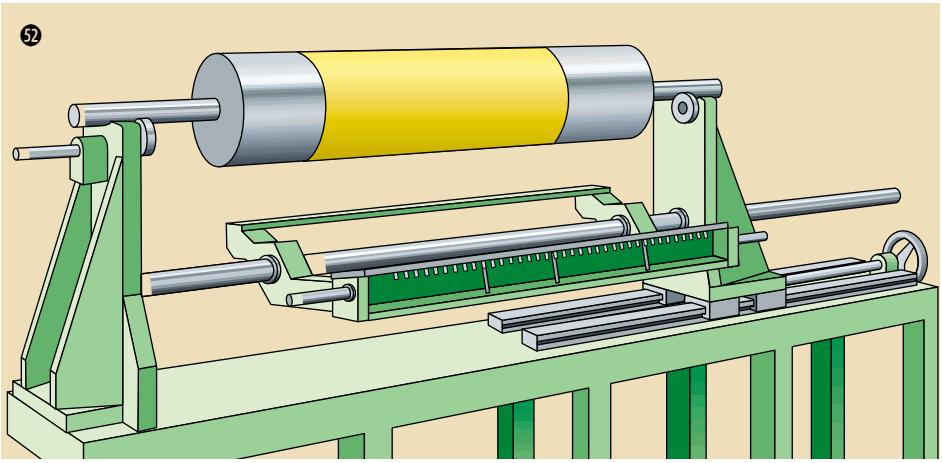
The plate punch uses a center-zeroing vertical slot and a series of horizontal slots left and right of center along one edge. It is thought that this slotting configuration causes less buckling or stretching of the plate than is sometimes associated with other pin shapes.

The plate mounter is a free-standing, plate-cylinder holding device, under which is located a plate-mounting pin bar that pivots up and permits the retractable plate-holding pins to contact the stickyback-covered cylinder (*Figure* 52).

Procedure for Punching Negatives

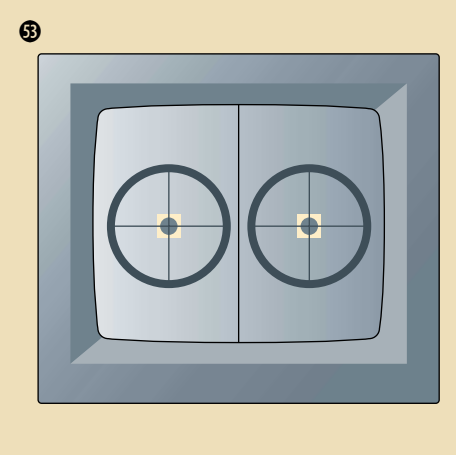
When punching negatives, use the following procedure:





51 By using a high-resolution micro-video camera, a closed-circuit, and a 20x split-monitor screen, this plate-punch unit offers a punch-to-target accuracy of 0.001" and a plate-to-plate repeatability of 0.0005".

52 On the plate mounter, a plate-mounting pin bar pivots up from the print cylinder to allow the retractable plate-holding pins to contact the stickyback-covered cylinder.



53 Electronic crossharis and plate-punch targets, enlarged 20x, as seen on the split monitor of the computerized plate punching unit.

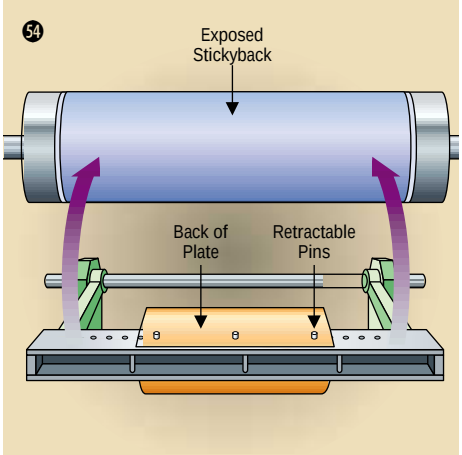
1. Place a transparent, prepunched acetate "carrier sheet" over the planning grid sheet. This allows the grid pattern to be seen clearly.
2. Place the first negative on top of the carrier sheet and planning grid. The first negative can be a composite, entire repeat-stripped working negative or a composite entire repeat-finished negative. The planning-grid sheet represents the plate cylinder divided into set areas.
3. Select the best position for the printing plates on the plate cylinder by moving the negative or job layout composite of negatives into that position on the grid. Tape the negative to the acetate carrier sheet in that position.
4. Select two target-punch positions, out of the image areas, along the grid-sheet – line "A" or "B" – corresponding to the inner or outer slotted holes, and record these grid-intersecting point numbers and letters on a job-specification sheet.
5. Establish the plate-punch positions on the "y" line along the top of the negative and record these positions on the job sheet.
6. Move the acetate carrier sheet, with its negative taped into position, to the target punch. Position the air-activated target punches to coincide with the target locations chosen on the grid, and punch the two holes at the targets locations in the negative simultaneously (*Figure* 50).

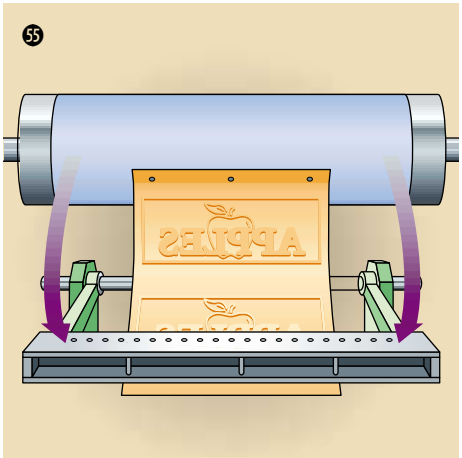
Procedure for Punching Printing Plates

The following procedure should be used when punching printing plates:

1. Lay out the same grid reference points on the vacuum table's optical-plate punch as the negative target punch. This allows the two closed-circuit video cameras and plate-punch heads to move into those same positions. The cameras project electronic crosshairs and the plate-punch targets on the split-screen monitor, enlarged to 20x (*Figure* 53).
2. Move the two cameras and the two plate-punch heads into the recorded grid-reference target points, selected in the planning stage and taken from the job specification sheet.
3. Refine the alignment of the camera crosshairs and the punch targets with the micrometer adjustments provided.
4. Place the fully processed printing plate on the vacuum table and align with the plate-target register marks, using the microvideo monitor. Further refine target positions by moving the adjustable vacuum table holding the plate.
5. Move the cameras and their transverse-holding bar to the plate-punch positioning line, recorded on the job sheet.
6. Move the punches into the recorded punch positions.
7. When camera crosshairs and plate target marks are precisely aligned on the split-screen video monitor, activate the punching button and punch the plate.

This entire procedure takes less than one minute and should be repeated for each printing plate.





Procedure for Plate Mounting

For this process, use the following procedure:

1. Place the first plate cylinder on the plate mounter.
2. Position the plate cylinder journals into a set of preloaded bearings.
3. Apply stickyback to the plate cylinder in the conventional way. This may be done with the cylinder off the mounting machine.
4. Find the pivoting pin-bar mounter, which is located below the plate cylinder. Locate the pins in the pin bar at the numbered positions given on the job sheet.
5. Load the first plate onto the retractable, spring-loaded pins that hold the plate to the pivoting pin bar. (*Figure* 54).
6. Remove the protective cover sheet from the stickyback.
7. Pivot the pin bar until the leading edge of the plate and retractable pins come into contact with the stickyback. Push the bar until the pins retract and the plate sticks to the cylinder across the entire leading edge, releasing itself from the pivoting bar.
8. Lower the pin bar (*Figure* 55) and rotate the plate cylinder slowly as the remainder of the plate is smoothed down.

Repeat these steps with all plate cylinders for the job. The actual mounting of each plate takes less than one minute. In most cases, cylinder handling and mounting for a six-color job takes less than one hour.

Advantages of the System

The pin-mounting system provides accuracy and speed of registration and mounting. It moves the responsibility for registration to the planning stage when plates are prepared.

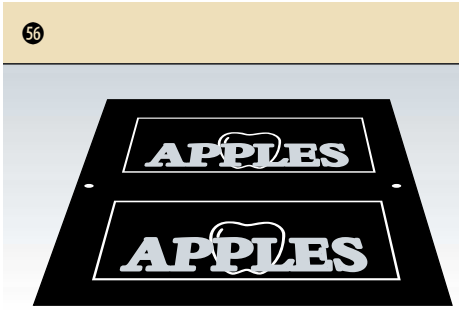
The system provides the ability to accurately mount multiple plates around and across the cylinder and to nest images. Mounting multiple plates often eliminates the need for step-and-repeating negatives and mounting large, unmanageable plates.

PLATE MOUNTING TO PINS IN THE PLATE CYLINDER

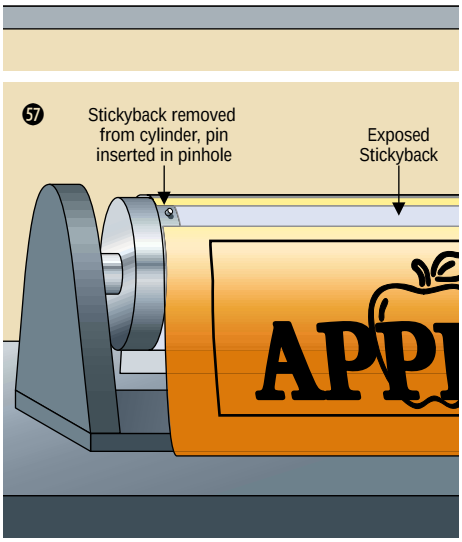
This system requires the printer to have the inventory of plate cylinders drilled with tiny holes to accept the 0.094" diameter shaft of the pins used for mounting. The holes in the cylinder must be precision bored, both in diameter and position, in order to correlate to the holes punched into the printing plate. The system will work with any plate cylinder width or circumference from 6" to 80".

54 The plate is loaded onto the retractable, spring-loaded pins to hold the plate to the pivoting pin bar.

55 The pin bar is lowered and the plate cylinder is slowly rotated until the remainder of the plate is smoothed.



56 The negative is blind punched with holes for the pins and the images stepped and repeated to form a single plate image.



57 The plate is affixed to the stickyback with the punched holes fitting over the pins.

The pin registration system is as follows:

1. Produce mechanical artwork with pin placements indicated at the center of the repeat and at a set distance from each edge of the web. Make a web layout showing pin placement and dimensions.
2. Prepare and make one-up negatives using the pin placements as shown on the black-and-white mechanical artwork.
3. Blind punch (before imaging) the negatives with the holes for the pins and the images are step-and-repeated in multiples to form a single plate image (*Figure* 56)
4. Make and lay a color key on pins corresponding to the artwork. This is a positive register control. If the color key is in perfect register, the plates will reflect this. This step ensures that negatives are correct for color separation, register, size and that the pinhole locations are accurate. Although this step is not essential, it is a way to verify film accuracy.
5. Punch a sheet of photopolymer plate with the same hole placement as the negatives and color key. Do this after back exposure, but before imaging the plate material.
6. Place the pins into the punched holes of the photopolymer plate and place the pin bar over the pins.
7. Expose the photopolymer plate to the negative.
8. After exposing the negative, remove the pins. Process, dry, cure and finish the plate. It is ready to be mounted on the cylinder.
9. Cover the plate cylinder with stickyback.
10. Uncover the pinholes in the cylinder by removing only a small piece of the stickyback.
11. Remove the small strip of the protective cover paper from the stickyback between the pinholes and insert the pins into the pinholes in the cylinder.
12. Place the plate onto the stickyback with the punched holes fitting over the pins (*Figure* 57).
13. Remove the rest of the stickyback cover paper and smooth the plate uniformly around the cylinder.
14. Remove the pins from the cylinder. It is now ready to be positioned in the press.

DIGITAL PIN REGISTRATION FOR CORRUGATED POSTPRINT

Computerized pin registration harnesses the digital prepress information to improve mounting accuracy. The system significantly reduces mounting time compared to conventional corrugated plate mounting, where several plates carrying image elements are

assembled and positioned on a single carrier. In conventional plate mounting, the individual plate elements are positioned by looking through a semitransparent mirror using eye-to-hand coordination. Both the viewing and the manual placing of plates induces errors which cannot be tolerated as increased print quality demands tighter print registration.

To use this technology, registration marks are added to the graphics and their positions are recorded in the digital file during the prepress stage. These register marks are output to the negatives and thus are captured on the plates when they are made.

During the insertion of the register marks to the graphic elements, the software assigns “x” and “y” coordinates to these positions. The coordinates are then sent to a computer-controlled drill (*Figure* 58), which drills the holes in the plate carrier sheet in the precise positions for locating the printing plates. The individual photopolymer plates, with the register marks on them, are drilled to accept register pins using the same drilling machine.

Double-sided stickyback is applied to the back of the printing plate ready for mounting on the carrier sheet. Pins are then inserted through the back of the carrier sheet and the holes in the plates are aligned with the pins to precisely position the plates in the proper relationship. Accuracy of this technology is quoted at 0.001" up to a 5" x 80" drilling area for all colors. Productivity can be increased even further by prepunching the carrier sheets and drilling all the colors for a multicolor job at the same time.

When this is done, a predrilled fastening bar is used which contains holes that are positioned exactly to the holes created when the carrier sheet is punched. Special plastic fastening pins are then used to attach the bar to the carrier sheet. This assures the fastening bar is always square to the image, eliminating the need to “cock”, or reposition the lead-edge slot in the printing cylinder, thus reducing press makeready time. Using this technology, plates can be mounted “in the round” or flat, depending on customer specification.

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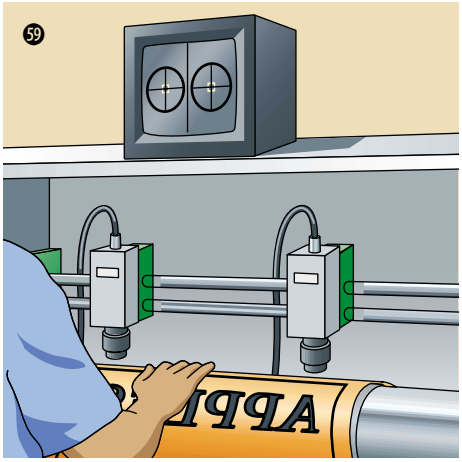


58 Computer software assigns “x” and “y” coordinates on the plate, which tells the computer-controlled drill the locations for the drill holes.

59 Two video cameras, positioned just above the plate cylnder, assist in the alignment of one color plate to another. Registration is achieved through the use of two micro dots placed on the plates and imaged by the video camera at a 140x magnification.

VIDEO-MOUNTING SYSTEMS

The latest approach to alignment of one color plate to another in the mounting process is through the use of video cameras (*Figure* 59). Registration is achieved through the use of two micro dots placed on the plate and imaged with the video camera at a typical magnification of 140x. The micro dots are 0.01" in diameter and are put in exactly the same location on each color plate. They are placed on the left and right side of the copy and in the center of the

60 An enlargement of four micro dots of the process colors. Perfect alignment would be a single black dot with no other colors showing. Using micro dots, plate-to-plate registration to within 0.001" can be achieved.

copy's web direction (*Figure* 60). When the job is in register, the dots will overprint each other and appear to be an almost perfect dot. *Figure* 60 shows an enlargement of four micro dots of the process colors. Perfect alignment would be a single black dot with no other colors showing. Using micro dots, plate-to-plate registration to within 0.001" can be achieved.

The procedure for mounting using micro dots is as follows:

1. Position the camera of the mounting system directly above the cylinder.
2. Apply stickyback to the first print cylinder
3. Remove the protective cover sheet from the stickyback.
4. Cut two strips of cover sheet and place it back on the stickyback in such a way as to leave a strip of exposed stickyback under the cameras.
5. Align the micro dot on one side of the copy with the camera.
6. Move the camera on the other side along the cylinder direction and move the plate to align the micro dot.
7. Lock down the camera and "tack" the plate to the exposed strip of stickyback.
8. Remove the rest of the cover sheet and smooth the plate onto the rest of the cylinder.

Once the first plate has been mounted, leave the cameras in place and mount the subsequent plates with their micro dots aligned to the cameras. While video mounting gives excellent alignment, it is still recommended to proof the job before going on press. This will reveal that no other makeready is needed or point out areas where makeready (including correcting high or low spots) can help to make the job run more smoothly on press.

SLEEVE-MOUNTING SYSTEMS

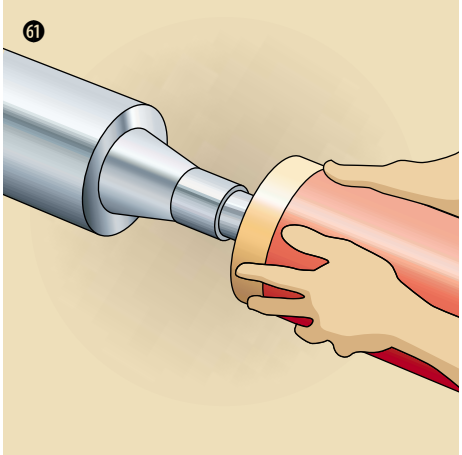
Fast… Effective… Economical – these characteristics are causing sleeve mounting systems to be widely embraced by the flexographic printing industry. Sleeves, (*Figure* 61) carrying prepositioned printing plates, can be quickly and easily mounted to, or removed from, a press cylinder. These devices prived considerable advantages to the printer, all of which contribute to reduced costs and increased efficiency. For example:

1. With the addition of only one more plate cylinder, a multicolored job can be premounted while another job is running. This is especially useful when only a limited number of plate cylinders are available for a particular print repeat size.
2. Repeat jobs can be stored on sleeves, which saves mounting time and plate and stickyback costs. The next time the job is run, it is simple to remount the sleeves and rerun the job. The plates are not damaged because they are not manhandled in any way since they were last in the press.
3. Jobs stored on sleeves can be easily remounted and will print in register. This can save time on difficult-to-register jobs.
4. Press downtime is reduced.
5. Continuous design printing plates may be formed on sleeves by coating them with either unexposed photopolymer or vulcanized rubber, which can be subsequently

engraved by light exposure or laser. By the same process, covered sleeves are ideally suited for solid flood coating and tint or varnish applications, allowing the opportunity to use only one plate cylinder for this purpose

6. Sleeve storage is easier and more convenient than plate cylinder storage, particularly on larger cylinders. Many convenient forms of storage are available, depending on the sleeve manufacturer. Sleeve storage is simplier due to the ease of handling a mounted sleeve which is much lighter than a plate cylinder. Transportation costs are also reduced dramatically and overnight shipping becomes feasible and affordable.
7. Flexibility is achieved by obtaining different repeat ranges from the same diameter plate cylinder. This is possible by mounting sleeves of different thicknesses. By careful calculations, the repeat size may be increased by the precise amounts that coincide with what will be needed to match extra teeth on the gear. This is done by using rubber-covered sleeves or thicker composite sleeves.
8. Sleeves allow a printer with a large stock of cylinders undercut for a certain plate thickness and mounting tape to change to a thinner plate. The decrease in the undercut for the thinner plate can be compensated for by increasing the thickness of the sleeve.
9. The majority of sleeve systems permit the cutting and trimming of plates once they are mounted on the sleeve. Obviously, care has to be taken not to perforate the sleeves.

The most important characteristic that the sleeve must demonstrate is that it will not slip. Unless this can be guaranteed, the sleeve cannot be used for quality flexo printing. A sleeve that slips is unacceptable due to the serious deterioration of print quality and the impossibility of maintaining register.



61 Plates are monted on a sleeve, which is then slid over the print cylinder with the aid of air pressure. After the run, the sleeve is slid off the cylilnder, plates intact, and stored for future pressruns, which will be marked by a drastic reducion in setup time. Pictured is a Strachen Henshaw sleeve.

TYPES OF SLEEVES

There are basically two types of sleeve systems: parallel (or cylindrical) and tapered (or conical). Parallel sleeves have constant and parallel inner and outer diameters and are designed to be mounted on existing plate cylinders. Tapered sleeves have a tapered inner diameter and constant outer diameter and are designed to mount on matched, tapered mandrels or cylinders.

Sleeves are available in different materials, depending on either the printer's personal preference or the type of application. The nickel sleeve is the thinnest sleeve available and has a standard wall thickness of 0.005". It permits the printer to become a sleeve user with minimum modification to existing equipment. The only modifications required are:

- Appropriate air holes need to be drilled in the plate cylinder.
- Thinner stickyback must be used for mounting the plate on the sleeve to compensate for the extra 0.005" thickness. The same thickness plate can be used.

Nickel sleeves are produced by plating nickel electrolytically onto a very precise

mandrel. Once the correct thickness of nickel has been achieved, the sleeve formed is removed from the mandrel and trimmed to the correct length. By using the electrolytic method, a completely seamless sleeve with extremely uniform thickness is achieved.

Composite sleeves are also available. The definition of composite in the plastics industry (where these materials were developed) is a polymer (plastic) which is reinforced with a fiber such as fiberglass or carbon fiber. Many combinations are possible due to the availability of different materials and methods for putting them together. The fiber can be continuous and woven to give greater strength and stiffness in both bilateral directions. Another method for producing sleeves is referred to as filament winding. This method lays continuous fibers in specific directions to give very exact design properties.

Composites can be tuned to achieve many different properties. For example, print-enhancing or "cushioned" sleeves are comprised of a urethane covering on top of a base composite sleeve. Sleeves can be made in different thicknesses to build up repeats. No matter which materials and manufacturing methods are used, personal preference often plays a part in which system is adopted by a printer. Cost is also a factor. One area of concern to a flexo printer in the design and use of composites is the weakness in the Z direction, which can result in the polymer delaminating from the fiber layer. Fiber direction obviously affects this property as does the choice of fiber.

The surface properties of composites are quite different from metallics. The surface is dependent on the polymer used and is not as resistant to knife cuts and gouges as metal. Another limitation is that most polymers cannot be used in the high temperature environments used to vulcanize elastomers. Because of this, vulcanizing on composites can be tricky and must be done within the temperature limitations of the material being used. In order to take full advantage of these material strengths, as well as controlling the costs, many printers are adding the composite sleeves as a third part of their system. They continue with their nickel plate carrier sleeve and the base cylinder. To this, they add the composite sleeve, when needed, to print a repeat for which they don't have a cylinder. The same result can be achieved by vulcanizing a thickness of rubber onto the nickel sleeve. The built-up sleeve can be used either with a printing plate or as a direct printing plate to produce continuous solids. It can also be used to apply tints or varnishes.

Another application is to laser engrave the rubber-covered sleeve making it into a continuous printing design roll. Previously, laser engraving was carried out on rubber vulcanized directly onto the plate cylinder. This made transportation of the heavy printing roll difficult and expensive. Now, a laser-engraved rubber-covered sleeve can be shipped with far greater ease.

Sleeves can be made which are covered with unexposed photopolymer. The thickness of the sleeve can be varied to achieve different repeat lengths and the final sleeve is a seamless sleeve with unexposed photopolymer. The floor of the plate can be established prior to mounting on the sleeve or while mounted. Once the photopolymer is affixed to the sleeve, it can be exposed in two ways. One is with the use of a negative contact film with conventional light exposure. Once exposed, the photopolymer is processed on the sleeve. A second method is to use direct imaging of the photopolymer on the sleeve. This is called computer-to-sleeve or CTS. In this process, the unexposed photopolymer has a mask on the top surface which is ablated by a laser imaging system. The system and process is the same as direct-to-plate (DTP), also called computer-to-plate (CTP), except that the photopolymer is a permanent part of the sleeve.

Computer-to-sleeve systems combine the advantages of sleeve mounting with those of digitally imaged photopolymer plates, namely lower dot gain and extended highlight range. In both methods of exposure, conventional or computer-to-plate, no distortion correction is needed since the plate is imaged in the round.

Mounting Procedures

The most popular method of ensuring that the sleeve maintains an aggressive, non-slip contact with the plate cylinder is to make the inside diameter of the sleeve slightly smaller than the outside diameter of the plate cylinder. Then, by means of compressed air, the sleeve is expanded sufficiently to slide onto the plate cylinder. Once it is in position, the air is disconnected and the sleeve clamps tightly onto the cylinder surface. This is achieved by a simple conversion of existing plate cylinders. Air is forced into the plate cylinder at one end and exits through a series of holes that are drilled close to the opposite end of the plate cylinder. The air flow expands the sleeve, which can now slide over the roll with ease. Care has to be exercised not to go past the air holes, because if this happens the means to expand the sleeve has been lost, as it can no longer be inflated by normal methods. This problem can be overcome by butting another sleeve of the same diameter against it, covering the air holes, and wrapping tape tightly around the joint of the two sleeves, so that the air flows underneath the sleeve once again, facilitating its removal.

In the case of solid-plate cylinders or very large cylinders, such as those used in preprinted linerboard applications an external manifold is used to supply the required air. Air enters a manifold and exits through the surface of the cylinder at the same end. The manifold is connected to the end of the plate cylinder each time a sleeve is mounted or demounted.

Sleeves are being used successfully on cylinders with diameters ranging from about 2" to 22" and in lengths up to 110". Special handling equipment may be required for large sleeves.

Sleeve Storage

For sleeve applications to offer the maximum cost and efficiency, an appropriate sleeve storage system needs to be used – one that offers easy access and identification of the stored sleeves. Some manufacturers supply the sleeve in a combined shipping and storage container that converts into a warehousing system. Some printers prefer to create their own sleeve storage using racks, rods, or other in-house adaptations. It is important to give sleeve storage the priority it deserves to benefit fully from all the advantages a sleeve system has to offer.

An Off-line, Nonproduction Flexo Proofing Press

A composite proof of process work can be valuable before going into the production run. It helps evaluate flexo plates, inks and substrates, and can be produced on a proofing press with a power-driven impression cylinder that is suitable for all flexo web-printing capabilities. The proofing press uses the basic flexo doctor-blade configuration, and the impression cylinder can handle any substrate. Plates made for the production run are mounted on an all-purpose-sized plate cylinder and are inked by a doctor-blade-wiped anilox roll. Each color is proofed individually and additional color plates are registered to the first-down plate by the use of two mounted microscopes.

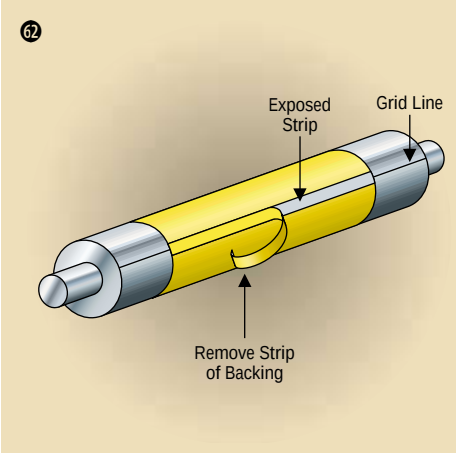
Flexo ink formulas, colors, lacquers and viscosities designated for the production run can be used to produce the composite proof. The result is a near replication of what can be expected from the press. The system produces several exact duplicate composite proofs for as many colors as needed and is eminently suited to process color reproduction.

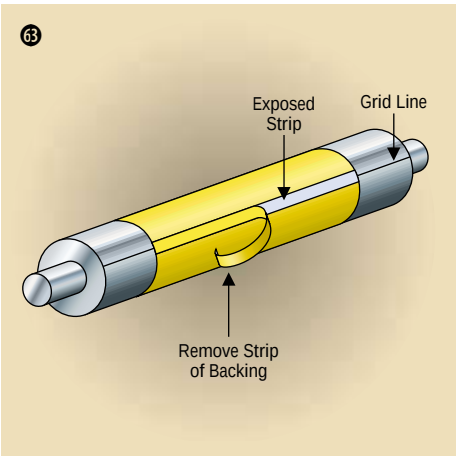
The proofing system will not produce a proof identical to that achievable on production equipment because two production presses will seldom produce identical results. Where hand-brayered ink of approximate colors without over-lacquer, or a single proof will not satisfy the demand, the result from this machine will produce multiple production-like proofs without consuming time and materials on production equipment.

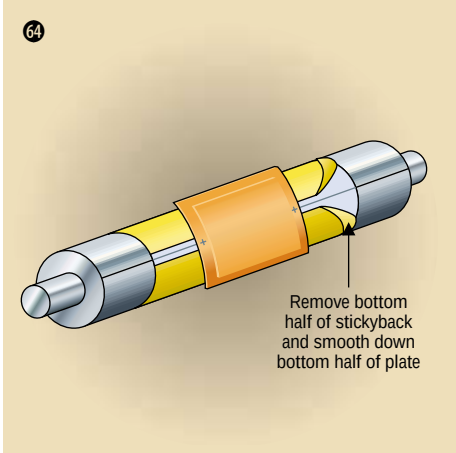
MOUNTING THE PROOF

The proofing press system works as follows:

1. Mount the plates to be proofed. Cut the substrate to the circumference of the impression cylinder. Insert both ends of the material into the gripper-tension bars and draw the substrate tightly around the cylinder.
2. Place the gear-driven plate cylinder, having a grid of plate-positioning surface scores, in the press on its bearing supports.
3. Apply stickyback to the plate cylinder in the conventional way, ensuring the horizontal center of the stickyback is over one of the grid lines.
4. Remove the 0.75"-wide horizontal strip of backing across the stickyback (*Figure* 62).
5. Lightly draw a horizontal line on the exposed stickyback, using a straightedge aligned with a cylinder score. (*Figure* 63).
6. To mount the first plate, align the horizontal plate-register marks with the drawn line.
7. Press the plate to the exposed stickyback.
8. Peel off the bottom half of the stickyback backing, ease the plate down and smooth into position. The top half of the plate is done similarily (*Figure* 64).







62 The first step to mounting the proof si to remove the backing from the sticky-back.

63 A horizontal line aligned with a cylinder score is lightly drawn on the exposed stickyback.

64 TThe bottom half of the stickyback is removed and the plate is eased and smoothed into position.

9. Lock the plate-cylinder gear in position, eliminating any rotational backlash.
10. Position both microscopes so their crosshairs are precisely aligned with the register marks on the mounted plate. Do not move the scopes for the remainder of the job, as the register marks on the plates for subsequent colors are aligned to the crosshairs in the two scopes.
11. Set the impression of the plate cylinder to the impression cylinder in the usual manner, using the impression carriage-dial indicators or engineering "slip gauges" (*Figure* 65).
12. Set the impression of the anilox roll to the plate cylinder in a similar manner.

The best impression of plate cylinder-to-impression cylinder and anilox roll-to-plate cylinder can be refined by trial proofing.

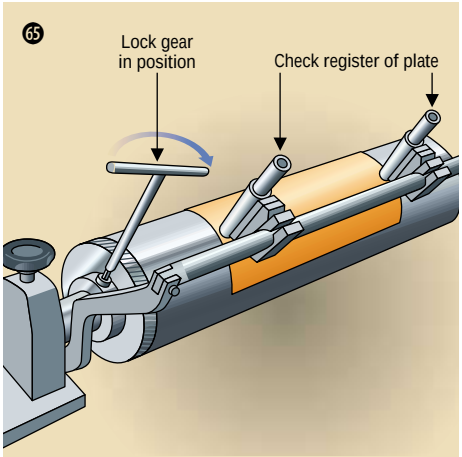
INKING THE PRINTING PLATE

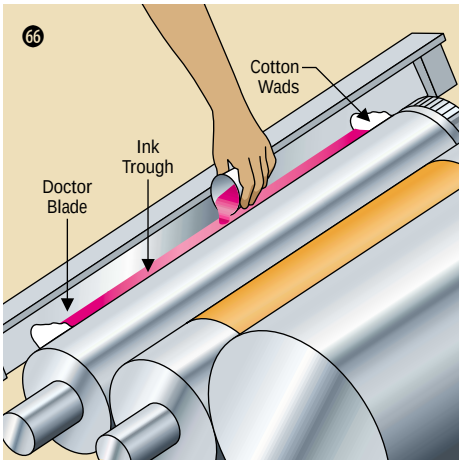
Use the following procedures:

1. The gear-driven anilox has an attached doctor blade that serves as the ink fountain. Hold the blade against the anilox roll with enough pressure to contain the ink.
2. The ends of the blade-to-anilox roll nip are dammed with small wads of cotton to form a containment trough wide enough to cover the plate image
3. Introduce a quantity of ink at the preset viscosity into the trough (*Figure* 66) and start the machine cycle.
4. The proofing press makes one full revolution of the impression cylinder carrying the substrate.
5. The first color is printed. Mount additional precut substrates on the impression cylinder for any duplicate proofs.
6. Prepare to print subsequent colors. Back away the anilox roll by releasing the pressure holding the doctor blade against the anilox, allowing the unused ink to fall into a catch tray beneath the

65 Engineering slip gauges, or impression carriage-dial indicators, are used to set the impressionm of the palte cylinder to the impression cylinder.

66 A quanity of ink of determined pH is introduced into the trough before the machines cycle.





anilox, backing out the plate cylinder and cleaning the entire station.

7. Remove the first plate from the sticky-back, taking care not to damage it, or disturb the microscopes.

8. Mount the next and subsequent plates with the plate-register marks aligned to the cross-hairs viewed through the two microscopes.

If the subsequent plates are mounted parallel and squarely, but the microscopes show them to be a fraction off-register, adjust the plate cylinder sideways and advance or retard to obtain perfect register without lifting the plates. Repeat the procedure for each subsequent color.

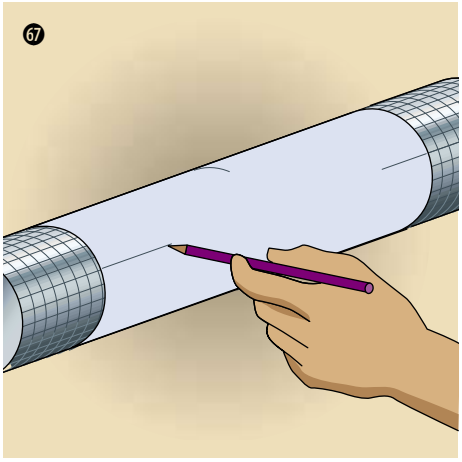
If rubber plates without a dimensionally-stable backing sheet are being used, it may be necessary to place a sheet of acetate over the first-down color proof in order to make a trial proof and confirm register, before proofing directly on the actual substrate. If photopolymer plates are used, the backing sheet often provides more dimensional stability, but an acetate preproof to confirm register is still advised.

Plate Mounting Without a Mounting and Proofing Machine

Although not recommended, in many shops it may be necessary to mount plates without a mounting device. This can be done on a rack beside the press or directly in the press, because of the nature of printing equipment and other circumstances (pin register techniques excluded). As an aid to accurate mounting, it is recommended that the surface of the print cylinders be engraved with a grid of longitudinal and circumferential lines. Premounting cushioned stickyback directly to the plate and then mounting the stickyback and plate to the print cylinder, as a unit, is not recommended, except for plates which are less than one quarter of the cylinder circumference. For larger plates, there is a possibility of the cushioned stickyback bunching, causing high spots under the plate.

Stickyback is applied to the print cylinder in the conventional manner. The steps to mount the plates are as follows:

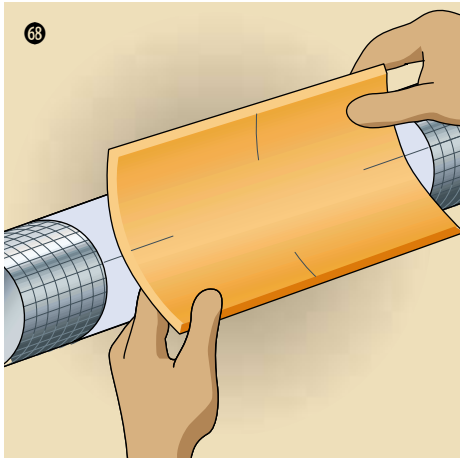
1. Project scribe lines from the cylinder onto the stickyback (*Figure* 67). This may be done with a straight edge and a sharp pencil or other instrument that will make a clean fine line on the surface of the adhesive.
2. Bevel the edges of the plate. This can be done by hand with either scissors or a knife by cutting on an angle, with a paper cutter, a foot-activated table shear, or a commercial plate trimmer designed for this purpose.
3. Clean the back of the plate thoroughly: rubber plates, clean with alcohol; photopolymer plates with clean water. Dry plates thoroughly.
4. Holding the plate with both hands, align the horizontal scribe line on the plate with the projected lateral scribe line made on the stickyback (*Figure* 67). The vertical scribe lines on the plate must also line up with those projected from the circumference of the cylinder onto the stickyback.
5. Carefully position the center of the plate on the stickyback, without stretching, and gradually smooth the



67 For shops that do not have a plate-mounting device, the surface of the print cylinder should be engraved with a grid of longitudinal and circumferential lines to aid in the premounting of the cushioned stickyback directly to the plate cylinder.

plate, pressing down evenly from center to head and from center to foot.

6. Examine the mounted plate for evidence of trapped air bubbles between adhesive and plate. Pierce air bubbles in nonprinting areas or by pressing down firmly against the adhesive.



68 To apply the plate onto the stickyback, the plate is aligned to the horizontal and vertical lines on the cylinder and the projected lateral scribe lines on the stickyback.

Note: *When mounting a large plate, place two pieces of backing on the stickyback, one above the horizontal scribe line and one below it, in such a way as to leave about a 1" strip of stickyback exposed across the area where it is to receive the plate. This permits positioning the center portion of the plate more easily and checking its vertical alignment before pressing the plate down completely. If the stickyback has been wrapped around the entire circumference of the cylinder with a butt seam where the two ends join, it is advisable to mount the first plate over this seam. This serves to lock the ends of the stickyback and prevent them from pulling away from the cylinder.*

Miscellaneous Procedures

Damage control is a primary concern of every flexographic printer. It's always in the press operator's best interest to avoid any type of delay, particularly one that might be caused by mishandling of the printing plates. This section describes some difficulties that could be encountered and the steps that should be taken to minimize their impact. Use of release agents, hold-down bands and bounce-avoidance procedures are covered.

REMOVING PLATES FROM THE CYLINDER

If the plate molded rubber plate is so firmly bonded that peeling it off will damage the plate or the stickyback, the following is suggested. Release one corner of the plate from the stickyback, then with a small artist's brush, apply naphtha or toluene to the pealed area in small dabs between the plate and the adhesive. The plate may then be gradually pulled away as the solvent softens and releases the adhesive. Allow the solvent to evaporate completely before remounting or storing the plate.

Polyester-backed photopolymer plates should release from the stickyback with minimal effort. Remove the photopolymer plate by loosening the leading edge all along the full width and pull it "squarely" from the cylinder. Pulling from a corner will most certainly buckle the polyester backing and possibly ruin the plate. Do not use solvents of any kind to help release the plate. The solvent may get between the photopolymer and its rigid polyester backing and cause the plate to delaminate. Some studies have suggested that, for some operations, saving a plate for reuse is not financially worthwhile.

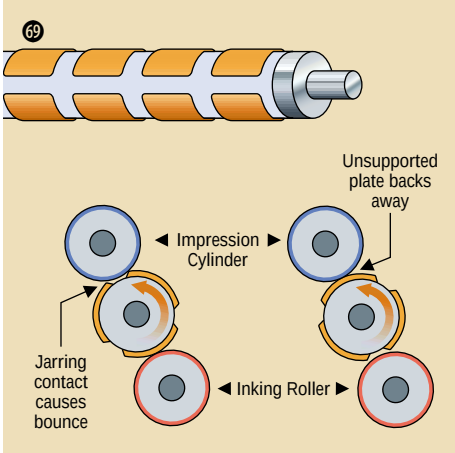
Using Release Agents

Adhesive systems used in the manufacturing of flexo cushion tapes have to meet stringent and conflicting requirements: They cannot allow the plate to lift or shift during production, but they must release from the plate and cylinder at the end of the run. Various solutions and sprays are applied to plate cylinders and the back of photopolymer plates to increase or reduce the level of adhesion. Exercise caution in their use.

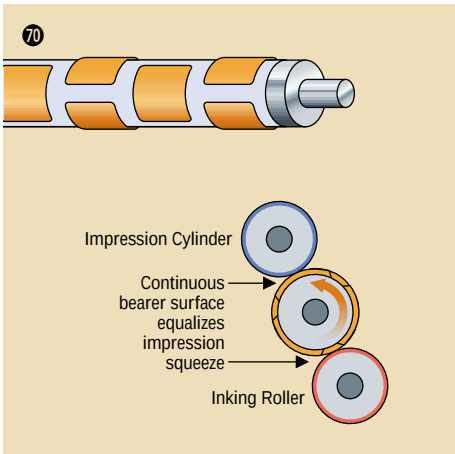
Using a release agent, such as shellac, on the back of rubber plates to facilitate their removal from the stickyback after the run requires great care and should be attempted only by very experienced personnel. To print properly, a rubber plate must be in absolutely tight contact with the cylinder. Improper application of release agents can impair this bond. If a release agent, or cushion adhesive, allows a plate to be removed too easily, it is a certain sign that the plate was not held tightly enough for proper printing. Problems that often result are misregistration or plate lift on press.

MOUNTING METAL-BACKED PLATES

With plain, metal-backed plates, align the notches along the sides of the metal with the scribe lines on the cylinder. In the case of pin-registered metal backs (plates having holes to locate them in register on the cylin-



69 Plate bounce is more likely to occur in the linear plate-mounting method, as this does not provide continuous or uniform impression squeeze during the full rotation of the cylinder.



70 To prevent plate and cylinder bounce, stagger plates to achieve a continuous bearing surface throughout full rotation.

ders), position the two holes in the backing on the two corresponding pins in the cylinder.

Either type of metal-backed plate may be secured to the cylinder by tightly clamping the hold-down bands furnished for this purpose. Tighten each band by pulling up one or two notches at a time, alternating from the band on one side of the plate to the other. ***Note:*** *Ensure the clamp is positioned over the seam of plates to pull the ends toward each other, otherwise the plate may buckle.*

PLATE STAGGERING

Plates mounted in straight banks across the cylinder are very likely to produce irregularities in the final printing because of cylinder and plate bounce. This linear method of mounting does not provide continuous nor uniform impression squeeze during the full rotation of the cylinder.

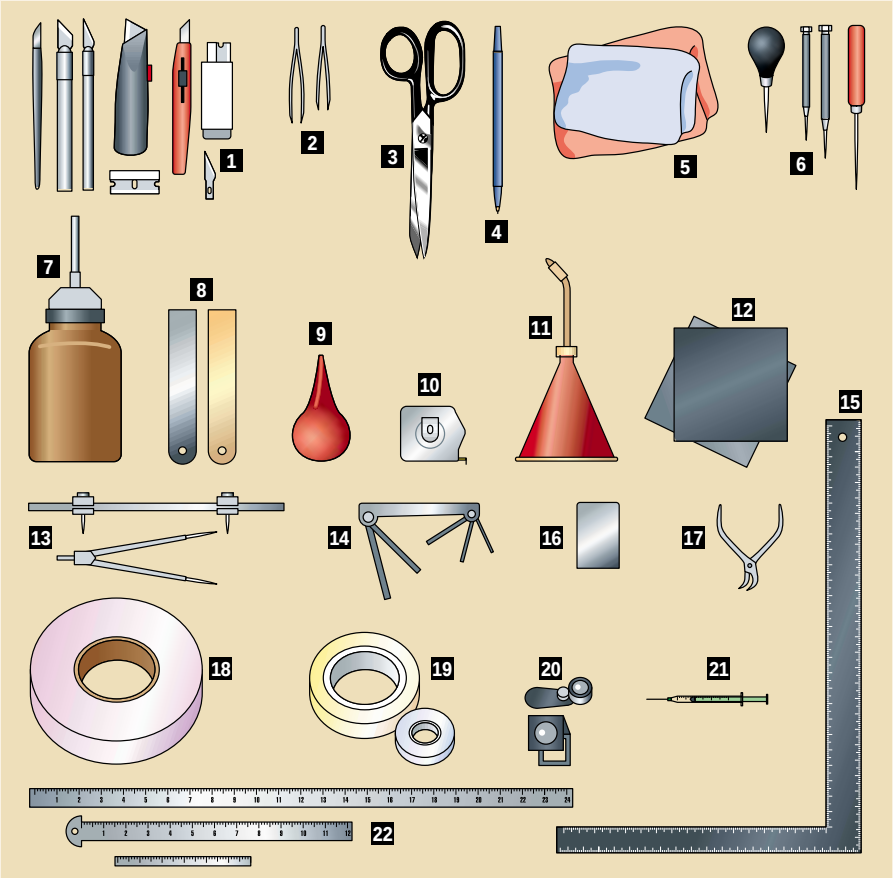
When the open "valleys" between banks of plates come around to a position facing the inking rollers (*Figure* 69), the bank on the opposite side, which should be printing, is not receiving the support necessary to sustain the proper impression squeeze. As a result, the cylinder deflects away from the web, and the print is irregular. As the open "valley" between the plates rotates into position against the impression cylinder, a "bounce" effect occurs as the leading edge of the printing surface comes into contact with the impression cylinder. This, too, can cause irregularities in the printing.

To prevent plate and cylinder bounce, stagger plates around the cylinder to provide a continuous bearing surface throughout the full rotation (*Figure* 70).

In some converting situations (for example, when printing is followed by a sheeting operation), it is impossible to stagger the plates. This is also true when a job calls for only one plate. To reduce the problem of deflection in these instances it is advisable to use cylinders of as large a diameter as possible and mount two identical plates around the larger cylinder, giving a double repeat. The addition of wide bearer-bars to print on the edges of the stock may also reduce plate and cylinder bounce, but it also requires additional stock width.

Appendix

A: TOOLS FOR MOUNTING AND PROOFING



Adhesive Cement [7]: Various types of adhesives are available depending on the application – bonding plates to stickyback, bonding stickyback to the plate cylinder, sealing the edges of the plates to the stickyback or building up low areas in makeready.

Allen Wrenches [14]: A full set is required to adjust any of the Allen screws on the cylinder gears or any working parts of the mounting and proofing machine.

Ball-point Pen [4]: For highlighting scribe lines in the nonimage area of the plates and for the marking of areas to be trimmed. A fine point will give greater accuracy. Darker ink is more easily seen on all but black plates, where white or yellow ink is better.

Bulb Syringe [9]:This is a common rubber ear syringe (or plastic squeeze-bottle) with a very small opening. Filled with solvent, it is a handy tool to apply small amounts of solvent between plate and stickyback to make plate separation easier.

Cont'd on following page

A: TOOLS FOR MOUNTING AND PROOFING

Cleaning Cloths [5]: For washing plate cylinders, gears or the mounting and proofing machine, a regular industrial rag is adequate. For cleaning plates, a lint-free cloth is necessary. Discarded nylon stockings are also ideal for washing plates.

Diameter or PI (π) Tape [10]: A flexible, steel rule with very precise markings for finding the diameter and circumference of a cylinder.

Emery Cloth [12]: Very fine grade is used for spot makeready, only on the back of a plate and over a very small area. Coarse grade is for roughing up the underside of the plate's leading and trailing edges (nonprinting areas of plates) to improve bonding with the stickyback and prevent plate lifting.

Feeler Gauges [8]: A solid bar of soft metal roughly 1" wide and 6" to 8" long, whose thickness must be made equal to that of the combined printing plate and stickyback. For 0.125" plates, 0.125" brass or aluminum stock is readily available. It is used at the mounter-proofer to establish a precise parallel of the plate cylinder to the impression cylinder. It is also used at the press to parallel the plate cylinder to the impression cylinder and the anilox roll to the plate cylinder.

Hook-nose Pliers [17]: For stripping out unwanted areas of rubber after cutting. They are especially useful when working with two-ply rubber solids.

Knives [1]: Different types and sizes are designed for cutting stickyback, trimming plates and making precise butting joints. Preferably, knives with replaceable or refreshable blades ensure sharp cutting at all times.

Magnifier or Loupe [20]: 20x or higher, used to inspect fine detail and dot work.

Needle Syringe [21]: Of the extraction type, it is 2 cc or 4 cc in size. Provides an excellent means of releasing air that may be trapped under a plate or stickyback.

Pica Ruler [22]: Used to check type size and leading.

Picks [6]: Steel picks, scribers or sharply-pointed instruments are helpful for various operations, such as piercing the nonimage area of rubber plates to release air trapped between the stickyback and the plate or the stickyback and the plate cylinder. Discarded dental tools are excellent for this purpose.

Scissors [3]: Used for general trimming and cutting of stickyback, plates and makeready tapes. They should be 5" or more in length and have sharp cutting blades.

Solvents [11]: Bensol, toluol, naphtha, alcohol, etc., are used in the mounting and proofing area and should be housed in prescribed safety containers. The same holds for the waste rags which are used with these solvents.

Steel Square [15]: For cutting stickyback to exact sizes.

Stickyback Smoother [16]: A piece of flexible spring steel about 0.025" thick and 2.5" x 3.5" in size. After piercing air traps in the stickyback, this tool smooths out the wrinkles. Use of this tool instead of your hand can make the stickyback lie more evenly without effecting its tackiness.

Tape [19]: Adhesive tape, cello, polyester, polyvinyl chloride, etc., available in various thicknesses from 0.0009" to 0.005", used to raise low-copy areas, such as an entire copy block or a big solid – by applying it to either the back of the plate, the back of the stickyback or directly to the bare cylinder. It offers the advantage of knowing just how much buildup is being applied with no waiting time for drying, as with brushed-on makeready materials.

Trammels and Dividers [13]: Used in checking precise plate spacing across the cylinder, such as from scribe line to scribe line, center to center, or point to point of copy.

Tweezers [2]: For holding small areas of plates that are being trimmed away, such as net-weight slugs or code numbers. Tweezers enable the operator to lift the unwanted area and guard against penetration of the stickyback.

Wrapping Film [18]: A low density polyethylene film (about 2.5" wide) for wrapping the plate cylinders after the plates have been mounted and proofed, it is useful in eliminating captive air pockets and giving the plates a uniform distribution of impression, ensuring good contact to the stickyback.

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5

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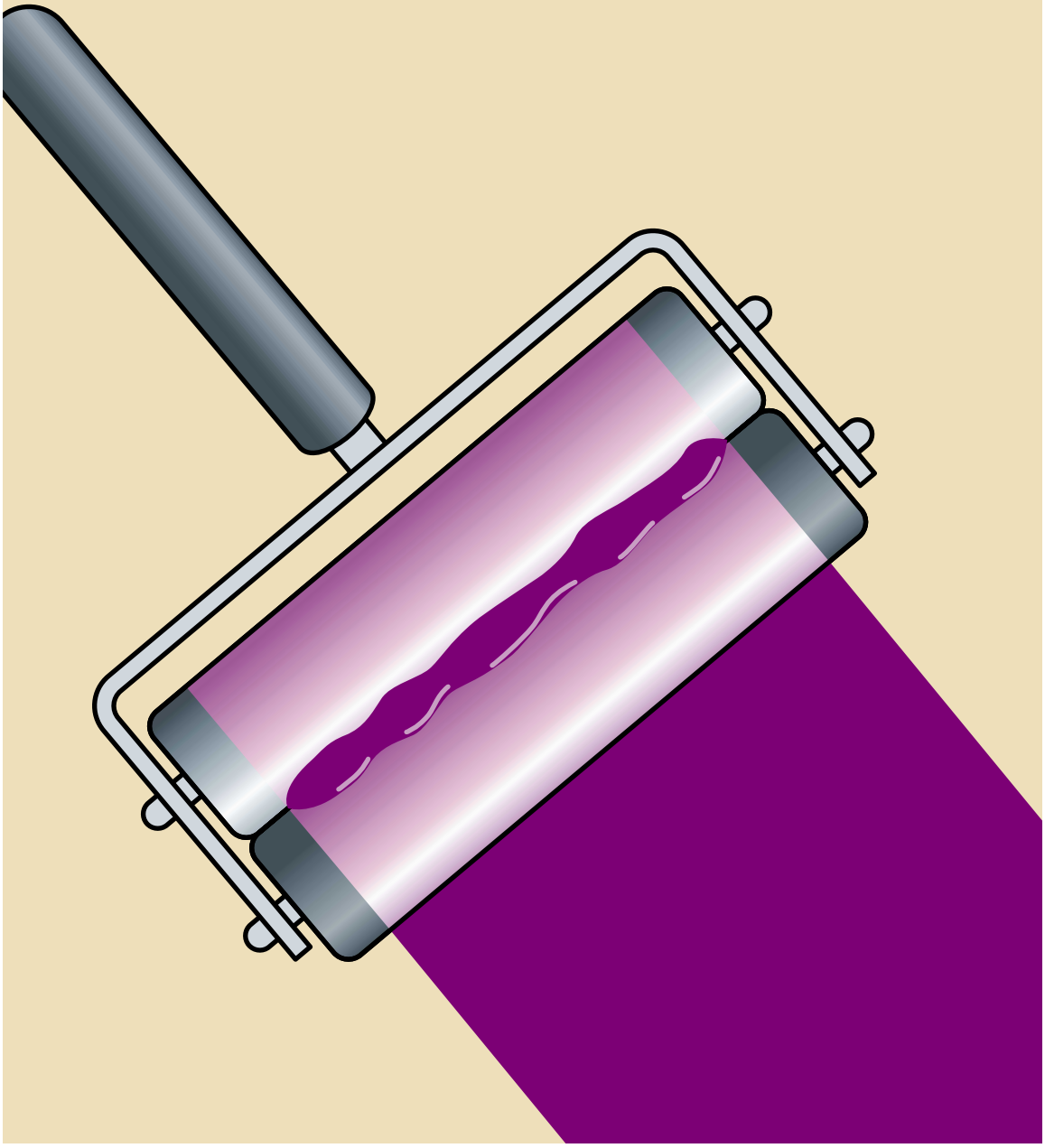
CHAPTER 1

Ink



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Introduction

Ink is critical to the flexographic printing process. It is the media that transfers an image from plate to substrate. Ink is used to convey a message and provide a package with decorative effects. It can be formulated to meet a specific need dictated by either press configuration or printing surface.

This chapter, the first in this two-part volume joining flexographic inks with substrates—two products that no printer can do without—is devoted to ink, as well as its properties and applications. It discusses the composition of the vast array of printing inks, as well as the classification of their components and the physical characteristics that each brings to the printing process. Information is presented in four distinct sections: end-use requirements, formulation, prepress practices and on-press procedures.

Mixing, blending, dispensing and filtering are all covered in this primer on effective ink management. Strength, sharpness, lay and color are reviewed. Press configurations and the influence that they have on ink requirements are explained. Anilox roll selection and maintenance guidelines are also offered.

You will learn that colorants, whether pigments or dyes, are the vehicles that give an ink its color. They can be conventional or fluorescent (ultraviolet). Resins, on the other hand, are responsible for a host of factors, including ink's printability, rheaology/viscosity (flow), adhesion and stability. Solvents are the carrier agents that transport ink from the fountain to drum to substrate. Additives mate the ink with the printing surface. They can enhance gloss level and, increase opacity. At the same time, additives can improve heat-, moisture-, fade- and rub-resistance. Directions for performing press-side tests to measure each of these qualities of ink are offered in the respective section.

No discussion of printing inks could be complete without marrying the different classifications of the media to the substrate most applicable for its use. Chapter Two of this volume is dedicated to that cause. It supplements information presented in Chapter One, which offers the basic, most-necessary details on both compatibility and conflict.

Substrates, as you may know, and will see, are grouped into five categories: paper and paperboard, corrugated board, laminates, foils and films. In this instructional volume, the properties of each are presented side-by-side with a detailed discussion of the applications that each is best suited forÑright down to the ink.

End-Use Requirements

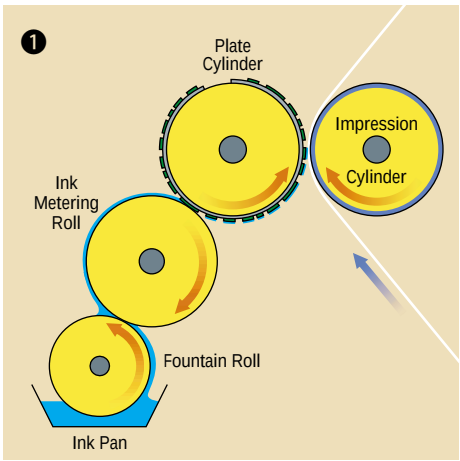
Since its beginnings in the 1920s and 1930s, the growth and acceptance of the flexographic process have been closely tied to advances in flexographic printing ink. At that time, the process was called aniline printing because its inks used aniline oil (a coal-tar derivative) as the coloring ingredient. It was essentially a rubber-stamp printing process employing a smooth ink roll and two rubber doctor rolls to develop the ink film.

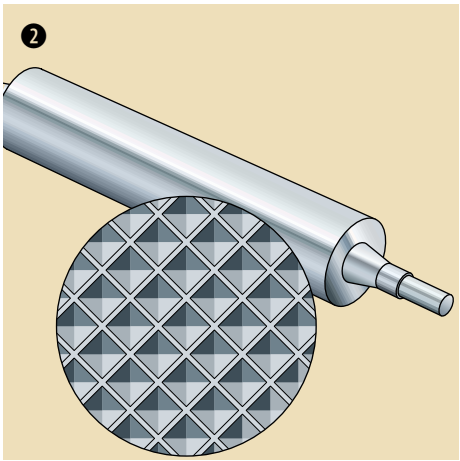
The evolution of flexo inks, from dyes dissolved in alcohol and laked with tannic acid, to solvent-based, and more recently water-borne and ultraviolet-cured systems, has been a major factor in the greatly expanded use of flexography in segments of the paper, plastics and packaging industries (*Figure* ❶)

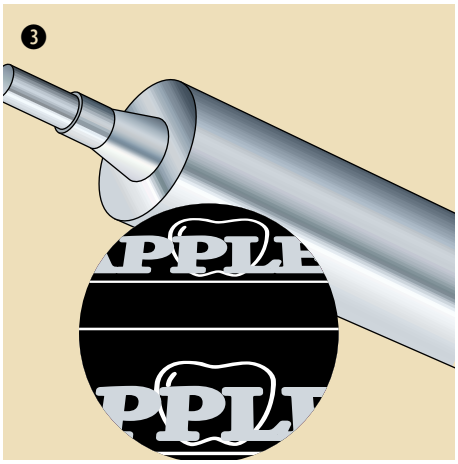
The earlier inks left much to be desired in terms of print quality, light fastness, adhesion and scuff resistance, which made them suited primarily for printing bags and envelopes. The development of high-viscosity, solvent-based, pigmented inks prior to World War II, not only produced flexo work of greater durability and better print quality, but also led to the design of the anilox roll, whose small cells gave better control and uniformity to the ink (*Figure* ❷).

Flexography's suitability for the stream of new packaging substrates that reached the marketplace, beginning with the introduction of cellophane in the 1930s, was another key factor in its increasing recognition and, the number of applications for the process.

Flexography was the only economical way of printing cellophane, unless the production run was large enough to justify the more







❶ A schematic of the flexography process.

❷ The enlarged view of the anilox roll shows the small cells crucial to give better control and uniform ink lay.

❸ Gravure cylinders are utilized for large runs.

❹ A sampling of items printed on various substrates, including polyethylene and polyester films, foil, metallized films, oriented and coextruded polypropylenes and coated films.

expensive gravure cylinders (*Figure* ❸). Solvent-based ink formulations containing nitrocellulose (and later polyamide resins) were developed that were good for printing on the polyethylene films introduced in the 1950s, as well as for the many modern-day materials and constructions that followed. Among these substrates were polyethylene and polyester films, foil, metallized films, oriented and coextruded polypropylenes, coated films and many different kinds of laminates. They required inks that could grip their less-porous surfaces and hold up under what were then unheard of application conditions (*Figure* ❹).

Water-based flexo inks were first tested in the 1930s for paper and paperboard, but did not realize significant commercial use until the 1950s. Demand for water-based inks grew in the 1960s as acrylic polymer technology developed, enabling a higher gloss and giving the inks better water and rub resistance. Since then, water-borne systems have become faster drying and have moved into high-speed printing, process printing, newer substrates and lamination applications. Their workplace-safe and environmentally friendly features have become especially attractive as regulatory actions have increased.

The regulatory climate has also been one of the important inducements for the use of radiation-cured flexo inks, which first appeared in the 1970s. Ultraviolet (UV) light and electronic beam (EB) systems using such inks, which are stable and compatible with the environment, are employed to speed operations and reduce solvent emissions.

APPLICATIONS

Today, flexo inks still find their greatest use, in packaging applications (*Figure* ❺). These applications range from their initial use for printing flexible packaging to corrugated materials, folding cartons, milk and other liquid cartons, food and rigid plastic containers, multiwall and paper bags, tags and labels, and gift wraps. The largest single use today is the printing of corrugated materials. Why? Quality graphics have become increasingly important for packaging and point-of-purchase display products. Flexible packaging is not far behind and continues to grow steadily as the industry moves from paper to plastic materials.

Other applications include household paper products such as towels, tissues and napkins as well as wall coverings. Flexo inks are also replacing letterpress and offset types in some newspaper operations and are also used in commercial publication and book printing. The total value of the flexo market, as reported by the Printing Industries of America, exceeds $54 billion. A breakdown of the business segments is shown in *Table 1*.

END-USE QUESTIONS TO ASK

Packaging applications, in particular, have created new demands for the properties and performance of flexo inks as new materials, printing technology, storage and shipping requirements, nontraditional uses and government regulations have reached the marketplace.

It has become critical for the printed package to print well under different conditions,

5 Today, flexogrpahy is widely used for flexible and corrugated packaging, folding cartons, milk and other liquid cartons, food and rigid-plastic containers, multiwall and paper bags, tags and labels, and gift wraps.

SIZE OF FLEXO MARKET SEGMENTS

	MARKET $ IN BILLIONS	ESTIMATED % FLEXO	FLEXO $ IN BILLIONS
Corrugated	$20.0	75%	$15.0
Folding Carton	8.0	20%	1.6
Flexible Packaging	16.0	75%	12.0
Labels	6.0	30%	1.8
Tag, Ticket, Tape	0.3	50%	0.2
Paper Bags, Multiwall Sacks	3.0	95%	2.9
Gift Wrap	0.6	45%	0.3
Wallpaper	0.5	30%	0.2
Set-up Paperboard Boxes	0.4	20%	0.1
TOTAL	**$54.8**	**62%**	**$34.1**

Source: 1996 Printing Industries of America.

Table 1

but to also withstand adverse storage and shipping environments, satisfy a host of end-use requirements, and maintain a fresh appearance during consumer use.

The following questions apply when determining the ink and coating end-use requirements:

- How will the package be stored? Will it be in a warehouse or outside?
- Will it be stretch-wrapped? The protection properties of the ink and/or varnish must be tailored accordingly.
- Will the package be exposed to sunlight, either directly or indirectly (such as through a window)? The fade resistance of the ink must be formulated to withstand the amount of exposure.
- How will the package be handled

through the customer's packaging and shipping processes.

- What kind of conveyor system will process the package and what type of stacking pattern will be used? The answers will determine the coefficient of friction (COF) or slide angle needed for the bag or box.
- What kind of exposure to the customer's materials will the print undergo, either through migration or during filling of the product? The ink or varnish will need to resist any product contact that results.
- Will there be any moisture or possible condensation to the package? If so, the ink or coating must possess the necessary water or humidity resistance.
- At what temperature will the customer's material be packed?
- How long will the package remain at this temperature? The temperature conditions will dictate the necessary heat- or freeze-resistance required.
- What will be the shipping conditions that the package must undergo?
- How will the printed material be shipped and/or stored? These will determine the level of necessary rub- and abrasion-resistance.

RANGE OF IMPORTANT INK PROPERTIES

Durability and resistance requirements and the increasing demand for products of enhanced quality, have placed increasing importance on the range of properties that flexographic inks must offer. Among the most significant ones are adhesion, color strength, gloss, opacity, rub-resistance, dimensional stability, mottle-free lay and block resistance.

Other important properties are surface tension, coefficient of friction, heat resistance, sealability, solvent resistance, fade resistance, odor control, and the ability to satisfy Food and Drug Administration (FDA) regulations for direct food contact and specific food additive uses.

MARKET SEGMENTS

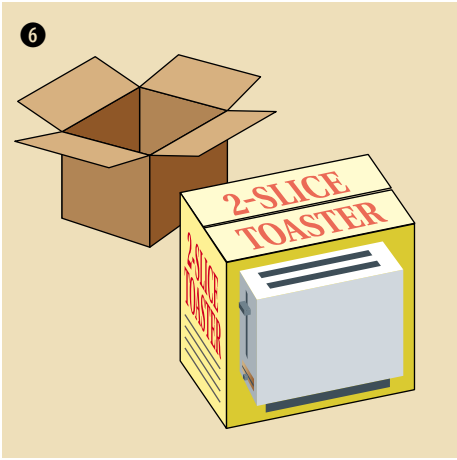
The relative significance of the important ink properties varies depending on the particular application. The applications can be grouped by market segments which call for specific end-use requirements.

Corrugated Materials

An ink-selection checklist for printing on corrugated should cover such considerations as stock, trap, anilox specification, press design, image design, layout, and special property requirements such as grease and gloss skid resistance. These considerations will apply for the most part in all the market segments.

Corrugated printing generally falls into one of three categories: brown box, mottled white and bleached kraft, and high quality display (*Figure* ❻).

Brown Box. End-use requirements are usually not critical in printing the traditional corrugated natural kraft box. Historically, ink selection is driven more by price than by performance. Color exactness and strength



❻ Corrugated printing is either brown box, mottled white (bleached kraft) or high quality display.

are not as important as economy of operation. The inks are generally standard GCMI* colors that are suited to meet a variety of printing equipment and bulk production demands.

Mottled White/Bleached. Printing this kind of corrugated board requires better quality inks (having harder resins and faster drying systems) for higher-speed equipment to obtain improved finish, dry rub resistance, and other physical characteristics. They should work well with photopolymer plates. Printers seeking high quality results on these stocks or natural kraft, using newer, high speed equipment, will require inks that also offer greater color fidelity and premium performance properties, such as scuff resistance. These inks are generally custom formulated to provide specific functional properties, such as wax-bleed resistance. Beverage cartons require inks with a high coefficient of friction to provide skid-resistant printed surfaces. They must also give clean, sharp prints and dry quickly.

High Quality Display. The printed corrugated box and other constructions are increasingly being used as silent salespeople and point-of-purchase (POP) display materials in retail stores. They have led to a demand for a level of quality that can compete with preprint work.

Most of the work is done on mottled or bleached stock and special high-holdout liners. The graphics are usually intricate and may include process work, trapping, large solids and fine type. The flexo ink used here must usually provide high color intensity and is often matched to custom spot colors. The ink makes or breaks the job because it is clearly the most visible part of the product.

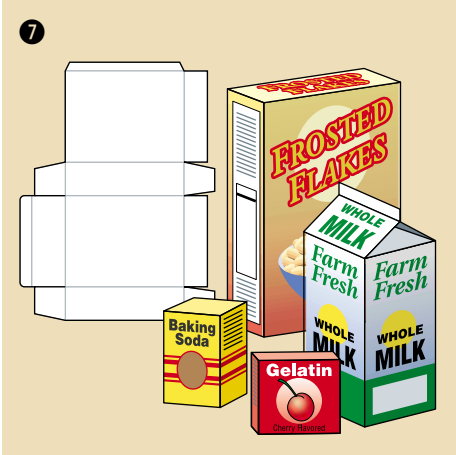
As corrugated board becomes a decorative product unto itself, in the form of boxes, eye-catching display material, or upgraded packaging in general; process printing is being adapted to provide the desired high-quality four-color results. It offers a full spectrum of colors as well as the lifelike reproduction of flesh tones.

High-solids flexo process inks have recently been developed to help deliver high-quality halftone work, usually on bleached or clay-coated stock. Unlike standard corrugated inks, they must be highly transparent and highly pigmented to afford proper hue and low grayness, so that they can be applied at the thin film levels needed for precise metering. They should possess a compatible surface tension in relation to the anilox roll, plate and substrate, and be formulated with process colors (cyan, magenta, yellow, and black) specifically for the unique printing conditions that may exist at the time. In preprint applications, the inks must also exhibit the heat and rub resistance that will withstand the heat and pressure of the subsequent corrugating operation. Overprints are employed to enhance gloss or sheen, as well as rub resistance. The trend is to use water-borne types with greater use of ultraviolet-cured overprints for the higher end of the market, such as display work.

Flexible Packaging

Printing of flexible packaging falls into a number of subsections, including laminated and retort pouches, candy wraps, merchandise bags, potato chip bags, frozen food bags, cheese wrap and bread bags. Flexo inks for these applications must generally exhibit the adhesion qualities and color strength for corona-treated film and provide sharp, clean print. For reverse printing, low levels of paraffin wax and other additives in the ink formulation are important, since higher paraffin levels and lower surface energy (dyne level) subsequently inhibit adhesion and lamination bond strengths. The inks should also possess high heat resistance, typically above 3,500° F (1,770° C),

* Glass Containers Manufacturers Institute, now known as the Glass Packaging Institute.



❼ Folding carton has become a growing segment in flexography, and must meet resistance to chemicals, grease, detergents, alkali, alcohol, heat and water. The addition of overprint protective coatings provide greater rub- and scuff-resistance.

and in some applications withstand boiling water. Excellent wet-out to films provides good ink-lay, smoothness, trapping and print quality.

For surface printing, the inks should exhibit good scuff resistance, typically 1,000 Sutherland Rubs with a four-pound weight, and high gloss. Gloss is especially important in surface-printed packaging film and is customarily accomplished by covering the ink with a clear overprint. A typical good gloss is 60 to 70 at 600° F. Excellent gloss falls in the 70 and up range. For high-gloss, high-impact product lines, inks are being overprinted with UV and cationic lacquers to achieve superior results. Overprints are used to add gloss to the printed flexible package, protect the ink from outside conditions, control the coefficient of friction so the package moves easily though the production machinery, and build barrier protection for the package contents.

The particular combination of properties will depend upon the specific application. Lightfastness is required to resist both fluorescent store lighting and outside exposure to sunlight. Pigment choice is critical in avoiding degradation from UV wavelengths.

Personal care product film packaging has its own set of requirements. Printed shampoo pouches that are stored in showers and exposed to indirect and direct contact with water, for example, obviously need to be water and moisture resistant. They must also withstand the chemical properties of the cleaning product which can be more deleterious to the printed film than mild caustic soda.

Inks for food-packaging films must not only satisfy FDA requirements, but also possess differing combinations of other properties depending upon the product and end use. Among the properties needed are low-odor levels, freeze-thaw stability, ice-water crinkle resistance, grease resistance, scratch resistance, different coefficient of friction levels and block resistance.

Folding Cartons

Inks for printing folding cartons, which is a growing segment for flexography at the expense of sheetfed offset and gravure, generally require high color intensity, fast-drying properties, good gloss, plasticity and good adhesion. They must print on clay-coated paperboard, polyethylene and foil. Many of their uses require resistance to chemicals, grease, detergents, alkali, alcohol, heat and water. Overprint protective coatings are utilized to reinforce barrier properties at the most vulnerable carton areas and provide greater rub and scuff resistance.

For fine-line printing, flexo process inks are formulated to give high density and good dot structure. They should also exhibit the excellent color fidelity and color strength suited to a wide spectrum of process color jobs. They must also meet requirements for color trapping (superimposition of color), color sequence and ink viscosity (*Figure* ❼). Metallic inks are available to provide brilliance, high gloss and clean prints.

Food Containers

Freedom from residual odor is critical for flexo inks in terms of their ability to withstand product contact, satisfy FDA regulations, and meet the many handling and stor-

age conditions involved in distributing and using these products.

Inks for printing milk cartons and other liquid packaging, for instance, should not create noticeable odors, contribute to off-flavors, or be affected by conditions of high relative humidity. Although water-borne inks are inherently hygroscopic, aqueous flexo systems, that resist water and withstand the soapy lubricants used on filling machinery, have been developed. These properties must not detract from their ability to print cleanly on carton stock or provide the required wet-rub resistance. They must also withstand waxing, polyethylene extrusion and other coating treatment which the stock undergoes.

Other printed food containers must meet similar property requirements depending upon their individual packaging, product and end-use. Printed paper cups and plates, and polystyrene foam stock also fall into this category. Their inks should give sharp, clean prints, a smooth nonabrasive, rub-resistant finish, and should resist water and food contact. Printed cups must also withstand the heat of hot liquids and waxing or polyethylene extrusion.

Multiwall/Paper/Plastic Bags

Multiwall sacks and paper bags have been printed by flexography for many years. Like corrugated materials, there is increasing demand for better graphics and hence improved inks and substrates that will give brighter, smoother finishes. Plastic bags are becoming increasingly important in this segment because they are cheaper and easier to make. End-use requirements determine the choice of ink for printing these bags for a gamut of applications that range from lawn product and pet food bags to grocery and retail shopping bags (*Figure* 8). For example, inks for use on both clear and white heavy-gauge multiwall polyethylene fertilizer bags should be suited to both outside and reverse printing. They should be resistant to pine bark, compost and cow manure, as well chemical blends of fertilizer. They should also be scuff, fade and weather resistant.

8 End-use requirements determine the choice of ink for printing on multiwall sacks or paper bags. The gamut of applications ranges from lawn product and pet food bags to grocery and retail shopping bags.

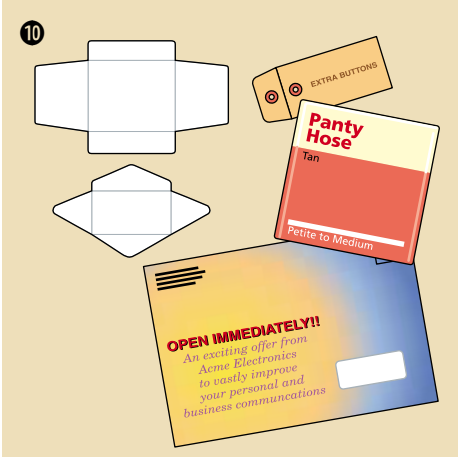
For sugar bags, a prime requirement is good scuff resistance against the abrading influence of loose sugar crystals trapped between the bags during shipment. Many sugar bag stocks are made of strong bleached kraft and require ink formulations that provide adequate strength and color brightness for their designs. A requirement for inks used to print satchel-bottom sacks is resistance to “cracking” in the reverse folds of the gusset.

Foods such as cookies and cereal products contain cooking oils which migrate and soften inks not modified to resist them. Inks must resist the specific oils and greases in the product to be packed. Some bagged products are packed hot from the ovens. Inks for this kind of application must have sufficient heat resistance to prevent blocking of the bags during the cool-down period.

Printing on potato chip, popsicle and ice cream freezer bags usually require inks with good light fastness and resistance to bleeding and blocking in water, greases, waxes, oil and most fats. On ice cream wraps and other bags that receive subsequent molten wax or other hot melt coatings, the inks must not prevent sealing, and the colors must not bleed in the molten wax or coating.

❾ The tag and label market is a growing segment in flexography. Like plastic packaging, these products are being used increasingly as a marketing tool. They lend themselves to diversity and segmentation.

❿ Flexography has also found a niche in household and office paper products, such as printing envelopes and letterhead.



Transparent inks are often used for aluminum foil printing to enhance the brilliance of the foil and produce an eye-appealing effect.

Tags and Labels

Water-borne and UV flexo inks became established in the tag and label market segment earlier than in the wide-web segment. Initial testing was comparatively easy to accomplish on narrow-web equipment and the printing surface predominantly used was friendlier to these inks. The tag and label market continues to grow because, like plastic packaging, these products are being used increasingly as a marketing tool and lend themselves to diversity and segmentation.

Rub resistance is more critical for the inks used here because there are many more different substrates and conditions experienced by labels than there are to packaging products. This diversity often makes water resistance more important because of the use of labels in a wider range of applications including shampoo, pharmaceutical and soap pouches.

Chemical resistance is often necessary. Pharmaceutical packaging, for example, often must withstand isopropyl alcohol that comes from exposure to a sterile environment (*Figure* ❾).

High gloss is another common requirement of printed label products, since they usually involve surface rather than reverse printing. This is usually accomplished with UV coatings. Lightfast requirements are similar to those of wide-web applications.

Household and Office Paper Products

Household paper products, towels, tissues, napkins and the like are almost exclusively printed with aqueous flexo inks. They are formulated for a wide range of absorbent stocks. These inks must not bleed or rub off in the presence of greasy foods and common household cleansers. Tack, not normally measured as a flexo ink property, must remain low throughout the printing process to prevent paper fiber and ink from plugging the printing plate.

Other uses include decorative gift wraps, ream wraps for copier paper, low-cost forms, letterheads and envelopes. Many of these applications do not require lightfastness. The decorative papers use inks that offer bright colors and special effects such as metallic or fluorescent prints (*Figure* ❿).

Publication/Commercial Printing

Water-based flexographic inks have become a viable alternative in the newspaper market. The process has been identified as an alternative to letterpress and offset

lithographic installations. Use has been enhanced by advances in photopolymer printing-plate technology and the ability to satisfy the growing four-color needs of the industry. Other cited advantages are elimination of VOCs, faster press speeds, reduced costs and improved quality.

Over the years, the primary requirements for newspaper inks were low cost and good mileage because newsprint, a rough surface that does not lend itself to quality work, is generally used for printing copy that is read once and then thrown away. Most newsprint is printed with offset inks that dry by penetration, which accounts for their low-rub resistance. Heat-set inks are also available, and give better printing results because they are bound to the sheet after drying and do not further penetrate the paper.

Flexography has also made inroads in book and other publishing areas, such as newspaper inserts and low-budget magazines. Book printing is a specialized field requiring different equipment and skills with papers ranging from heavyweight coverstock to very lightweight, almost tissue-thin paper.

As flexography expands in specific market segments, it is finding applications in the commercial printing, of anything from simple invitations to sophisticated brochures. Print shops that flexography is employed in range in scope from a simple one-press operation to a multifaceted business utilizing a complicated maze of equipment.

TESTING END-USE INK PROPERTIES

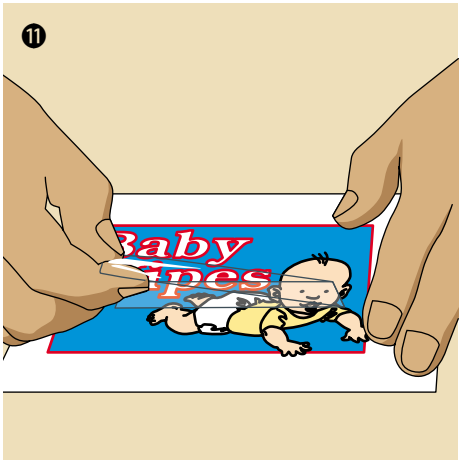
A number of tests have been established over the years to evaluate the properties of inks required for an increasingly broad spectrum of uses. They are described in detail in reference material from the National Association of Printing Ink Manufacturers (NAPIM), ANSI Standard Test Methods (ASTM), the Flexographic Technical Association (FTA), and Technical Association of the Pulp and Paper Industry (TAPPI).

Test procedures for some of the more important properties are discussed here. They fall generally into two categories: those that test the durability of the ink film and those that test its appearance. These tests are not a complete list, but are offered as guidelines for communicating ink requirements and demonstrating performance. The most important criterion for any test procedure is that it be performed consistently to ensure that the manufacture of inks and their subsequent application on press meet the desired specifications and tolerances.

Substrate adhesion is most commonly measured using the pressure-sensitive tape adhesion test, which compares the ink-to-substrate bond to the bond of the adhesive between tape and the ink surface.

To conduct the test, an 8" or wider sample of the printed or coated substrate to be evaluated is placed on a flat surface and fastened either mechanically with clamps or tape. Sample tension should be sufficient to prevent wrinkles and hold the sample flat (*Figure* ⓫).

A 1" by 6" pressure-sensitive tape (3M 610 brand or equivalent) is applied full length to the cross-direction width of the sample. Any air bubbles are removed with one pass only

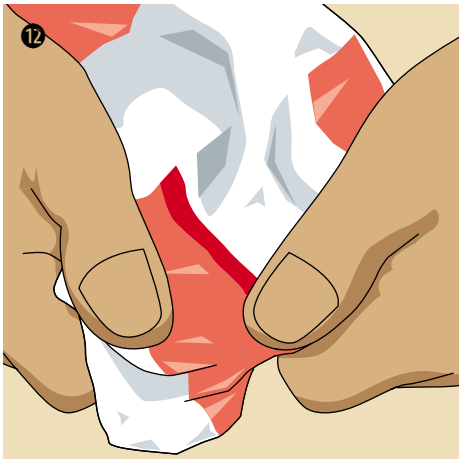


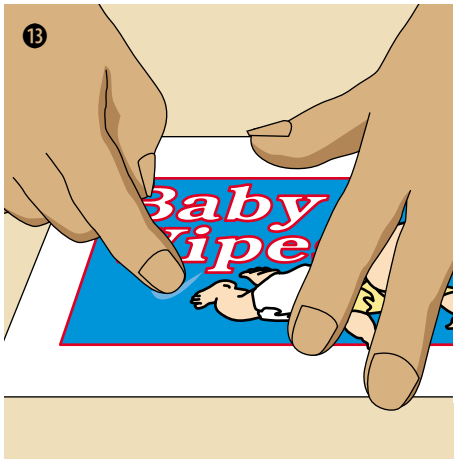
⓫ Substrate adhesion is most commonly measured using the pressure-sensitive tape adhesion test. It compares the ink-to-substrate bond to the bond of the adhesive between tape and ink surface.

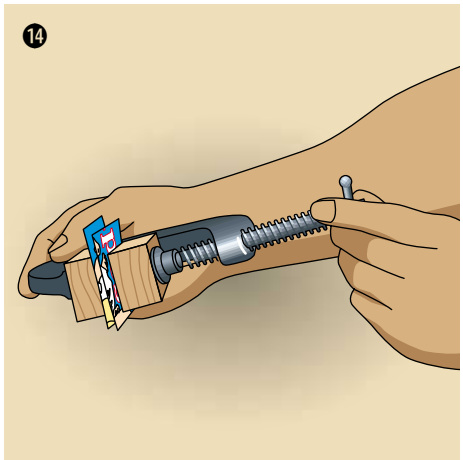
⓬ Crinkle adhesion determines the flexibility and bonding characteristics of the ink when a flexible substrate is crinkled.

⓭ Scratch resistance is determined by placing a sheet of the printed substrate on a smooth, resilient surface, a paper pad for example, and scratching with the back of the index fingernail.

⓮ A "C" clamp, press-side, block-resistance test provides a quick, running indication of whether thorough drying and complete solvent removal is happening on the press.







of a rubber-covered roller, and then the tape is immediately removed by pulling at an angle of 180°.

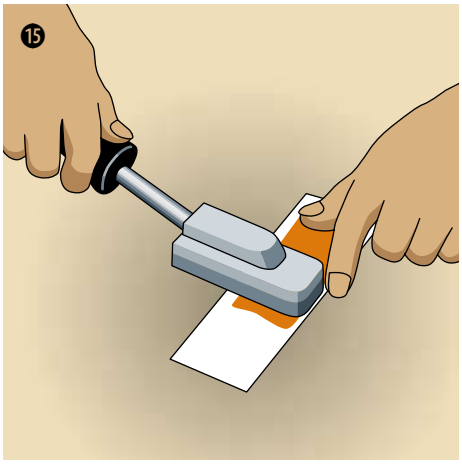
The tape and substrate are examined for evidence of adhesion failure. Adhesion is reported as the estimated percentage of lift on the substrate.

Crinkle adhesion determines the flexibility and bonding characteristics of the ink when a flexible substrate is crinkled. A piece of the printed substrate is grasped between the thumb and forefinger of each hand with about 0.05" of substrate between the two thumbs. The hands are brought almost together and rotated fairly rapidly about 10 times (*Figure* ⓬). Avoid generating too much heat or cutting into the print with the fingernails. On coated substrates, it is necessary to determine if the failure is ink adhesion or coating separation.

Scratch resistance is determined by placing a sheet of the printed substrate on a smooth, resilient surface, a paper pad for example, and scratching with the back of the index fingernail. Fast "swipes" are made using moderate pressure while avoiding cutting the ink film (*Figure* ⓭).

Block resistance is the ability of a printed surface to separate from an adjacent surface without sticking or disturbing either. There are a number of block tests. *Figure* ⓮ shows the "C" clamp press-side test generally used to provide a quick, running indication of whether thorough drying and complete solvent removal is happening on the press. A widely accepted block test is the IC block test. Test samples are assembled in an IC block tester and placed in an oven equipped with automatic humidity and temperature controls. This permits the testing of a series of samples in "sandwich" form and provides uniformly accurate results.

Lamination adhesion is critical for inks used on a substrate designed to enhance barrier and other property combinations, especially those developed for packaging applications. The inks do not need gloss or surface conditioners, but they must have good adhesion to the printed substrate and to the adhesive



⓯ To test for heat resistance on a printed substrate, the sliding-iron test requires that a hand iron, set at a certain temperature, be drawn across the printed surface a pre-determined number of times as any break-down of the ink or surface is noted.

materials. They must also withstand the temperature of the lamination operation. Ink tests for laminations are generally the same as for single substrates. If the ink is on the surface of the outer substrate, requirements are the same as for surface-printed, single substrates. If the ink is printed on one of the inner substrate surfaces, though reverse-printing of an outside transparent film, or surface-printing of an inner substrate, it must pass the pressure-sensitive tape test, the crinkle test for adhesion, and pressure block-resistance test with the printed surface in contact with the backside of the substrate.

Rub resistance is required of many printed inks to enable the package to withstand handling between the press and the point of sale. Rub resistance may also be described as resistance to scuff or abrasion. The Sutherland rub test has been established as the standard for measuring this property.

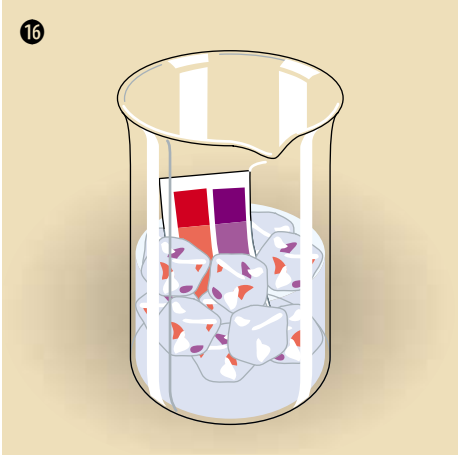
In a typical dry-rub procedure, a 7.5" test strip (with a solid printed image l" by l.5" centered on the sample) is clipped to the four-pound testing block (printed surface away from the rubber pads). The printed sample is mounted (print side up) on the rubber pad of the base plate. The weight is placed over the sample with one of the 1" by 2" test-block rubber pads over the ink. Both surfaces should be free of dirt. The tester should be set for 100 strokes and, when the rubs have been completed, both the inked surface and the plain surface on the test block should be examined for signs of transfer.

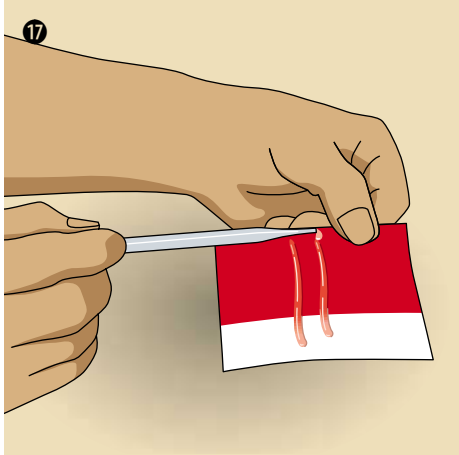
To measure wet-rub resistance, the test strips are mounted in the same manner as for dry rubs on the two-pound test block. Two to six drops of water are placed on the printed surface so that they will be covered by the test block. The block is positioned and press the test started. After one stroke, both surfaces are examined for color transfer. Individual strokes are repeated until ink failure is noted. The number of strokes required to cause failure is recorded.

Heat resistance is a companion requirement to rub resistance in many printed packaging applications and is needed to withstand the heat applied by sealing equipment close to the package. The heat sealing devices may be the sliding, heated flat shoe or crimp-type jaw designs. Sliding iron and crimp-seal tests have been established to test required heat resistance.

The sliding iron test (*Figure* ⓯) requires that a hand iron is drawn at the desired temperature (read with a surface pyrometer) across the printed or lacquered surface a predetermined number of times, usually three. After this, any breakdown of the ink or lacquer surface is noted, as is any drag on the iron. Either of these results indicate unsatisfactory heat resistance.

In the crimp seal test, either a laboratory model or actual production crimp jaw on the heat-seal equipment is set for correct temperature, pressure and dwell time to duplicate production requirements. The jaw temperature required on high-speed automatic packaging machines will be noticeably higher than the temperature to seal the heat-seal substrate. The sample is sandwiched between aluminum foil or paper and placed between the jaws of the heat sealer. The crimp-sealing operation is repeated several times on different areas of the substrate to





⓰ The ice-water crinkle test checks the flexibility and integral strength of a print subjected to ice, refrigerator or freezer conditions.

⓱ Acid and alkali resistance is tested by applying a drop of the appropriate reagent to the sample print. After a few moments, it is allowed to run off the printed area onto the unprinted section. The print area is gently scratched to observe if the ink vehicle has been affected.

provide a more critical evaluation of ink transfer. Results are acceptable, if there is no cling or transfer of ink to foil. It helps to operate the crimp jaw against a plain piece of paper after the test. Any ink transfer or sticking of the crimp jaws to the printed substrate indicates unsatisfactory heat resistance or ink flexibility.

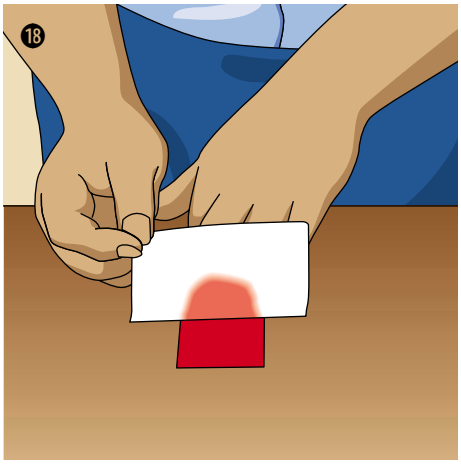
In some applications, the printed area must heat seal to itself or to an unprinted surface. Heat sealing can be tested with either the sliding iron or the crimp seal jaws. The heat seal is pulled by hand or on a seal puller that gives a numerical rating and compares seal strength to that known to be acceptable.

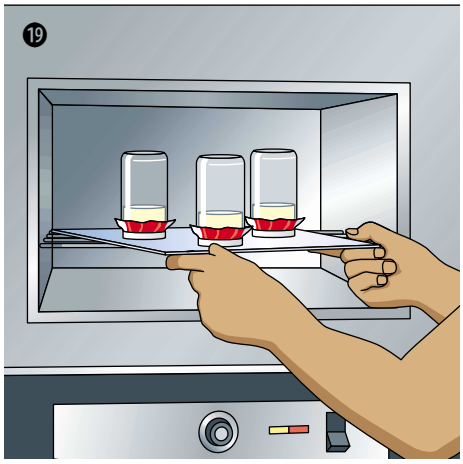
Ice-water crinkle test checks the flexibility and integral strength of a print subjected to ice, refrigerator or freezer conditions. Samples are immersed in a beaker of water and cracked ice for 30 minutes and then removed. While they are still wet, the samples are grasped firmly between thumb and forefinger of each hand with about 1" of print between the two thumbs. With the hands together, the samples are rubbed 10 times rapidly in opposite directions. One complete cycle consists of both a back and forward motion of the wrists. The percentage of ink removed is recorded and compared to the standard (*Figure* ⓰).

To test for freeze-thaw resistance, the printed samples are immersed in a beaker of water and put in a freezer for 16 hours. After removal, the beaker is allowed to thaw to normal room temperature and then the samples are given the crinkle test.

Moisture bleed or transfer resistance test is important for packages that come out of the freezer and sit on the kitchen counter to thaw. The printed ink should not bleed onto the counter as moisture condenses on the cold package. Using the Sutherland rub test, a strip of blotting paper 5.5" by 2" is mounted on the test block with the felt or smooth side out. The blotter is saturated with water. The wet blotter is placed on the sample to be tested and left in place for four minutes. The block is removed without rubbing and examined for ink transfer to the blotter. An alternative procedure is to place the print sample in a beaker of water for 24 hours. The sample is then removed and wiped with a white tissue. Both the tissue and the water in the beaker are inspected for any color bleed.

Moisture vapor transmission resistance test protects packaged products such as cookies and snacks from the humidity of the surrounding atmosphere. Instruments are available to measure the moisture vapor transmission rate (MVTR) of printed packaging materials. Such units automatically record





⓲ To test for a substrate's soap and detergent resistance, a small sample of printed substrate is placed on top of an unbleached and unsized muslin pad that has been saturated with a concentrated soap or detergent solution. Pressure is applied to the pad and print for a length of time. The sample is then examined and graded according to the amount of discoloration on the surface of the muslin.

⓳ To determine a substrate's oil resistance, the product oil and the print sample is put into a wide-mouth mason jar. The sample is inverted on a glass tray and placed in an oven at controlled temperature and humidity for the specified time.

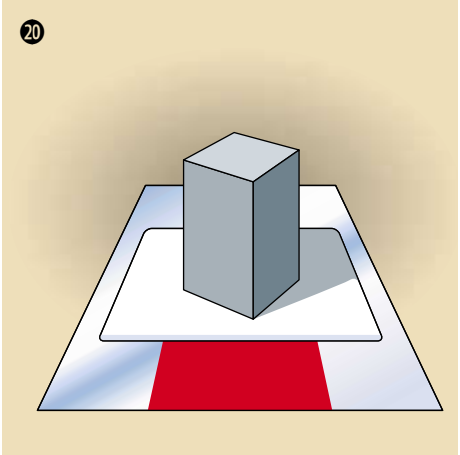
the time required for moisture to pass through the test sample. Results are reported in grams per 100 square inches per 24 hours.

Acid and alkali resistance is required of printed ink films that come in contact with dairy products, juices, and other products that contain acids. To test, a drop or two of the appropriate reagent is applied to the sample print (*Figure* ⓱). After a few moments, it is allowed to run off the printed area onto the unprinted section where any dissolved color can be seen. The print area is gently scratched to observe if the ink vehicle has been affected.

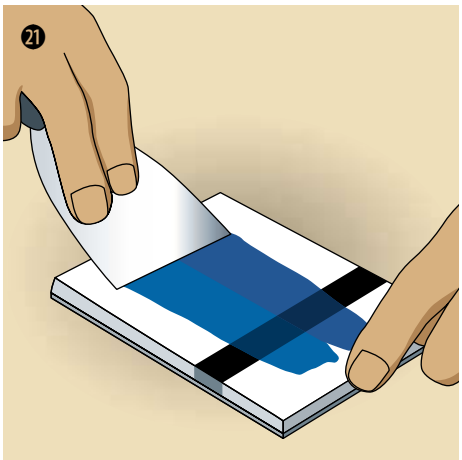
Soap and detergent resistance is essential for the many flexo-printed materials used to package and label soaps, detergents, flakes, and granules. One method of testing is to pour 10 cc of a concentrated solution of soap or detergent in water on a 4" by 4" folded, unbleached and unsized muslin pad (*Figure* ⓲). A test print of 3" by 3" or larger size is placed face up on a smooth glass plate, and the muslin pad is placed on the print. Over the pad is placed a flat 12-ounce machined plate, which is left for a period of time determined by the product and stock specifications. The sample is then examined and graded according to the amount of discoloration on the surface of the muslin and the change in appearance of the test print. Similar practical tests have been devised to determine the resistance of ink formulations to smudging with soap or detergent pastes and to soaps in bar or cake form.

Oil resistance is necessary for inks that come in contact either directly or indirectly with packaged foods containing oil naturally or as a process additive. To determine resistance to oils that may penetrate the substrate, about 1" of the product oil is put into a wide mouth fruit jar. The printed sample is placed on top of the jar with the printed surface up (or down with impervious films) and the jar is sealed with an open-top ring jar closure. The sample is inverted on a glass tray and placed in an oven for 48 hours at 1,200° F (490° C) and 90% humidity (*Figure* ⓳). At the end of the cycle, the printed surface is checked for adhesion by both the pressure-sensitive tape and crinkle tests.

Boiling water resistance is needed for printed convenience food packages in which food is heated before serving. For a typical boiling water test, the printed sample is cut into strips and placed in 200 ml. of boiling water for 5 minutes. The printed strips and water are examined for evidence of bleed or discoloration which connotes ink failure. For steam resistance needed in sterilization and food processing applications, tests are run in equipment ranging from household pressure



⓴ Plasticizer bleed-resistance test procedure requires saturating a piece of white-blotter stock with plasticizer and placing it on the test print . A light weight is put on the sandwich, which is then placed in an oven at controlled temperature and humidity for the specified time. The blotter is examined for plasticizer stain.



㉑ Color measurements can be taken by comparing wet inks done with draw-downs, where an ink drop is spread over a substrate with a rigid blade, block of steel or by anilox proof and the rollout is made with an anilox hand proofer.

cookers to autoclaves at temperatures from 2,150° to 4,000° F (1,020° to 2,040° C). Prints are then inspected for bleed, discoloration and ink breakdown.

Plasticizer bleed resistance test becomes important for printing films such as vinyl that contain plasticizers. Plasticizers can cause inks to bleed into the film or onto another material in contact with the ink. A commonly used test procedure is to saturate a piece of white-blotter stock with plasticizer and place it on the test print (*Figure* ⓴). A light weight is put on the sandwich, which is then placed in an oven at controlled temperature and humidity for the specified time. The blotter is examined for plasticizer stain. Properties that ensure good ink appearance are equally important as those that contribute to an ink film's durability. They include aspects of color (hue match, intensity and value) density, tone quality, image detail, opacity, fade resistance and gloss.

Color measurements are still commonly performed with the naked eye, which remains one of the most sensitive judges of color and its variations. Visual color judgments should be made under standard viewing conditions such as the American National Standards Institute PH2-30-1989 viewing standard. Production prints should be compared to the color standard on the substrate on which the ink will be printed. Comparisons of wet inks can be made by draw-downs (*Figure* ㉑) in which an ink drop is spread over a substrate with a rigid blade or block of steel or by anilox proof in which the rollout is made with an anilox hand proofer.

Color measurements can also be taken using colorimeters and spectrophotometers (*Figure* ㉒) which offer consistent and measurable results. These instruments allow operators to monitor production control, color difference calculations, color specification and tolerance tasks. Measurements should be performed at the instrument's largest viewport area possible. Two samples each from the front, middle and end of the pressrun, on both sides of the sheet, and for each color, should be measured. Readings of solid-ink densities at several areas of specimen surface should be taken to obtain an indication of uniformity and an average ink-density value.

Print density can be measured with a reflection densitometer. The instrument must be calibrated before testing. The LO (white standard) and HI (black standard) values for each color are set and then individual color patches are read as determined by the instrument. Calibration values are verified for each standard patch and adjustments made as necessary. Two substrate samples each from the front, middle, and end of the press run are taken. Readings at 10 locations on each

sample for each of the colors, in solid ink-density areas.

Tone quality can be determined by measuring dot area (percentage of ink coverage on the substrate) with a reflection densitometer. Two samples each from the front, middle and end of the pressrun for each substrate are tested for all colors for each sample. The instrument must be calibrated before testing. The dot area function is selected and the densities of both the substrate and the percent solid are read to obtain the dot area percentage. Readings are taken at five random spots from each sample color and averaged to obtain the dot area percentage for the sample.

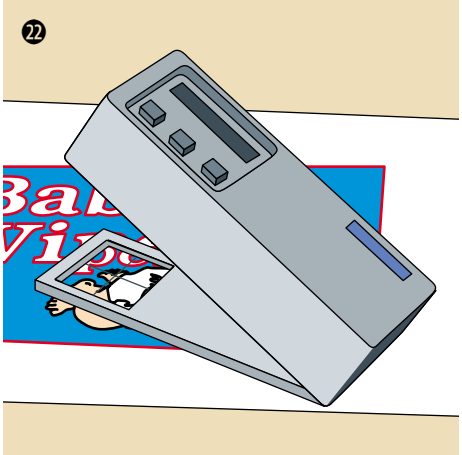
Image detail can be checked using a digital-frame grabber equipped with high resolution optics and a personal computer equipped with image analysis software to quantify the following dot characteristics: maximum and minimum dot area, concentricity, maximum and minimum diameter and density profile. At least 50 dots are measured per sample and readings are taken from five random spots of each sample color. Measurements can also be made using a densitometer.

Opacity or contrast ratio can be measured using a spectrophotometer. The ink sample is printed using an appropriate technique, on a black line sheet. The sample is measured on both the white and black portions of the substrate. The system will then calculate the contrast ratio or approximate opacity of the film.

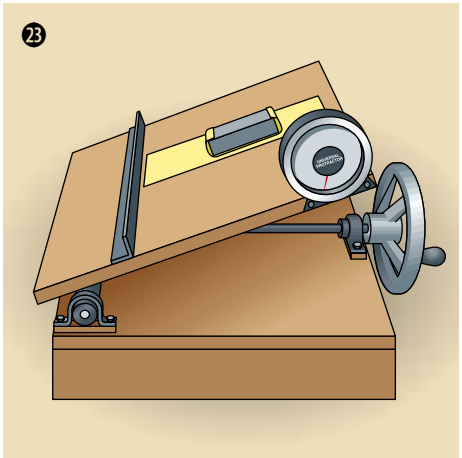
Fade resistance requirements will depend on the application. Inks on an outside billboard, for example, will require much more fade resistance than those on a grocery product with a short shelf life. Rough comparisons are made by covering a portion of each sample with an opaque material. The samples are exposed to sunlight. Equipment such as the Fadeometer or Weatherometer can be used to conduct accelerated light-fading tests.

Gloss of a finished print can be normally judged visually, but instrument readings can be obtained with a gloss meter (60° angle) and some spectrophotometers to determine the specular gloss of the material surface. Tile standards are cleaned and the instrument is calibrated according to instructions. Measurements are taken of two samples each from the front, middle and end of the run. Reading areas should be consistent in ink coverage or solid ink densities. The readings should be repeated for all colors, recorded and averaged.

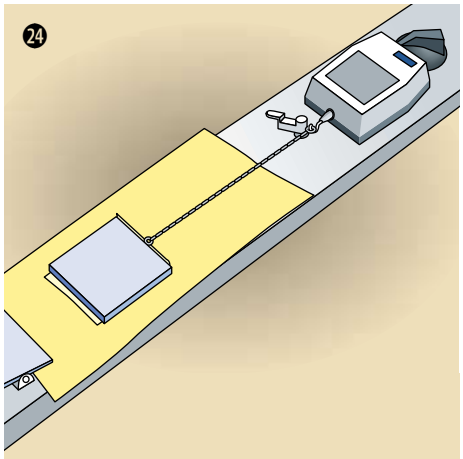
Coefficient of friction (COF) properties indicate the ease or resistance of a surface to move or slide against another surface, and are important both to successful production processes, such as automatic packaging operations, and to applications such as skid resistance of stacks of multiwall bags. To determine the



22 Color measurements can be taken using colorimeters and spectrophotometers, which offer consistent and measurable results.



23 To determine the resistance to sliding of a printed sample, the substrate is attached, face up, to the end of the inclinable arm of a plane. A second piece is attached to a weight positioned at the right end of the arm. The arm is inclined slowly and steadily. At the point where the weight block begins to move down the incline, the angle is read on the protractor scale.



㉔ A friction coefficient tester takes measurements of both static and kinetic COF. At the same time, it also calculates the slip resistance.

resistance to sliding of a printed sample, a strip of plain or printed substrate is attached, face up, to the end of the inclinable arm of the plane. A second piece is attached to the standard weight which is positioned at the right end of the arm. The arm is inclined slowly and steadily. At the point where the weight block begins to move down the incline, the angle is read on the protractor scale (*Figure* ㉓). A more accurate measurement of coefficient of friction uses an IBM friction coefficient tester to provide numerical values for both static and kinetic COF. The instrument applies force to test strips (one clamped to the unit, one free to move) and calculates slip characteristics (*Figure* ㉔).

Odor, or absence thereof, is particularly important in food and personal product packaging applications. To test, the printed specimen is placed in a jar, sealed with a cap and then placed in an oven at 1,000° F (380° C) for 2 hours. The steps are repeated for unprinted control substrate. The jar is opened and a qualitative assessment of the odor is recorded.

Ink Formulation

Having identified and specified the end-use requirements for the printed package and understood the converting conditions, the ink supplier is in a position to formulate an ink system to meet the needs of the job. These end-use requirements, as discussed in the first chapter, can impose limits on the materials available for use by the ink formulator. Therefore, it is necessary for the formulator to have a comprehensive understanding of the physical properties of the raw materials used to produce inks, their interactions and their limitations in producing a usable ink. The converter and end-user must possess similar knowledge.

Printing inks are colored media designed to reproduce an image on a printing surface. They are primarily used to convey a message, provide protection, or give a decorative effect to the material on which they are applied. Inks are extremely versatile and have been used on a wide variety of papers, plastics, metals, glass and textile surfaces. The majority of printing inks consist of a colorant, either an insoluble solid or dye, suspended or dissolved in a liquid vehicle. The resulting combination forms a colored fluid capable of distribution and transfer on a printing press.

In addition to providing the desired visual characteristics, inks are formulated to meet the specific needs of the printing process: they must dry under specified conditions; adhere to a given material; and have specific resistance properties, dictated by the intermediate processing and the final end-use of the finished product.

Inks for flexography have two prominent characteristics that set them apart from inks used in most other printing processes: they are fluid and quick drying.

THE BASICS OF INK TECHNOLOGY

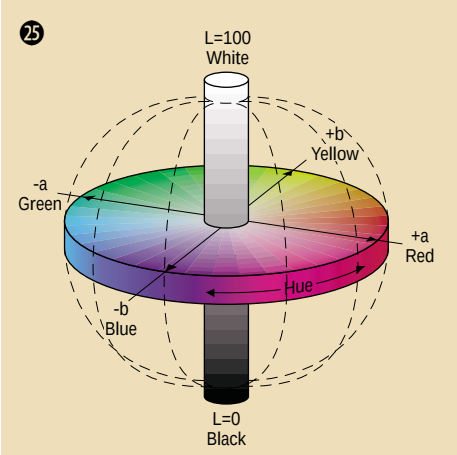
This section will explore these aforementioned requirements and the impact that the individual components and other constituents have on flexographic ink manufacturing, print properties, performance, and the environment.

Color

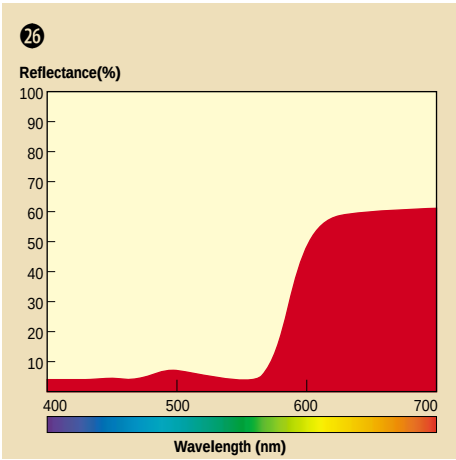
Sir Isaac Newton, using a glass prism, demonstrated that white light could be split up into a “rainbow” of hues: red, orange, yellow, green, blue and violet, which he called the visible spectrum. Newton also observed that the rays themselves are not colored, but, when they interact with an object, that the sensation we refer to as color is perceived.

With very few exceptions, objects do not emit colored light, but only look colored when under illumination. An object that appears black under standard illumination does so because it absorbs all the light falling onto it. Conversely, an object which appears white under the same lighting conditions looks as it does because it reflects all the light incident upon it. If the object absorbs some portions of this “standard” spectrum more than others, it will appear colored. For example, an object that absorbs only red light will appear cyan.

It is important to note that the colors perceived depend on the illuminating source. Different sources of light, e.g., incandescent,



❷❺ Hues can be arranged in a "color circle". This "map" or color space provides the ability to specify colors in numerical terms (L,C,h), which can be accurately measured using a spectrophotometer.



❷❻ A graph can be plotted of wavelength vs. percent reflectance to give a spectral or color curve that represents the color of the object. This curve can then be used as a standard when trying to match that color.

sodium, fluorescent, halogen and mercury vapor, emit visible light with different wavelength compositions. The lack of certain wavelengths or parts of the spectrum means that these light sources can display color. Consider a sodium lamp: light from this lamp is pure yellow and contains no blue component. Therefore articles which appear blue (absorbing red and green wavelengths) in normal daylight appear almost black under a sodium lamp. Although this is an extreme example, it illustrates the need to view all colors under identical, specified light sources for color matching purposes.

The visual characteristics of an ink are recognized in terms of its color and can be defined by three independent variables: hue, saturation, and lightness. Hue (H) actually describes the color, for example, yellow, red, or green. These "hues" can be arranged in a "color circle" (*Figure* ❷❺). Saturation or chroma (C) refers to the intensity and strength of the color, with the strongest, most saturated colors being on the periphery of the circle.

Lightness (L) represents purity, or how light/dark the color is, and is indicated on the z axis. This "map" or color space provides the ability to specify colors in numerical terms (L,C,H) which can be accurately measured using a spectrophotometer. This device is much more sensitive than the human eye and can be used to measure the absorption spectrum of an object by illuminating it with a standard light source of known intensity and measuring the intensities of the various wavelengths reflected. The equipment can then plot a graph of wavelength vs. percent reflectance to give a spectral or color curve (*Figure* ❷❻) that represents the color of the object. This curve can then be used as a standard when trying to match the color.

Colorants

Pigments together with dyestuffs, provide the color or visual identity of an ink and represent the largest share of the total cost. They are present to provide both decorative and functional properties: for example, lightfastness, opacity/transparency and product resistance. Both types of colorants are chemical compounds that alter appearance by the selective absorption and/or reflection of light energy. For organic pigments and dyes, this is determined by specific groups of atoms, called chromophores (C=C, C=O, C=N, N=N), present within the molecules which absorb light energy. Different combinations of chromophores absorb different levels of energy, thereby producing different observed colors. Other chemical groups, known as auxochromes (OH, Cl, Br, NH2 , CH3), while not responsible for selective absorption, help

enhance the effects. Processing conditions during pigment manufacture and subsequent chemical treatments also affect the observed colors. The color of inorganic pigments is also a function of chemical composition and oxidation state, and is influenced by the crystal form of the substance.

A pigment is largely insoluble in the ink media, requiring it to be dispersed, while dyestuffs are soluble in the vehicle system. Along with this solubility difference, there are other basic variations between pigments and dyes as listed in *Table 2*. Clearly, the properties required of the ink and finished product dictate the colorant used.

Dyes

The dyes used in flexographic printing fall into four categories:

Solvent Soluble. Solubility in a range of organic solvent is a typical physical characteristic of solvent-soluble dies. These dyes often contain the heavy metals Chromium and Cobalt, which lead to environmental, health and safety concerns. Used for their purity of shade and transparency on foil coatings, they have better lightfastness than the basic dyes.

Basic or Cationic Dyes. Although they show high color intensity, brilliancy and solubility in blends of alcohols and water, the use of cationic dyes in the flexo industry has decreased because of toxicity concerns. These dyes are often used in conjunction with mordants or fixative agents, such as tannic acid, to improve physical properties like water resistance and lightfastness. These dies are suitable only for short-term use on paper with minimal-resistance requirements. They still remain the primary components for the triarylmethane pigment range.

Disperse Dyes. The primary use of disperse dyes in the printing industry is in heat-transfer inks for printing on textiles. After dispersal in a flexographic vehicle, the dye-based ink is printed on paper. The printed image is brought into contact with the fabric under conditions of high heat and pressure. The dye sublimes, penetrating the fabric where it condenses, giving bright saturated colors.

Acid Dyes. Acid dyes have a strong affinity for cellulosic materials and are used for water-based fugitive check inks, invisible inks in painting books, and in dyeing paper. Primarily soluble in water, they give bright hues with light-fastness ranging from very poor to good.

Pigments

There are numerous different types of pigments. Some are available naturally, primarily as minerals, but the majority are synthetic, meaning that they are generated from petro-

PIGMENT AND DYE VARIATIONS

PROPERTIES	DYES	PIGMENTS
Color	Strong, vivid and clean	Weak to strong, dirty to clean
Lightfastness	Poor	Fair to excellent
Bleed Resistance	Poor	Fair to excellent
Chemical Resistance	Poor	Fair to excellent
Heat Resistance	Poor to fair	Fair to excellent
Optics	Very transparent	Opaque to transparent
Rheology	Excellent	Poor to good
Toxicity	Fair (except FC&D dyes)	Fair to very good

Table 2

leum feedstocks. A simple, though imperfect, way to classify them is as organic and inorganic pigments.

Organic pigments are those derived from carbon-based materials, while inorganic pigments are compounds of various metals which contain no carbon atoms with the exception of carbon black. Although there are numerous types of pigments, few find their way into ink formulas. Many are uneconomical, do not provide the necessary resistance or performance properties, or have associated environmental or toxicity hazards which preclude their use in flexographic inks.

The following section is a detailed description of the most commonly used pigments within the industry. Each pigment can be identified by names in common use, together with the appropriate color index number. (The Color Index is a method devised by the Society of Dyeists and Colorists for classifying pigments based on their chemical type and structure). Miscellaneous materials including metallic powders, pearlescents, fluorescents and specialty pigments are covered separately.

Inorganic Pigments

With a few minor exceptions, inorganic pigments have certain notable features. These include: high lightfastness, economy, high opacity, weak tinctorial strength, high specific gravity and a lack of cleanliness of hue. Toxicity is also a common feature associated with inorganic pigments that contain harmful metals such as cadmium, lead, chrome and molybdenum. Inorganic pigments commonly used in flexographic inks include: titanium dioxide, carbon blacks, iron blues, iron oxides and extenders such as calcium carbonate, silica, lithopone and clay.

Titanium Dioxide. This is the most important white pigment (PW 6) in use today due to its chemical inertness. A variety of grades are available. The different grades are surface treated with coatings of silicon oxides, zirconium, aluminum, zinc, or organic chemicals to aid dispersion, maximize opacity or gloss and improve durability. There are two major crystal forms: anatase and rutile. The rutile grade is more opaque, but slightly more abrasive and yellow than the anatase grades.

Most grades are produced using the chloride process, rather than the environmentally unfriendly sulfate process. The chloride process generates a harder crystal structure with higher dry brightness. The anatase grade is preferred in situations where doctor blade, cylinder or die blade wear is a problem. A dispersed particle size of approximately 0.2 microns is necessary to achieve optimal light scattering.

Carbon Blacks. These pigments have an extremely fine particle size with a high surface area, which can cause body and flow problems. Like titanium dioxide, they show outstanding chemical inertness, being extremely resistant to acids, alkalis, light, heat and solvents. Almost all grades of carbon black (PBk. 7) available are produced by the furnace process. Such furnace grades often undergo further chemical processing with oxygen and surfactants to mimic the superior wetting and flow of the now virtually defunct channel blacks.

Iron Blues. Also known as Milori, Bronze, Chinese, or Prussian Blue (PB 27), iron blues range in shade from a dirty reddish tone to a cleaner green shade and can show considerable bronzing. These pigments show excellent resistance to solvents, fats and light (except tints with titanium dioxide), but are difficult to grind. They have poor alkali resistance and are unsuitable for use in water-based systems or for use on soap wrappers. These pigments should not be used in oxidatively sensitive ink formulas.

Iron Oxides. Typically opaque and tinctorially weak, iron oxides vary in shade from dirty yellow (PY 42), through dull red brown (PR 101, PR 102, PBr. 6, PBr. 7), to black (PBk. 7). They exhibit exceptional chemical and

weather resistance, are strong UV absorbers, economical and suitable for direct food contact. They can be extremely difficult to disperse, and use of micronized grades is advised to prevent mill- and press-wear problems.

Extenders

Extender pigments have a myriad of properties. They are used to reduce costs without affecting printing properties, e.g., calcium carbonate (PW 18). They are used to reduce abrasion and provide opacity, e.g., lithopone (PW 5), or prevent settling and aid printability, e.g., clay (PW 19). Certain extenders are used to aid flatting or reduce tack, e.g., silica (PW 27).

Organic Pigments

Organic pigments can be subdivided into three categories pigmentary colors, high performance pigments and metal salt pigments. **Pigmentary Colors** are "true" pigments – very insoluble compounds that happen to be colored. Many important groups of pigments, particularly the yellow and blues, are represented in this area. Pigmentary colors are generally water-resistant and relatively unaffected by reagents, such as acids and alkalis. However, the absence of salt groups does make them prone to solvent solubility and fat or wax sensitivity. The resistance properties of pigments are improved by increasing their molecular complexity and molecular weight.

• **Diarylide Yellows.** Characterized by high strength and good resistance to acids and alkalis, this group of pigments ranges in transparency. AAOT (PY 14) and AAA yellow (PY 12) are inherently opaque pigments that can be coated with resin during manufacture to improve their transparency. In contrast, AAOA (PY 17) and HR Yellows (PY 83) are intrinsically transparent. AAOT Yellow, a greenish-yellow pigment, is the most commonly used yellow pigment within the United States for flexo packaging. It displays good flow and working characteristics, good print strength, reasonable gloss and acceptable lightfastness. HR Yellow (PY 83), an extremely red-shade pigment, has a higher level of chemical complexity and molecular weight than PY 14, giving it excellent lightfastness, transparency, heat and solvent resistance. It is suitable for many demanding applications.

• **Hansa Yellows.** Typically greener in shade than the Diarylide pigments, they have significantly greater lightfastness at the expense of tinctorial strength and heatfastness. These lower-molecular weight pigments are also prone to bleed in fats, oils, plasticizers and aromatic hydrocarbons. Common pigments include Hansa 10G (PY 3) and Hansa 5GX (PY 74).

• **Naphthol Reds**. A very wide range of pigments based on the b-oxynaphthyl (BON) unit. These red pigments are commonly durable soap-fast reds with good lightfastness. However, as with any pigment, their properties vary with chemical structure. Care should be exercised in selecting the correct Naphthol red for a given application. Naphthol reds lack the cleanliness, gloss, fat resistance and cost effectiveness of the metal salt pigments. Care has to be taken in formulation to maintain flow properties. Six of the most common Naphthol pigments – Red 112, Red 2, Red 5, Red 7, Red 23, and Red 12 – are arranged in shade order with PR 112 being the yellowest shade and PR 12 offering the bluest shade of red.

• **Phthalocyanines**. In most respects, these are ideal pigments in that they provide strong, clean shades together with outstanding resistance properties at a reasonable cost. With the Phthalo blues there are three crystal forms available: alpha (PB 15 and PB 15:1, red shade), beta (PB 15:3 and PB 15:4, green shade), and epsilon (PB 15:6, redder than alpha). The most important in terms of volume are the beta forms. Another special-

ized Phthalo blue is the metal-free variety (PB 16) used in situations where copper cannot be tolerated even if it is "locked up" in the pigment. There are two Phthalo greens available: PG 7 and PG 36. They are considerably more expensive than the phthalo blues and only used where mixtures of phthalo blue and yellow are inadequate. The two grades vary in shade with PG 36 being yellower and weaker than the PG 7.

High Performance Pigments. There are a great number of specialty high performance pigments available including: isoindolines, perylenes, diketopolypyrolidones and indanthrones. When cost allows, indanthrones are being used to a greater extent in flexographic inks. Two, special and costly, red and violet pigments are used when extreme resistance properties are required. These two are Quinacridone Red (PR 122), which is similar in color to Rhodamine Red, and Carbazole or Dioxazine Violet (PV 23). Their properties are similar to those of the Phthalocyanines pigment, but unfortunately, the same cannot be said of their costs.

Metal-salt Pigments are water-soluble "dyes" that have been converted into water-insoluble salts. Most notable in this area are a specific group of red pigments and the Fanals, e.g., methyl violet (Fanal is an early trade name given to triarylmethane class of pigments). Metal-salt pigments show excellent resistance to fats, oils and waxes. Except for the fanals, they remain relatively unaffected in the presence of solvents; however, all are extremely sensitive to aqueous reagents (acids, alkalis, soaps).

• **2B Reds**. Calcium 2B Red (PR 48:2) is a versatile blue-red shade with good working properties and reasonable lightfastness. The Barium 2B Red (PR 48:1) is yellower than the calcium salt and preferred for its opacity and better flow, though environmental concerns sometimes preclude its use. The Manganese 2B Red (PR 48:4), which is a clean medium-scarlet shade, is notable for its lightfastness and is used in applications requiring outdoor exposure. All these pigments are prone to "hydration," in that when exposed to water for prolonged periods, they tend to change shade, becoming more yellow.

• **Lithol Reds**. Like the 2B reds, the hues of these pigments vary with the salt. Economical pigments, like the calcium lithol (PR 49:2) can be used successfully in both water-based and solvent-based inks.

• **Lake Red C.** This low cost pigment (PR 53:1) has good working characteristics: it is a clean, bright yellow-red that has good fat or oil resistance. Drawbacks include poor resistance properties to light, even at full strength, and reactivity with acids and alkalis. Use has been diminishing because of barium content.

• **Clarion Red or Ethyl Lake Red C**. Similar chemically to Lake Red C (PR 53:1) in that it is a barium salt that can limit its utility, Clarion Red (PO 46) is a highly transparent orange-red shade with good gloss.

• **Lithol Rubine.** Commercially available as the calcium salt, (PR 57:1), lithol rubine is often referred to as a 4B pigment. Although many grades are available, it typically has good transparency, prints well, and is commonly used because of its shade, transparency and cleanliness as a process magenta. Red 2G (PR 52:1) offers a similar if slightly bluer shade, but has a slight advantage with gloss and flow.

Triphenylmethane Salts. This group includes the pigments more commonly known as Methyl Violet (PV 3, PV 27), Rhodamine Red (PR 81, PR 169), Alkali Blue (PB 56), and Brilliant Green (PG 1). They are expensive due to the high cost of raw materials, however, their brightness and cleanliness of shade cannot be achieved in any other way at a competitive cost. Resistance properties on the whole are poor. They all bleed into various organic solvents, soaps, fats, oils and plasticizers. Extreme care has to be taken when formulating with inks based on these

pigments, including reviewing the process and end use, to prevent any problems.

Chemical structure dictates that the properties shown by the pigments in the different classes listed above vary significantly. For a more detailed look at the generic properties of various pigments consult *Table 3*. In this table, the numbers for lightfastness are presented on a scale of 1 to 5, where 5 is best. The scale for chemical resistance is from 1 to 8, where 8 is best.

Laked Pigments. A laked pigment is produced when a water-soluble salt is precipitated onto an inorganic carrier such as alumina hydrate or barium sulfate. Such pigments have minimal use in the ink industry, but are used as food colorants or artists colors, e.g., Tartrazine Yellow lake.

Miscellaneous Pigments

Fluorescent Pigments. These pigments are comprised of weak solutions of specialty dyes in a resin matrix. The chemical composition of the dye gives them the unusual property of fluorescence. This phenomenon occurs when a substance absorbs light of a shorter wavelength (UV light, which is not visible to the human eye, in this case) and re-emits it as visible light. Therefore, these substances emit more visible light than they absorb, which multiplies their brilliance to the eye. Because the resin matrix is variable, these pigments are offered with a variety of functional properties including: specific solvent resistance, water resistance, and limited heat resistance. However, there still remain some severe functional and application limitations:

• **Light-fastness**. Because dyes are used to achieve the color in fluorescent pigments, the light-fastness is poor.

• **Color Strength.** Fluorescent pigments have low pigment-tinctorial strength due to large particle size. This low tinctorial strength requires a heavy film-weight application either from multiple passes or by using large, deep anilox cells. Heavy application weights may also give rise to drying problems.

• **Particle Size.** Maximizing fluorescence requires a large pigment particle size. This larger size can result in the pigment settling, or in plugged anilox cells. Attempts to reduce particle size severely curtail fluorescence.

• **Contamination.** Excessive toning or incorporation of other pigment types into the fluorescent ink will reduce or remove the fluorescent effect.

• **Stability**. Other components used within the ink must be selected to prevent attack upon the resin matrix, which destabilizes and destroys the pigment.

An alternative to using pigments is to use soluble fluorescent toners. These materials can be easily incorporated into vehicles to produce useful flexographic inks. The only drawback is that these toners are dyes, and therefore subject to the same resistance properties.

Metallic Pigments. These pigments are used to impart a metallic appearance on the printed substrate and mimic silvers and golds. Metallic pigments are derived from micronized flakes of aluminum (Al) metal and alloys of copper (Cu) and zinc (Zn), respectively. Unfortunately there are intrinsic problems with metallic inks:

• **Reactivity**. The metals used to make these pigments, particularly aluminum and copper, are reactive. The vehicles chosen to disperse these pigments have to be inert, e.g., polyamides or solvent acrylics. Both acidic and alkaline vehicles can react to different degrees with both metals. For example, copper in combination with nitrocellulose causes a reaction that releases nitrogen oxide (No_x) gases and significant amounts of heat, resulting in a dangerous fire hazard. Similarly, although more controllable, aluminum reacts with the water and amines present in a water-based ink to generate hydrogen gas. Both examples illustrate the care

PIGMENT PROPERTIES

PIGMENT	COLOR INDEX	SHADE	FLOW	OPACITY	LIGHTFASTNESS/ CHEMICAL RESISTANCE FULL	TINT	ALKALI	ALCOHOL	FATS	SOAPS	COMMENTS
Alkali Blue	PB 56	Strong R/S blue	P	Semi	2	1	2	4	5	3	Very alkali sensitive
Alumina Hydrate	PW 24	Extender	M	Trans	N/A	N/A	2	5	5	5	Poor ucid resistance
Barium 2B Red	PR 48.1	Bright Y/S red	G	Semi	4	2	2	5	4	2	Contains barium
Barium Lithol	PR 49.1	Bright B/S red	M	Semi	2	2	2	4	3	2	Contains barium
Calcium 2B Red	PR 48.2	Very blue shade	M	Semi	6	4	2	5	5	1	
Calcium Carbonate	PW 18	Extender	G	Trans	N/A	N/A	5	5	5	5	Poor acid resistance
Calcium Lithol	PR 49.2	Strong B/S red	M	Semi	2	2	3	4	3	3	
Carbazole Violet	PV 23	Dull R/S purple	M	Semi	7	6	5	5	5	5	Expensive
Carbon Black	PB 7	Black	M	Opaq	8	8	5	5	5	5	
China Clay	PW 19	Extender	M	Semi	N/A	N/A	5	5	5	5	Low-cost extender
Clarion Red	PO 46	Y/S red	G	Trans	3	2	2	5	5	2	Contains barium
Cu-free Phthalo Blue	PB 16	Dirty G/S blue	M	Trans	8	7	5	5	5	5	S1 less heat stable
CuFe Rhodamine	PR 169	Strong rose pink	M	Trans	5	3	2	2	4	1	Darkens in light
Dianisidine Orange	PO 13	Y/S orange	M	Semi	5	4	5	4	4	5	
Diarylide Orange	PO 34	Bright	M	Trans	6	4	5	5	4	5	
Diarylide Yellow	PY 14	Warm yellow	G	Semi	5	3	5	5	5	5	
Diarylide Yellow	PY 17	Lemon yellow	P	Trans	6	4	5	5	4	5	
DNA Orange	PO 5	Dirty red-orange	G	Opaq	6	4	4	4	2	2	
Hansa Yellow	PY 74	G/S yellow	G	Opaq	6 – 7	5	5	4	2	5	Sublimes on heating
HR Yellow	PY 83	Red shade	M	Trans	6	4	5	5	5	5	
Iron Blue	PB 27	Dirty blue violet	M	Trans	4	3	2	3	4	2	Dirtier than PV 3
Iron Blue	PB 27	Dirty R/S blue	M	Opaq	6	4	1	4	4	2	Hard pigment
Iron Oxide Yellow	PY 42	Dirty yellow	G	Opaq	8	8	5	5	5	5	FDA suitable
Lake Red C	PR 53.1	Warm Y/S red	M	Trans	3	2	2	5	4	2	Contains barium
Lithol Rubine	PR 57.1	Strong B/S red	M	Trans	3	2	2	5	4	1	Std. process color
Lithopone	PW 5	White	E	Opaq	8	8	5	5	5	5	Poor acid resistance
Mac BON Red	PR 52.1	Strong B/S red	G	Trans	4	3	2	5	4	1	
Manganese 2B Red	PR 48.4	Med. scarlet	M	Semi	7	5	2	5	5	2	
Naphlhol Dark Red	PR 23	Dark B/S red	P	Trans	6	3	4	2	5	5	Good in NC chip
Naphtbol Carmine FB	PR 5	Strong B/S red	M	Semi	7	5	5	4	4	5	Very high cost
Naphthol Bordeaux	PR12	Very blue shade	P	Semi	6	4	5	5	4	5	Dull, very soapfast
Naphthol F5RK Red	PR 170	Bright B/S red	P	Semi	7	4	5	4	5	5	Very high cost
Naphthol FRR Red	PR 2	Bright Y/S red	M	Semi	6	4	5	4	2	5	
Naphthol Red FGR	PR 112	Clean med. red	M	Trans	6	6	5	5	4	5	Soap-fast scarlet
Phthalo	PB 15.4	G/S blue	M	Trans	8	7	5	5	5	5	Process
Phthalo Blue	PB 15.1	R/S blue	P	Trans	8	7	5	5	5	5	
Phthalo Green	PG 36	Y/S green	P	Trans	8	7	5	5	5	5	
Phthalo Green	PG 7	Bright green	P	Trans	8	7	5	5	5	5	Expensive, poor flow
PTMA Methyl Violet	PV 3	Bluish violet	G	Trans	5	3	4	1	4	2	Darkens in light
PTMA Rhodamine B	PV I	Clean magenta	G	Trans	4	3	4	1	5	2	
PTMA Rhodamine Y	PR 81	Rose pink shade	G	Trans	4	3	2	3	3	2	Bleed prone
Quinacridone Red	PR 122	Bright B/S red	M	Semi	8	7	5	5	5	5	Duller than PR 81
Silica	PW 27	Extender	P	Trans	N/A	N/A	5	5	5	5	Matting agents
Titanium Dioxide	PW 6	White	G	Opaq	8	8	5	5	5	5	Can be abrasive

KEY: E=Excellent G=Good M=Medium P=Poor Opaq=Opaque Semi=Semitransparent Trans=Transparent

Table 3

required to formulate a safe metallic ink.

• **Rub and Cohesion.** One of the goals with metallic inks is to provide a printed surface that can mimic a true metal surface, by having a similarly high reflectivity. To achieve this reflectivity, the pigments are specially treated and size-graded to help determine their orientation in the printed ink film. For high reflectivity or brightness, it is important that the metallic flakes are flat or plate-like and that they stack on top of each other in an ordered fashion. Unfortunately, this stacking results in poor cohesion in the metallic ink itself and consequently poor rub. These properties can be improved, but always at the expense of brightness.

• **Specific Gravity.** Because of their high specific gravity, metallic inks are prone to settling, especially in low-viscosity systems, reduced inks and ink fountains with minimal agitation.

Pearlescents. These titanium-treated mica-based (silicon oxide) pigments are used for their optical properties, which impart a pearlescent effect. Plate-like in structure, these inert pigments can be incorporated into a wide range of vehicle systems. Minimal dispersion should be used to avoid destroying platelets and care taken to avoid settling. High binder levels are required to "fix" pearlescents. They can be used with iron oxide dispersions to achieve simulated gold and silver, and are useful where aluminum or bronze cannot be used.

Thermochromic Pigments. These expensive pigments consist of thermally sensitive liquid crystals encapsulated in a transparent polymer shell. The fragile nature of this polymer shell means that the pigments are usable only in water-based systems with minimal organic solvent content and that high-shear processes must be avoided. To get a noticeable response, a heavy film weight must be applied, requiring multiple passes.

INK VEHICLES

INGREDIENT	RESPONSIBLE FOR
Resin	Pigment dispersibility and carrier Ink transfer and printability Adhesion and functional properties
Solvent	Viscosity control Drying speed
Additives	Defoaming Rub and slip modification
Anti-oxidants	Flexiblity modifiers

Table 4

INK VEHICLE

The "transparent" part of the ink is the vehicle. The purpose of the vehicle is to act as carrier for the colorant, to bind this colorant to the substrate being printed, and to contribute the functional properties required by the finished print. This ink vehicle is a composite of resins, solvents and additives. *Table 4* outlines these elements and their functional properties.

Resins

There are a large number of resins available to the ink formulator; following are the most common.

• **Nitrocellulose**. The most common resin used in solvent flexographic inks is nitrocellulose. It offers good pigment wetting, low odor, good solvent release, high heat resistance, economy and wide compatibility. This compatibility allows nitrocellulose to be modified with other resins that have complementary properties to offer the possibility of producing inks for nearly all substrates. Available in a variety of viscosity grades, the degree of nitration and hydrolysis achieved during resin production determines the solubility and physical properties, such as viscosity and heat resistance.

• **Rosin Esters**. These esters include maleic and fumaric modified rosins. Medium acid-

value maleics have utility in alcohol-based flexographic inks and are used in combination with nitrocellulose and polyamides for papers, films, and foils. High acid-value resins have utility in water-based flexo inks as grinding and modifying vehicles. They typically improve printability and gloss by aiding ink flow and transfer. They also can be used to help increase the heat resistance of softer resins.

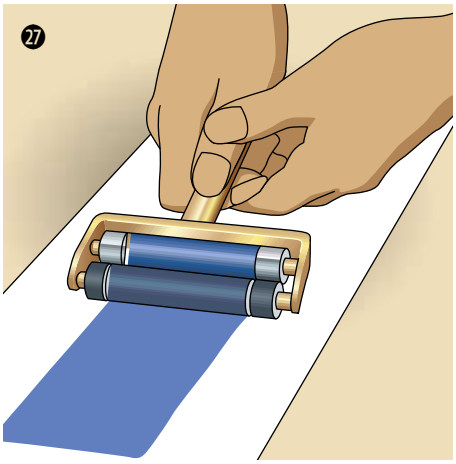
• **Polyamide Resins**. These resins can be broadly categorized into three types: alcohol soluble, co-solvent soluble and hot melt. Those with a molecular weight (MW) below 4,000 have good alcohol solubility and nitrocellulose compatibility. When incorporated into flexographic inks, they impart excellent adhesion to a variety of corona-treated and coated-polyolefin films. They are also noted for their excellent printability, transfer, high gloss and solvent release properties. They are also compatible with shellac, rosin esters, phenolics and polyketones. Although they exhibit outstanding pigment wetting, they are ill suited for use as sole grinding vehicles and commonly require modification with "harder" resins. Co-solvent polyamides require a blend of an alcohol and aliphatic/aromatic hydrocarbon for solubilization. Noted for their wide-ranging adhesion, co-solvent polyamides are slightly harder than the alcohol-soluble types and are commonly used for their release properties in cold-seal release packaging. The polyamide resins derived from hot melt adhesive-grade materials display adhesion to most substrates and are widely used in "universal" laminating inks. Their higher molecular weight means that they show lower resin compatibility than other polyamides, poorer pigment wetting, and lower solubility, which impacts on color strength and print performance (*Figure* 27).

Care should be taken with any polyamides to avoid incorporation of heavy metals from drying agents or pigments. These metals catalyze the oxidation of the dimerized fatty acids used in the production of the resin to produce extremely rancid odors and a distinct possibility of print blocking.

• **Acrylic Resins**. These resins have found wider use in flexographic inks in recent years. In solvent-based inks, acrylics are used primarily for their adhesion characteristics in combination with nitrocellulose or other cellulose esters. Careful formulation is needed to ensure the sufficient presence of "active" solvent that will maintain the solubility of the resin without significantly affecting the printing plate and to minimize solvent retention. Acrylic or acrylate resins also form the basis of most water-based and UV/EB-curable resin technology currently on the market. These technologies are discussed in greater depth in following sections.

• **Polyketone Resins**. These resins are used as modifiers to assist gloss and adhesion. Polyketones are inert, hard, non-film-forming resins that dry rapidly, but show tendencies to "skin over," potentially leading to increased solvent retention.

• **Polyvinylbutyral Resins**. These resins, derived from polyvinyl alcohol and aldehyde butyra, are used for their flexibility and adhesion properties in lamination and heat-sealing inks. Specially purified grades are available; however, care should still be exercised when selecting these materials for food-use



27 Polyamide gloss and transfer test.

applications since rancid odors can arise from one of the constituent components.

• **Polyurethane Resins**. For flexographic inks, these resins typically function as high molecular-weight plasticizers, conferring increased adhesion, flexibility and toughness. Used widely in Europe for high performance surface print and lamination inks, their use in the United States is limited because of high cost.

• **Epoxides**. These resins find utility in cross-linking systems as reactive diluents and resins in UV cationic inks, and in combination with polyamine resins in high performance catalytic lacquers.

Solvents

The colorant and resin constituents of an ink are both solids. Therefore, the primary function of the solvent is to convert these ingredients into a fluid form capable of being printed. Solvent selection is critical in determining the performance of the printing ink and is governed by a number of factors. The solvents used should:

- solubilize the resin or resins chosen to produce a fluid, rheologically suitable vehicle during all phases of the print process;
- be easily removed by evaporation or absorption.
- impart minimal odor in printed ink film;
- aid substrate wetting and adhesion;
- not affect the printing plate or fountain roll;
- interact minimally with other ink ingredients, thereby preventing ink instability; and
- comply with customer specifications, and with local, state and federal legislation governing environmental, health and safety issues.

Solvency power is the most important factor in considering the utility of a solvent. In polymer solutions of high concentration, liquids with high solvency power produce solutions with the lowest viscosity. This property can be used as a guide to judge the relative merits of a solvent for a particular resin. Such solvents commonly fall into three categories: active, diluent and latent. Solvents which can solely dissolve a resin are denoted as active. Liquids which are non-solvents for the primary resin, but which can be added to an existing resin solution without increasing viscosity or causing precipitation are called diluents. Occasionally, it is found for certain principal resins that blends of liquids considered to be diluents or non-solvents for this resin interact to form a co-solvent blend capable of solubilizing the material. These solvents are regarded as latent solvents for this resin.

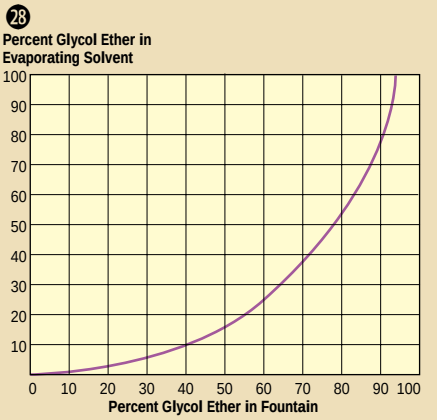
Just as an ink may contain a variety of resins to achieve the required physical properties, most inks are formulated to contain a mixture of solvents offering a satisfactory balance of solubility, rheology and drying speed. If a solvent blend is used, it is crucial that the slowest evaporating solvent be a good solvent for the ink system. Problems with loss of gloss, adhesion, poor printability, film integrity and product resistance will result if the last solvent to evaporate is a non-solvent for the resin system used. This behavior is commonly referred to as ink souring or kick-out. Conversely, the solvent blend chosen should not have such an affinity for the resin system that there is difficulty in removing the solvent.

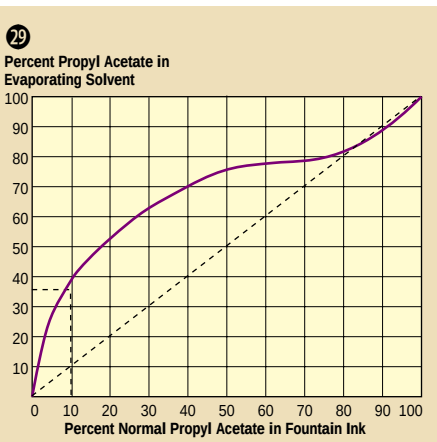
Prior to printing, the viscosity of the ink is reduced by the addition of an appropriate solvent blend. During a print run, the solvent or solvents will evaporate from the ink fountain. The composition of this escaping solvent blend is determined by a number of well-known factors, including:

- the vapor pressure of each constituent solvent;
- molecular solvent and resin interactions;

㉘ The importance of solvent balance is shown in this graph, where the solid curve represents the composition of the solvent vapors from the various mixtures.

㉙ A comparison of glycol ether solvent and n-propyl alcohol levels shows the percent of glycol ether evaporating is significantly lower than the level of glycol ether in the fountain.





- and ambient conditions, e.g., temperature or atmospheric pressure.

To prevent imbalance, any solvent blend added as a replacement should be of a similar nature to the escaping solvents. Failure to use a compatible replacement may also result in resin kick-out or ink souring, loss of gloss, increasing ink viscosity or lack of adhesion. Such problems are more noticeable in jobs where ink usage is limited, such as process work or small spot colors and it is the responsibility of the ink formulator to identify a suitable "balanced solvent" to prevent this from occurring.

The importance of solvent balance is demonstrated in *Figure* ㉘. The horizontal axis represents the percentage of n-propyl acetate in an ink fountain that contains a blend of n-propyl acetate and n-propyl alcohol. The vertical axis represents the percent of n-propyl acetate in the solvent evaporating from the fountain. The solid curve represents the composition of the solvent vapors from the various mixtures. For example, if you start with a fountain blend of 10% n-propyl acetate, it follows that the solvent vapors contain 35% n-propyl acetate. This excessive loss of n-propyl acetate will shift the solvent balance and result in a leaner, less acetate rich solvent resulting in print problems. In this case, the problem can be avoided by using a 35:65 blend of n-propyl acetate/n-propyl alcohol to replace the solvents lost by evaporation from the ink fountain.

In summary, the original ink and any fresh ink added to the fountain should be diluted to target viscosity with the 10:90 blend of n-propyl acetate/n-propyl alcohol. Any subsequent manual viscosity reduction, while on press, should be carried out with the 35:65 blend of n-propyl acetate/n-propyl alcohol to maintain solvent balance.

Similarly, *Figure* ㉙ shows a plot of a glycol ether solvent and n-propyl alcohol. In this case, the percent of glycol ether evaporating is significantly lower than the level of glycol ether in the fountain. It would be extremely dangerous to replace any evaporating solvent with the same blend used to make the initial cut. The fountain would become increasingly richer in glycol ether, leading to poor drying, blocking in the rewind, retained odor, and lamination problems such as blistering, tunneling and poor-bond strengths.

Most solvents present a fire hazard, and it is important to take note of flash points and explosive limits. In addition, some solvents are considered hazardous to health or the environment above certain concentrations. The properties of a number of common solvents used in flexographic inks are detailed in *Table 5*.

SOLVENT PROPERTIES

SOLVENT	DRYING RATE[a]	BOILING POINT °F	BOILING POINT °C	SPECIFIC GRAVITY	FLASH POINT °F	FLASH POINT °C	FLAMMABILITY LIMITS LOWER%	FLAMMABILITY LIMITS UPPER%
Ethyl alcohol	4.4	173°	78°	0.79	55°	13°	4.3%	19.0%
n-Propyl Alcohol	2.39	208°	98°	0.80	77°	25°	2.1%	13.5%
n-Propyl Acetate	5.78	215°	102°	0.89	58°	14°	2.1%	8.0%
Isopropyl Acetate	9.5	191°	88°	0.87	40°	4°	1.8%	8.0%
Heptane	13.5	209°	98°	0.68	39°	4°	1.8%	6.7%
VM&P Naptha	4.1	212°–320°	100°–160°	0.67	20°–50°	-7°–10°	1.1%	6.7%
Dowanol PM	2.3	250°	121°	0.92	97°	36°	0.9%	13.1%
Propylene Glycol	0.03	370°	188°	1.04	210°	99°	1.1%	9.2%
Acetone	15.7	134°	57°	0.79	0°	15°	0.9%	12.8%
Methyl Ethyl Ketone	10.6	176°	80°	0.80	20°	7°	2.6%	10.0%
Toluene	5.7	232°	111°	0.87	40°	4°	1.8%	7.1%
Water	1.0	212°	100°	1.0	—	—	1.2%	—
Ammonia	—	232°	111°	0.9	—	—	—	—

[a] *Water=1*

Table 5

Additives

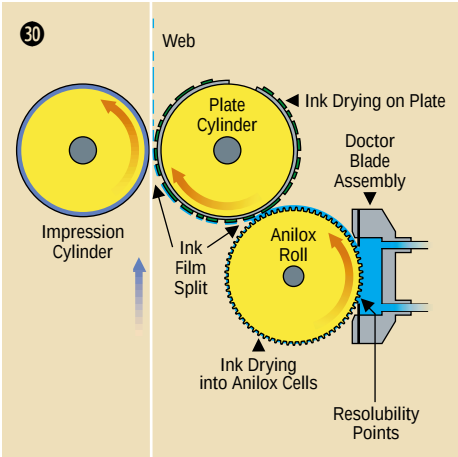
Although the pigments, resins and solvents chosen provide the ink formula "skeleton," it is often necessary to enhance or modify certain ink characteristics to achieve the necessary performance. While various additives are used to modify the performance of the ink, it is important to recognize that with a correctly formulated vehicle, the use of additives will be minimized. Poorly formulated vehicles will require material additions that may cause secondary problems, which in turn require the use of further additives. The additives typically used in modifying flexographic ink fall into many categories. The most common, briefly detailed below:

• **Plasticizers**. The main function of a plasticizer in an ink film is to make the dried print more flexible and elastic. They do this by acting as non-volatile solvents for the film, forming resins. Certain plasticizers are used to promote specific properties in the printed ink film, such as increased gloss, improved flexibility or increased adhesion on difficult substrates.

• **Waxes**. Different chemical types of wax can be incorporated into flexographic inks (1–3% dry weight) to achieve mar resistance, reduce blocking or set-off, and improve slip and water repellency. Keep usage as low as possible as excess wax levels may lead to reduced gloss, poor ink rheology and reduced transfer characteristics.

• **Silicones**. This class of materials find use at low levels (0.1–1.0%) as substrate- or pigment-wetting agents, additives to improve mar/slip, anti-foams and release agents. While it appears they have wide utility, they do have drawbacks. Excessive use can lead to print defects such as pinholing or crawling. Also the presence of low-molecular-weight silicones (<50 centiStokes) in inks can lead to the poisoning of catalytic beds within incineration units.

• **Surfactants**. These additives are used to improve wetting and spreading. Surfactants are regarded as high performance detergents, finding use as dispersion aids, flow promoters and wetting aids on difficult substrates. Care has to be exercised in surfac-



30 In order for an ink to print well, it must possess the rheology to be transported through the inking system onto the anilox. It has to have sufficient wet tack to transfer from the anilox onto the plate and then finally to the substrate.

tant choice. Watch for problems with foaming, adhesion or reduced water resistance.

• **Defoamers**. Foaming is a problem that most commonly occurs in water-based inks and is evident under conditions of high agitation. Obviously, prevention is better than cure, but where foaming is present it can be dealt with by the addition of defoaming agents. Such materials work by dramatically reducing surface tension in the system, causing existing bubbles to burst, and preventing unstable foams from forming. These materials are usually derived from mineral oils or silicones.

• **Pure Chemicals**. This category of additives covers a diverse group of materials including acids, alkalis, metal chelates, polyols, metal salts and anti-oxidants. Such materials can function as adhesion promoters, fixatives, drying aids, stabilizers and cure agents, as determined by the ink chemistry and formulation.

INK CHARACTERISTICS

There are a number of fundamental properties required of flexographic inks that are determined by the nature and demands of the printing process and the final application of the print:

- rheology;
- transfer;
- color and strength;
- print appearance;
- adhesion; and
- functional properties.

The fundamental property required of an ink is that it prints well. To do this, it must possess the rheology or fluidity to be transported through the inking system onto the anilox. It has to have sufficient wet tack to transfer from the anilox onto the plate and then finally to the substrate (*Figure* 30). The drying speed of the ink needs to be such that it remains fluid while on the press, but dries rapidly after application to the substrate. The ink must be of suitable shade and strength. It must print cleanly, adhere to the chosen substrate and provide the properties necessary to meet customer specifications.

Rheology. Fluidity and low viscosity are crucial to the flexographic process. While on press, the ink is required to be pumped and transported through various pieces of equipment and subjected to extreme shear forces. Maintaining a fluid ink at a low viscosity reduces the wear and tear on press components and can be achieved by the incorporation of suitable solvents. The actual viscosity chosen for printing is determined by a variety of factors including the metering system, substrate characteristics, press speed and print requirements.

Transfer. Of all the ingredients present in the ink, the binder system impacts most heavily on transfer. In general, as the molecular weight of the chosen resin and the resin solids present in the ink increase, so does the transfer. Transfer properties of differing formulations or resin systems can be easily compared in the laboratory by applying the test inks – after ensuring the strength and viscosities are equal – side by side using a hand anilox proofer.

Color and Strength. The color and strength of a flexographic print are largely determined

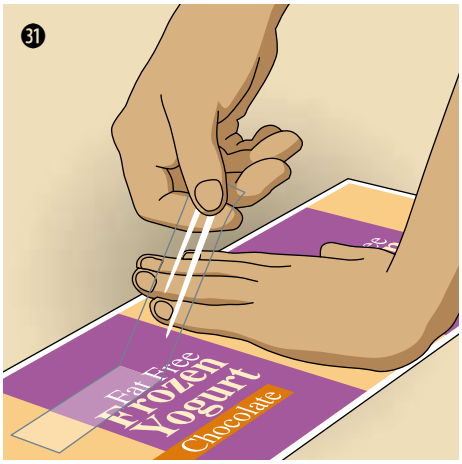
by the type and concentration of the colorant used within the ink and the thickness of the wet film applied. Other factors such as substrate and converting processes can also affect appearance. The thickness of the wet film laid down is determined largely by the metering system employed and can vary in different applications from 2–12 microns. Since this variation is so large, it is difficult to formulate an ink consistently with the precise amount of colorant present to meet requirements. To combat this, the ink maker commonly supplies the ink at a higher color strength and viscosity to allow adjustments to be made on press.

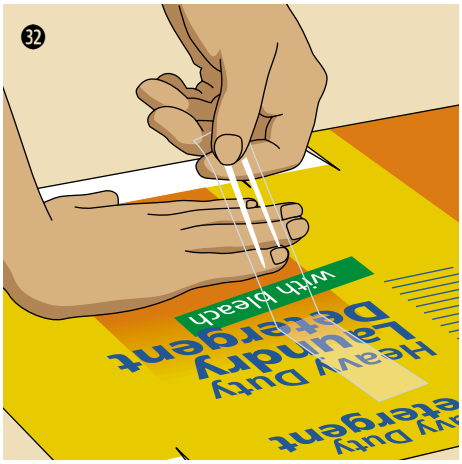
Print Appearance. In addition to basic color requirements, the ink may have to be glossy, matte, transparent or opaque as determined by the design and substrate. The ink should also print clean, smooth solids, fine type and process screens. To achieve these properties, it is desirable that the ink display good flow, wetting and resolubility. Most inks today are formulated with pigments, due to required end-use application. Care has to be taken with pigment selection to prevent poor "ink working" and flow properties. This caution also extends to higher performance binders like high molecular-weight polyamides that exhibit low solvent solubility, which can lead to dirty printing.

After printing, it is critical that the ink dries quickly. This need is particularly noticeable when printing a multiple "trap" job on a common impression press. In such cases, the minimal gap between subsequent printing units and the speed of the press necessitate the rapid drying of the ink. Drying rate should not be so rapid that it causes the ink to dry on the plate or anilox. A balance must be struck. Any ink that dries on either the anilox or plate should be easily resolubilized on the next revolution, minimizing the risk of poor image reproduction or dirty working. Care has to be exercised when "trapping" or printing color-on-color to prevent solvents from the overprinting color resolubilizing the first layer down. This rewetting can lead to solvent retention, loss of print quality or print blocking.

Adhesion. This property is particularly important with non-absorbent substrates such as polyethylene or polypropylene. With paper or board printing, adhesion problems with an ink seldom arise.

The binder is the most important primary constituent in determining ink adhesion. It is common for an ink to require a blend of resins to achieve the desired level of adhesion and other performance properties. Each substrate presents different challenges, and in general the more inert the substrate, the more difficult it is to obtain adhesion. In practice, this means that resins conferring





31 In this figure, common, everyday cellophane tape is used for the adhesion test by placing it on the printed substrate.

32 To test for adhesion, the tape is peeled off and examined for the effect on both tape and substrate.

adhesion on the myriad of available substrates must be identified on a case-by-case basis (*Figures* 31 32).

End-use Application. This requirement has a particular bearing on the formulation of an ink. There may be requirements during processing, as outlined in the previous chapter, for heat resistance, the ability to be laminated and certain slip or scuff characteristics. The package may have to show product resistance to fats, oils, detergents, solvents acids or alkalis. Consideration of the printed product's end use can be used to determine the gross performance needs. However, all technical requirements for a particular application should be fully specified by the customer prior to formulation. *Table 6* shows a few flexographic end-use markets and the general properties required.

The enormity of formulating an ink capable of complying with all these requirements should not be underestimated. One also needs to keep in mind the added complications of converting needs, regulatory concerns and quality performance objectives.

Converting Needs. The converting processes in operation have a dramatic influence on the formulation of an ink. Changes in the ink may require changes in the process. For example, while solvent-based inks may not require a corona treatment unit to print successfully on polyolefinic films, it is almost certainly required with water-based inks.

Some of these process parameters are outlined in *Table 7*.

Regulatory Controls. The composition of an ink has to account for local, state and government regulations covering:

- air remissions;
- metal content;
- material toxicity; and
- food and drug standards.

Sweeping environmental legislation within the last 20 years has necessitated major reformulation efforts to remove, replace or reduce harmful materials, and require even tighter controls over incoming raw materials. This situation is becoming ever more complex since federal legislation is increasingly enacted differently on a regional basis, depending on local conditions and needs. The changes ultimately require the ink manufacturer to supply different ink formulations for identical applications, based on geographic environmental need. This topic is expanded upon in a following section.

END-USE APPLICATIONS

END USE	SUBSTRATE CONSTRUCTION	INK PERFORMANCE REQUIREMENTS
Bakery	Ink-LDPE	High performance, low COF, low retained solvent, ice water crinkle resistance
Milk Carton	Ink-LDPE-Board	Product resistance, alkali resistance, wet/dry rub resistance
Snack Package	OPP/Polyester-Ink Adhesive polyethylene	Low retained solvent High bond strength
Confectionery	Coex. OPP-Ink Cold seal adhesive	Low odor, low solvent retention Cold-seal release
Display, Corrugated	Ink-bleached Kraft	High gloss, rub/scruff resistance

Table 6

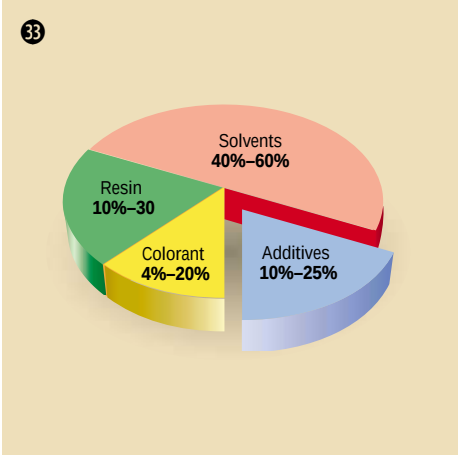
CONVERTING NEEDS – PERFORMANCE ISSUES
PRINTING
1. Corona Treaters.
2. BC and OH Dryer Capacities.
3. Line Speeds.
4. Tension Controls.
5. Cooling Rolls.
6. Ink Pumps/Viscosity Controls.
7. Run Times.
8. Design Parameters: % Coverage, Traps.
9. Press Room Temperature and Humidity.
LAMINATIONS
1. Ink-to-Substrate Adhesion.
2. Ink-to-Laminate Adhesion.
3. Corona Treaters.
4. Use of Primers.
5. Wetting of Ink by Adhesive.
6. Extrudate Temperature.
7. Extrudate Compositions.

Table 7

INK FORMULATION AND SELECTION

Having an understanding of the properties of the materials used within inks, the print and conversion processes utilized, and the end-use application, allows inks to be formulated to meet all required specifications. As mentioned previously, flexographic inks consist of four main ingredients: colorant, binder, solvent and additives. The composition varies widely depending on the choice of substrate, press conditions, and final use. *Figures* 33 illustrates the ingredients which make up a typical ink.

It is normal to classify inks into product types according to formulation, substrate used and performance properties, rather than have discrete inks for individual situations. This helps avoid product proliferation and inventory problems both at the ink manufacturer and converter.



33 Four primary ingredients constitute flexographic inks: colorant, binder, solvent and additives.

Product categorization eases ink selection and benefits manufacturing and product quality through improved inventory control and material planning. The system has to maintain flexibility since flexographic industry is subject to increasingly rapid changes that may require ink modification. A selection of characteristic formulations is outlined with respect to the substrate printed and end-use needs (*Table 8*).

Water-based Inks

Water-reducible flexo inks, based on casein, were first used in the 1940s on corrugated cartons. During the 1950s and 1960s, as printability improved, their use in paper/paperboard printing increased. The implementation of the Clean Air Acts during the early 1980s spurred the development of water-based technology. Today, water-based inks are used successfully in all areas of flexographic printing. Conversion to water-based inks, particularly in demanding applications, has been a success where this change has been accompanied by an increase in press-drying capacity, improved ink-metering systems, and the replacement of press compo-

INK FORMULATIONS

HIGH-GLOSS INK FOR LDPE (low density polyethylene).

Used for bakery and deep-freeze applications. Requires fast drying because of press speeds, low odor for food packaging. Deep freeze and water resistance require careful selection of pigments. Waxes required to prevent blocking and sticking in roll and wickets.

The traditional ink for polyethylene is based on polyamide, although at one time it was shellac. To achieve acceptable adhesion, the film must have a surface energy of 38 to 42 dynes/cm. Below this level, poor ink adhesion will be observed. Above this energy level, the water resistance of the printed film and its heat sealability may be compromised.

MAKE UP	%
organic pigment	12.0
alcohol-soluble polyamide	22.0
nitrocellulose (dry)	4.0
n-propyl alcohol	34.0
ethanol	13.0
n-propyl acetate	12.0
polyethylene wax	2.0
amide wax	1.0
	100.0

HEAT-RESISTANT, HIGH-ABRASION INK FOR POLYPROPYLENE.

Inert nature of polypropylene film requires use of adhesion promoter. Nitrocellulose has necessary heat reistance and hardness. Urethane provides adhesion and flexibility. PTFE and silicone provide scuff resistance. For use on VFFS and HFFS filling machinery. Low odor needed if used for food packaging.

MAKE UP	%
organic pigment	12.0
nitrocellulose (dry)	10.0
polyurethane	14.0
n-propyl alcohol	36.0
ethanol	10.0
n-propyl acetate	15.8
adhesion promoter	1.0
PTFE wax	1.0
silicone	0 . 2
	100.0

SOLVENT INK FOR FOLDING CARTON

Color strength is a primary concern along with good print quality, rapid drying, good flexibility (folding) and scuff for sheeting equipment. Wax and plasticizers improve scuff and flexibility. Isopropyl acetate and ethanol speed up drying for less absorbent coated stocks.

MAKE UP	%
calcium 2B pigment	14.0
titanium dioxide	6.0
maleic resin (dry)	8.0
nitrocellulose (dry)	11.5
n-propyl alcohol	25.0
ethanol	18.0
isopropyl acetate	10.0
plasticizer	5.0
wax compound	3.5
	100.0

Table 8

nents based on "electrically" different metals (e.g., copper, iron) that come into contact with the ink. Installing corona-discharge equipment for film printing, and retraining press operators also must be part of the picture. While water-based inks bear some similarity to their solvent-based counterparts, there are some differences, particularly in the chemistry of the resins used and their handling.

Colorants. The colorants available for use are largely identical to those used in solvent inks. Many have been specially treated or prepared to make them suitable for use in water systems where alkali or water solubility are concerns.

Vehicles. The primary vehicles used can be classified either as alkali-soluble vehicles, emulsions or colloidal-dispersion vehicles. The fundamental requisite in all these is that they retain water solubility while being printed but become water insoluble after printing and drying. These apparently contradictory requirements are largely achieved by using water-insoluble carboxylated (acid-containing) resins and converting them to their water-soluble salts, using volatile alkaline materials such as ammonia or organic amines. Organic amines such as monoethanolamine evaporate more slowly than ammonia, so resins solubilized with an organic amine dry more slowly and take more time to achieve water and product resistance.

Just as solvent balance in solvent inks governs print performance, the alkalinity or amount of alkali present in the water-based ink determines performance. The amount of alkali present can be measured using a pH meter, which measures acidity or alkalinity and is associated with water-based inks. The pH value can vary in range from 1.0 (battery acid) to 14.0 (household ammonia solution), where 7.0 is neutral – equivalent to distilled water. A pH higher than 7.0 indicates increased alkalinity. Maintaining a level of alkalinity, typically between pH 8.6–9.4, is vital to controlling the performance of an ink on press. Such control can be a problem with long runs of water-based inks, particularly with printing a low coverage design in hot weather.

A comparison of the properties of these vehicles is given in *Table 9*.

Auxiliary Solvents. A variety of alcohols, glycols and glycol ethers are used to control drying speed, improve resolubility or aid film formation. Caution should be exercised when using these materials to prevent fire and health hazards.

Additives. The additives used within water-based inks include waxes, plasticizers and defoamers and are largely similar to those used in solvent inks, with the exception that the chemistries used have been modified to make them suitable for an aqueous environment.

VEHICLE PROPERTIES

SOLVENT	SOLUTION POLYMER	EMULSION POLYMER	COLLOIDAL DISPERSION
Printability	E	F	P
Drying Speed	P	G	VG
Product Resistance	P	G	E
Resolubility	E	P	VP
Applied Solids	L	H	VH
Freeze Stability	G	F	P
Foaming	G	P	P
Pigment Dispersion	E	P	NR

KEY:
E=Excellent
G=Good
VG=Very Good
P=Poor
L=Low
H=High
VH=Very High
NR=Not Recommended

Table 9

Using Water-based Inks

The problems encountered in handling water-based inks typically stem both from the physical properties of water and the chemistry of the ink and include:

- pH control;
- volatility of water;
- specific heat capacity of water;
- conductivity; and
- surface energy.

Water-based inks are commonly regarded as easier to handle than solvent-based inks because of their lower volatility. However, this is a misconception since pH control in water-based inks is just as vital as maintaining solvent balance in solvent-based inks. Water-based inks are most stable within certain pH limits. After prolonged use, the pH can drop below the lower limit leading to false heavy body and resin kick-out (similar to solvent-based ink souring). A pH reading higher than the suggested upper limit can lead to both drying, odor and product resistance problems (similar to solvent retention).

Caution has to be exercised in reducing the viscosity of water-based inks as they tend to lose viscosity faster than solvent-based inks. Over-reduction often leads to poor print quality, e.g., crawling and poorer performance properties.

Water dries much more slowly than typical flexographic solvents like propyl alcohol or propyl acetate (*See Table 5, Solvent Properties*). To compensate for this, water-based inks are often formulated to have higher resin and pigment solids. The higher solids allow a thinner wet-ink film to be printed, which speeds up drying – especially on non-absorbent substrates – while maintaining performance properties (*Table 10*). Since inks on non-absorbent substrates dry solely by evaporation, the drying capacity of the press is very important. It is critical that the inter-unit and overhead drying units operate under negative pressure with an air velocity of approximately 3,500 cu.ft/min. The higher specific heat capacity of water also requires the ovens to be set at slightly higher settings to achieve the same web temperature as with solvent-based inks.

In the case of absorbent substrates, the need for efficient driers is lessened. On highly absorbent stocks, the free water is drawn into the surface, often by capillary action, leaving the pigment and resin solids deposited on the surface. This can occur in as quickly as 0.1 second. Drying can also be enhanced on acidic paper stocks where the acid neutralizes the solubilizing amines.

Although no longer a major problem with ceramic aniloxes, water-based inks are often associated with increased chrome anilox wear for two reasons. The first is mechanical: water-based inks have less lubricity and cause mechanical breakdown of the chrome anilox from frictional wear. The second is chemical: the inks aid the generation of a galvanic cell by functioning as an electrical conductor between dissimilar metals.

Ink will only transfer or "wet out" on a substrate when the surface tension of the ink is lower than that of the substrate to be print-

WATER-BASED INK FORMULATION

Typical water-based flexographic formulations are as follows:

	For Nonabsorbent Substrate	For Absorbent Substrate
35% pigment dispersion	50.0	40.0
acrylic solution polymer	10.0	30.0
acrylic emulsion	30.0	12.5
water	5.0	13.0
organic amine	1.0	1.0
polyethylene wax compound	3.0	3.0
surfactant	0.5	—
organic anti-foam	0.5	0.5
TOTALS	**100**	**100**

Table 10

ed. Pure water has a surface tension of 72 dynes/cm, while the surface energy of most untreated polyolefin films lies in a range of 31 to 35 dynes/cm. To facilitate the printing of water-based inks on film substrates, it is necessary to reduce the surface tension of the inks by incorporating wetting agents and boosting the surface energy of the film using corona discharge or flame treatment. Film treatment, while aiding ink adhesion, also helps in "burning off" the migratory fatty acid amides which are used as a slip agent in the film. Such slip agents commonly migrate to the surface of the film, and at high levels can cause wetting problems like pinholing or reticulation.

Catalytic Inks. The resistance properties of prints produced from conventional inks that dry by evaporation are dictated by the properties of the resins employed. With the flexographic process, the choice of resins is limited by the available range of solvents, which in turn places limits on resistance properties achievable with regular flexographic inks. This problem can be overcome by utilizing ink systems that undergo specific chemical reactions upon drying. The principle types are usually based on epoxy amine or aziridine acid chemistry and rely on a reaction to crosslink the individual reactive elements together to generate a composite polymer with improved heat, solvent and product resistance and more gloss and adhesion than a conventional ink. The inks do have some disadvantages:

- the need to mix two components;
- limited pot life after mixing; and
- specific cure conditions.

Such inks typically have discrete curing conditions requiring a high temperature and long-drying time to complete reaction. Care has to be taken to ensure that the materials used to produce the ink and those inks or materials in contact with the printed catalytic material do not act as cure inhibitors.

UV- and Electron Beam-Cured Inks

Drying vs. Curing. In simplest terms, drying of an ink film occurs with conventional inks when the ink vehicle (solvent or water) evaporates or is absorbed, leaving behind the solids (pigments, resins, waxes, etc.) to form a film on the substrate surface. In radiation curing, on the other hand, all of the components in the ink or coating remain on the surface of the substrate, but are chemically transformed into a hard film through exposure to ultraviolet (UV) lights or a concentrated beam of highly energized electrons (EB). The difference lies in the chemistry of the materials in the inks and coatings and in the pressroom equipment needed to "energize" the curing process.

Rudimentary Ink Chemistry. The materials used in radiation-curable ink formulas are considerably more "user friendly" today than ever before. Advancements in raw materials will continue to make radiation-curable inks and coatings more commonplace in the years ahead. The major components of UV and EB inks and the function of each of these chemicals are as follows:

• **Reactive Diluent (Monomer)**. A reactive diluent monomer is a simple, lightweight chemical similar to a solvent in its ability to thin down the ink. Monomers help determine the characteristics of the ink, such as gloss, hardness and flexibility. These low-viscosity monomers, which can be readily absorbed by unprotected skin, are also the chemicals which give uncured UV and EB inks their most hazardous characteristics. The potential of a monomer to cause skin irritancy or sensitization problems can be gauged from a given Draize value. The Draize value is a 1 to 4 numeric measure of its irritation or sensitization potential. The higher the Draize value, the more hazardous the material. Most commercially available UV or EB flexographic products utilize materials with a Draize values of 2 or less and do not pose any major health and safety concerns, providing of

course, that all handling guidelines are followed.

• **Resin (Oligomer)**. The resin in radiation-curable inks is actually called an "oligomer." As in conventional inks, the resin is the chemical backbone of the ink. Among others, it provides the body, wetting ability, binding and functional properties of the ink.

• **Photoinitiators**. In UV inks, the photoinitiator is the chemical which becomes "excited" and starts the curing reaction when exposed to ultraviolet light. The excited photoinitiator passes that energy to the other components. At that point, any component which becomes excited has the ability to attract other components to itself and transfer energy to the newly attracted component. Photoinitiators are not required in EB inks. The highly charged energy of the electron beam is sufficient to activate polymerization.

• **Additives**. These materials include waxes, wetting agents and rheology modifiers. They provide the added customizing touches to the ink.

• **Pigments.** Pigment particle size and concentration can affect the curing rate of a UV ink. Pigments are selected for color and wetability, or oil-absorption ratio; and for their receptivity to UV light. Among process colors, yellow and magenta are the easiest to cure, followed by cyan and black. Because black tends simply to absorb the wavelengths of UV light, more energy is required for a satisfactory cure.

Polymerization. In conventional UV or EB chemistry, any component that has reacted is called a "free radical." It is the free radicals that have the energy to keep the curing or "polymerization" chain reaction going. Each chemical chain continues growing until one of two things happen: The excited chains use up all of the available components or the UV/EB source is removed and a foreign substance, such as oxygen, quenches or halts the reaction.

In contrast, irradiation of the photoinitiator used in a cationic UV ink generates a strong "Bronsted" acid, which reacts with the other components (aliphatic epoxides and vinyl ethers). This reaction varies from free-radical UV chemistry in that removal of the UV source does not quench the reaction. The cationic ink or coating continues to cure for up to 24 hours after UV exposure.

As flexo printing improves in quality and application, the need for specialized physical properties also continues to grow. Increased chemical or product resistance is the largest attraction to this process. The additional benefits of low energy cost, minimized downtime and the reduction of VOCs, will also continue to drive the market.

FLEXOGRAPHIC INK MANUFACTURING PROCESS

Flexographic inks, whether solvent- or water-based, are generally manufactured using the same processes: mixing, dispersing and filtering.

Many ink companies produce their inks from scratch using dry pigments for water- or solvent-based inks, or press-cakes for water-based inks. Others choose to purchase predispersed concentrated bases, and let them down with vehicles of their choice. These concentrated bases are normally produced by the same methods as finished inks. Many ink makers produce their own concentrated bases in-house rather than going outside for them.

The manufacture of a flexographic printing ink (*Figure* ❸❹) typically begins with the mixing of the raw materials to produce a uniform blend. From there, the product continues into the dispersion stage where the actual work in breaking up the agglomerates is completed.

There are a large number of flexographic ink manufacturers in the United States. Because of the present health/safety and

environmental regulations, a fair number of these companies are dedicated to water-based inks, while other companies still manufacture both water- and solvent-based inks. In general, the same equipment can be used for the manufacture of either.

Mixing

The dispersion step begins with a pigment made up of clusters called agglomerates. Each agglomerate is made up of smaller crystals that can have either air or water absorbed on its surface. Mixing, as the first step in the dispersion process, separates these agglomerates into a homogenous blend with the ink vehicle. The more efficiently this is done, the easier and less power-consuming the actual dispersion step becomes. Typically two types of mixers are employed in the manufacture of flexographic inks, cavitation and rotor stator mixers.

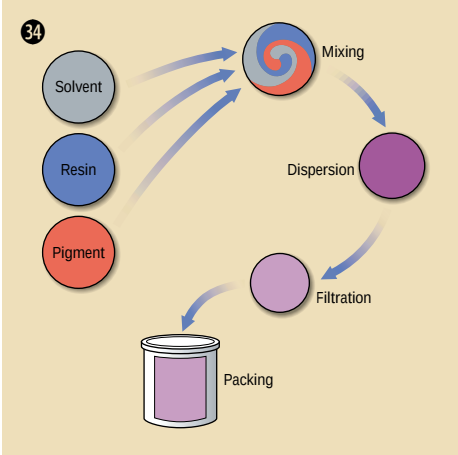
The cavitation mixer uses an impeller to produce a vortex. The impeller size and design varies by manufacturer and vessel size. Shear is at a minimum with this type of mixer. Rotor stator mixers have an impeller rotating in a so-called disintegrating head (stator). This head is fixed, and there is a very small clearance between the rotor and stator. This configuration allows for some shear to be generated. Some inorganic pigments such as titanium dioxide white can truly be dispersed during the mixing stage, but, in general, this process is just a precursor to actual dispersion, separating but not breaking up the agglomerates.

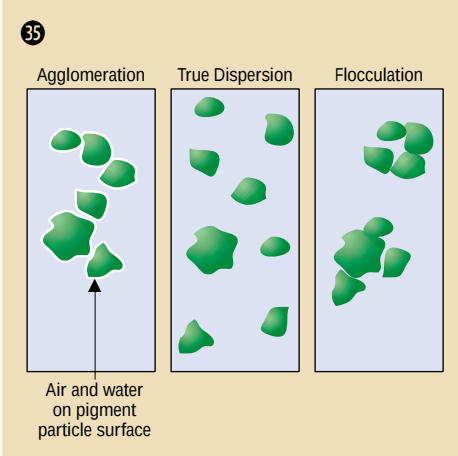
Dispersion

To achieve dispersion (*Figure* 35), pigment agglomerates are broken up as close to the individual crystal size as possible. The degree of dispersion is really how close one can get to this ideal. The dispersion process must therefore accomplish three things to be considered successful:

- It must remove the air or water on the crystal surface and replace it with the desired vehicle. This is called wetting.
- The particles must be separated and uniformly distributed throughout the vehicle.
- The crystal surface must be stabilized so that re-agglomeration or flocculation will not occur.

To accomplish this, a combination of shear and impact is used. By applying these forces throughout a viscous liquid, the agglomerates are literally broken down and then the absorbed air or water is “wiped off.” The vehicle then replaces the air and/or water on the surface of the pigment particle. Stability is normally accomplished in one of two ways:





34 The manufacture of a flexographic printing ink typically begins with the mixing of the raw materials to produce a uniform blend. From there, the product continues into the dispersion stage where the actual work in breaking up the agglomerates is completed.

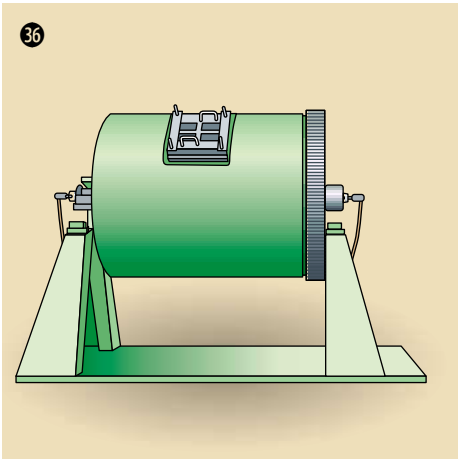
35 To achieve dispersion, pigment agglomerates must be broken up as close to the individual crystal size as possible.

1. By the introduction of ions or molecules capable of satisfying the surface charges on the solid pigment particles. These ions give each particle a similar, uniform charge resulting in repulsion, or
2. The use of non-ionic materials that adsorb onto the pigment surface and produce steric hindrance. This complex also results in particle repulsion.

Typically, ink resins will accomplish the required stability. If they fail, surfactants specific to the pigments are used in the formulations.

The first real piece of dispersion equipment used in the manufacture of flexographic inks was the pebble or ball mill (*Figure* 36). The mill is a horizontal closed-end cylindrical vessel filled to about half its height with porcelain or steel balls. This piece of equipment combines mixing with dispersion. It has a loading hatch on top and an evacuation valve on the opposite side. The ball mill is filled with the raw materials, sealed and rotated on its horizontal axis. The mill media is carried up to the top of the mill during the rotation and cascades down. This action produces the impact and shear to break up agglomerates and typically 16 hours will give the desired results.

These mills are manufactured in a wide assortment of sizes and use a variety of media.



36 The pebble or ball mill-combines mixing with dispersion. This action produces the impact and shear to break up agglomerates. The ball mill is filled with the raw materials, sealed and rotated on its horizontal axis until the mill media is carried up to the top of the mill and then cascades down.

There are many advantages obtained using ball mills for dispersion:

- Dispersion is uniform throughout the batch.
- Grinding time can accurately control degree of dispersion.
- Production procedures can be standardized for the mill used.
- No premix is required.
- There is no loss of volatiles. The vessel is sealed.
- Highly concentrated bases can be produced for later letdown.
- The process is not very labor intensive. The mill is opened, loaded, sealed, run for 16 hours (normally between 4:00 p.m. and 8:00 a.m.), the degree of dispersion checked and unloaded.

There are, however, some major disadvantages to this type of equipment:

- Batch size is limited to mill capacity.
- The time factor is the same regardless of mill size.
- Power costs are high.

In the early 1950s, it was realized that if one could produce more impacts per unit of time, then dispersion could be accomplished sooner. This improvement was actually accomplished by combining a premix with a very small but dense media – sand – and agitating it with an impeller. The problem, however, was how to separate the dispersion from the sand. Continuing along these same lines, in 1958, DuPont's S. Hockberg patented the process of sand milling (*Figure* 37). The premix is pumped upward through the mill, a vertical cylinder containing the media. A series of plates is mounted on the agitator shaft, and the top of the mill is screened to prevent the media from escaping with the dispersed ink. Flow rate through the mill is controlled by the pumps

and determines dwell time. This in turn controls the degree of dispersion.

This piece of dispersion equipment overcame the disadvantages of the ball mill. To minimize the disadvantages, there have been numerous innovative improvements made to the basic sand mill. Among these were the following:

- Sand has generally been replaced by a more dense, somewhat larger media. This media maximizes impact forces and minimizes the possibility of contamination of the ink with sand grit.
- The screen was closed off to the atmosphere, and a true mechanical seal was added, allowing operation under a slight positive pressure. This change minimized any loss of volatile ink components and allowed heavier viscosities to be pumped through the mill without carrying up the media and overflowing the mill.
- The vertical mill has evolved into the horizontal mill (*Figure* 38). This is said to improve performance by creating better flow and increasing the media loading capacity from 50% to 80% of the mill volume.
- Larger diameter shafts are generally equipped to carry cooling water. Disk designs have been modified to increase the number of impacts in a given time.

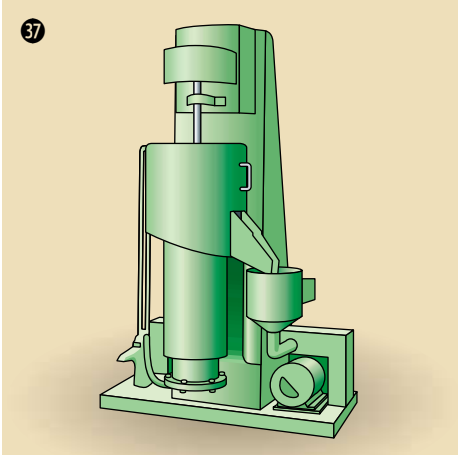
Ink companies are utilizing technology to achieve the highest quality ink possible. Most equipment is available in lab or pilot size, so production parameters can be optimized in advance and new raw materials can be tested under actual conditions.

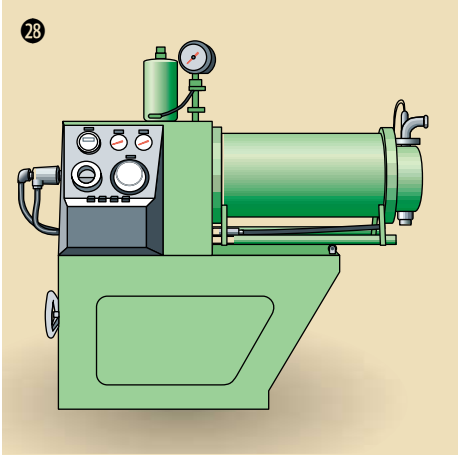
Filtration

The final process prior to drawing the finished ink into kits, drums or tote tanks is the filtration step. Before the use of very fine screens and low cell volumes, ink manufacturers regularly used either cheesecloth or a fine grade of organdy to filter the finished inks. This process took out any large particles that could cause problems on the press. The anilox cells were large enough so that any undispersed agglomerates would normally not cause problems.

Today, the advent of fine-screen halftone and process printing requires the use of very fine anilox screens and low volume cells. This change has driven the need for much better filtration. The undispersed agglomerates can plug these cells and lodge in doctor-blade nips, causing the loss of quality printing. There are several types of filters in common use today. Any one of them, used properly, will remove any large and fine particulate matter that might cause problems.

Bag filters are one of the most common





37 Original sandmilling process required premix to be pumped upward through the mill in a vertical cylinder. The media passed through a series of plates on the agitator shaft. Pumps controlled flow rate, set dwell time and controlled dispersion.

38 The vertical mill evolved into the horizontal mill, where performance is improved by creating better flow and increasing the media loading capacity from 50% to 80% of the mill volume.

types of filters used. Felt-type bags with sizes rated from 100 microns to 25 microns are available and can be used with gravity flow or commercial pumping systems. There are cautions to be noted.

- With the use of pumping systems, it is critical that recommended operating pressures not be exceeded. If they are, the filter might be bypassed and unfiltered ink will contaminate the batch.
- With gravity flow it is common to see plant workers "beating" the filters with ink knives to get faster flow. Beating deforms the bag and can allow larger particles through.

The cartridge filter is often used to filter flexographic ink. Natural or synthetic fibers are wound around a porous core, and the ink is pumped through the core and fibers. A wide variety of micron-size cartridges are available. Here too, if pressures are exceeded, unfiltered ink can bypass the filter and contaminate the batch.

A new type of filter that is beginning to see more use in the manufacture of flexographic inks is the vibrating screen filter. Ink is pumped onto a rigid vibrating sieve and the large particles are retained on the screen. A large number of sieve sizes are available, some with new innovations like self-cleaning filters.

Most flexographic ink manufacturers today are using 100-micron filters as their standard size. For special inks, 50-micron or even 25-micron filters are used. Also, mechanical systems are equipped with magnetic filters to ensure that no contamination from metal particles may have been introduced during the shot mill stage.

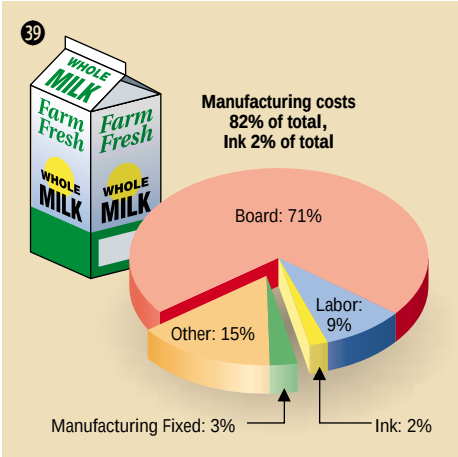
Ink Prepress

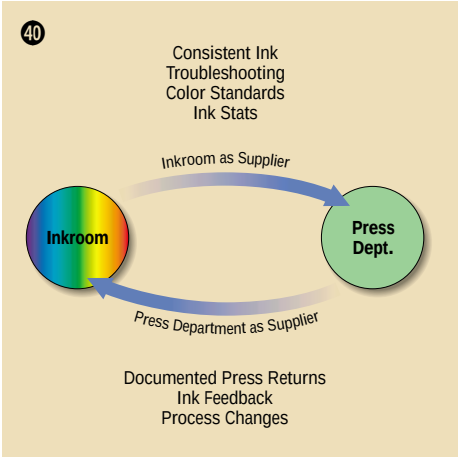
In the past 10 years, there has been a growing trend in the prepress area toward treating ink management as a key process. Converters have found that attention to this area pays high dividends in in the form of reduced waste and increased pressroom productivity. Professional management of the inkroom is now an essential part of running a competitive converting operation. The days of the dingy, dirty manual inkroom are rapidly disappearing and being replaced by computer-managed information systems and automated product dispensing. What goes on in the inkroom today?

Most printing operations have one or two people controlling the department. Besides providing ink to the presses, the inkroom usually controls color standards, ink purchases, inventory, waste, waste reports, usage records and the very important volatile organic compound (VOC) reports. In addition, the inkroom is a management resource, having essential input into purchases of new equipment and in many process improvements.

Ink is a small part of the total cost of the printed product. For example, cost figures for liquid packaging converters show that ink is only 2% of the total (*Figure* 39). It is apparent that ink which is defective or mismanaged can cause considerable waste in the converting operation. Problems due to incorrect ink use can reveal themselves immediately, or in some cases further down the value-added chain, where the cost of the problem is multiplied.

The purpose of any ink-blending operation is to deliver the right amount of the right ink to the right press at the right time. This is a simplistic view of a fairly complex process and easier said than done (*Figure* 40).





39 Ink is a small part of the total cost of the printed product.

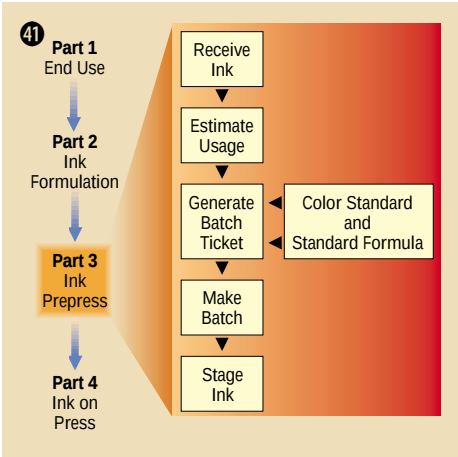
40 The purpose of any ink-blending operation is to deliver the right amount of the right ink to the right press at the right time.

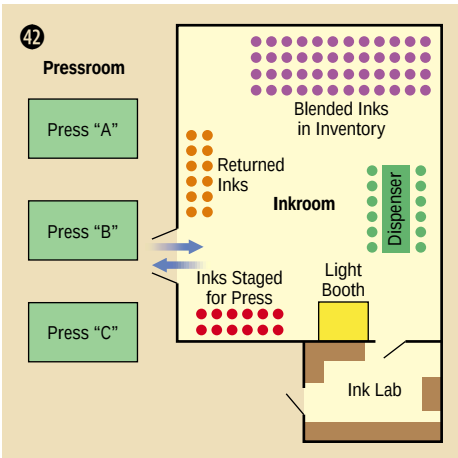
Waste due to bad ink can have many causes. Some typical causes of production waste due to ink-related issues are;

- off-shade;
- wrong ink delivered to the press;
- too little or too much ink delivered to the press; or
- the ink is not at press-ready viscosity.

41 Ink prepress covers the steps and procedures that take place between receiving the ink from the ink supplier and delivery of ink to the press.

42 A typical ink room layout occupies approximately 1,000 square feet.





Another common cause of press downtime, due to ink-related waste issues, is that the press department has not been instructed on how to use the ink system in question. For example, the job may meet all appearance standards yet fail an adhesion test because the press department was not aware of the web temperature requirements to pin on the ink. Thus the ink prepress product is not just ink, it is also information, service and training. The inkroom must regard the press department as the customer for product and service. At the same time, the press department, as a consumer, has responsibilities to the inkroom. The inkroom must receive timely process change information, correctly marked press returns and feedback of ink performance on press.

PREPRESS PROCESS

Ink prepress covers the steps and procedures that take place between receiving the ink from the ink supplier and delivery of ink to the press (*Figure* 41). These boundaries are typical, but not absolute, in terms of what is necessary for a successful operation. For instance, some ink departments are responsible for managing ink into the press pumps, while others may actually do some ink formulation and ink assembly normally associated with the ink supplier. The main objectives are to understand where the boundaries have been drawn in the converter operation, manage the input products from the ink supplier(s), and optimize outputs of products and services to the press department. Once the boundaries have been drawn, communicated and understood, ink prepress operations can be designed to meet all needs.

THE INKROOM DESIGN

A typical inkroom occupies about 1,000 square feet. The drawing shows how an inkroom this size could be organized (*Figure* 42). There are two areas: an office/laboratory area and an ink-handling area. In the laboratory area, color matching, proofing, quality control, diagnostic testing and ink management information system (MIS) functions are performed. This room would be connected electronically with the ink supplier and perhaps with the converter MIS department and shop floor data system.

Major equipment in the ink lab includes the following:

- proofer;
- weighing scales;
- color measurement device; and
- computer with ink management software and modem

Major equipment for ink production would include the following:

- ink-dispensing system;

- air mixer;
- drum dolly; and
- hand truck.

It should be noted that the ink-dispensing system can be as simple as drums on racks with appropriate valves or as complex as a computer-controlled dispenser.

INKROOM SYSTEMS

Regardless of the print, end-use and the types of presses being served, the inkroom must have procedures in place that define and control key areas.

Safety

This is always the number-one priority in any manufacturing operation; but it is particularly important in the inkroom, due to the nature of the materials being handled. Proper handling of chemicals is essential. Formal training programs for the operators are mandated by legislation and must be documented. If flammable materials are present, a special emphasis should be placed on maintaining explosion-proof systems, grounding of containers and arranging exhaust in areas where open containers are present.

The safety of the inkroom is very important and must be audited on a regular basis. The result will make for a safer workplace. Housekeeping, personal safety equipment, personal hygiene and adherence to safe work practices are key factors to be reviewed in an ink operation.

Color Standard

There should be a process in place that generates, approves and stores color standards for use in the inkroom, as well as in the actual printing operation. This can save a lot of discussion, time and money, as well as preserve the printer's reputation with customers. A good system should provide a current standard, signed and dated. There should be at least three samples available: one on file in the inkroom for color matching, one for pressroom use, and one in a master file that is used only if the other two are in question. All standards should be updated at least once a year. At the very least, they should be inspected and, if still acceptable, a new date applied.

Proofing System

The heart of any ink-blending operation is a correlated proofing system that can predict the ink strength and shade that will be obtained on the press. Only by having a good proofing system can the inkroom be confident in its ability to deliver "press ready" inks to the printing operation. This will save hours of press downtime and help eliminate color variation complaints. The method should be one that can be used by everyone in the inkroom with consistent results. This system will also allow for better matching on press return ink.

Where a printing operation has a mix of different presses and inking systems, different proofing methods may be required to ensure that there is a correlation between the proof from the inkroom and the print from the press.

Inventory Control

Ink should be used on a first-in, first-out basis, due to the shelf-life limitations of any chemical mixture. The issue here is simply using the oldest ink first. The ink supplier should have dates on all containers to facilitate this process. If there is no date of manufacture on the container, get one from the supplier. Some suppliers utilize date-coding systems that may not be immediately apparent.

There should also be a system of control that always allows ink to be available while maintaining the lowest possible inventory. A basic min-max system can work well with a weekly inventory and facilitate ordering in time to fill the pipeline. An area that is often

overlooked is press returns. Press returns should be identified and weighed, and the containers kept sealed to improve the probability of reuse. Since waste inks become a regulated hazardous waste, control of press returns will save the time and cost of disposing of these materials.

Usage Records

Accurate records play a central part in the control of inventories. They will also help to reduce waste, since most colors are matched for a specific job and anything not used is returned to inventory with the hope that it can be used later. A basic system consists of recording the weight of ink made, the weight returned, and the run size. This will provide a record for each job, allowing for a more accurate estimate of ink requirements for future runs. More sophisticated computerized systems are available to track this information. The objective is the same – have the right amount of ink on press and only return the minimum amount of ink to the inkroom. This will reduce cost, waste and on-hand inventory.

Information Systems

A great deal of information is usually managed by the inkroom. Some examples are:

Ink Systems. Ink formulations must be matched to specific substrates based upon their compatibility and end-use properties.

Ink Additives. Anything added to the ink must be identified and information provided for their proper use. Misusing additives can result in downstream problems.

Press Performance. On press, color data and corrective actions are important to track. This is valuable feedback that can save the department from solving the same problems over and over.

Scheduling. The ink department should have a good system that links the ink operation with the press schedule and press setup, thereby coordinating the timing of ink needs on the press and quick reaction to changes in schedule.

Equipment. There is less equipment in an inkroom than the pressroom, but it is just as important and must always be working properly. Scales must be accurate and in good working order. The mixer must run smoothly and be sized to handle the batch-size requirements of the operation. Hoists and other lifting equipment must have the rated capacity to handle all containers present, and they must move easily without restriction. Manual material handling equipment should also be inspected on a regular basis to ensure they are in good working condition. Color-control equipment (i.e., color booths, spectrophotometers, etc.) must be calibrated and maintained to ensure optimum performance.

COLOR MANAGEMENT

Color communicates. Color sells. Color is the sizzle that drives the sale of virtually every consumer product in the world. It evokes a wide range of emotions that draw the buyer to the product. Color management professionals know that color is a crucial part of the selling process because it is such an important part of the "buying decision." If color is used effectively in the manufacturing and marketing of an item, potential buyers will perceive added value in that product.

To use color effectively in a flexo package design requires an understanding of the entire process, from initial design to final package (*Figure* 43). Many elements and professionals are involved, each relying on interaction with the other. Print buyers and designers start the process, taking into account consumer preferences. Colors must be specified and communicated, from the visual appeal of the final package to the capabilities and tolerances of the flexographic printing process. In a package design, color and all other elements must be

43 Colors must be communicated and specified, taking into account the capabilities and tolerances of the flexographic printing process. In a package design, color and all other elements must be within the capability of the production process.

within the capability of the production process.

At each step of production, output from the previous step becomes the input to the next process. Colors are communicated among several different individuals who may render and reproduce the colors on many different devices. For final production, a contract proof, viewed under standard conditions, will show a close approximation of the final printed product. Once the client has agreed on the contract proof, the ink department is responsible for supplying ink and color standards that allow the agreed upon color to be obtained; impression after impression and press run after press run. To assure consistent reproduction, color measurement and control is essential. This section will touch on this subject in three parts: color theory, color measurement, and color matching. Color theory and color management application are explained more fully in the Process Color Printing volume.

COLOR THEORY

Color results from the interaction between light, an object and the viewer (*Figure* 44). The human observer, or viewer, sees this modified light and perceives it as a distinct color. All three elements, light, object and viewer, must be present for color as we know it to exist.

Light Source and Color

If an object is viewed using other than a white-light source, the perceived color will take on the hue of the illumination. While

sunlight is the most natural way to view objects, it is not an ideal light source to judge the color of objects; it is simply too variable. Artificial light sources are available and may be controlled and specified to simulate average, natural daylight, and incandescent and fluorescent lamps.

A scale of color temperature, expressed as degrees Kelvin (°K), is used to quantify light sources. Various artificial light sources have color temperatures that range from about 4,000° K to 6,800° K. The D50 CIE Standard Illuminant has a color temperature of 5,000° K, representing average natural daylight, and is the color temperature most widely used in graphic arts viewing booths. *Figure* 45 shows three light sources along with their spectral curves. The spectral curve shows the amount of light of the source throughout the visible range of wavelengths, which is roughly from 400 to 700 nanometers.

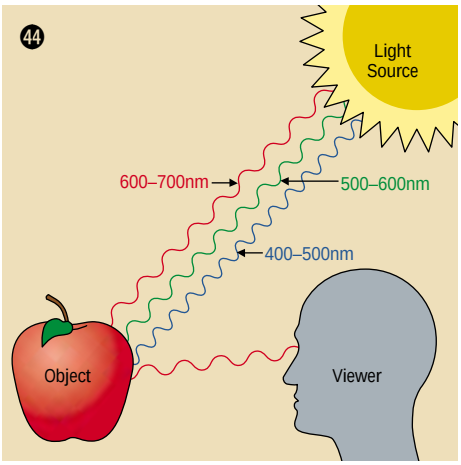
Metamerism

To complicate matters further, there is a common situation where two objects appear to have identical color under one specific light source and then do not match under other light sources. This phenomenon is known as metamerism and is caused by use of different pigment combinations to achieve the individual color matches. Fortunately, the metameric condition is both detectable and controllable.

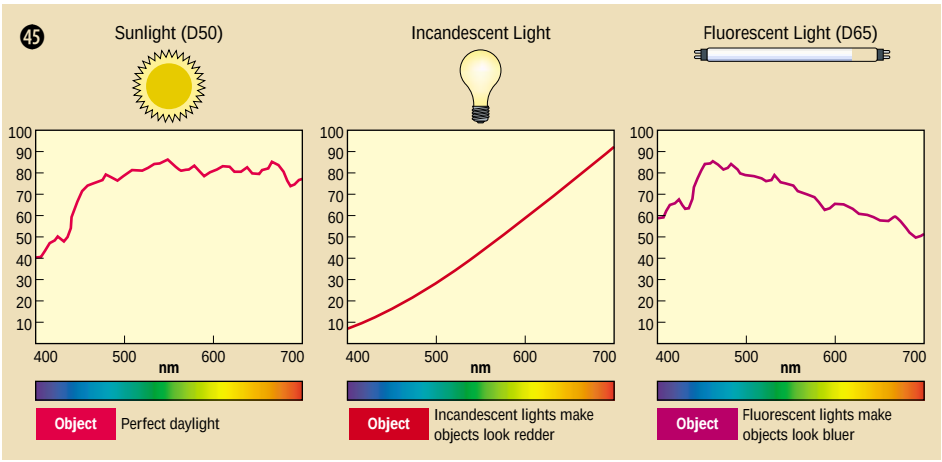
To avoid metamerism, specific, fixed pigment combinations are used for a given color match. The problem can be detected by viewing "matching" objects under different light sources. Metamerism can be quantified by spectrophotometric measurements using different illuminants or simulated lighting conditions.

COLOR MEASUREMENT

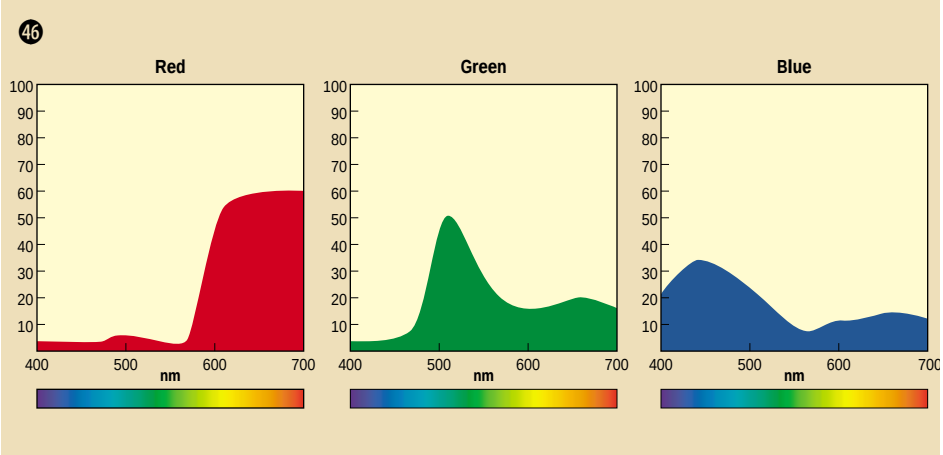
To compare, communicate and store color data, it is necessary to adopt a measurement system. The human visual system is the most discriminating when comparing colors, but it is neither able to assign numbers to colors,



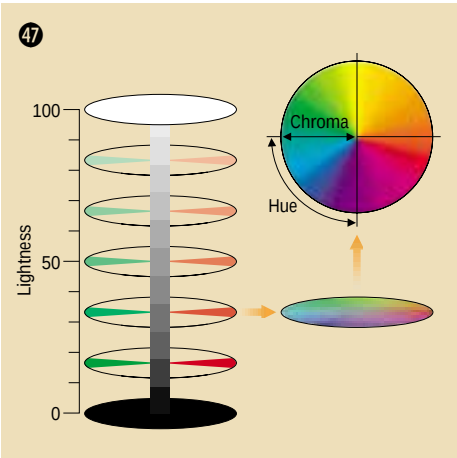
44 Color results from the interaction between light, an object and the viewer. The viewer sees this modified light and perceives it as a distinct color. All three elements, light, object and viewer, must be present for color as we know it to exist.



45 This diagram shows three light sources along with their spectral curves. The spectral curve shows the amount of light of the source throughout the visible range of wavelengths which is roughly from 400 to 700 nanometers.



46 This diagram shows the spectra of a red, green and blue object. Data from the spectral curve can then be used to calculate the relative coordinates of the color in the perceptual-based color space.



47 The L*C*h° system turns the color space into a cylindrical model, and by specifying the lightness, chroma and hue values for a specific color, a unique numeric description is generated.

nor remember them accurately. That is why some sort of a numerical measurement standard and an organized method of communicating color is needed.

The pattern of wavelengths that reflects from an object is the spectral data, which is often called the "fingerprint." Spectral measurements can only be taken by using a spectrophotometer. The data measured can be plotted as a spectral curve, providing a graphic representation of the specific color. The x-axis represents the wavelength of reflected light in nanometers and the y-axis denotes the percentage of light reflected. This x-y plot is the most accurate description of color that can be achieved. *Figure* 27 showed the spectrum of the "red" in the rose. *Figure* 46 shows the spectra of a red, green and blue object. The data from this spectral curve can be used to calculate the relative coordinates of the color in the perceptual-based color space introduced earlier in *Figure* 26.

Perceptual-based Color Space CIE – L*C*h° or L*a*b

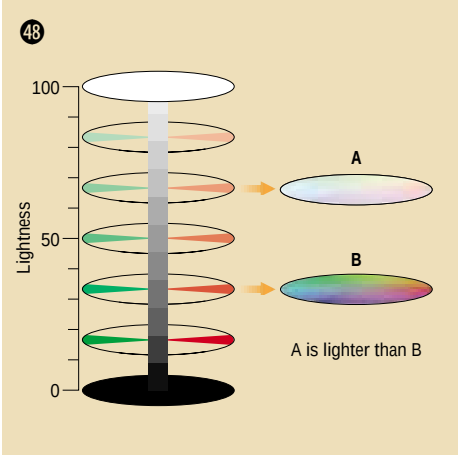
The next step in color management is to take the spectral data and express it in a mode that allows the description of colors and color differences numerically. The spectral curve of a particular color can be used to demonstrate the relationship between wave attributes and the way we perceive these attributes.

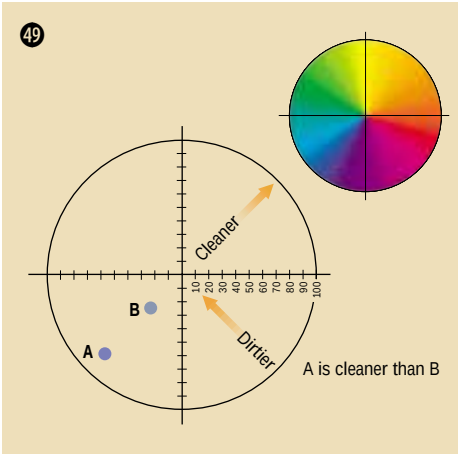
When comparing colors visually, the basic color or hue difference (h) is seen first; followed by the saturation or chroma difference (C); and last, the lightness or darkness difference (L). Light waves also have three attributes that directly affect the perception of hue, saturation, and lightness. The dominant wavelength of light in the spectral curve determines the perceived hue of the color. The wave purity or sharpness of the peak in the spectral curve, determines saturation. The height (total energy) determines the lightness.

A numerical color model has been developed which is intuitive and easy to understand (*Figure* 47). The L*C*h° system had turned

48 Colors can be classified as light or dark when comparing the L values.

49 Chroma changes on the horizontal plane, where the colors in the center are gray (dull) and become more saturated (vivid) as they move toward the perimeter.





the color space into a cylindrical model and by specifying the lightness, chroma and hue values for a specific color, a unique numeric description is generated. The L*C*h° numerical equivalents of the system provide another method of expressing the coordinates of the color in the same color space.

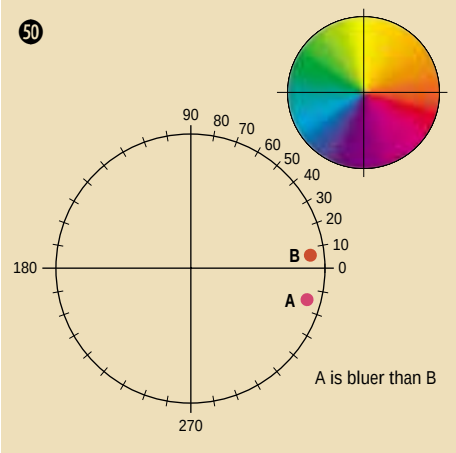
Lightness (L): This characteristic of color describes its luminous intensity-that is, the degree of "lightness." Colors can be classified as light or dark when comparing the L values (*Figure* 48). For example, when placing a tomato and a radish side-by-side, the red of the tomato appears to be much lighter. In contrast, the radish has a darker red value.

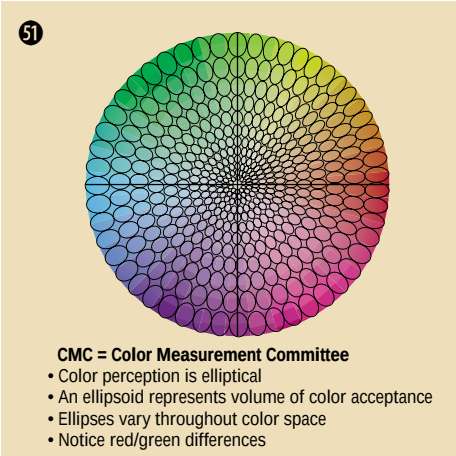
Chroma (C): The vividness or dullness of a color describes its chroma. In other words, chroma indicates how close the color is to gray or the pure hue. Chroma changes on the horizontal plane, where the colors in the center are gray (dull) and become more saturated (vivid) as they move toward the perimeter (*Figure* 49). This color attribute is also referred to as "saturation." Again comparing the tomato to the radish, the tomato is much more vivid; the radish appears duller.

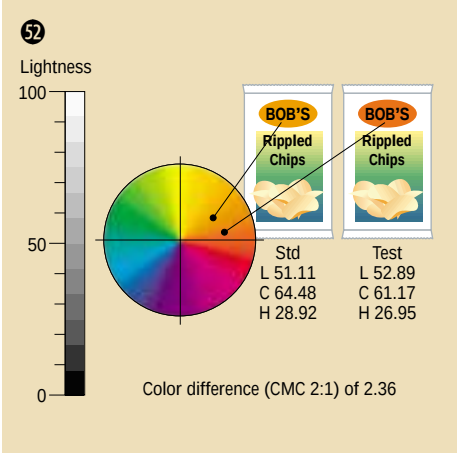
Hue (h): When asked to identify the color of an object, the hue is most likely mentioned first (*Figure* 50). Quite simply, hue is an object's perceived color – red, green, orange, and so on.

Color Tolerancing (CMC). In the L*C*h° color space, the tolerance for an acceptable color match is bounded by a three-dimensional space with varying limits for lightness, hue and chroma. In the diagram (*Figure* 51), the variations of the ellipse size throughout the L*C*h° color space for one particular L value can be seen. The ellipses in the orange area are longer and narrower than the ones across the green area, which appear much rounder and broader. The ellipses also change in size and shape as color increases in chroma. The Color Measurement Committee (CMC) has provided calculations that mathematically define an ellipsoid around each color standard with the three dimensions corresponding to the hue, chroma and lightness. The ellipsoid represents the range of acceptance, and automatically varies in size depending on the position of the color in the color space. CMC is not a new color space, but is rather a tolerancing system within the L*C*h° color space, which provides good agreement between visual assessment and instrument measurements.

The eye generally has greater tolerance for shifts in the lightness (L) dimension of a color than in the chromaticity (C) or hue (h) dimensions. Therefore, a tolerance ratio of about 2:1 is accepted (the lightness attribute is weighted twice as much as the hue and chroma attributes.) Though no color tolerancing







system is perfect, the CMC equation best represents color differences as they are seen. It is becoming a recognized industry standard. A color difference between two objects on the CMC L*C*h° scale is expressed as a total color difference and is referred to as – delta E CMC 2:1. A delta E value of 1 is an approximation representing a color difference just detectable by the average human observer. The diagram (*Figure* 52) shows typical numbers generated by color computer software when checking "Bob's rippled chips" bags[1]. The color difference of 2.36 CMC 2:1 is readily seen by the trained eye and may be unacceptable.

[1] The color difference shown here is for illustration only and will differ from the value of 2.36 quoted due to the variability of the printing process.

It should be pointed out that many presses cannot maintain better than 2 ΔE CMC 2:1, hence the need to constantly "tweak" the ink or the press settings. A word of caution: The color computer is only a tool that assists with achieving acceptable color; it should never be allowed to overrule the trained eye. If the measuring instruments are not used properly, under the correct conditions they will not output useful information, and even then the information must be interpreted by the user.

INSTRUMENTS

In most cases, the instrument used to measure color is only accurate when it has been calibrated. Most instruments require a "warming up" period before the readings are stable and the instrument calibration should be regularly checked against a color standard.

Densitometer

The densitometer is the least sophisticated color control instruments in design and, generally, the least costly. The main design incorporates the use of three- or four-colored filters. Each filter color, (red, green, blue) allows approximately one third of the visual spectrum of light to pass through and reach a photo-detector. By analyzing the combination of signals from the light trans-

50 Color plotted in this manner provides a subjective desciption of a color.

51 The Color Measurement Committee (CMC) has provided calculations that mathematically define an ellipsoid around each color standard with the three dimensions corresponding to the hue, chroma and lightness. The ellipsoid represents the range of acceptance, and automatically varies in size depending on the position of the color in the color space.

52 The diagram shows typical numbers generated by color computer software when checking a print sample. The color difference readily seen by the trained eye may be unacceptable.

mitted through the colored filters, the densitometer can determine some of the attributes of the color being measured.

A densitometer is able to compare color, but not in the same manner as the human eye. Densitometers vary widely in the number of functions that they perform, but the main function of a densitometer is to measure density. This value correlates very well to ink-film thickness and is used to calculate other print attributes, such as hue error, grayness and tone reproduction in process printing.

Colorimeters

For capabilities beyond those of the densitiometer, colorimeters are the basic color measuring tools. Two types of colorimeters are available on the market today: tristimulus and spectral-based.

Tristimulus. The tristimulus colorimeter is very similar in design to the densitometer. It has red, green and blue filters that are used to split the visible spectrum into thirds. The primary differences in the tristimulus colorimeter is two-fold. First, the tristimulus colorimeter is engineered to see color like the human eye, whereas the densitometer is equipped with specific sensitivities for process-ink colors. Second, the microprocessor in the tristimulus instrument works with very different numbers and algorithms. Colorimetric formulas generally yield three numbers that allow the user to plot the measured color as a point in a three-dimensional space.

Spectral. A spectral-based colorimeter, or spectrocolorimeter, divides the visible spectrum into very narrow segments, each representing only a very small and select portion (bandwidth) of the spectrum. Because it divides the spectrum into many parts, a spectrocolorimeter can gather more information and is more accurate than a tristimulus colorimeter or densitometer. Consequently, these spectral devices have greater repeatability and inter-instrument agreement; therefore, they carry a higher price tag than the more simple designs. As with the tristimulus unit, the spectral-based instrument presents the color measurement as the same three L*C*h° (L*a*b) numbers. Increased sensitivity to slight color differences makes the colorimeter a very useful tool for testing incoming inks and substrates. Colorimeters also find use in production departments where corporate colors or special matches are printed and compared to a standard.

Spectrophotometers

Spectrophotometers work in a similar way to spectral-based colorimeters. They split the visible spectrum into very small segments using either narrow-band filters or a diffraction grating. All spectrophotometers can output the same data as colorimeters, however, the spectrophotometer is a more sophisticated instrument and able to output the information as a spectral curve. This curve is derived from taking the percentage reflectance at each wavelength measured and plotting it on a graph. Once each point has been plotted, the dots are connected to produce a curve that is unique to each pigment color measured. These curves can be used like a fingerprint to identify the pigments that make up an ink.

The spectrophotometer is the ideal instrument to use when mixing inks. The instrument can save a great deal of time spent on hit-and-miss ink mixing. Its use will improve the batch-to-batch consistency of ink, along with ensuring consistency between different ink department individuals.

COLOR-MATCHING THEORY

The most useful visual tool in color matching is the color wheel (*Figure* 53), a slice of L*C*h° color space. The colors of the spectrum are arranged in a circle as

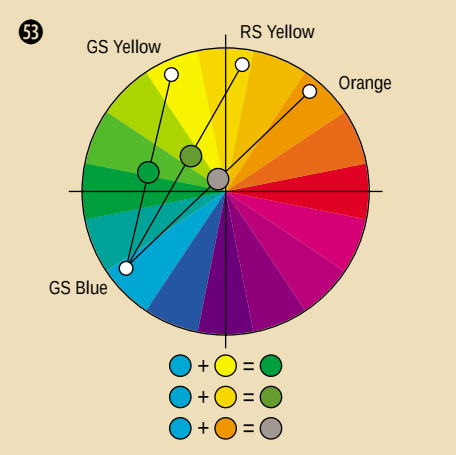
shown in the diagram, reducing chroma to black at the center. When color matching, this wheel should be kept in mind. Mixing pigments which are adjacent on the color wheel results in colors that are clean or bright. For instance, if green-shade cyan (GC blue) is mixed with green-shade yellow (GS yellow) the mixture will be a clean, bright green.

Drawing a line on the color wheel between the two pigments shows how close to the center gray area the line will travel. If the same GC blue is mixed with red-shade (RS) yellow on the opposite side of the color wheel, the line on the color wheel joining the two pigments travels closer to the center gray area and the mixed ink will be a dull, dirty olive-green.

The concept here is that when color matching, the ingredients should be kept close in the color wheel to obtain clean, bright color matches and further apart to "dirty up" the match. It is important that color-match formulas are constructed with individual pigments that are not too far apart. For example, a brown should not be matched using red, yellow and blue, preferably it should be matched with red, yellow and black (the center point on the wheel). Formulas containing several pigments from distant areas of the color wheel will change hue very quickly with small viscosity changes.

It is critical to be able to talk about color in a way that is intuitively understood. One way is to use the color wheel and remember the position of individual colors on the wheel. In this way, when the hue of a batch of red ink is compared against the standard red ink, the batch may be more yellow or more blue in hue than the standard (*Figure* 54). If the batch is identical in hue it may, for example, be too strong or too dark. If this is the case, it would have a lower L value than the standard. An addition of extender or solvent to the batch would correct this.

As the ink is weakened, all three color attributes (L*C*h°) are affected at the same time (*Figure* 55). This chart summarizes what happens to the L*C*h° numbers as various colors of ink are weakened. It should be noted that the ink can be weakened by adding solvent, by adding extender or by use of a lower-volume anilox roller.



53 The most useful visual aid in color matching is the color wheel, a slice of L*C*h° color space.

54 When the hue of a batch of red ink is compared against the standard red ink, the batch may be more yellow or more blue in hue than the standard, as is indicated on this color wheel.

COLOR-MATCHING PROCEDURE

A general flowchart for mixing a special color ink is shown in *Figure* 56. It shows the procedure for making a small, 100-gram batch to test and develop the specific formula. End-use requirements may dictate the choice of pigments available for a particular color formulation. Any colors that might be a problem, such as small amounts of rho-

55 This chart summarizes what happens to the L*C*h° numbers as various colors of ink are weakened. It should be noted that the ink can be weakened by adding solvent, by adding extender or by use of a lower-volume anilox roller.

56 A general flowchart for mixing a special color ink shows the procedure for making a small, 100-gram batch to test and develop the specific formula.

55

	L Value will:	C Value will:	H Value will:
Yellows	**Go lighter** to a higher number	**Go dirtier** to a lower number	**Go greener** to a higher number
Oranges	**Go lighter** to a higher number	**Go dirtier** to a lower number	**Go yellower** to a higher number
Reds	**Go lighter** to a higher number	**Go dirtier** to a lower number	**Go bluer** to a lower number
Blues	**Go lighter** to a higher number	**Go dirtier** to a lower number	**Go greener** to a lower number
Greens	**Go lighter** to a higher number	**Go dirtier** to a lower number	**Stay about the same**

damine pigment in a white tint, should be avoided. The combination of rhodamine and titanium dioxide is unstable due to chemical reactivity.

If fade-resistance or outside exposure are required, the pigments chosen should be suitable. When specified by the end-use requirements, the pigments used should be stable to aggressive products such as milk, acids, alkalis, oils and solvents. Finally, the lowest cost combination of pigments should be used to achieve the color. Once the small test batch is made, the amount of material can be scaled up for the press run quantity. The initial formula can be obtained from a variety of sources: historical data, experience (especially for similar colors), or computer formulation software.

1. **Weigh Sample.** A 100-gram sample of the initial formulation is weighed in the ink laboratory. Pigment selection is based on the color being matched using the color wheel as a guideline. There are other considerations for the optimum color match. Use the fewest number of colors in the match since this makes weighing and control of the ink for the press much simpler and easier to adjust and control.
2. **Adjust Viscosity and Strength.** This step is based very much on experience and knowledge of both the ink system and the press where it will be used. Actual

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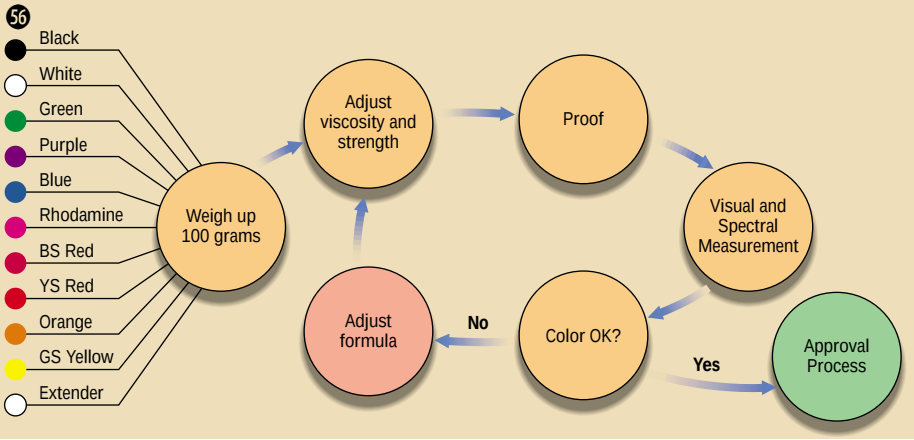
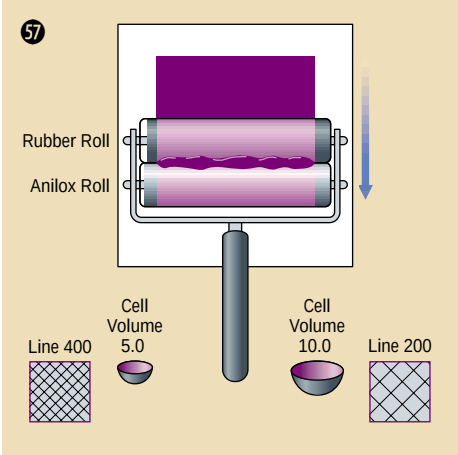


pigment concentration and the ink film thickness which the press inking system will lay down govern this step. Any changes to the ink system or the press, must be conveyed to the color matcher-an obvious statement but a frequently violated procedure.

3. **Proof.** A draw-down is made using a method that matches the coating weight and appearance of the actual press. The substrate used for proofing should be the one that will be used in production. If the ink is to be reverse-printed on film and backed with white ink, it should be proofed this way. If the ink is to be printed on coated board and UV-lacquered, once again it should be proofed this way.
4. **Inspection.** Does the proof match the color target ? This is where the skills and experience of the color matcher are demonstrated. The proof sample is compared to the color standard approved by the end user. While the final decision is made using a visual comparison, spectrophotometric measurements are a useful tool to aid the color matcher. The most difficult task is to match a color standard that has been printed by a process other than flexo and/or on a different substrate. A typical scenario is where an ink for printing on film is being matched to a spot color, which is printed offset-litho on paper. When the ink color technician is satisfied with the match, it can be measured and stored in the color computer.
5. **Approval Process.** Color-match proofs are sent to the customer for approval and copies are retained in the inkroom. Signed, approved proofs from the customer then serve as the color target for making ink for the qualifying pressrun.

PROOFING METHODS

As indicated earlier, the main requirement of a proofing method is that it lay down the same amount of ink as the press and also match the press print appearance in terms of uniformity. There are many proofing methods used for flexo printing. They range from a simple blade draw-down on paper, to actual flexo printing on a pilot scale press. On the one hand, the blade draw-down may be too crude for many applications, and at the other end of the scale, the pilot press too expensive and time consuming. Three commonly used proofing methods, which are quick and accurate, will be reviewed here: the flexo hand proofer, the automated bar proofer and the laboratory flexo proofing machine.



57 The flexo hand proofer consists of a rubber roller and anilox roller mounted in a frame. The ink is dripped into the nip formed by these two rollers, and the draw-down is made by running the roller over the substrate at even speed and pressure.

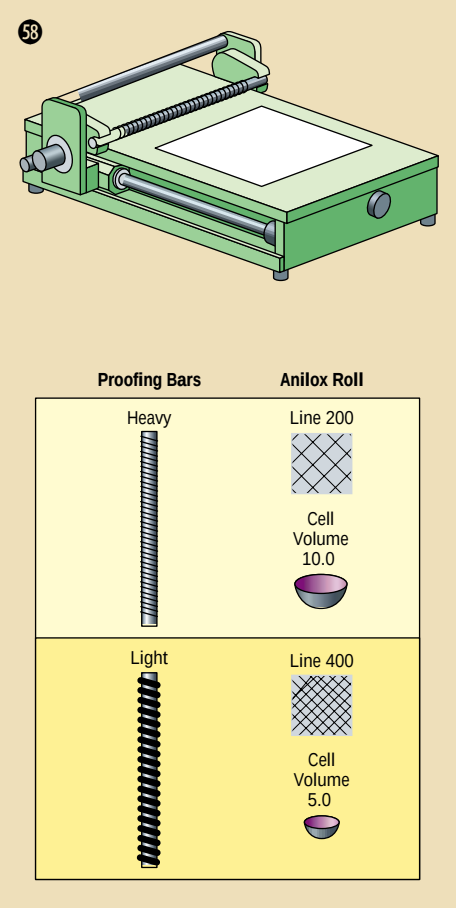
Flexo Hand Proofer

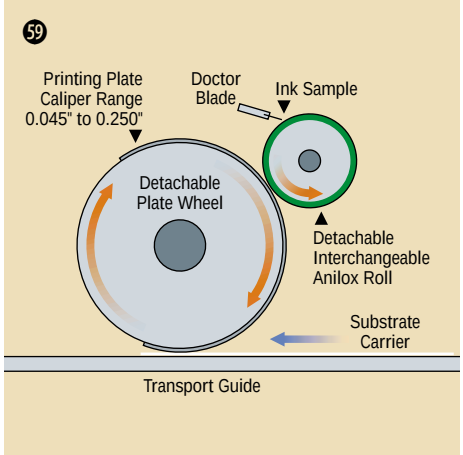
This proofing device consists of a rubber roller and anilox roller mounted in a frame. The ink is dripped into the nip formed by these two rollers, and the draw-down is made by running the roller over the substrate at even speed and pressure (*Figure* 57). There is some variability in the flexo hand proofer, mainly caused by operator differences in speed and pressure used during the draw-down. Less pressure and more speed transfers more ink.

The inherent amount of ink transferred can be changed by changing the anilox roller

58 The bar proofer is a mechanically driven device where speed and pressure are controlled and reproducible.

59 A laboratory flexo proofing machine brings the anilox roll in contact with the print wheel, which in turn contacts the sample. This automatic cycle makes printing the substrate and proofing the sample ink a controlled process.





volume and by using rubber rollers of harder or softer durometer. Many inkrooms use several flexo hand proofers of various ink delivery rates to correlate with individual presses or even specific decks within a press. The flexo hand proofer is capable of laying down ink films which match the press in terms of appearance, even on substrates which are uneven.

Bar Proofer

The bar proofer is a mechanically driven device where speed and pressure are controlled and reproducible. The results from this device are not operator dependent. A wire-wound rod draws ink down on the substrate (*Figure* 58). The amount of ink that is deposited is dependent on the thickness of the wire on the rod; thicker wire lays down more ink. Different coating rods, or proofing bars, are used to correlate with specific press conditions. The main disadvantage of this method of proofing is that the proofing bars are not able to lay down ink as smoothly as the press on uneven substrates.

Laboratory Flexo Proofing Machine

This machine generally has a detachable printing wheel about 7” in diameter on which a photopolymer plate is mounted in a typical way (*Figure* 59). The machine also has a detachable anilox roll and a doctor-blade system. A full range of anilox rolls are available to suite the actual press configuration.

The substrate sample is mounted on a rigid carrier and placed on the transport guide. Printing speed, anilox pressure and printing pressure are selected according to the press application.

A sample of ink is applied to the nip between doctor blade and anilox and the machine is started. The automatic cycle brings the anilox roll in contact with the print wheel which in turn contacts the sample. The print wheel makes one rotation, printing the substrate and proofing the sample ink in a very controlled manner.

Authenticating the Proofing System

A simple experiment may be conducted to verify that the inkroom proofing method correlates with the press. From a press that is printing efficiently, collect: a sample of ink from the ink reservoir, some unprinted stock and a newly printed sample. Proof the ink sample on the unprinted stock with the normal proofing method and compare it to the press sample, preferably using a spectrophotometer. If the L (lightness) value difference is less than 0.5 units, the correlation is acceptable. If not, the proofing method should be adjusted until the L value is within 0.5 units. The value of 0.5 units in lightness is used as a guide only and may vary for different processes and customer requirements. Future releases of FIRST (Flexographic Image Reproduction Specifications & Tolerances) will address the issue of correlation of proof to press.

INK-ASSEMBLY OPTIONS

Inks supplied from the ink company are available in several different physical forms, each of which has distinct advantages and disadvantages. Some converting plants have a diverse product range, sometimes involving printing on both films and paper, requiring several different ink systems to meet all applications and end-use specifications. Here is a review of ink assembly options available.

Pigmented Bases and Blend Varnishes

In this option, the ink company manufactures and supplies the printer with about 10 highly pigmented bases in a base resin. Each of these bases contains a single pigment, such as cyan blue, OT yellow or titanium dioxide. The printer then mixes the pigmented bases together with a blend varnish to formulate the color and quantity of ink for a specific need.

A proven example of a pigmented base can be seen in nitrocellulose-ink formulation. Most colors in the PMS book may be reproduced by blending 10 nitrocellulose bases together with an appropriate blend varnish. The formula for a nitrocellulose gloss, green ink, formulated for film printing, blended from pigmented bases would look like this:

nitrocellulose cyan blue base	10%
nitrocellulose OT yellow base	40%
gloss, film, blend varnish	50%

There are several advantages to this ink-assembly method. The ink strength may be increased or decreased by raising or lowering the amount of pigmented base in the ink. The ink can be formulated for other end-use applications; for example, where heat resistance is needed, a heat-resistant blend varnish is substituted for the gloss-blend varnish. Low inventories and quick response times are possible when blending inks from bases and blend varnishes. When this method is adopted by the converter, more responsibility for testing the finished ink for end-use properties is moved from the ink company to the in-house blending system. Use of the wrong blend varnish could obviously have drastic effects on the converted product. It should be noted that similar water-based blending systems are available, many of which are based on acrylic resins.

Single Pigment Finished Inks

The ink company supplies the converter with about 10 single-pigment finished inks. When matching colors, the specified color is blended from this range of finished inks, and the matched colors and inks are used for a specific end-use application. For example, the formula for a nitrocellulose gloss, film, green ink, blended from single pigment finished inks would look like this:

gloss film cyan blue ink	20%
gloss film OT yellow ink	80%

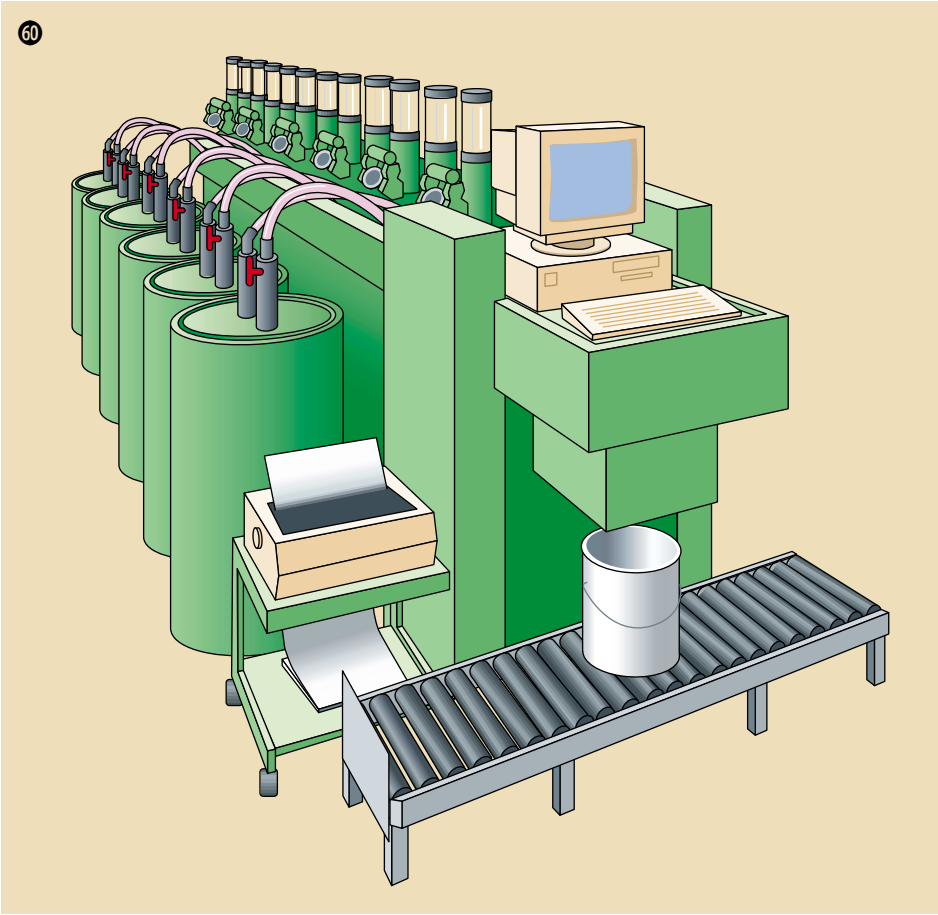
Any gloss film job can be accommodated

by this ink system, and all of the functional properties of the ink system would be certified by the ink supplier. If the color is correct but the ink is too weak, perhaps due to use of a lower-volume anilox roll, the only way to correct the situation is by adding concentrated base colors. Many converters will stock some pigmented bases to address this problem. Adding base to an ink must be done only with the permission of the ink company, since the strength problem may be corrected at the expense of finished properties such as ink adhesion.

If this same green was needed in a heat-resistant formulation, it would need to be blended from single-pigment heat-resistant finished inks. Ink suppliers work with their customers to keep inventories down by developing multi-purpose ink systems. One ink system with the correct balance of heat resistance and gloss can, in many cases, replace the individually formulated heat-resistant gloss ink systems.

Matched Finished Inks

With this option, the ink is supplied by the ink company as a pre-matched finished ink (for example green gloss film), in which case it would be certified for color, press readiness and end-use properties when received by the converter. This way of purchasing inks is normally reserved for large-use items that repeat frequently. In these cases, the ink company has manufacturing equipment better sized to produce the ink economically.



60 While adequate quality and consistency can be achieved by ink-blending rooms using manual methods, best practices involve dispensing systems, with various levels of computer control and automation.

INK BLENDING

The ink-blending operation is a key component in the smooth running of a converting operation. The most expensive part of a converting operation is the pressroom, with huge capital investment in presses which must be kept running on schedule. To do this, the inkroom must deliver the proper amount of the proper ink to press every time. While adequate quality and consistency can be achieved by ink-blending rooms using manual methods, the best systems involve dispensing systems, (*Figure* 60) with various levels of computer control and automation.

Progressive converters who have installed automated dispensing systems have minimized ink-related downtime and dramatically reduced returned ink inventories. With these systems in place, expensive return ink is promptly reused by the system. Ideally, the ink supplier will furnish the formulas (color matches) and ink, and the automated ink dispenser will calculate the precise amount of each component required to blend the color and then dose each component with precise accuracy. With the software and know-how in these systems, it is possible to produce nearly all the colors from only eight component colors, plus black, white and extender. The number of base components necessary will depend on the product mix and can be determined in consultation with the ink supplier.

Software Capability

An ink-blending system can contain data for formulas, supplier information, basic components, substrates, printing presses, orders, ink usage and costs. These databases enable the plant to have a complete bookkeeping system for flexo inks. Other functions available include bar coding and labeling.

When evaluating a computerized ink-blending system, it is important to examine the associated software. Many systems do not have their own return-ink software, but depend on spectrophotometer software for managing return inks. Color reformulation with the spectrophotometer can be performed, but it is not the best solution for everyone. The spectrophotometer is an aid, but still requires a strong technical knowledge of color theory and generation of ink system color databases by the ink department.

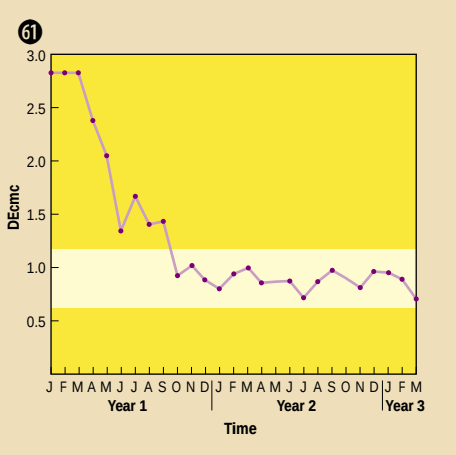
On the other hand, ink-blending systems with integrated press return software are very easy to operate. If the operator wants to blend a color, the system will prompt the operator that there is rework ink in inventory with some of the same components. If more than one return ink is available, the computer will display the ink in both chronological order and cost-of-ink order. The operator can choose whether or not to use the rework ink. Most dispensing systems have software links available for spectrophotometers for use in color formulation and quality control.

Gravimetric vs. Volumetric

The heart of the dispensing system is the dispensing unit which accurately dispenses all basic inks. The basic inks often have different viscosity and flow. Historically, gravimetric-blending systems have proved to be more accurate than volumetric-based systems. Gravimetric systems typically operate within an accuracy range of one gram. Volumetric dispensers operate with an accuracy range of 2%, which is as accurate as a gravimetric dispenser for small batches. However, if 50 gallons (450 lbs.) of ink are dispensed, the volumetric batch could vary by as much as 9 lbs. Air entrapment in the ink will cause a dispensing error in the volumetric system, whereas with the gravimetric system the weight is constantly checked.

It is absolutely required that the ink-blending system be closed and continuously circulating to eliminate variability due to set-

61 The graph shown is from actual experience and represents a complete revamping of product quality coming from the inkroom. In this situation, the pressroom became confident in the color from the inkroom and was able to focus on press variables to improve print quality further.



tling or separation of ink ingredients. It is also important that the ink circulate throughout the whole system including the dispensing head.

Here are some advantages of in-house automated ink-blending systems:

Just-in-time (JIT) Ink Production. Automated dispensing allows the printer to blend inks immediately for a press run and blend only the ink that is needed.

Exact Quantity of ink Per Order. Historically, more ink was ordered than was needed to avoid any chance of running out of ink and shutting down a press. With automated dispensing more ink can be produced at the press of a button. This prevents the constant buildup of excess ink that must be reworked.

Constant Quality. Automated dispensers ensure exact reproducibility on repeat orders. The color produced for a job last week or last month will be exactly the same color when it is blended next time. Ink inventory build-up is again reduced due to the correction of wrong colors and rejected batches.

HOW TO ADJUST TOLERANCES

The question of achievable, realistic tolerances for special-color inks is the subject of some debate and will be addressed in future releases of FIRST. Ideally, on the same stock and press, running the same conditions, a repeatability of delta E, of 2.0 CMC 2:1 or less is desired. This is a tight tolerance which may or may not be achievable for a given process and color. It may not even be needed for a given color and, in the final analysis, a visual assessment should be made to determine the required delta E for customer acceptance. Overall color consistency will improve, however, simply by measuring the process and giving feedback to the inkroom and pressroom. This is not an easy task since many work habits have to be changed. The graph shown in *Figure* 61 is from actual experience and represents a complete revamping of product quality coming from the inkroom. In this situation, the pressroom became confident in the color from the inkroom and was able to focus on press variables to improve print quality further.

When the on-press color is approved and the delta E value is within the established tolerance, replace the signed-proof spectral values with the CMC L*C*h° values of the press proof. This is important since this is the real target to aim for every time the job is run. When an ink batch is proofed before the job goes to press, compare the batch to the color that was achieved on press. If the delta E of the initial pressrun was approved with a delta value greater than the established tolerance, the press print spectral values should not be saved. However, attempt to get closer the next time the same job is run and then save the new spectral values.

Once an approved standard and CMC L*C*h° spectral values are established, it is necessary to determine the numerical tolerances that can be established around the color. To do this, samples of subsequent job approvals need to be saved. Job approval samples (the more the better) for the next several runs of an identical job should be saved. Under ideal conditions, two or more people should visually evaluate all of the prints at one time against the original signed

and approved proofs, as well as against the original standard. Unacceptable prints should be discarded, and a spectrophotometer used to read the others. The remaining values should be averaged via color computer software to make a new numerical standard. This becomes the newly established tolerance for batch and press approvals and avoids unnecessary ink adjustments on press.

It is now time to make an ink batch for the press. Clean containers and scales to weigh the formula accurately should be used. Electronic scales are more expensive to purchase, but they are also more accurate than most of the less expensive mechanical scales. An electronic scale can prove to be a very wise investment in the long run.

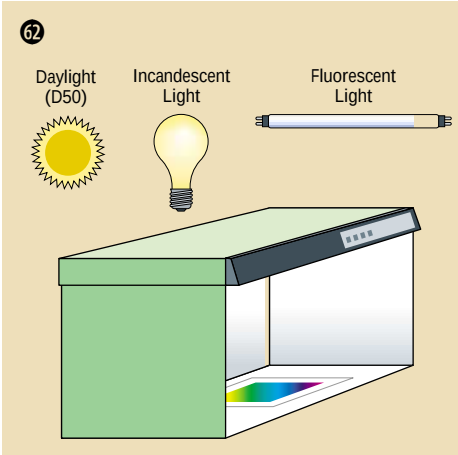
The ink batch should be proofed identically to the customer-approved proof (same stock, back-up, overprint, etc.). This proof should be evaluated visually against both the signed proof and the original color standard. The batch proof should be compared numerically to the previously entered standard. If the light-to-dark difference between the colors is greater than 0.5, the batch proof should be re-read, or another batch proof (lighter or darker) made and then re-read. The chroma or hue of the colors should not be evaluated if the batch proof light-to-dark difference is greater than 0.5. This will help ensure the correct color is achieved on press. If the proof looks acceptable but chroma or hue deltas greater than 1.0 exist, the color should be adjusted accordingly. Once the combined deltas of L, C, and h are under 1.0, the color should appear acceptable. The ink batch is now ready for the press.

Again, note that the values of 0.5 in lightness and 1.0 in chroma and hue may not be achievable for every process. Testing and visual examination in conjunction with spectrophotometric measurements can establish realistic and achievable values for a particular process. Once established, they become the standards for that process.

Once the ink is in a clean press which is running up to speed, compare and evaluate the press print to the customer's approved proof and the original color standard. Evaluate the press print to the customer's signed proof with the spectrophotometer. If the delta E of the press proof is greater than 1.0, examine the L differences between the colors. If the press print is darker than 0.5, the color needs to be lightened with solvent or extender. If the press print is lighter than 0.5 and there is extender in the ink formula, equal percentages of the base colors need to be added to strengthen the ink. If the color formula does not contain extender, adjust the press settings or change the anilox. The print should be approved with the combined color (CMC L*C*h°) differences. Do not look at the color comparisons between the print generated in the ink room and the press pull until the light-to-dark difference between these colors is under 0.5. This will help eliminate some of the small variables such as strike through, paper color shifts, or other minor process variables that could cause slight color changes. The inkroom proofing method must represent what the press will later produce for the customer.

Once the inkroom proof is made and the light-to-dark difference meets the standard, the proof should be viewed under the light source required by the customer, if possible. In many cases, the converter is unaware of where the customer will evaluate the prints for color approvals. Therefore, the colors should be evaluated under a "daylight" light and an incandescent light to eliminate metameric potential (*Figure* 62). Make sure that the inkroom proof and color target are evaluated with a common back-up material behind the prints. A color booth should be available for all color work. The color booth allows the print to be compared under different standard light sources.

The color computer measures reflectance spectrophotometric curves for printed col-



62 The colors should be evaluated under a "daylight" light and an incandescent light to eliminate metameric potential. The inkroom proof and color target should be evaluated with a common back-up material behind the prints.

ors. From these curves, the computer calculates mathematical values that completely describe the color. It can store these values and compare them to other prints, and determine if they are the same or within commercial tolerance.

The color computer will not replace eyes, experience or judgment. It is a tool that always remembers and never gets tired. Most printers, ink suppliers and many customers use color computers to control their processes and to certify incoming materials.

Ink on Press

It is critical to understand the dynamic interaction between the ink and the various printing components in order to minimize variations in printed materials and maximize efficiency. This chapter will examine the various press configurations and how they influence ink selection and performance. It will also look at the ink-metering system, press dryers, printing plates, and film movement through the press.

Significant changes take place in the mechanical conditions on press, so it is important to understand how these changes relate to, and effect the inks. Proper ink handling on press is critical to trouble-free printing. Color control, viscosity and pH adjustments for water-based inks will be explored. These areas are becoming more important due to the increased usage of water-based inks and high performance solvent inks.

Both the ink and the press are influenced by the specific environment in which they are used or located. Humidity and temperature play important roles in proper drying and resolubility of the ink. These factors affect how well ovens dry inks.

Any printed material must be evaluated agianst a quality standard. Beside the obvious color and strength of a print, it is important to know how to evaluate density for process printing and to put objective numbers on evaluating the line print areas. Other areas of concern are various end-use testing requirements. Among the tests to be discussed will be rub and slip for surface inks and bond determinations for lamination applications.

Commonly used substrates, how they compare, and the advantages and disadvantages of the various substrates will be covered in this section as well. While new substrates are being introduced on a regular basis, it is important to realize that even though two substrates may be based on the same chemistry, the actual print surface may vary and the printability of the individual substrates may be different.

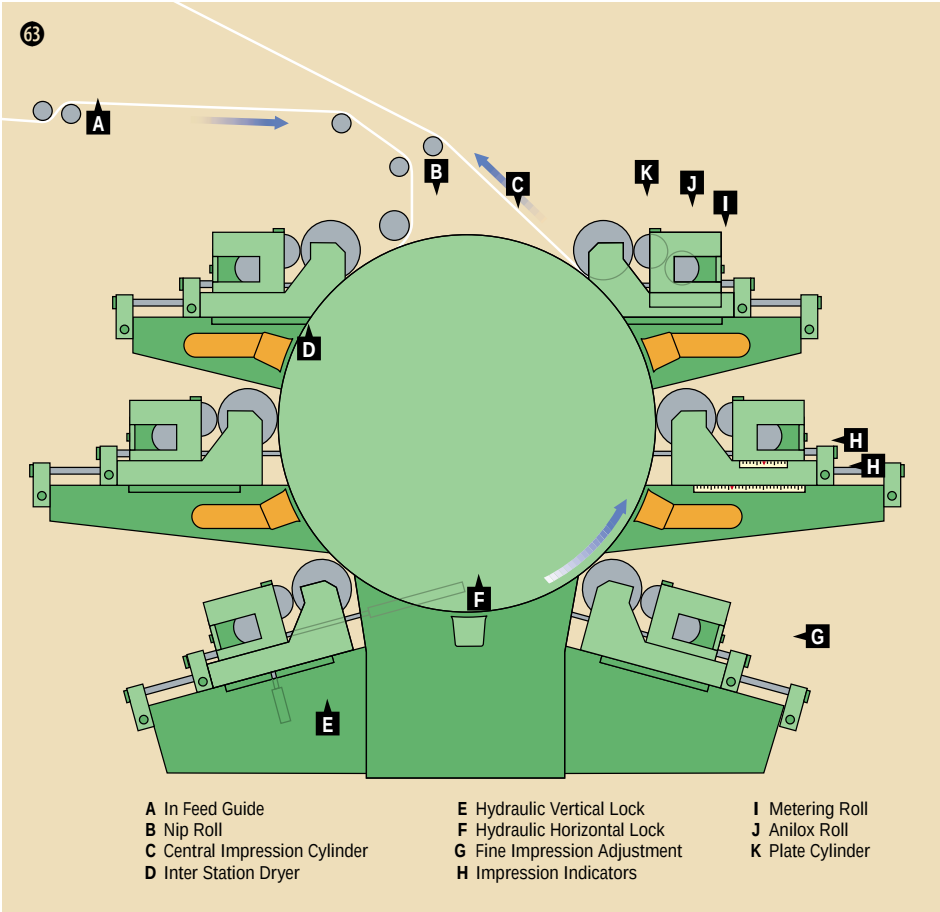
The last section will review the ink chemistry and press-application conditions of a relatively new and quickly evolving area in flexographic printing – UV inks.

PRESS CONFIGURATION

Press configuration includes the unwind, printing, drying and rewind sections of the press. These sections may all vary somewhat in structure and composition. As requirements for improved quality and more complex print designs are introduced, equipment, materials and configurations are all being optimized to meet current demands.

Printing sections of a central-impression (CI) press (*Figure* 63), stack press (*Figure* 64) and in-line press (*Figures* 65 66) are basically identical. All but the central-impression configuration have separate printing units, each with their own individual impression roller. The central-impression configuration utilizes separate printing stations, but the impression cylinder is common to all the printing decks. The structure of the printing section is independent of the press design. The amount of ink applied to a substrate and the manner and fidelity with which it is applied depends on the ink-metering process. Ink design is generally not dependent on press configuration but is determined by what type of metering

63 A typical central impression press configuration.



system is being used and the position of the specific color unit in the press.

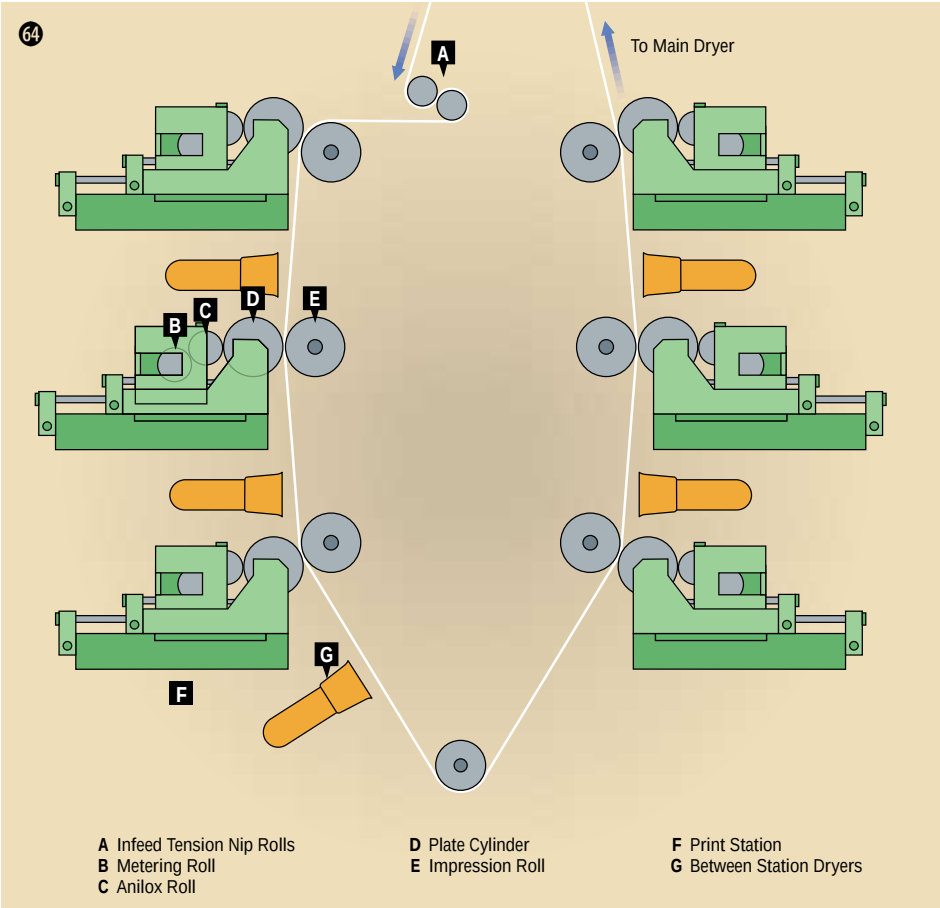
INK-METERING SYSTEMS

Ink-metering systems are used to control the amount of ink transferred from ink reservoir to printing plate and subsequently to the substrate. The ink-distribution system on a flexographic printing press has three components; the ink, the anilox roll and the doctoring method. Ink is generally pumped from the reservoir to the ink pan or doctor-blade chamber on the press and is picked up by the cells of the anilox roll through physical transfer or capillary action. The surface of the anilox roll is then doctored or wiped clean so that surface ink film is minimal or totally removed. Doctoring is performed by a rotating rubber covered roller or by a doctor blade, so that only the ink in the cells passes beyond the doctoring nip. The ink in the cells is then transferred to the printing plate and on to the substrate.

It is important to understand that the primary and sole function of the anilox roll is to meter and control the volume of ink transferred to the printing plate. The amount or volume of ink is determined by the number and size of engraved cells on the surface of the anilox roll and the method of doctoring or wiping. Currently, there are three doctoring methods in use today.

Fountain-roll Doctoring

The oldest and most common method used



64 A typical stack press layout.

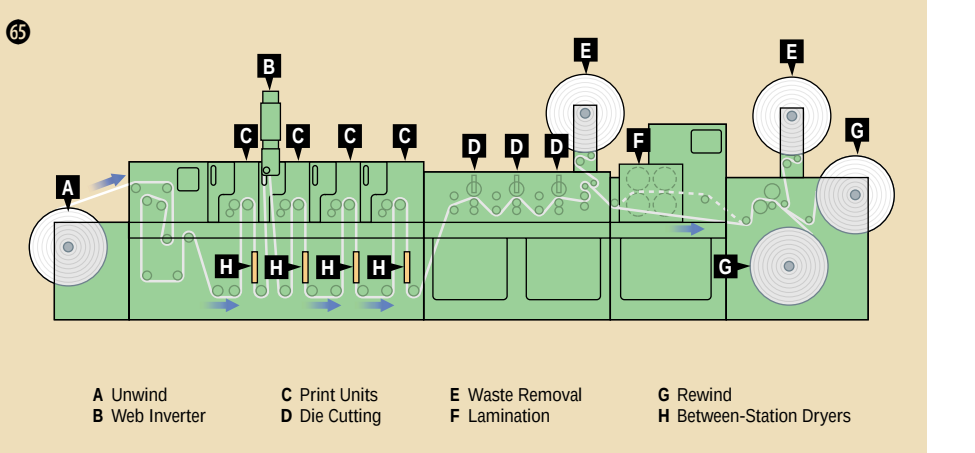
in the industry is known as the two-roll system (*Figure* 67). This system uses a rubber or elastomeric covered cylinder known as the fountain roll. It is driven by a separate drive system and rotates at a constant speed, generally much slower than the anilox roll. Anilox rollers must be driven at the same surface speed as the plate cylinder in order to achieve a smooth ink transfer to the printing plate. This is usually accomplished through a gear-train arrangement where the impression cylinder drives the plate cylinder, which in turn drives the anilox roll, thus ensuring they all rotate at the same surface speed. Thus, the anilox roll rotates at a different speed than the fountain roll. The rotational difference between these two rollers can vary depending upon the speed at which the press is being run. This ratio can range from a low of 3 rotations of the anilox roll to each rotation of the rubber fountain roll to as high as 10 or 12 to 1.

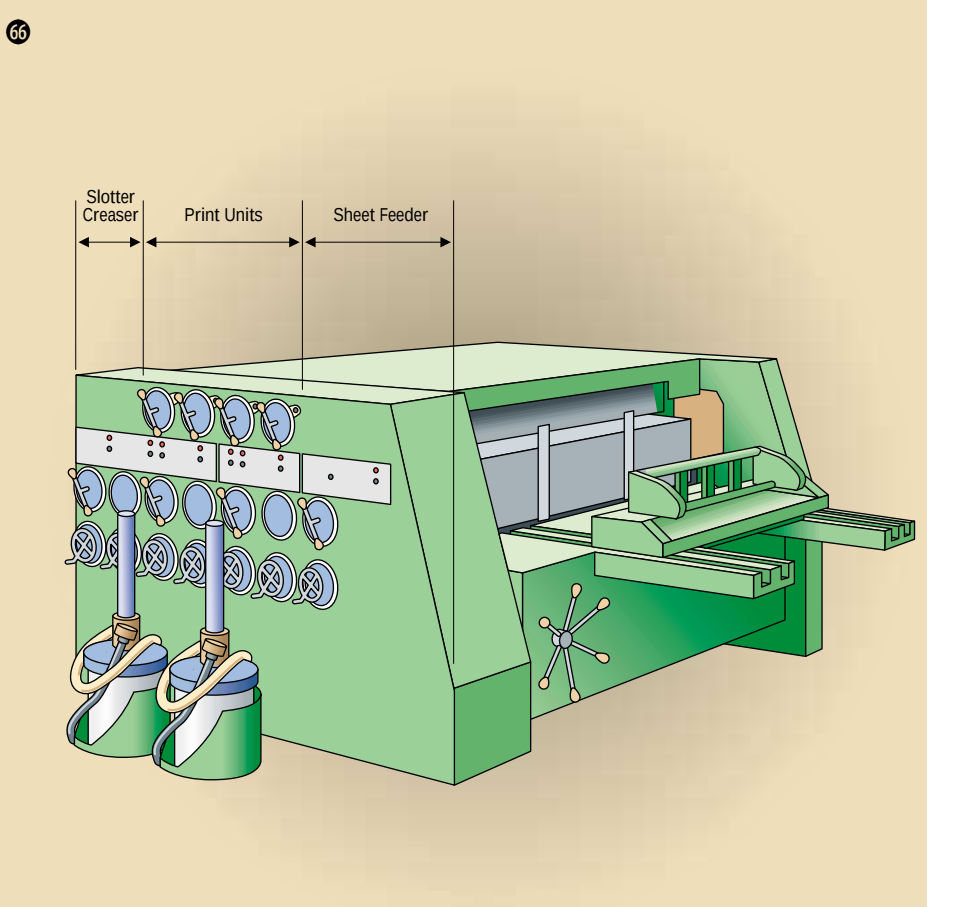
In the fountain-roll system, ink is pumped into the ink pan so that the rubber fountain roll is partially immersed in the ink. In order to obtain maximum durability of the rollers and to provide lubrication to this nip, it is recommended that the fountain roll be immersed to approximately one-third to one-half of the fountain roll radius. This depth of immersion will enhance the function of the fountain roll to pick up and transfer sufficient ink to the anilox roll.

When the fountain roller is positioned in contact with the anilox roll, ink picked up by the surface of the fountain roll is transferred to the cells of the anilox. The slower rotation

65 A typical in-line press layout.

66 A typical sheet-fed corrugated press unit.





of the fountain roller provides a wiping action, thus doctoring an even ink film on the anilox surface. It is critical that the hardness of the fountain roll covering be compatible with the anilox engraving cell count. If the covering is too soft, when contact is made, the covering will displace more readily and too much ink will pass through to flood the surface of the anilox. When this happens, press operators must make additional press-side adjustments at this nip. Excessive pressure on the anilox roll to

fountain roll nip can cause premature wear to both rollers and in extreme cases the steel journals may be bent or broken.

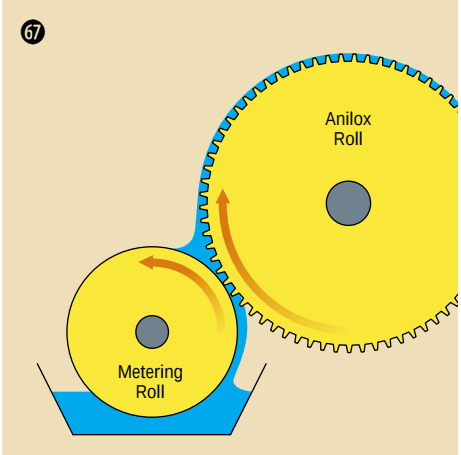
Speed-Sensitive Ink Transfer. The two-roll system has worked well for many years and has produced quality graphics, but it has disadvantages. One problem is that as print speed is increased, more ink is passed through the nip because of the natural hydraulic action caused by the viscous ink. Excessive ink transfer to the printing plate requires more press adjustments to be made. Nip pressure is controlled at the side frames of the press.

On very wide presses, there could be some variation of surface ink film thickness at the center of the anilox roll, when compared to the surface ink film thickness at the ends of the anilox. This is due to the hydraulic action causing a bow, or deflection in the center of the fountain roll. The use of a hard-rubber covering can reduce this excess ink transfer somewhat. Speed sensitivity has been a major problem with this system and there have been many creative attempts to solve this.

One way to reduce the deflection factor is through use of a crown on the surface of the rubber fountain roll. Crowning requires the center of the roll to be made larger than the edges and the roll diameter tapered toward the ends. Thus, when the press is run at higher speeds, there is a more even distribution of the ink. Another way to solve this problem is to skew the rubber fountain roll, so that it contacts the anilox roll at a slightly different angle to allow a more even ink transfer.

Reverse-angle Doctor Blade

Some flexographic printers added a reverse-angle doctor blade to their two-roll system in order to obtain more positive control over the ink film transfer over a wider range of operating speeds. When using a reverse-angle doctor-blade system, where a rubber fountain roll transfers ink to the anilox roll, it is important that the fountain roll is never positioned in contact with the anilox. A gap of at least 0.002" must be rigidly maintained during the pressrun. This converts the fountain roll to primarily an ink-feeding roll that floods the surface of the anilox. The flooded surface allows the doctor blade to operate more efficiently due to lubrication provided by the excess ink film on the anilox roll surface. Smaller gaps between fountain and anilox rolls may not allow a sufficient ink-film thickness to properly lubricate the doctor blade, causing premature wear to both the blade and anilox roll.

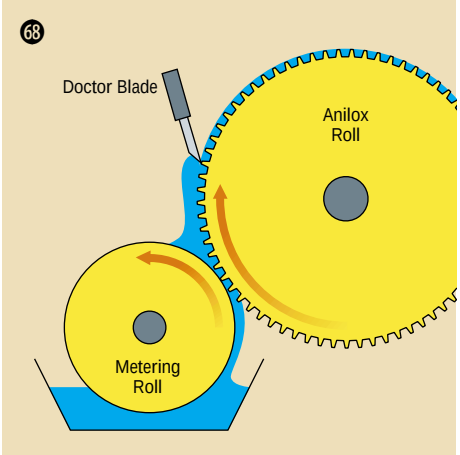


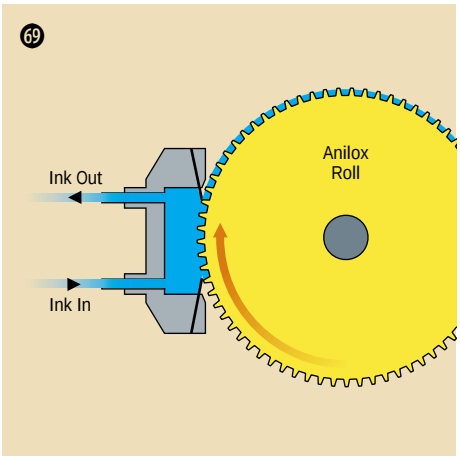
67 In a two-roll metering system, the anilox roll rotates at the same surface speed as the plate cylinder, while the fountain roll rotates at a constant slow speed. Both rolls, though, rotate at the same surface speed.

Reverse-angle doctor blades are primarily used without a rubber-covered fountain roll. In this system the surface of the anilox roll is flooded with ink, either by being partially submerged in the ink fountain (*Figure* 68), or through a pumped ink-applicator system. Many flexo presses have been built with the single reverse-angle doctor-blade system. The doctor blade should make contact with the surface of the anilox roll at a 30° angle to the tangent point, with a tolerance of ±2°. At this angle, the doctor blade shears or shaves the excess ink from the anilox surface, leaving only the ink in the anilox cells for transfer to the printing plate. The reverse-angle doctor-blade system allows a precise ink-film thickness to be transferred to the printing plate at a wide range of operating speeds, without the need for press-side adjustments.

68 A reverse-angle doctor-blade system allows a precise ink-film thickness to be transferred to the printing plate at various operating speeds without press-side adjustments.

69 Chambered doctor-blades are the newest systems in fleoxography. Comprised of two doctor blades, a reverse-angle blade to doctor the ink from the anilox roll; and a containment blade, to hold the ink in the chamber.





The pressure setting of the reverse-angle doctor blade should be maintained at a minimum level consistent with the uniform transfer of a thin ink film. Tests were conducted many years ago by press manufacturers, ink makers, anilox roll manufacturers and others which concluded that the correct pressure setting of a reverse angle doctor blade should not exceed quarter-ounce of pressure per inch. The tests showed that when the pressure was increased to half ounce per inch, a noticeable amount of wear to the anilox cells was detected.

A variety of doctor blade materials have entered the industry over the years, ranging from high tensile, tempered blue steel; to plastic, some of which is reinforced with synthetic fibers. Many of these changes came about because of the conversion from solvent-based to water-soluble ink systems. Each flexographic printer should determine the type of doctor blade material which performs best for the particular operation. Some plants have found that a stainless-steel doctor blade works best, while other plants use non-reinforced plastic materials. Regardless of the material used for the doctor blade itself, the primary concern must be on the pressure setting. Keep in mind that excessive pressure can only create friction, which in turn will create excessive wear.

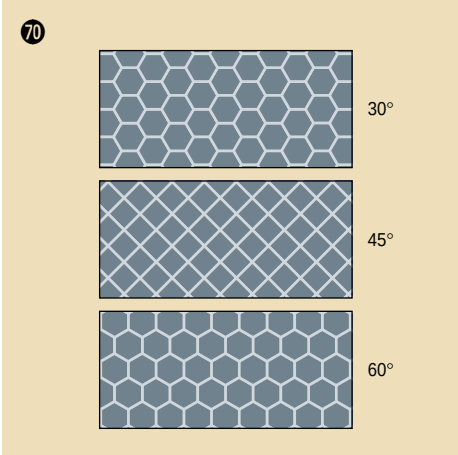
Chambered Doctor Blade

The chambered doctor-blade system is the newest system used by the flexographic printing industry. The chamber blade unit is comprised of two doctor blades, one of which is a reverse-angle doctor blade that does the job of actually doctoring the ink from the anilox roll, and the other is a containment blade that holds the ink in the chamber. The two blades are preset at specific angles for proper doctoring and are affixed to a backing plate that forms the three-sided unit (*Figure* 69). When this unit is applied to the anilox roll, a chamber is formed between the anilox roll and the three-sided fixture. The sides of the anilox roll are sealed with pads of felt, rubber or plastic material. These side-sealing mechanisms may be spring-loaded or pressure-loaded. When ink is pumped into the chamber, it becomes somewhat pressurized.

Chambered doctor-blade systems help reduced the solvent or water evaporation from the ink, keeping the ink flow characteristics under control. A critical element in the operation of the chambered doctor-blade system is that the pressure settings must be maintained as recommended by the original equipment manufacturer. Some of these units have air-loaded pressure controls, while others offer manual controls and include a set screw installed as a protective stop to prevent

excessive pressure. Do not attempt to readjust these stops. Excessive pressure settings can destroy an anilox roll in a very short period of time.

Safety Concerns. When handling doctor blades, either to clean them or install them, all safety precautions should be taken. Regardless of the material, doctor blades are sharp and can cause serious injury if not handled with care. Steel blades are generally in the 0.004" to 0.009" thickness range and should be considered to be as sharp as a razor blade. Handle them with care and caution.



70 The different anilox engraving angles. 60° angle works best for flexographic printing. 45° angle is used for flexo printing of newspaper. 30° angle is used for industrial coating applications.

THE ANILOX ROLL

With the improvement of quality standards for inks, printing plates and presses, flexography is now able to perform process printing which was not possible in the past. One of the many reasons for this improvement has been the ability to maintain a specific volume of ink transfer over a long period of time. The primary function of the anilox roll is to meter and control the flow of ink from the reservoir to the printing plate. With the development of laser engraving and ceramic coatings for anilox rolls, the longevity problem has been answered. To obtain maximum productivity from the anilox roll, it is important to understand how they are produced.

The anilox roll is a cylinder that has been engraved with a uniform pattern of cells around and across the entire surface. Cells may be mechanically engraved with an engraving tool, chemically etched or engraved through the use of a laser beam. Regardless of the method of engraving, each cell must be uniform and identical in both size and depth to ensure that a controlled, uniform ink-film thickness is transferred to the printing plate.

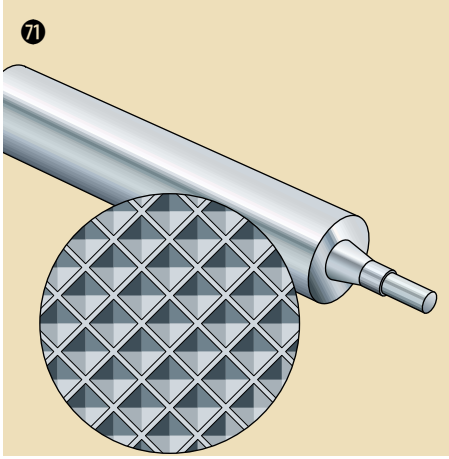
Anilox Nomenclature

The engraving on an anilox roll has been given many names, among them are cells, lines or screens. These names refer to the actual cells that are engraved on the roller. Anilox cells that are mechanically engraved are set at a 45° angle to the roll axis and anilox cells are counted along that angle. Laser engraved anilox rolls can be produced at any given angle, but the industry has settled on the 60° engraving angle after detailed testing for ink receptivity and ink transfer characteristics. Testing revealed that the 60° angle worked best for flexographic printing. Other angles of engraving are used for specific purposes or industries, such as the 45° angle which has been the standard for flexo printing of newspapers, or the 30° angle which seems to be widely accepted for industrial coating applications (*Figure* 70).

The nomenclature of an anilox roll relates to the number of cells in one linear inch along the engraving angle. For example a 165 anilox roll would contain 165 cells in a linear inch. Occasionally, this cell count may differ slightly and is rounded out to the closest number. A nominal 200-line anilox roll for example, may actually contain 203 or 204 cells in a linear inch.

Mechanical Engraving

The anilox roll was originally engraved mechanically by using an engraving tool. The engraving tool was forced into the sur-



71 Enlarged detail of a mechanically-engraved anilox roll showing the reverse pattern made from the engraving tool used to emboss the surface of the roll.

face of a steel- or copper-plated cylinder with sufficient pressure to emboss the surface metal of the cylinder into the cavities formed by the teeth of the engraving tool. The result is a reverse pattern of the tool on the surface of the anilox roll (*Figure* 71).

Each tooth on the tool begins with a single punch designed to hold a specific volume of ink. From the single punch, an engraving tool is made with every tooth measured for accuracy. Thus, when the tool is used to make an anilox roll, each cell formed is identical.

When the cells have been formed in the base metal of the anilox roll, the next step is to protect the surface of the cells from corrosion and wear. This is accomplished by electroplating nickel over the engraving to provide corrosion resistance and then applying a layer of double-hard chrome plating to provide durability. While chrome plating provides excellent ink receptivity and release, it cannot withstand the pressures of doctor-blade metering and wears rapidly. Attempts have been made and continue to be made, to extend the life of anilox rolls by electroplating specialized coatings to provide durability, but most have been unsuccessful.

Ceramic-coated Anilox Rolls

Because chrome-plated anilox rolls did not have the durability to withstand the pressure settings of a doctor-blade system, ceramic coating was developed. Ceramic coatings are applied through a plasma-coating system in which ceramic particles are melted at very high temperatures and forced onto the surface of a cylinder by using a gas-fired propellant. The ceramic coating provides an extremely durable and very hard surface which resists wear and impact that would normally damage a chrome-plated roller. The result is the mechanically engraved, ceramic-coated anilox roll, in which a ceramic coating is applied to an engraved surface in place of the chrome plating.

A major problem with ceramic coating over an engraving is that the coating is limited to medium-range anilox cell counts of 200 or 220. Attempts to ceramic-coat finer anilox cell counts found that cell integrity was lost because the cells would become filled with ceramic material. In order to preserve cell definition, most anilox roll suppliers limited the ceramic coating to a maximum engraving of 200 or 220. Most manufacturers limit the amount of ceramic coating over an engraving to 0.001" for fine screens and 0.003" for coarser engravings.

Laser Engraving

Since ceramic coating of fine line-engraved anilox rolls was not practical, a new method of engraving was required. Furthermore, with the development of the chambered doctor-blade system a more durable surfaced anilox roll was a necessity. Through much research and development, the laser-engraved ceramic anilox roll was invented and has become an integral part of the flexographic printing industry. A laser-engraved roller begins with a cylinder which is plasma coated with a thick layer of chromium oxide ceramic material. Chromium oxide material was selected for the coating because ink release and ink receptivity characteristics are comparable to chrome plating. This coating material has an extremely hard surface

which resists impact and abrasion, providing a very durable roll surface.

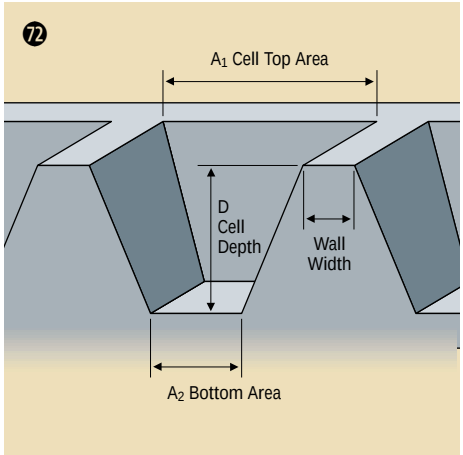
The ceramic coating is ground and polished with a diamond wheel to a super-smooth finish and then a laser beam is used to burn a cell directly into the ceramic material. Laser engraving equipment is computer-controlled and is capable of engraving very fine anilox cells. Cell counts of 1,000 upwards to 1,500 or more per linear inch are now possible with the use of a laser-engraving machine. Laser engraving offers much more flexibility and the same cell count can be made in different cell depths and volumes. The 60° angle of the laser-engraved cell forms a hexagonal "nested" cell structure offering better ink release and cell efficiency than the 45° angled cells.

Volumetric Carrying Capacity

Since all of the cells on an anilox roll are identical in size, the volumetric carrying capacity can be determined by the actual measurement of a single cell using a mathematical formula. Volumetric carrying capacity is the amount of ink contained in the total number of cells within a square inch. Because of the development and improvement of anilox rolls over the years, there have been many changes in the equipment used to measure and calculate volume. For chrome-plated mechanical engravings, optical measuring instruments are generally used. A microscope is used to measure the depth of the cell, the cell opening at the top and the width of the bottom of the cell (*Figure* 72). These measurements are read in microns (25,400 microns to an inch). When the measurements have been made and the cell count established, the following formula is used to calculate the specific volume in billion cubic microns per square inch.

$$\textbf{SPECIFIC VOLUME} = \textbf{CV} \times \textbf{C2}$$
$$\textbf{CV} = \textbf{D/3}\left[(\textbf{O2} + \textbf{B2}) + (\textbf{O} \times \textbf{B})\right]$$

Where:



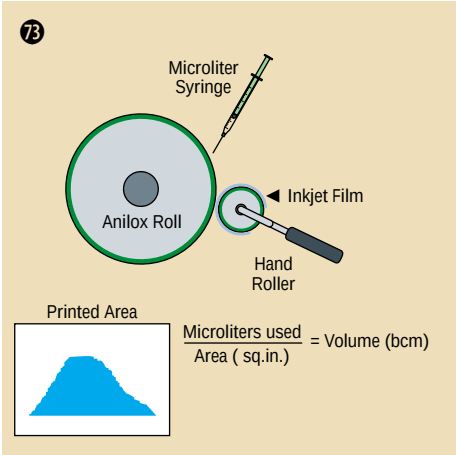
72 Volumetric carrying capacity is the amount of ink contained in the total number of cells within a square inch. Measurements of cell depth, cell opening at the top and the cell width at the bottom of the cell are then plugged into the specific volume formula.

CV = volume of single cell
C = cell count (165, 200 etc.)
D = depth of cell
$\mathbf{A_1}$ = cell top area
$\mathbf{A_2}$ = cell bottom area

Knowing the specific volume or volumetric carrying capacity of the anilox roll allows the flexo printer to determine if the anilox roll is carrying the precise amount of ink needed to properly ink the printing plate. A loss in volume may be attributed to either wear of the cell or to plugging of the cell because of improper or infrequent cleaning.

Liquid Volume Calculations. When a microscope is used to measure an anilox cell, the measurements are determined by the light that is reflected back into the lens. Since ceramic material absorbs light, there is little reflection and an accurate measurement of the cell is extremely difficult.

A liquid volume method was developed based upon the principle that a known volume of fluid will spread only as far as the surface roughness or cell structure on the roller allows it to be spread. A known quantity of ink (usually 25 microliters) is applied to the surface of the anilox roll using a precise pipette or syringe. The ink is then spread around the circumference with a hand-held doctor blade. A sheet of white



73 Liquid-volume measurement requires the ink-jet film to be rolled around the tack roller with the treated surface outside. The covered roller is then pressed against the surface of the anilox and ink from the micro-liter syringe is introduced into the nip. The ink-jet film is rolled against the anilox, spreading and printing the ink volume simultaneously.

bond paper is placed over the ink smear and a footprint of the area covered with ink is made. The area is measured and a calculation is made to determine the volumetric carrying capacity.

While this method is very accurate, it is dependent upon the ability of the individual to uniformly apply the bead of ink, spread the ink, take the footprint and finally measure the outline. There will be differences in the calculated volume among individuals doing the volume check because of the level of experience in performing that task. As a result, the liquid-volume measurement should be taken from three different areas on the anilox roll and the volumes averaged. The average should be used as a starting point to determine wear and durability of the anilox roll.

An improvement on the method just explained incorporates the use of a surface-treated clear-polyester sheet, like those used in inkjet printers, and a wide hand-held tack roller, like the ones used to remove dust from negative films. The ink-jet film is rolled around the tack roller with the treated surface outside. The covered roller is pressed against the surface of the anilox and the ink from the microliter-syringe is introduced into the nip (*Figure* 73). The ink-jet film is rolled against the anilox, spreading and printing the ink volume simultaneously. This method removes most of the operator error. Comparative volumes of new and partially worn or plugged rolls may be checked by simply weighing the cut silhouette of the ink patches.

Vertical Scanning Interferometry. A more scientific approach to accurately measure volume involves using an interferometric scanning device. This device was designed by incorporating the technology used in manufacturing fiber-optic equipment and computer discs. It is also used in several aerospace programs by the United States government. The interferometric measuring method has been adopted by the leading manufacturers of anilox rolls as the most accurate measuring device currently developed. The cost of these more scientific measurement instruments may be too high for the average flexographic printer to consider. As a result, many printers correlate the readings by the anilox roll manufacturer with actual liquid volume measurement taken by their inspection personnel. Charts using both volume measuring systems can be logged by the printer to determine the durability of anilox rolls, thus enabling timely roll changes before a critical print job is to be scheduled.

The interferometric device uses a three-dimensional scanning head positioned on an anilox roll while connected to a computer and a TV monitor. The device scans all of the cells in the viewing eyepiece at a rate of some 5,000 readings per second. Light waves are bounced against each of the interior anilox cell walls from the top to the bottom of each cell and the distance is recorded. This information goes into the computer, which has been programmed with the proper algorithm. The computer then calculates the volumes of each of the cells in the viewing area and averages them to determine the volume for that particular anilox roll. Tests by the United States Bureau of Standards have found this interferometric method to be accurate to within 0.03%.

Anilox Selection

Selecting the best anilox roll for the type of flexographic printing produced can be somewhat perplexing, but knowing a few details can make this decision much easier. First of all, there are flexo printers in many different industries and each one prints on a wide variety of substrates. Wide-web printers print on film, paper or foil. Narrow-web printers use absorbent or chrome-coated glossy stock. Corrugated printers print on a multitude of surfaces from bleached high-holdout to highly absorbent kraft linerboard. Each of these substrates has individual characteristics relating to ink absorbency and drying that the printer should be aware of. The same anilox roll cell-count and volume cannot be used to print the same image on each of these diverse substrates. As a result, this textbook cannot provide an accurate determination of which cell count and volume will work best for each of these industries.

Wide-web film printers may use a 220-line anilox roll with a volumetric carrying capacity of 7.7BCM/in^2 to print a large solid, while a corrugated box printer may use a 180-line anilox roll with a volume of 9.5 BCM/in^2 in order to print the same image on kraft linerboard. With these different substrates and image requirements, the flexo printer should consult his anilox roll supplier to customize the anilox roll and volume to best suit each specific need.

Table 10 can be used as a guideline for the selection of anilox cell counts and volumes for coarse screen rulings. Again, each printer must assess which anilox roll performs best for his own need.

Note: *Cell counts and volumes in Table 10 are based upon standard print requirements and printing plates for halftone screens with fewer than 85-lines per inch. Results are dependent upon a number of variables including the condition and the type of printing press, the speed of printing, the skill of press operator and the surface finish of the substrate. For advanced and high graphics requirements, both ink- and anilox-roll suppliers must be consulted and work together.*

The flexo printing ideology is to print with the thinnest ink film possible, while maintaining color density, and to run the press as fast as possible. This is accomplished only through the use of high-strength inks that quickly dry and a fine anilox roll with a small volumetric carrying capacity. With this in mind, there are several guidelines to consider when purchasing anilox rolls.

First of all, the printer must assess the condition of the printing press and the experience of the press crew, so that he/she is assured the desired image requirements can be achieved. The press crew must be capable of operating the press to attain that objective. In addition, the press crew has to have been thoroughly trained in the mechanics of the press. The press must have been fingerprinted to determine press characteristics such as, pressure settings, registration and dot

ANILOX SELECTION GUIDE

SUBSTRATE	ABSORBENT (PAPER)		NONABSORBENT (FILM)	
IMAGE	CELL COUNT	VOLUME (BCM)	CELL COUNT	VOLUME (BCM)
Solids	180	9.5	220	7.5
Line	200	8.3	250	7.0
Halftone	250	7.0	360	4.5

Table 10

DOT SIZE EQUAL TO ANILOX CELL OPENING

SCREEN RULING (LPI)	1% DOT (MICRONS)	ANILOX CELL COUNT (PER IN)	2% DOT (MICRONS)	ANILOX CELL COUNT (PER IN)	3% DOT (MICRONS)	ANILOX CELL COUNT (PER IN)
85	34	655	48	481	58	400
100	29	754	41	557	50	464
110	26	817	37	606	45	506
120	24	878	34	654	41	547
133	22	956	31	715	37	599
150	19	1052	27	792	33	666
175	16	1187	23	901	28	760
200	14	1313	20	1004	25	851

Table 11

gain. Once all of these conditions have been met, the anilox selection process can begin.

After the image requirements have been determined, the printer can begin to develop specifications for the anilox roll. If the image is pictorial and process printing is a requirement, then several considerations must be taken into account. One is that the line screen of the printing plate must be known, so that the anilox roll cell count is fine enough to correctly ink each of the halftone or process screen dots.

While there are several schools of thought concerning the ratio of anilox cell count to halftone or process dots, the prevailing one is to have the anilox roll four times or more than that of the halftone line screen. For example, if the printing is a 110-line screen plate, then the anilox roll must be 440 or finer in order to ink each of the dots without having a single dot dunk into an anilox roll cell. Dot dunking can be a concern, especially where a printing plate has very fine highlight dots of 1% , 2% or even 3%. Should the printing plate contain highlight dots of 3% or less, then the printer should consider using an anilox roll with a higher screen count, i.e., five or even six times the halftone screen count.

Tables 11 and *12* provide dimensional information on halftone dot and anilox cell dimensions. The tables are based on a cell wall thickness of 5 microns. *Table 11* shows the size, in microns, of 1%, 2% and 3% dots at various screen rulings. Next, the size of the dot is the cell count, where the opening of the anilox cell just equals the size of the dot. For example, at 120 lpi, a 2 % dot has a diameter of 34 microns. This corresponds to an anilox-cell count of 654. Hence, a 660 anilox roll would have a cell size smaller than the 2% dot. *Table 11* shows the cell opening for some common anilox-cell counts. The tables can be used to help determine which anilox roll to use.

Optimum Volumes. Volumetric carrying capacity is an important consideration when selecting anilox rolls with screen counts of 440 or higher. With all anilox rolls, the recommended volumetric carrying capacity should be determined by the depth-to-opening ratio in order to obtain clean ink receptivity and ink release from the anilox cells. It is suggested that anilox rolls should have a depth-to-opening ratio between 23% to 33%, in order to allow the ink to smoothly enter and release from the anilox cells. Higher ratios, where the cells are deeper, may have a tendency to plug with dried ink after a period of use. The deeper cell does not evacuate a sufficient amount of ink to allow total resolubility of the remaining ink in the cell when mixed with fresh new ink. Thus, the ink will

ANILOX CELL OPENING	
ANILOX COUNT (CELLS PER INCH)	CELL OPENING (MICRONS)
250	97
300	80
360	66
400	59
440	53
500	46
600	37
660	33
700	31
800	27
1,000	20
1,200	16

Table 12

dry more rapidly and plug the anilox cell.

Shallower cells are very difficult to produce and duplication of the cell volume may not be maintained when re-engraving. Shallower cells also have distorted cell walls separating each cell and may not allow smooth entrance and exit of the ink.

Anilox cell counts and volumes for process printing can range from a low of 220 lines with a volume of 7.7 BCM to a high of 900 lines with a volume of 1.5 BCM. The finer the cell count, the smaller the cell size and smaller volume.

Appendix A lists some recommendations for cell count and volume.

Banded Anilox Rolls. In order to correctly determine which anilox roll works best, the flexo printer should purchase a banded anilox roll from his supplier. This roll should be engraved with bands of different anilox cell counts and volumes. These bands can be as small as a few inches or as large as a foot or more. Test plates can be made to order for a specific industry and some plate makers may have stock test plates available which will contain useful information. The use of banded anilox rolls should provide useful information to the printer so that specifications can be determined for the anilox roll cell count and volume that works best on the press for particular print jobs. Every flexo printer should know the capability of their printing press and a test using a banded anilox roll should enable that printer to develop a storehouse of data to assist in providing better quality printing to the clients.

Anilox Maintenance

As printing has become more demanding, anilox cells have become smaller and shallower, the drying time of inks has decreased. Add to this the requirements brought about by new ink-metering systems, and it is clear that the ink industry has improved ink quality. Better dispersions are necessary to obtain desired strength and clean print from the shallow ds. If the incorrect ink formula is used, it is possible for large pigment particles to plug anilox cells.

Regardless of the type of anilox roll used, whether it is a fine-screen laser engraving or a very coarse chrome-plated roll, it still must be cleaned as often as possible. Considering that water-borne ink systems are used in the majority of flexo printing operations and the characteristics of this ink are similar to latex paint, it is easy to see that cleaning is a critical part of extending the life of anilox rollers. The anilox roll should be scrubbed with the correct brush and an approved cleaning solution. Brass-bristle brushes should only be used for chrome-plated anilox rolls, while fine-bristle stainless-steel brush should be used for cleaning laser-engraved ceramic-coated rollers. Caution must be exercised in the selection of a cleaning solution. Flexo printers should consult with both their ink supplier and their anilox roll supplier for an approved flexo cleaning solution. The use of a high pH or caustic cleaning solution can void any warranty expressed by the roll supplier.

Anilox rolls should be cleaned as often as

possible, but in every instance no fewer than once a day, or once every shift. A cleaning program should be employed to thoroughly clean and brush anilox rolls whenever the printing station is to be idled. Should the anilox roll become clogged with dried ink, then an aggressive cleaning method must be employed, such as pressure washing or ultrasonic cleaning.

Anilox rolls must be cleaned while the ink is still wet and fluid. This will reduce the clean-up time and make the job of cleaning much easier. Dried ink is difficult to remove from the bottom of the anilox cell and cured ink may not come off at all. A maintenance program should be developed and discussed with the anilox roll supplier in order to provide maximum productivity and maximum longevity of the rollers. Many roll suppliers even sell a recommended cleaning solution.

Should pressure washing of anilox rolls be an accepted procedure, then it is suggested that a complete training program be developed. Some pressure washers have an automatic traversing wand and vacuum system where the cleaning media, such as bicarbonate of soda, is blasted onto the anilox roll surface and removed instantaneously. These systems are regulated as to traversing speed and pressure settings. Other systems have a manual wand unit and the manufacturers of these manual-controlled units recommend that the wand be traversed across the roller at a rate of 12 in/sec. Slower movement may cause irreversible damage to the anilox roll surface.

Additionally, there are ultrasonic cleaning units, soak tanks and other cleaning systems available to the flexo printer. Ultrasonic cleaning systems are excellent for cleaning high line anilox rolls, but recently there has been evidence that they may cause damage to the cell structure. Therefore, ultrasonic cleaning should be used with caution.

Since cleaning of the anilox roll is pivotal to the longevity of the roll, the use of any cleaning procedure or system should be thoroughly discussed and approved by your roll supplier. Regardless of the type of anilox, ink cannot be allowed to dry in the cells. Ink flow over rollers must be maintained when the press is stopped, or the rolls must be cleaned immediately. The specific cleaning material should be that recommended by the ink supplier.

In the clean-up phase, solvent-based inks are more forgiving than water-based systems. Solvent-based inks not only can wait longer before being cleaned, but the inks also resolubilize in a wider range of solvents with less elbow grease. Water-based inks must be cleaned immediately. A combination such as this one can be used:

10%–20%	Mild Alkali (no ammonia)
60%–70%	Water
20%	Solvent (propyl alcohol or a propyl ether derivative)

Excessive alkali and/or amines can cause pitting in chromed cylinders and so should not be used. Make sure to rinse well after cleaning, or it can cause problems in the next inks used with that cylinder. This is true for water- and solvent-based inks.

Many inks are not compatible with each other, so when changing from one ink to another for a different job, be sure to clean very thoroughly. This practice will avoid potential for the inks to kick out in the cell and cause multiple problems.

INK PUMPS

While there are many different types of pumps available today, those in wide use are the peristaltic and the centrifugal pumps. Peristaltic pumps are used primarily on short runs, as they are easy to clean and change over. They do require somewhat more maintenance, however, and inks do not circulate well with this pump.

The centrifugal pump is the most widely used today. It works well on long runs and requires little maintenance. The pump action

keeps the ink circulating. Regardless of the type of ink pump used, some common guidelines should be followed:

- the pump should be designed with materials that are compatible with ink components;
- if water-based inks are being used, it is important that the pumps be corrosion resistant; and
- if solvent-based inks are used, the pumps should have components that are resistant to the various ink solvents.

Ink-return hoses should be submerged into the ink sump as low as possible, that is, always below the ink surface. This reduces the production of foam in the ink pump. Although critical for water-based inks, it is also beneficial for solvent-based inks. The pump must deliver the required flow of ink over a wide range of viscosities, fountain heights and coverage rate, and it is recommended that the pump be as universal as possible. It must be relatively easy to clean the pump, and there should not be any internal surfaces that can hold dry ink. The inking system should self-drain when the pump is shut off, otherwise, ink waste increases and the required cleaning becomes more difficult.

Flexo ink tends to "layer" if allowed to sit in a container. Also, solvent additives need to be mixed thoroughly and quickly, before they are circulated to the print deck. If using piston, screw, peristaltic or diaphragm pumps, additional tank agitation, usually a smaller mixer, is probably needed. The pump intake should reach almost to the bottom of the ink reservoir to pick up heavier materials and facilitate maximum pump-out at the end of a run.

When using any type of doctor blade, uniform and constant pressure must be maintained across its full length. Pulsating pumps (piston, diaphragm) can cause higher pressure against the doctor blade, lifting it off the cylinder.

Ink Sump Design

A properly designed ink sump should contain a minimum amount of ink. This will reduce the amount of press-return ink that would have to be reworked into a new print job. In addition, by maintaining a minimum amount of ink in the sump, the solvent balance of the ink is better controlled.

An ink sump should also have good circulation through the entire print deck, with no dead spots in the ink pan. This will reduce any tendency for the ink to settle in the pan. This is especially important when using heavy gravity colorants, such as white or metallic, and also with fluorescent inks that are not highly dispersed.

The ink sump should be covered to avoid loss of solvents during the pressrun. This will not only save money by reducing the amount of make-up solvent needed, but it will also maintain a more constant solvent balance in the ink, resulting in cleaner printing.

Press-Side Ink Filtration

When inks are manufactured, they are filtered while being filled into their shipping containers. After the inks are put into the sump, they can become contaminated by a variety of factors. If printing on paper, there can be a major contamination with paper fibers.

Regardless of what substrate is printed, contamination is always possible. To remove this contamination, use in-line press filters. This prevents dirty printing and/or clogged anilox rollers. Any ink that has been previously used in a press and is being reused must be filtered before being returned to the press. Clean ink is absolutely necessary to high print quality. With the current bladed presses, dirt may get trapped under the blade and cause anilox damage.

PRESS SETTINGS

Keeping a log of all the jobs that are run is

an important tool for problem solving in the future. Numerous data – the press settings, ink conditions, substrate information, and pressroom conditions – should be placed into the log. The printing industry contains a multitude of variables – substrates, types and ages of presses, drier capability, press speeds, ink systems, solvent combinations, time of year and pressroom conditions. It is impossible to document every single variable for every single job that is run. Even if possible, going back to this information in the future would be a problem. There simply would not be enough time to go through all these records. The more data accumulated, the easier it could become to solve a problem which was not seen on previous runs.

Inks are the one variable that can be easily controlled as the other variables change. For example, an ink system might be running with few to no problems on a daily basis. One day, the ink doesn't appear to be drying the way it should. Is this an ink problem? Probably not, but the ink is the one variable in the printing process which can be most easily altered. After further analyzing the drying problem, it is apparent that the between-station dryers are set to lower temperatures than normal. After turning these dryers up to their usual temperature, the problem disappears. This is a typical, yet simple, problem which is seen in the pressroom. If an adequate log book was kept, the problem-solving time could be kept to a minimum.

The previous example was a simple problem. Perhaps the between-station dryers remedy helped, but the problem was not-completely fixed. After further analyzing, it is noticed that it is midsummer and the humidity is at its worst. The alcohol used to dilute the ink might be hydrophilic, that is, it likes water, and is sucking moisture right out of the air. This creates water buildup in the ink, causing the drying problem. The ink representative now provides a new solvent combination with an alcohol which is hydrophobic and the problem disappears.

Keeping an accurate log book (*See Appendix B*), records (*See Appendix C,D,E*) and maintaining press settings is a good way to troubleshoot. The next step is to discuss actual press settings and what they should be.

Dyne Level of Substrates

Affect On Printability. Surface tension is a condition existing at the free surface of a liquid, resembling the properties of an elastic skin under tension. Dynes per centimeter is a measure of surface tension. One dyne is the force that a milligram exerts under the influence of gravity. Substrates as well as inks have a dyne value. A practical example of what dyne and surface tension is all about can be seen in the reaction of water on a waxed surface.

Plain water will bead up on a waxed surface because the surface tension of the water is greater than that of the wax. If a surfactant, such as detergent or alcohol, is added to the water, it will spread and wet the wax surface. This is known as wetting out.

In printing, if the ink beads up on the surface of the substrate, there are serious printing problems. The ink must wet out the substrate completely.

The rule of thumb is: in order for the ink to wet out the substrate, the ink has to have lower dyne value than the substrate. As a reference, the dyne value of substrates should be somewhere between 36 and 42, with 38 to 40 being the norm. Flexo inks can vary but as long as the dyne value of the ink is less than 36, the ink will wet out.

Most polymeric-film substrates have dyne values lower than 36. In this case, the most widely used method to increase the dyne level of the substrate is to use an in-line corona surface treatment. Corona treating uses electrical charges to oxidize the surface on the printing side of the stock and raise the dyne value. The treatment also may burn off any surface contaminants such as placisti-

cisers that have leached to the surface. The term burn is used loosely here. The surface is not really burnt, but pretreated by removing surface contaminants. The end result is a high dyne-value substrate. Caution should be used when corona treating.

When the dyne value of the stock is not high enough, the most common problem is pinholing. When the printed material is examined microscopically, small holes are visible in the printed area. The worse the treatment, the worse the pinholing. In severe cases where the dyne values are well below that of the ink, the ink may not wet out at all. Other printability and adhesion problems can arise when the surface tension of ink to substrate are not correct.

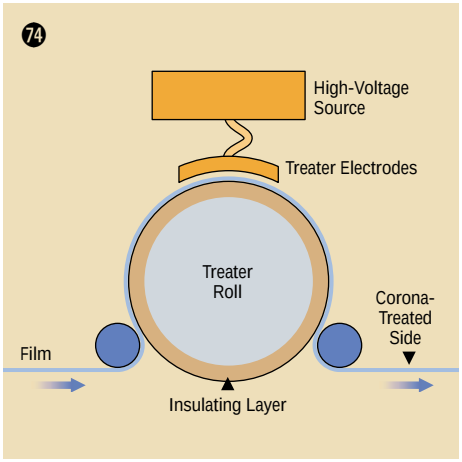
Dyne Readings And Water-based Inks. Most solvents have dyne values in the 20s or 30s. When combined with the resins, pigments and additives, the finished solvent ink will usually have a dyne value in the mid-30s. Therefore the substrate, having a dyne value in the upper 30s or lower 40s, will properly wet out. The dyne value of water however is around 72.8.

The emulsion resins, used to formulate water-soluble inks, have a low dyne value. When water is added, the surface tension is increased. In order to make the water-based inks have a suitable dyne level, small amounts of solvent, usually alcohol, or a surfactant are added. Surfactant is a general word for many different chemical additives on the market. Another word often used in place of surfactant is wetting agent.

The term "water-based ink," does not mean that it is solvent-free. Usually there will be small amounts of volatiles added to lower the dyne and help printability. Ink companies are always searching for "zero VOC" inks, and zero VOC inks can be made, but they have poor printability and usually offer little in resistance properties. The addition of these chemicals helps the ink to wet out on the surface of the substrate usually by lowering the dyne value.

In-line Surface Treating. With the increased use of water-based inks, it is more common to see in-line corona discharge surface treating on flexo presses (*Figure* 74). The printing of various films is greatly improved when the film is pretreated in-line with printing, because it improves ink lay and ink adhesion. Some concerns, however, remain. When treating film prior to printing, it is possible to over treat the film. This can cause increased water sensitivity, as well as an increased tendency to block in the rewind. There is an adjustment on the corona discharge to set the amount of treatment and if turned too high, some substrates could become damaged or distorted. All that is necessary is to treat the film enough to raise the dyne higher than the ink so there is good printability. Not all substrates can be treated. Check with the substrate supplier before treating.

The gauge of a substrate, or thickness, can effect the level of corona treatment. If printing with a substrate, for example polyethylene, and a switch is made to a higher-gauge polyethylene, the treatment level must be altered to that of the heavier film to achieve the same printability. If 38 dynes was acceptable on the thin-gauge material, it may be necessary to treat the thicker substrate to a different level to obtain the same printability.



74 With the increased use of water-based inks, it is common to see in-line corona discharge surface treating on flexo presses.

Tension Control

A balance is necessary. If the rewind web tension is too high, the potential exists for blocking problems. On the other hand, if the rewind tension is too low when an adhesive laminated structure is printed, there exists a potential for tunneling in the print. Other problems associated with poor tension control include:

- loss of color to color registration;
- deformation of the web; and
- poor productivity.

Dryers

By design, solvent-based flexo inks dry by evaporation. Ink is applied in a thin layer on a substrate and then typically is hit with heated forced air. Both additional heat and air dry the ink and dramatically reduce the amount of solvent that is retained in that layer. As the industry has matured, the quantity of solvent retained in the dried ink has become of paramount importance to packaging buyers because it has been linked to objectionable odors and can degrade the desired functional properties. There is a big gap between drying the ink on a package and a printed package with low retained solvents. Heated air without significant velocity will do little to disrupt this condition and therefore will not effectively dry the ink. A high-velocity jet of air, however, has enough energy to force through the boundary layer and to continue the drying process effectively.

Dryer manufacturers stress what they call the three Ts of drying: Time, Temperature, Turbulence. The effectiveness of an oven can be measured by the time available for drying. This of course translates into the oven length on a web-fed press. The correct use of temperature is essential to accelerate the evaporation of the solvents from the ink. And finally, efficient air turbulence can overcome the negative influence of the boundary layer.

The drying of water-based inks is very much the same as the drying of solvent-based inks, only more difficult. There are two reasons why water is more difficult to dry. First, water vapor is typically already part of the atmosphere. If a previous model is used, but water-based inks substituted, an equilibrium state is reached very quickly because of the presence of atmospheric moisture, making drying difficult. Again, as with the solvent-based inks, additional heat and volume only postpone the inevitable. The second problem with water-based inks is the amount of energy required to evaporate the water portion. The amount of energy required to convert any compound from its liquid state to its gaseous state is called the latent heat of vaporization. Water requires several times more energy to change its state from a liquid to a gas than typical flexo organic solvents do. In comparison to ethyl alcohol, water requires three times the energy to vaporize.

This does not mean that a press running water-based inks will have to run at one third the speed of its solvent counterpart. There are several factors that help improve the drying performance of water-based inks. Typically, water-based inks have a higher percentage of solids. Higher solids translate to less water to be removed. Second, due to the nature of the type of resins available in water systems, a thinner layer of ink is often employed. In addition, when water is combined in an azeotropic mixture with certain solvents, the evaporation can be accelerated. These factors can reduce the dryer demands. All of these discussions relate to nonporous substrates. On porous materials, like paper and paperboard, a percentage of the water can be absorbed by the substrate itself reducing the dryer demand. At high speeds, however, the absorption is reduced, requiring the dryer to be relied on for thorough and complete drying.

Dryer Temperatures Between Station and Tunnel. Both stack and central-impression presses have in-between color dryers and a

final overhead tunnel dryer. Together, these dryers provide for thorough ink drying. The between-station dryers are positioned, as the term would imply, between each deck on the press. The purpose of these dryers is to dry the ink film, removing volatiles sufficiently enough for the next color to be printed on top of the first. This is known as trapping. Optimum trapping is achieved when the first-down color is faster drying than the following colors. This is particularly important in process printing. It is not the purpose of the between-station dryers to dry the ink film completely. The print passes these dryers in a split second. There simply is not enough time for the ink film to be dried completely here.

If the between-station dryers are not set high enough, the first layer of ink will not be dry enough to accept the second or third ink. The result will be poor print quality, along with the possibility of ink contamination. For example, if the first ink is a white and the second is a red, when the red plate comes in contact with the white ink, some white ink could transfer to the red plate since the white ink isn't dried. The red plate now carries the white ink to the red anilox. After some time, the white ink makes its way into the red ink sump, turning it pink.

If the between-station dryers are set too high in temperature, the ink surface will dry almost like a skin or a crust with wet ink under it. This can create printability problems such as pock marks or "fisheyes." Also, the volatiles which lay under the skin will not be fully removed when it comes out of the tunnel dryers, causing retained solvents. The problem with high amounts of retained solvents for surface printing is the possibility of blocking in the rewind. With laminations, high retained solvents get trapped between the laminant and printed substrate, causing poor bond strengths.

The tunnel dryer is usually the large, flat dryer across the top of the press. There is no between-station dryer after the last deck on the press. After the final application of ink, the substrate goes directly to the tunnel dryer. Here all the ink films are dried to remove as many volatiles as time permits. There will still usually be some small amount of retained solvents. For all the volatiles to be removed, the press would have to run slow enough to allow the printed material to spend sufficient time in the tunnel. This is just not feasible.; the press speeds would be too slow for economical operations. Ink drying depends not only on air temperature, but also on negative air flow across the web to be dried. A balance must be achieved between air temperature and air flow.

Oven Temperature vs. Web Temperature. Care must be taken when talking about the temperature of ovens or the temperature it takes to dry or cure an ink. The temperature of an oven is usually not the temperature of the web. It would take a longer period of time for the web to reach the actual oven temperature than the press speeds allow. In other words, if the between-station oven temperature is 200° F, the web passing by in a split second will reach temperatures substantially lower than 200° F. However, if the tunnel dryer is set at 200° F, the web spends considerably more time in the tunnel dryer. Therefore, the actual web temperature will be considerably closer to 200° F than initially passing the between-station dryers.

Keep in mind some important points. If the ink representative says that the ink running requires a 150° F pin-on temperature, he/she means that the web must reach 150° F. The ovens will need to be set at considerably higher temperatures, depending upon other variables such as press speed. Web temperatures can be best determined by using an infrared pyrometer. The other point to keep In mind is how much heat can the substrate tolerate without being damaged or distorted. Attempting to run a catalytic coating which requires 240° F web temperatures to cure, with a polyethylene's substrate which can-

not tolerate high heat, problems will occur. The temperature required by the coating would destroy the film.

Using the same substrate with the dryers set at 180° F to get good adhesion and low retained solvent in the ink film, the film may be able to handle this temperature. Since the actual web temperature will be significantly lower, the film can still distort. If the film begins to distort, the print may appear to be out of register. The press operator will respond by trying to get the register in line mechanically. This problem is film-related not press-related. It is always important to be aware of the substrate limitation when dealing with temperature. Do not always rely upon the meters on the press, unless they are checked often for accuracy. If there is not enough heat on the web, the ink film will not dry or cure properly. Remember, too much heat can ruin the substrate.

Also, the dryers should be balanced on a regular basis. What is done in this process can depend upon the dryers on the particular press. When the dryers are properly balanced, the between-station dryers should all have an equal volume of air blowing through them. If not, the deck with less air volume could have trouble drying, while the deck with more air volume could be running into skinning problems. Equal amounts of air should be blowing out along the length of the dryer – gear side of the press to operator side. If not, one side of the web may not be drying efficiently. The air flow also needs to be directed at the web, not on the plates or the anilox rolls. If air blows on these rollers, ink will dry in, causing other problems such as dirty printing. In a balanced dryer system, the tunnel dryers need to be accurate in temperature control. The volume and velocity of air needs to be at its optimum. This is the last place the ink will have the opportunity to dry with the aid of heat and forced air. If the dryers are not at maximum efficiency, the end result could be high retained solvents, blocking, or poor bond strengths in the case of lamination inks.

Conditions of Dryers. Other factors beside temperature are important to the press, including the velocity of the air, the volume of the air and time. The speed at which an ink dries limits press operating speeds. Ink dries when the solvents are allowed to evaporate. Drying can be accelerated by heating the web, circulating air over the web, or both. Simply stated, this is what press dryers do. Drying is also accelerated by using fast-evaporating solvents and by lowering ink viscosity to print a thinner ink film. Porous webs also speed evaporation because they are highly absorbent.

To print one color effectively, or many that don't touch or overlap one another on the web, the solvent must be removed and the ink essentially dry before it reaches the rewind stand. In designs where inks must overlap or trap over another (whether for register, large-area overprinting or halftones) the ink must dry in sequence as it is printed. Complete drying is not always necessary between colors, but sufficient drying must occur to prevent the subsequent color from rewetting the first and blending with it or picking it off the web. Bypassing or skipping vacant decks, when possible, will give more time for sequential drying and allow higher operating speeds. Final drying before rewinding must occur to prevent roll blocking, ink offsetting on the back of successive webs or solvent retention and its residual odors.

Normally, inks are formulated to dry rapidly enough to allow proper sequential drying. When inks have been reused, circulated excessively, or adulterated with improper additives and allowed to get out of chemical balance, drying problems occur that affect operating speeds. Depending on the area size of overprint or trap and the ink film thickness, many open porous substrates can be printed at speed without using dryers. Other less or nonabsorbent webs require

combinations of air, heat, between-color dryers, overhead tunnel dryers and the addition of faster-drying solvents.

If between-color dryers are not available or not functioning properly, sequential drying can be achieved by adding faster solvents in first-down colors, unchanged inks in the middle station and slower solvents in the last-down colors. Dryers can become ineffective if partially clogged with ink, dirt or web fragments. Air-duct dampers which have been changed from the factory settings can give too much or too little air. The balance of in-feed and exhaust air must be correctly maintained to draw away and exhaust the solvent-laden air.

If too much air is blowing out of the between-station dryers, there is a possibility of air blowing onto the plates or the anilox rolls. When this happens, the ink will begin to dry on the plates or in the cells of the anilox. When the ink dries on the plates, dirty printing will be the result. When the ink dries in the cells of the anilox, the cell volume will begin to diminish, causing less transfer of ink and a loss of color strength. "Mottled" printing can result if the ink is drying in some areas more than others. The air velocity correlates closely with the air volume. Usually, the higher the velocity, the higher the volume. Velocity is particularly important during the hot and humid summer months, when many printers have drying problem. The key here is to have as high a velocity as possible to blow the humidity away from the web. If the velocity is low, the humidity can remain over the web. This would be like trying to dry the clothes outside in August when the humidity is 80%. As expected, things dry much more quickly under lower-humidity conditions. Higher velocity will help to remove the humidity away from the web making it easier to dry.

Drying On Absorbent Substrates. Water-based inks for absorbent surfaces depend on several factors for drying: evaporation, penetration, precipitation and chemical action. Evaporative drying occurs through the action of air and heat. Heated air is passed over the surface of the print and removes the volatile components from the ink. Penetration drying occurs on absorbent substrates. The ink is drawn into the surface, often by capillary action, and the print can no longer be readily smudged or transferred to another surface. On suitable papers, this drying method can be quick (0.1 second). During ink absorption, a fractionation, or layering, effect occurs where certain parts of the ink are preferentially absorbed, leading to a precipitation toward the ink surface. The acidity of some papers acts as a drying agent for the ink by neutralizing the solubilizing amines.

The term "absorbent" for substrates includes many varieties of paper and paperboard stocks. It varies from lightweight tissue to corrugated board to glassine to papers with coatings based on many natural and synthetic binders. The more absorbent the substrate, the less need there is for efficient dryers. Water-based corrugated inks run at high speeds without any form of dryers. At the other end of the scale, glassine and some coated papers behave more like films and do require good drying.

Chemical drying occurs with paper towel and tissue inks formulated to benefit from cellulose chemistry. Water-based dyes or pigments and resins capable of reacting chemically with the cellulose fibers are used in these inks. Once this reaction has taken place, the printed product can resist many household chemicals. Other considerations when printing water-based inks on absorbent papers include:

- the tendency of water inks to curl or pucker paper;
- the problem of ink buildup on central-impression (CI) cylinder drums, caused by excessive ink penetrations through the substrate;
- catalytic lacquers will not always cure over water-based inks; and

- ink properties depend on stock absorbency; lower absorbency often lowers heat resistance, scuff resistance and product resistance, but increases gloss.

Press Speeds

Another variable which is vital to good printing is the press speed. Most printers want to run as fast as possible, which is understandable. However, the goal is to run as fast as possible without sacrificing quality. Many inks do not run the same on different presses, and the same ink on the same press will run differently at different times of the year. Press settings have to correlate the capabilities of the press and the effect of the other variables already mentioned. The rule of thumb is to run the press as fast as possible, yet continue to achieve the necessary drying and printability. Every press will be different. Sometimes the same ink can be run in two different presses in the same pressroom on the same substrate, yet the speeds will differ. This speed difference largely has to do with the capabilities of the dryers. This again is where a log book can help determine what the press speeds should be based on past history.

Press speeds are often limited by mechanical effects. However, press speeds can also be altered by the ink-solvent blends and the reducer blends. The difference between these two blends is that the ink-solvent blend consists of the types and amounts of solvents present in the virgin ink when purchased. The reducer blends are the solvents used to reduce the virgin inks to press viscosity. These two blends can be quite different. The ink-solvent blend is the composition of solvents in the ink when manufactured. This could be a large variety, maybe as many as five or six different solvents. The purposes of all these different solvents is to control drying speed and to keep the resin in solution. The printer does not need to know all the different solvents in a particular ink, but should know that sometimes a solvent will evaporate out of the ink. This usually happens over long runs or if the lids are left off the sumps. When these solvents are lost to evaporation over time, the ink may not behave as it should. Therefore, a make-up solvent may be required to keep the resin in solution and keep print quality at its original high level. These make-up solvents are usually faster drying solvents as they are the first to evaporate, such as heptane. The ink representative should determine if a make-up solvent is needed and what it should be.

The reducer blend is usually one or two solvents, sometimes three, that reduce the virgin inks to press viscosity. This is usually done in the pressroom. In flexo, the staple solvent would be some type of alcohol in larger amounts and usually a small amount of ester such as normal propyl acetate. This is for solvent-based inks only and other solvents could be used. If solvent changes are required for different ink systems or at different times of the year, these alterations should be noted in a log book, as well as any press settings that need to be altered, along with the other changes.

Rewind Tension

The basic requirement of a good rewind-tension system is to wind rolls with straight edges and uniform density, while preserving the accuracy of register and repeat length. It is not the purpose of this book to discuss the different types of rewinders or the mechanics of them. From an ink standpoint, however, fit is important to remember that the ink is being sandwiched between the substrate in the rewind. The more tension used in the rewind, the higher the possibility of ink blocking to the backside of the substrate. This is especially true if the drying capabilities of the press are not as good as should be.

Another area of concern is rewind tension when printing lamination inks for future lamination. In this case, it is not in-line laminat-

ing. The concern here is that lamination inks have very little or zero waxes in them. The absence of waxes makes an ink more prone to block; yet, their presence can often hinder bond strengths of laminations. Therefore, waxes are used sparingly in lamination inks so bond strengths are not affected. Lamination inks are extensively tested for this, but these conditions exist and excessive rewind tension could contribute to ink blocking.

Chill Rollers

After the printed material leaves the tunnel dryer, the substrate is hot. Before it can be rewound onto a roll, it must be cooled. This is usually done with the aid of a chill-roller, which has water or brine being flushed through the center. The printed substrate gets cooled as it passes over the roller, so that it is as close to ambient temperature as possible when rewound. This is primarily done so that the substrate does not expand or contract after being rewound. This could cause unwanted pressure in the rewind resulting in blocking or damaged material. If the temperature difference between the web and the chill-rollers is too great, condensation can occur. Water droplets on the printed material makes the substrate wet while the ink film is dried but not set in the rewind.

Often an ink will require some time for complete setting after being printed, sometimes as much as 24 hours. During this setting time, additives in the ink such as waxes will bloom to the surface. This is why ink adhesion often gets better after aging. The water from the chill-roll condensation can affect the fresh ink film before it has a chance to set. This could result in blocking, poor adhesion or damage to the print.

Drying of Catalyzed Inks

Catalyzed inks – also known as two part systems – have characteristics which cannot be achieved with conventional inks, such as high gloss or superior chemical resistance. The ink is delivered to the printer along with a catalyst. At press-side, the ink handlers add the catalyst to the ink in the recommended amounts. Catalyzed inks ususally require a substantially higher amount of heat to dry. If insufficient heat is used and the print is not thoroughly dried, the ink film will remain tacky and block. Even if blocking doesn't occur, the ink may not have all the final characteristics needed. For this reason, it is vital when using catalytic inks that the proper amount of heat be used.

For these same reasons, it is also important that the proper amount of catalyst be used. Catalyzed inks are formulated and tested using a specific amount of catalyst.[2] Too much or not enough could result in any number of problems such as blocking, poor gloss, or poor chemical resistance due to improper curing. The reason for the catalyst to be added at press-side, rather than during manufacturing, is because the catalyst reacts with the ink. This reaction is time-limited. In other words, once catalyzed, the ink has a limited life and has to be used usually within 24 hours. For best results, it should be used immediately. The stability of the ink after 24 hours is poor, though the time it takes for this instability to appear will vary depending upon the system. The inks will get heavier in viscosity, sometimes almost turning gelatinous. Some of these cross-linked systems utilize a catalyst which dissipates over 24 hours. At that time, more of the catalyst needs to be added. These inks can usually be cross-linked only twice before the ink needs to be discarded.

This is one of the main reasons why printers do not like to use catalytic inks – whatever isn't used in 24 hours has to be discarded. There is no way to salvage the ink. This can lead to large ink costs if the amount of ink in the press is not limited. Also, the cost to dis-

[2] Catalyst, cross-linker and curing agents are synonomous terms.

pose of waste ink can be substantial. Another reason curing inks are not popular is because of the risk of using improper amounts of catalyst. Press-side testing can be done to check for the right amount of catalyst; however, errors can be made. With conventional inks, there isn't a question about the proper amount of catalyst. Finally, some of the catalysts used are hazardous chemicals, and they must be handled carefully.

INK VISCOSITY

The viscosity of an ink will affect many aspects of printability including print strength, print sharpness, ink lay and color. Viscosity is one of the easiest variables to change on a press, and it is the variable that has the most significant effect on the resulting print. Ink viscosity should be checked at least once an hour and more frequent checks are generally recommended by the ink suppliers. Dot sharpness in process printing, or clean printing of fine-type edges when line printing, are both greatly influenced by ink viscosity. If the viscosity is too low, the ink will often show dot growth causing the image to lose its sharpness and print dirty. It is very easy to reduce or increase the print strength by slight adjustments in the print viscosity. Because of this, viscosity is often the first thing changed when dealing with print-strength adjustments. If viscosity adjustments do not meet the requirements for print strength, anilox changes are usually the next step. In water-based inks, however, the opposite should be done. The correct anilox is critical and is selected first, and subsequent viscosity changes are small.

The lay of an ink can be affected by viscosity. If an ink viscosity is too low, the ink may crawl on the substrate before it dries. Crawling will result in a print of inconsistent ink thickness and smoothness. Crawling is more apparent in dark colors than with pastels or lighter shades of pigments. If crawling or mottle is seen, the ink viscosity should be increased, or a pigmented extender should be added. Ink run with viscosity too high can also show inconsistent lay and dirty printing. This is typically the result of ink caking on the plates or ink not transferring properly to the substrate. In process printing, it is very important that the proper viscosity be determined for an ink before any density adjustments are made. Once this viscosity is identified, a balanced extender should be added to meet specific density specifications. The influence of viscosity on color should be noted. Small viscosity changes can also produce shade changes in a print. A red color may become more yellow as it gets higher in viscosity and bluer as it goes lower.

Thus, when printing problems occur, a holistic approach must be used to identify the proper corrective actions. When a color is not acceptable, it is imperative to determine whether toner should be added or a viscosity adjustment made – all aspects of the printing process must be considered before making this determination. Although viscosity changes may be the quickest approach, the consequences of these changes must be reviewed.

First, a note concerning water-based inks. Viscosity can be related to pH in water-borne inks. It is critical that inks be adjusted for pH prior to any adjustment for viscosity. If this is not done, the addition of a water reducer can cause the inks to become over-reduced. Excessive viscosity reduction of water inks can cause many problems including a weak color, poor lay, poor drying, offsetting and poor lamination bonds. Rather, small amounts of amine to adjust pH may result in better rheology and lower viscosity. These factors support the importance placed on automatic viscometers and viscosity instrument calibration.

Both water-based and solvent-based inks can have a tendency to be thixotropic. Thixotropy is a tendency of a liquid to show

a large drop in viscosity when agitated. Therefore, inks should always be well mixed and pumped in the ink system before viscosity readings are taken. In addition to mixing an ink, temperature is a concern when checking viscosity. The viscosity of liquids is affected by temperature. This is easy to understand when one considers the common example of motor oil. When it is cool, the oil is much more viscous than when it is warm. An ink behaves in the same way. If the viscosity is measured when the ink is relatively cool, higher readings are obtained than when the ink temperature increases on press with shear and agitation.

Methods of Measurement

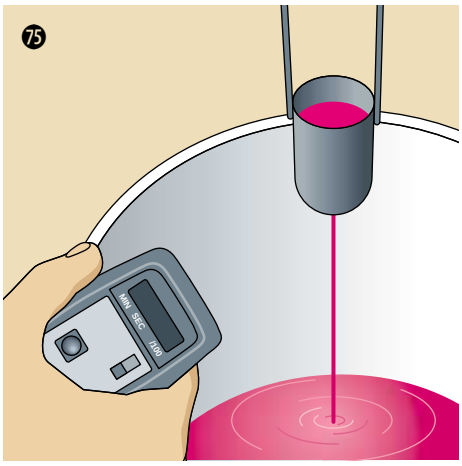
Regardless of the methods used for viscosity measurement, it is important that the ink be agitated prior to checking viscosity. This agitation reflects how the ink will respond while running on the press. Many inks may exhibit some degree of thixotropy. If inks are adjusted before agitation, they may be too low in viscosity once put in the press and agitated. It is also critical that calibration of viscosity measuring equipment be done on a regular basis. Since temperature will have an effect on viscosity, it is important that measurements be made at specific ink temperatures.

Zahn Cup. The most common method of press-side viscosity determination in flexo is with a Zahn cup (*Figure* 75). A Zahn cup is a metal cup of predetermined volume with a specific size hole on the bottom. The ink's viscosity is the amount of time it takes for a full cup to empty. Zahn cups come in various numbers. Flexo application ranges are typically from 2 to 5. The higher the number, the more viscous the material it can handle. Application on press in flexo is most commonly measured with either a #2 or #3 Zahn cup. Ink viscosity determines which cup to use. Readings considered accurate are between 20–40 seconds on any specific cup. If the reading is higher or lower than the 20 and 40 second range, a higher number or lower number cup should be used.

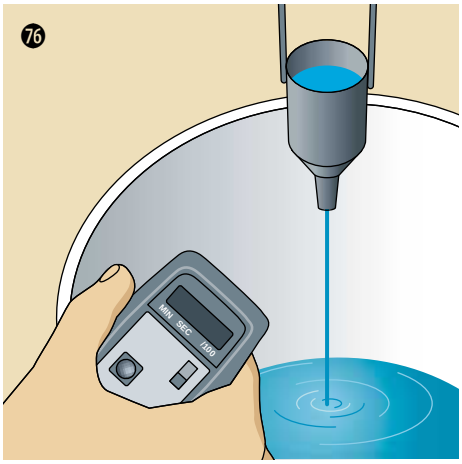
Shell Cup. The Shell Cup (*Figure* 76) is another type of metal cup used to determine ink viscosity. Unlike the Zahn, the Shell has a narrow tube on the bottom of the cup for the ink to flow through. It is more commonly used in gravure applications than in flexo. However, because it is more accurate than a Zahn, some printers have moved to the Shell for on-press ink viscosity checks. Because of the narrow tube on the bottom of the cup, care must be taken to be sure the tube is clean. Many individuals use a pipe cleaner inserted through the tube to be sure all ink is removed after taking a viscosity reading.

See Appendix C for conversion from Zahn cup readings to Shell cup readings.

Viscometers. Press units are often equipped with automatic viscometers to maintain a specific viscosity while a job is being run. This avoids constant measurement by an individual and results in improved consistency of ink viscosity. The automatic viscometer is connected to a make-up solvent-blend, which is added to the ink as needed. In addition to Zahn and Shell cups, there are several other types of instruments available to measure viscosity, but these are generally limited to lab environments.



75 The most common method of press-side viscosity determination in flexo is with a Zahn cup.



76 Another method of checking viscosity is using a Shell Cup, which is more commonly used in gravure applications than in flexo. However, because it is more accurate than a Zahn, printers favor this method for on-press checks.

Regardless of which instrument is used to measure viscosity, calibration must be done on a regular basis. Slight variations in readings can result in significant print problems. Calibration should be done when new equipment is received, and a log should be established to maintain a regular calibration program.

Color Adjustment at Press

The basics of ink viscosity – how it is measured and some of the factors that affect it have been discussed. The next topic is how to use ink viscosity and ink metering to adjust and control color strength. In any printing configuration, the actual metering system will determine the ink strength needed to achieve the desired color. The color strength achieved when ink is added to the press may be acceptable. If it is too strong, however, at least three options exist:

- Add solvent or water depending on the system, thereby reducing viscosity and strength. This is the easiest way to adjust down color strength. It may, however, lead to drying problems in water-based inks or even drying problems in solvent systems.
- Add extender varnish; this second way to reduce color strength is often best as it provides color strength reduction with the least effect on drying or blocking and optimum color value.
- Change the anilox to reduce color volume. This approach provides the least effect on the ink itself and probably the best long-term balance of good printing and high color intensity.

On the other hand, if the ink is too weak, different options exist:

- If the ink is pre-reduced on press start-up, uncut ink should be added to the fountain or reservoir. This will build strength and viscosity. This is certainly the easiest cure if the higher viscosity has not caused printing quality problems. Increasing viscosity and increasing strength often go together with dirty printing.
- If an ink based on a dispersion and let-down varnish is being used, additional dispersion may be added. This can eventually lead, however, to poor adhesion or a loss of other properties as the dispersion is not a complete ink vehicle.
- If other factors are equal, changing the anilox to a higher volume is certainly preferred. Here more ink is carried to the substrate at the lowest viscosity possible to provide optimum strength with the cleanest colors.

Printing the same color ink at excessive strength or viscosity makes the color itself muddy looking. At the same time, dirty printing often occurs. A more transparent, finer dispersion will negate this effect somewhat. However, it often does so with a loss of color intensity and an increase in cost. Sometimes black is added to an ink to “fake” higher strength. While this trick often will help, it does so at the expense of color sharpness, and the result is somewhat muddy.

Ideally, the ink supplier will provide an ink that will yield the proper color values and intensities with only minor metering or vis-

cosity adjustments. If, however, the ink is already on press and color changes are necessary, there are several areas of concern:

- A good, well-lighted area is needed for color viewing. A standard light box is recommended, since color varies under different lights. A well-lighted area in the pressroom is the last chance to ensure a good color match to a color standard. A board of retained prints from previous rolls is also important for comparison so that no color drift occurs. Whatever standard light is used, it should be comparable to the light that the product will be viewed by.
- Metamerism is defined as two colors that match under one light source, but are different under another light source. A standard light source in the pressroom will help prevent this effect. However, metamerism is not due only to light effects on the color; different pigments used in a color match will also create the effect. Therefore, if matching at press-side, try to use the same pigments as originally used in the color match. If this is not possible, be alert to metamerism problems that may occur. If metamerism does occur, the only solution is to change pigments.
- If color is altered at press side, be sure that end-use problems aren't created. All colors have different fastness properties, and the end use for a given print job may have very specific needs.
- The substrate is also of great concern. If it has a color of its own, this may well affect the outcome of the print job. It may be necessary to use opaque pigments to hide the substrate. These opaque pigments will also, of course, have an effect on other colors on the job. If inks are used to hide the substrate, metering effects and viscosity control become critical. Any changes during the run will create color shifts.
- Finally, another area of concern with on-press color adjusting is the combination of ink trap and ink transparency. If the job being printed has multiple traps (whether these be color-over-white or color-over-color), the final color achieved is a combination of the colors involved. Any changes in the color matches of the involved single colors will alter the trapped colors as well. These changes may involve revising a particular color match on press or altering the transparency of the ink involved with the actual color staying the same. Both of these changes can affect the final color printed.

Trapping. The trapping of one color over another is very dependent on ink metering, viscosity and drying. All of these factors must be at their optimum for good trapping.

First-down inks that dry too slow or are too low in viscosity will allow second-down inks to dive into them, creating muddy colors and dirty print. For good trapping, first-down inks must dry faster than subsequent inks. Thinner inks usually dry faster, but in water systems this may not be true because there is more water to dry. Excessively low viscosity can cause dirty, sloppy trapping. A balance has to be maintained as high viscosity and fast dry can cause dirty colors in the trap, as well as poor color fidelity.

MANAGING pH WITH WATER-SOLUBLE INK SYSTEMS

Perhaps the most essential element of water-soluble inks on press is the proper control of pH. This is not an issue for solvent-based or UV inks. Water-soluble inks, however, can become virtually useless if the pH is not maintained correctly.

What Is pH?

The pH value is the degree of acidity or

alkalinity of a substance measured on a scale of 0 to 14. From 0 to 7 is acid, and from 7 to 14 is alkaline. The neutral point is 7. Although many believe water to be neutral, it is important to remember that water is usually, but not necessarily, approximately 7 pH. The pH of water is determined by the pH of the soil in the surrounding source area. In some areas, this pH is also affected by the pH of the rain water (acid or otherwise).

Resins used in the manufacture of water-based inks are both of the solution and emulsion types, which can be carefully formulated for tailor-made performance relative to specific press speeds, drying conditions, application volumes and the like. The resins used are generally alkali-soluble, acrylic polymers. Simply, that means the resins – when synthesized into high molecular weight polymers – have numerous active acid sites. In this slightly acidic condition, the resins are not suitable for printing and are coiled. The result is that the body of the polymers is heavy, and the viscosity is very high, rendering ink neither pourable nor pumpable in a press-and-ink pan loop. When the polymers are adjusted with an amine or other alkali to an alkaline pH range of 8.0 to 9.5, the resins perform optimally and have the best characteristics for dispersing and wetting-out pigments, for transferring and laying out on the substrate, and imparting the product resistance requirements.

While printing with water-based inks, the heat produced from running the press and heat from the outside environment can lower the pH of the ink by evaporating the ammonia and/or amines in the ink. As the amine evaporates, the pH of the ink falls, and the resin begins to revert back to the heavy-body, higher viscosity ink. At that point, adjusting the viscosity with water will not quickly or effectively lower the viscosity or heavy body because it is a chemical problem and not a physical one. It is very important that the pH of the ink be raised. One 6-ounce cup of ammonia or an appropriate amine aded to 20 gallons of ink will raise the pH of the ink from 8.0 to 8.9. A heavy, high viscosity ink can occur at a pH around 8.1 to 8.3. *Table 13* outlines what happens with an ink and pH.

In summer months, it is advisable to monitor and adjust pH on an hourly schedule. In the cooler months, every two to three hours should be adequate.

When the pH of an ink becomes too low, the ink will begin to body up or get higher in viscosity. The resins in the ink begin to fall out of solution. The lids on drums or buckets of ink can sometimes be seen to have ink strings coming from them as a result of poor resin solubility. At low pH, the ink will also begin to transfer improperly from the anilox to the plate and from the plate to the substrate, causing a decrease in color strength. Also, the inks will start to build up on the plates, causing dirty printing. These are some of the noticeable signs of low pH. Other problems could occur with the printed material as well, which are harder to detect. If the pH of the ink is too high, the printed material will usually have poorer water resistance than normal. This may not be an issue if the ink is not designed for water resistance in the first place. The job may be run without any noticeable print problems, but there is a chance for a potential claim when the print rubs off under wet conditions. In addition, if the inks are too high in pH, the amine odor can also become a problem.

How pH is Measured

There are several different ways to measure pH. The best way is to use a reliable pH meter, which can be purchased from any scientific equipment facility .and can cost from $100 to several thousand dollars. For the purpose of ink-pH control in the pressroom, a pH meter costing several hundred dollars is usually sufficient.

The least-expensive version is a pocket model, which has too high a variance range

PROPER pH CONDITIONS FOR WATER-BASED INKS	
6.0–7.0	**PRECIPITATE:** Ink and resin separate. Result is a high viscosity and a poor print
7.0–8.0	**INK UNSTABLE:** Dirty, fuzzy print; high viscosity, heavy body and some buildup on anilox and plate.
8.0–9.5	**GOOD FLOW CHARACTERISTICS:** Good print, good adhesion and excellent wet-out properties. If viscosity is high, adjust by adding 2%–5% water. High viscosity doesn't necessarily mean a low pH, but a low pH means a high viscosity.
9.5–11.0	**POTENTIAL PIGMENT BURN-OUT:** Excess foam, corrosive to steel and iron. Lack of water resistance is possible.

Table 13

for these purposes. These only read to one decimal place and have a variance of ±0.2. With this type of instrument, a pH reading of 8.5 might appear to be up to specification. However, with a variance range of ±0.2 the ink could actually have a pH of 8.3, which is too low and could create printing problems. A pH meter which reads to two decimal places and has a variance range of only ±0.01 is recommended. Using this type of meter, the same ink that reads between 8.3 and 8.7 would show a pH of 8.49 ±0.01.

This doesn't mean that the pocket model doesn't have its place in the pressroom. For example, it is feasible to have a pocket model at every press, but impractical to have a $200 model at every press. It is important that press personnel be trained to check the pH of water-based inks at least every four hours. If they have a pocket model, which is also much easier to use, they can check the pH of the inks often and easily. If the ink has a pH of 9.0, even with a ±0.2 variance, the ink would still be in spec. If they run into situations where the pH of the ink is questionable, a sample of the ink could be brought to the location of the more accurate instrument, usually the quality control laboratory. If the only pH meter in the facility is the one in the quality control laboratory, the likeliness of press personnel bringing samples of all the inks to be checked every four hours is slim to none. Purchasing anything more than an instrument which reads to two decimal places and a variance range of ±0.01 is overkill for many purposes. Some of the more expensive units can read to four or even six decimal places with variance ranges of 0.000001. This type of accuracy would never be needed with water-based inks.

Adjusting pH

When running press-return inks (inks which have previously been used) or running for a long period of time, the pH of a water-based ink can fall. When the pH of the ink has slipped below its specified level, an adjustment is usually necessary.

The ink supplier will specify how and with what amine to adjust the pH. Different water-based inks will need adjustments differently. If a new water-based ink system is being used in the pressroom, the first questions that should be asked are: How often should the pH be checked? What amine should be used to adjust the pH? How should it be added? What is the proper pH range for this ink system?

The proper way to adjust the pH of most water-based inks is to make up a mixture of water and ammonia, or whatever amine is recommended. This mixture should be approximately nine parts water to one part amine. Undiluted amine should never be added to the ink, because it can cause a shocking effect to the ink, and make it kick out, or have suspended particles form. Even if the ink doesn't kick out, it is very difficult to adjust the pH properly with a full strength amine. An ink that is at pH 8.0 requires only a slight increase to reach the prper level. It

would be very easy to add too much amine, and the result could be an ink with a pH of 10, 11, or higher.

The alkaline mixture should be added slowly while agitating the ink. The viscosity of the ink should decrease as more alkaline mixture is added. This is partly because of the additional water, but more importantly, the resultant lower viscosity is due to the pH rising to the desired range. Add only a little at a time, stopping to check the pH, making sure not to overshoot the target range.

Unfortunately, there is nothing that can be added to inks which are too high in pH. It might seem that adding an acid would reduce the pH level. In theory, it might give the desired pH, but the resins and additives in the inks are intolerant to acids and the result would be wasted ink. The only possible addition to an ink with too high a pH would be more virgin ink, and this is only effective if the pH of the virgin ink is lower. When adding amines, stop once the ink is in the desired pH range. A pH level of 9.5 is not better than 9.0; anywhere in the range is ideal. Adding more amine once desired range is achieved only increases the chances of overshooting the range.

After the pH is in the desired range, the viscosity should be checked to ensure it is still where it needs to be. If the viscosity is too high, a little plain water can be added to get to the desired viscosity. Always adjust the ph before adjusting the viscosity!

For almost any problem encountered while running water-based inks the pH level is the first thing to check. While pH is not the only problem that will be encountered, and pH is not the root of all water-based ink problems, it is a good first step.

WATER- VS. SOLVENT-BASED INKS

Water dries more slowly than most solvents. With many printers moving to water-based inks, how do they deal with slower-drying inks? Ironically, one of the largest water-based problems we see is that the inks dry too fast, and solvents need to be added to remedy this problem. The following will hopefully explain how this actually works.

Most water-based inks are formulated to be stronger in color strength. Therefore, less ink is needed to achieve the desired color strength than solvent-based inks. By applying less ink, usually by using finer line aniloxes, less water is also applied. The less water applied, the less water there is to dry. In addition, many printers run water-based inks at slightly higher viscosities than solvent-based inks. This allows for more color strength with less water present in the ink. Finally, resins unique to water-based systems are incorporated in the form of emulsions. The resin is not dissolved in the water the way it is in a solution varnish but remains suspended as a particulate. What this does for drying is that it allows virgin inks to be formulated at lower viscosities. The lower the viscosity of a virgin ink, the less water it takes to reduce it to press printing viscosity. Once again, the less water, the easier the drying.

With all these methods of reducing the amount of water in the final ink film, a point is reached where in many cases, slow solvents (often glycol ethers) are added to water-based inks to slow them down, so they print cleaner. This has created problems for many printers over the years, where the use of these glycol ethers has sometimes become rampant. Many press operators see that a little glycol helps them to print cleaner causing less downtime to clean plates, and assume that if a little is good, more is better. This assumption is wrong! Glycol ethers need to be used only when absolutely necessary and only in the recommended amounts. Too much glycol ethers added to inks will cause long-term problems that the press operator won't see.

First, glycol ethers do not always dry completely even with the best of dryers. The retained glycol ether in the print can cause blocking problems in the rewind. Sometimes the retained glycol ether causes only slight blocking, but when unwound from the roll, the gloss of the ink is severely diminished. Also, water resistance can be affected by retained glycol ethers. Using glycol ethers can be an asset to the pressroom, but only when used correctly. A good general rule for the addition of glycol is to add 2% to the sump while agitating. If more is needed, add 1% at a time until a maximum of 5% is reached. Consult with your ink representative for recommendations based on your ink system.

Drying speed of an ink is dependent on the water and solvents in that ink, as well as on the pH of the ink and the amine or ammonia used in it. The most common amine used for fast drying in water-based inks is ammonia, but, many other amines exist and are widely used due to drying speed considerations or performance issues. Ammonia is used more widely because its odor is considered less offensive than many other amines, and it is not a volatile organic compound (VOC). If an ink is too high in pH, the smell of the amine or ammonia can sometimes fill the pressroom causing eye irritations or even rashes. Although this usually occurs only in severe cases, many people have allergies to amines. Care must be taken to avoid excess amine and to keep press fountains well covered.

CLIMATIC EFFECTS

How well an ink performs on press is affected by the pressroom conditions. Temperature and humidity will affect how well an ink will dry and therefore how fast a press can be run. This is especially true for water-borne inks. In addition, the pressroom conditions can also affect resin solubility, ink viscosity and overall ink performance. Whether running water-borne or solvent-based inks, climate is an important variable that must be understood.

Humidity

Since water-borne inks dry by evaporation of water from the print, conditions which are optimal for this removal will assist in drying. Dry air can accept more moisture than humid air. Higher humidity can result in poorer press speeds.

Solvent-based inks can also be affected by climatic conditions. High humidity can result in the alcohol in the ink absorbing moisture from the air. This additional water in the ink can cause certain resins to have poorer solubility and result in dirty printing. Keeping fountains covered and reducing the amount of ink in the sump can minimize this absorption of moisture by the ink.

Temperature

Warmer air can hold more moisture than colder air. Therefore, water inks will dry best under warm conditions with low humidity. To a lesser degree, solvent inks are affected by climatic temperature conditions. Solvent will evaporate more quickly under higher temperatures. Due to the relative evaporation speeds of common solvents used in flexo inks, the window is much greater for acceptable temperature conditions with solvent-based inks then it is with water-based inks.

Temperature and humidity are closely related to water-borne-ink performance. If humidity is high, additional heat may be required. If the temperature is high it may increase the level of humidity that will result in acceptable results.

Air Circulation

For water-based inks, dryers on the press should also be designed to allow for maximum air passage. This will allow the saturated air to be replaced with lower humidity air and assist in better drying. Care should be used to prevent unbalanced dryers. Unbal-

anced dryers, which blow air onto the plates and/or anilox rollers, can result in ink drying on the plates or drying in the anilox roller causing dirty printing. Increasing temperature alone on a press running water-borne inks may not be enough to attain acceptable drying results. Optimum conditions for water-borne inks are high temperature, low humidity and maximum air circulation.

Air circulation in the dryers is also important for solvent-based inks. Since the air coming into the ovens from the outside is low in solvent content, it can readily accept the solvents from the inks. With the move to solvent incineration and solvent recovery, dryers are being designed to permit higher levels of solvent to accumulate before the air is removed. This optimizes the incineration or recovery aspect of the dryers. Under these conditions, solvent removal from the printed web may be lessened, due to the higher solvent content in the dryers. Where there is no solvent recovery or solvent incineration, concern over solvent levels in the dryers is not a major issue if the dryers are performing correctly.

Climatic Effects on Ink Blocking

High humidity or high temperatures can cause conditions in the rewind that will result in ink blocking. High humidity can cause condensation on the chill rollers, and this moisture can transfer to the substrate. Moisture in the rewind can cause certain substrates to block. Chill rollers should be checked on a regular basis to ensure they are not forming condensation on the surface. High humidity can also prevent complete drying of water-borne inks. This residual moisture in the inks can increase potential blocking problems.

Blocking of the web is affected by temperature, pressure and time. If high temperature conditions persist, the printed web may not be cooled properly before rewinding. This, coupled with too high a rewind tension, can promote blocking. To control this situation, the use of chill rollers on the press is needed. These chill rollers must be monitored to spot condensation and correct the problem immediately.

Climatic Effects on Ink Solubility

One of the most serious concerns with ink solubility involves the absorption of water into the alcohol in flexo inks. If these inks also contain certain resins, such as nitrocellulose, the presence of the water will significantly affect the solubility of the nitrocellulose resin. The result is a blushing of the ink, giving it a flat appearance or causing a kick-out. The solution usually involves switching to a higher-molecular-weight alcohol, adding additional acetate or adding glycol ether solvents. Care must be taken not to add too much acetate to avoid potential plate-swell problems. If slower solvents are used, blocking may become a concern.

Water-based inks may show poorer solubility in high heat conditions due to a loss of amine in the ink. Most water-borne inks formulated for printing nonporous substrates, use a very fast-drying amine, which tends to evaporate out of the ink under high temperatures. Loss of the amine results in poorer resin solubility. By covering the sumps and minimizing the amount of ink in each sump, the evaporation of amine can be reduced.

Climatic Effects on Dirty Printing

Dirty printing can be the result of poor ink resolubility. It can result from the ink drying too fast or too slow. In either case, the ink builds up on the plate. With both water-borne and solvent-based inks, there is an optimum temperature at which the ink will print best. One of the major causes of ink drying on the plate is the presence of stray air from the in-between dryers. This air blowing on the plates causes the ink to dry and eventually build up until it prints in the nonimage area. Checking the in-between

dryers to ensure they are balanced will address this concern. The key to avoiding ink resolubility problems is to provide proper drying conditions.

Climatic Effects on Retained Solvents

Poor drying of either water- or solvent-based inks will result in higher levels of retained solvents. This becomes a bigger problem as the number of ink traps increases. These increased traps cause the first-down inks to hold onto their solvent in the in-between dryers and hamper the removal of the trapped solvents in the final tunnel dryer. This can be minimized with proper solvent selection. The key is to have the slowest solvent in the solvent blend be a true solvent for the ink.

It is not unusual to have retained solvent levels higher than desirable, due to skinning on the ink surface because the web temperature is too high. Reducing web temperature is the first step to correct this problem. If not successful, the solvent blend in the inks should be adjusted. This would include a review of true solvents for the resin system. Water-based inks printed in high humidity conditions tend to also show higher retained-solvent levels, due to poor drying. One successful approach is to treat the air going into the ovens by removing some of the moisture.

Climatic Effects on Press Speeds

Water-borne inks generally will print at optimum press speeds with higher temperatures and lower humidity. At a certain point, excessive temperatures can cause either skinning over on the web, or ink drying and building up on the printing plates. Optimum temperature and humidity should be coupled with maximum air circulation to achieve optimum drying results. Solvent-based inks can also experience ink buildup on the printing plates if the air temperature is too high. The window of acceptable temperature and humidity, however, is greater with solvent-based inks than with water-based inks.

UV FLEXO INKS

Ultraviolet flexographic inks differ significantly in composition from solvent-based inks (*Table 14*). Most inks contain pigments and special additives, but what separates UV inks from conventional solvent- or water-based inks is the use of oligomers, monomers and photoinitiators. The oligomer is the resin, or vehicle, of the UV ink. The functional properties are dictated by the choice of oligomers and monomers.

Unlike conventional inks, the press properties of UV inks are not sacrificed by attempting to achieve superior end use or performance characteristics. This is due to the ink's capacity for intermolecular bonding or crosslinking. Another unique trait of UV inks is that their superior functional properties can be modified by the addition of monomers. Monomers, like solvents in conventional inks, are used to adjust the viscosity of an ink. Unlike their solvent counterparts, monomers do not evaporate, but rather crosslink and become part of the cured ink film.

Photoinitiators are molecules that absorb UV energy and then use that energy to initiate a polymer chain reaction. The two most common photochemical mechanisms used in UV flexo inks are free radical and cationic. They each have their advantages and disadvantages, so it is important to look into both chemistries when choosing a UV ink.

UV Curing

After the ink is printed on the substrate, it is passed under a source of UV energy, typically a UV-curing system. The UV-curing system is composed of a UV lamp, a reflector, a power supply and a control unit. The lamp is a transparent quartz tube filled with an inert gas, typically argon and a small amount of

mercury (*Figure* 77). Quartz is used because it is transparent to UV, whereas normal glass is not. Mercury is used because of its strong emissions in the ultraviolet range. The systems are rated in watts per linear inch. Newer systems are normally 400 to 600 watts per linear inch. The reflectors for UV-curing units typically employ the elliptical or focused geometry to optimize the energy delivered to the chemistry (*Figure* 78). This focused UV energy is then absorbed by the photoinitiators. The photoinitiators transform into free radicals for the acrylate chemistry or Bronsted acids for the cationic chemistry (*Table 15*).

Free-radical and cationic inks utilize a chemically different set of oligomers and monomers, so the end properties are also affected. Free-radical acrylate chemistry is based on acrylate-modified epoxies, urethanes, polyesters and other materials. Co-initiators are added to prevent oxygen inhibition of the free-radical curing. Cationic chemistry is based on epoxies, which cross-link when reacting to acids. The initiator in cationic curing is a blocked-acid catalyst which is released by UV energy. There are advantages and disadvantages to each chemistry (*Table 16*).

Despite many concerns about embracing what they consider as experimental new technology, printers should be aware that UV is not new and not experimental. Ultraviolet inks have been commercially available for more than 25 years. The flexo market – especially the domestic wide-web flexo market – is just the next printing method to find a use for the technology. UV is the next step in the natural progression of flexographic printing technology, just as it was in offset lithography, and perhaps just as it will be in gravure. In the simplest terms, UV-curing is nothing more than a different way to dry inks on a printing press.

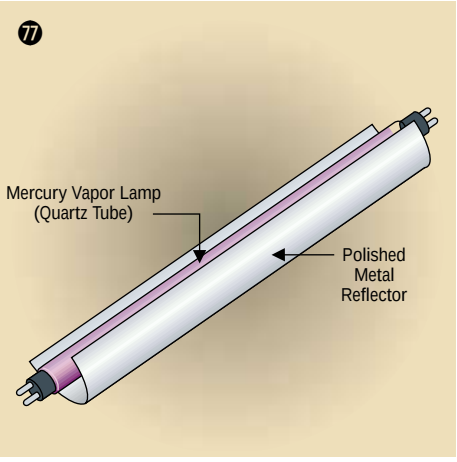
INK COMPOSITION

CONVENTIONAL INK	UV INK
Pigments	Pigments
Solvents	Monomers
Resins	Oligomers
Additives	Additives
	Photoinitiators

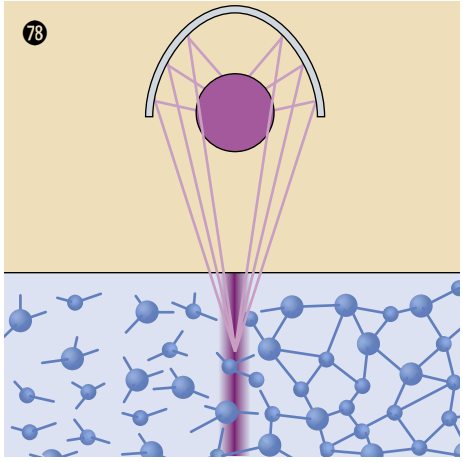
Table 14

UV- vs. Solvent-based Inks

Solvent-based inks certainly have their advantages. They are typically easy to clean up, and wet out most printing substrates well. The biggest advantage of solvent flexo technology, however, is the comfort level it



77 A standard UV lamp is a transparent quartz tube filled with an inert gas, typically argon and a small amount of mercury.



78 Reflectors for UV-curing units optimize the energy delivered to the chemistry. This focused UV energy is then absorbed by the photoinitiators. The photoinitiators evolve into free radicals for the acrylate chemistry or Bronsted acids for the cationic chemistry.

UV POLYMERIZATION MECHANISMS

ACRYLATE & CATIONIC UV POLYMERIZATION MECHANISMS

Ultraviolet Energy Photoinitiation

Free Radicals Acrylate Chemistry	Bronsted Acids Cationic Chemistry
Monomer/Oligomer	Monomer/Oligomer
Cured Polymer	Cured Polymer

Table 15

inspires for both press operators and pressroom managers. Ink suppliers have been fine-tuning these formulations for 40 years. This is the tried-and-true technology. It has worked in the past, so it will surely work in the future. On the downside are VOCs. You can burn them, you can collect them, but you can't ignore the environmental repercussions of solvents. Using this technology is only going to be more and more difficult as we proceed into the 21st century.

On porous substrates like paper, water-based inks are hard to beat. Overall equipment costs can be lower since explosion-proof wiring, solvent incineration or, for that matter, UV lamps are not required. And water inks are at least perceived by the layman to be the most benign. On nonporous substrates, ink formulators continue to explore better ways to wetout the stock. Compared to the solvent technology, water-based ink technology is relatively new. Unless the laws of nature can be fooled and water evaporates as if it is solvent, then water-based inks may be limited for this application.

What are the advantages of UV inks? The most obvious are the environmental benefits. By eliminating solvents, printers can enjoy two bonuses: removal of a potential fire hazard and EPA compliance. Local, state, and federal EPAs have wholeheartedly embraced the UV-curing concept. Several printers have commented that the EPA seemed positively overjoyed at the prospect that the printers were considering a conversion from solvent to UV. Since UV inks don't dry until they are passed under a UV lamp, the ink stays completely open. Unsightly

CATIONIC WITH ACRYLATE CHEMISTRY

DISADVANTAGES	ADVANTAGES
Cationics are relatively new to flexo and require differenent handling	Low potiential skin irritaion
Amines will poison the cure of cationics	Not oxygen inhibited
Amine functional substrates are problematic	True metallic pigments can be used
Amine funcitonal pigments cannot be used (fluorescents)	Static dissipation
Perceived higher pricing	Reduced shrinkage – improved adhesion to films
For CI press, speeds of white ink limited by cure time after UV lamps	Post cure
	Low odor
	Food package: LD_{50}'s are known
	Product shelf live
	Inherent low viscosity

Table18

print defects, like dot bridging caused by dried ink on the printing plate, are all but eliminated. The inherently higher viscosity of UV flexo inks aids in reducing dot gain in process printing and vignettes. Print quality and consistency is also aided by the lack of viscosity changes during the press run. UV-curing equipment is not cheap, but when examining the comparative cost versus conventional ovens on new presses, the differences are small.

Two issues seem to concern people the most about UV inks. First is the question of safe handling and usage. All inks are chemicals and as such need to be handled with care. They can't be eaten or worn, and they don't belong in the eyes. Good hygiene is important when handling any ink. If treated with the care and healthy respect that chemicals deserve, then inks will be able to do the job they were intended for. The other concern people have expressed or want assurances on is on how to confirm that the UV ink is cured. There are several cure tests that can be performed press-side, as well as more detailed, time consuming tests such as analytical measurements, which are correlated to the more simple press-side tests.

ENERGY-CURED PRODUCTS

The following program is recommended for the safe use of energy-cured formulations and should be applied in the areas of ink or coating handling, mixing, and cleaning of equipment. The necessary items should be readily available to the working area. Precautions for handling energy-cured inks and coatings are as follows:

1. Minimize exposure to UV/EB materials.
2. The use of barrier creams for the hands as a preventive measure is recommended for those workers who may handle the products in common, short-term exposure situations.
3. Glove protection is recommended for personnel where continuous or long-term exposure is expected and can not be avoided. This is particularly true during wash-up procedures where solvents may be in use.
4. It is recommended that some form of eye protection be available to pressroom personnel and be used around the pressroom during the working day. Glasses act as a first-line defense against accidentally introducing ink, coating, or wash solvents directly into the eye. They also reduce the chances of rubbing the eyes with contaminated hands. Should ink or coating be accidentally introduced into the eye, flush with water for at least five minutes and follow in-plant first aid procedures. Consult a physician.
5. It is recommended that all personnel adopt the practice of cleaning ink or coating off their skin with soap and water, and not with solvent, which is the more common practice. Solvent cleans quicker, but it removes the natural fats and oils of the skin and may aid the penetration of the ink and coatings into the deeper layers of the skin. This can intensify irritation problems, rather than helping prevent them.
6. It is recommended that personnel cleaning large spills of energy-cured inks or coatings use gloves. In addition, used wipers from any clean-up should be placed in a separate container so that the wiper does not become a source of additional contamination. Solvents may be used with care in cleaning spills on floors and equipment.
7. Keep ink and coating-handling equipment clean and keep used wipers in a receptacle. This cuts down on incidental contact to other workers. Keep ink and coating containers closed.
8. Discourage the practice of eating on the job or in the work areas and encourage

in every way possible good personal hygiene.

PROCESS PRINTING

Process color printing is the technique used to reproduce a subject using yellow, magenta, and cyan colors, plus black (for improved contrast). The process is similar for all printing methods, but varies according to ink-metering techniques.

High quality process printing by flexography depends on control of the variables in the process:

Ink Distribution. The evolution in the ink distribution and metering systems for process printing has seen a move from the two-roll to bladed systems, using approximately a 440 to 550 line, 4.0 BCM volume (billion cubic microns per square inch) chrome anilox, to ceramic anilox rolls whose line count may be anywhere from 550 to as high as 1,500 lines with a cell volume as low as 0.9 BCM. The improvement in flexo process printing in recent years can be traced to this evolution in ink metering and the concurrent change in flexo plates and inks, as well as printing skill and techniques.

A typical process cylinder today is 600 to 700 lines, quite possibly at a cell volume as low as 1.3 BCM. Work is being done at higher lineage, but this can be difficult. With higher line count, the cell and cell volumes become much smaller and ink makers have a difficult time achieving color strength and staying open with the very thin ink films. Lower line counts and higher volumes can be used, but print quality will suffer as high dot gain and bridging occur. Problems of this type can result from too much ink being sent to the plate from the anilox.

Printing Inks. The new inking systems for process printing continue to require a constant, easily controllable viscosity. This generally means Newtonian flow, but also means that at application viscosity, when transferring from anilox to plate, the ink should be relatively short in flow to prevent bridging and dirty print. Process printing viscosities with bladed metering are 26–29 seconds/#2 Zahn cup. For a given ink, if at 26 seconds the strength is too high, add extender varnish (and often a pigmented extender) to adjust color. Solvent additions will make the ink too sloppy and cause dot gain and dirty print.

Applied ink density is a function of the ink metering system, the ink and its viscosity, and the operator working together. Most printers do set up their own color-density targets, which depend on their equipment, color separations, and experience. FIRST (Flexographic Image Reproduction Specifications & Tolerances) recommended density targets are shown in *Table 17*.

Most presses are set up so that colors trap from light to dark – yellow to magenta to cyan to black. The yellow may or may not be transparent. All subsequent colors must be highly transparent, so that light will pass easily through all ink layers. This sequence may be true for surface print. Reverse print, on clear film, is just the opposite, although the basic principle is the same. As we go to higher intensity ink for thinner ink films, more transparency is critical to obtaining true color and high contrast. The sequence of inks may change with different inks and applications. The key is to remain consistent for a given process and not change the sequence from one job to another.

The highest ink viscosity that can be run to achieve the desired density without dirty print is optimum. The viscosities given above are averages. These are several benefits from higher viscosity printing inks:

- dot gain is minimized;
- printing is sharper, cleaner;
- bridging is reduced; and
- density and contrast values are improved.

FIRST* SOLID INK DENSITY

	PAPER	FILM
CYAN	1.28–1.42	1.18–1.32
MAGENTA	1.18–1.32	1.13–1.27
YELLOW	0.95–1.05	0.95–1.05
BLACK	1.43–1.57	1.33–1.47

** Flexographic Image Reproduction Specifications and Tolerances*

Table 17

Unfortunately, viscosity cannot be increased infinitely. There is a best range. When it gets too high, dirty printing and offsetting will be problems. Also, at high viscosities, ink drying can be more difficult to control and transfer may lag due to ink drying in the cells of the anilox.

Ink drying in process application is quite complex. There are three distinct relationships to consider:

- Ink-film Thickness and Drying
- Ink Transfer and Drying
- Ink Viscosity and Drying

The first impression would seem to be: use the slowest solvent possible and all problems will be solved. This is not the case. There are many different slow solvents, and they do not all have the same effect on ink-film thickness, ink viscosity, and transfer. Some slow solvents will cause ink film to swell, and ink viscosity to increase – both these effects tend to reduce ink intensity and make the job look weak. Some solvents reduce ink tack; this also reduces strength and may cause dirty print. Slow solvents also can cause odor problems if used to excess. The solution is to use small amounts (5%–10%) of very slow solvents rather than large amounts of slower solvents,. Blanket suggestions cannot be made. The solvents used should be recommended by the ink supplier.

Press Speed. Press speed and the drying speed of the inks are directly related. In the earlier presses, color intensity and press speed were directly related. As press speed increased, color strength of the applied ink also increased. The advent of bladed presses eliminated this problem and today, ink strength is generally not dependent on press speed. In chambered-blade systems, if ink flow into the chamber does not keep up with press speed, ink starvation can occur, resulting in a weak looking print. In addition to concern with the ink metering, a press set-up at 300 fpm may require resetting of impressions, when higher running speeds (say 900 fpm) are used, in order to maintain color densities.

Plates. Good process printing depends on achieving a light kiss impression between the anilox and the plate. Too much impression can show up as weakness, fast drying, and dirty print. A kiss impression must be maintained between plate and substrate as well, or the dots printed will be misshapen and the job will look weak and dirty as ink piles up in the wrong places on the printing plate.

Substrates. Another variable that must be dealt with in process printing is the substrate. Due to the transparent nature of process inks, the finished appearance and colors of a given job are highly dependent on the color and smoothness of the substrate. Any color in the substrate will appear in the printed ink area. The color must be adjusted by means of the separations or by using a first-down white to hide the substrate color. Poor substrate smoothness, or anything on the substrate that will negatively affect ink transfer, will create problems and sometimes these can be cured using a first-down varnish or white. Higher ink viscosities can sometimes help, but often these cause other problems.

Press Characterization

To determine how each of the print variables come together to create a finished halftone color process print, a press characterization or “fingerprint test” of the printing process is carried out by the actual press

crew. The test should reflect actual day-to-day operating conditions and optimum press performance. FIRST contains specific guidelines as to how the press characterization process should be conducted, including a test target (*Figure* 79). During the characterization, the printing parameters for the individual press conditions will be established.

Controlling the Print. Using a densitometer, the solid ink densities should be checked. Color strength can be adjusted by adding extender (to lower density) or toner (to raise density) to bring color density to within specificatons. The printed sheet should be inspected carefully. Any obvious print problems (slur, uneven print, over-impression, moiré, etc.) should be corrected at this stage. All pertinent data should be recorded, including:.

- plate type and thickness;
- viscosity of ink;
- density of ink;
- Anilox cell count and volume;
- impression settings;
- blade pressure; and
- press speed.

Interpretation of Print Results. There are several ways to interpret the printed result:

- visually;
- microscopically (microscope with scale);
- densitiometrically (color densitometer); and
- spectrophotometrically (spectrophotometer).

The human eye is a very sensitive color measurement device. Unfortunately, visual sensitivity is based on comparisons of color hue shifts or densities over time, which the brain has no way of accurately recording.

The modern reflection densitometer is an invaluable tool for the process printer. It allows communication in numerical values by simplifying the process of establishing reference standards for predictable results.

Making halftone process printing an everyday reality is greatly aided when the human element of color evaluation is reduced. As subsequent density readings are taken, shifts in hues or densities may be noticed and corrections can be made in the ink or press settings to reestablish the target readings.

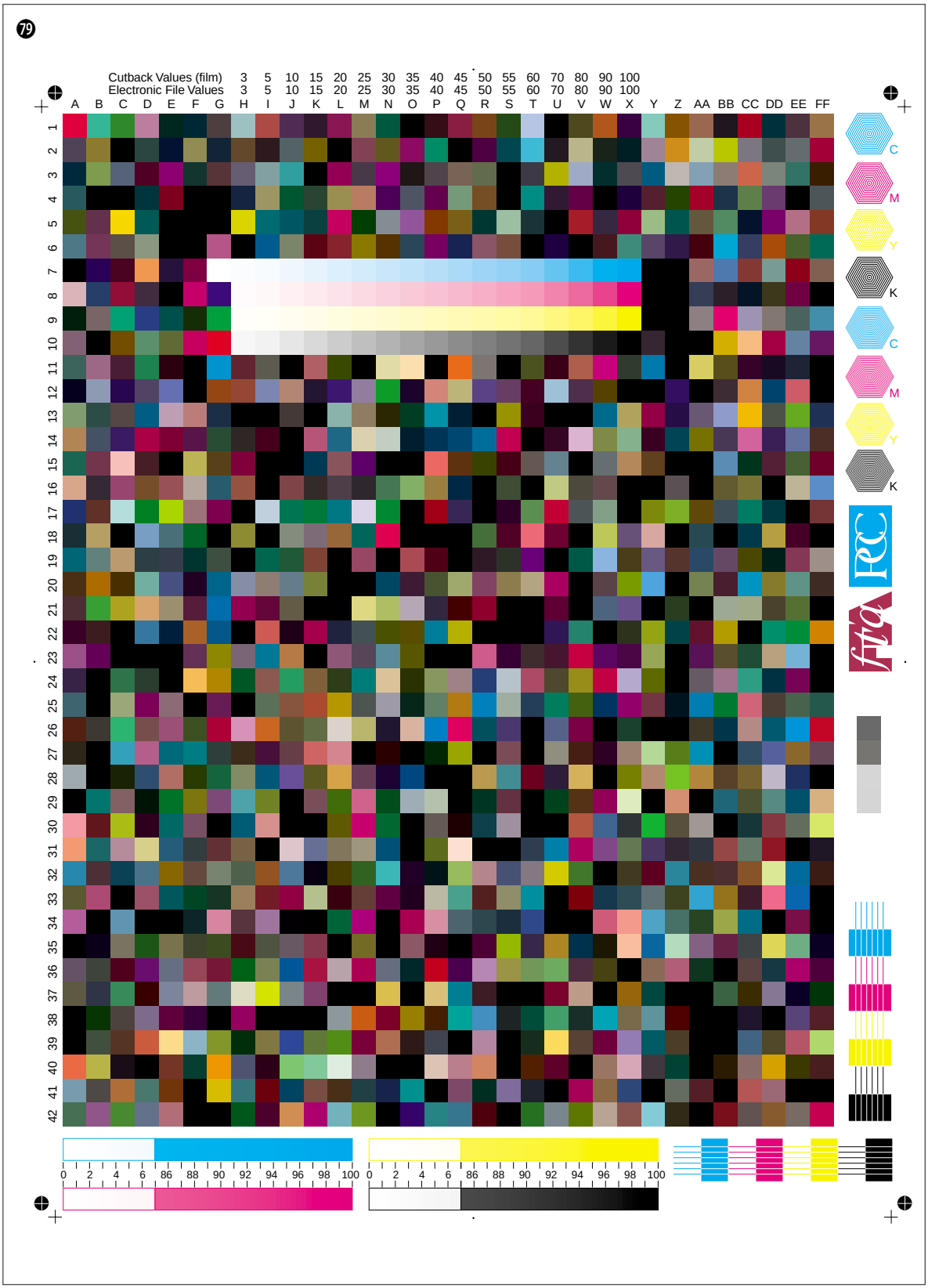
Using a spectrophotometer enables process printing to be controlled using color measurements as the human eye perceives color. More details are covered in the Process Printing chapter.

The following observations and records should be taken every time a halftone process color job is printed.

Printing Quality. First, the print evaluator should visually examine the print and the printed target to make sure it is the best achievable result. The targets should be sharp, free of unwanted printing between dots and lines, and in tight register. There should be no dot deformation such as, slurring, moire, or gear marks. Using a densitometer, solid ink densities should be measured to assure they meet specifications.

Dot Gain and Tonal Range. Selected screen values for each color are read with a densitometer. These readings may be converted to dot percentages using the Murray-Davis formula built into the microprocessor of the densitometer. These readings provide important information on dot growth and tonal reproduction.

Gray Balance. Gray balance targets are three-color overprints of cyan, magenta and yellow, balanced to appear neutral or gray. They are typically placed next to a patch of black with the same visual tone value. This provides for an extremely sensitive visual control on the printing process since the eye is very sensitive to slight shifts in color from a neutral gray. The gray balance targets are typically composed of shadow, midtones and quarter-tones. Gray balance targets can also be measured using either a densitome-


79
Cutback Values (film) 3 5 10 15 20 25 30 35 40 45 50 55 60 70 80 90 100
Electronic File Values 3 5 10 15 20 25 30 35 40 45 50 55 60 70 80 90 100
A B C D E F G H I J K L M N O P Q R S T U V W X Y Z AA BB CC DD EE FF
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38 39 40 41 42
C
M
Y
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C
M
Y
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FTA RC
0 2 4 6 86 88 90 92 94 96 98 100
0 2 4 6 86 88 90 92 94 96 98 100

ter or spectrophotometer and the values compared against the values obtained at the press characterization.

For high quality process color reproduction, the information from the press characterization or fingerprint test, should be used to produce repeatable results. The separations developed from the test will work best only for the printing conditions established during the test. Ink densities, viscosities, metering, and the other general press conditions must be maintained during production.

PRESS APPROVALS

When a job is printed, there are several properties that must be checked on a continuous basis. These include print quality, ink adhesion, color, strength, print register, etc. The following sections describe some of the more common properties that should be checked press side during a run.

Print Quality

When a job is printed, the overall print quality must be checked. This would include sharpness of fine type and reverse-outs, ink lay, ink gloss–and in process printing, overall dot structure. Along with print quality, it should also be noted that all colors are being printed in the proper trap sequence. This would also include ensuring that the correct colors are in each of the printing decks. A job should also be inspected to ensure that there are no spelling errors, missed words or logos, and that all the colors, primers, and/or overprints are being printed. On more than one occasion, jobs have been printed where a color was accidentally left off the job. Details of the following tests were covered in other parts of this volume.

Ink Adhesion

Ink adhesion is perhaps the most common press-side test done. It is also one of the most powerful diagnostic tools. An ink-adhesion test should be performed at the beginning of each roll of printed material. Poor tape adhesion can be the result of any of the following:

- Wrong side of the film was printed.
- The wrong film is in the press.
- The film has insufficient treatment to allow acceptable ink adhesion.
- Dryer temperatures are insufficient.
- The wrong ink is in the press.

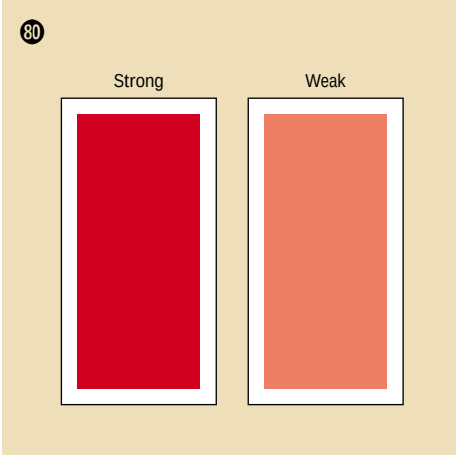
Ink Color

When printed colors, including white are printed and evaluated, the hue, chroma, and lightness should be measured using a spectrophotometer. As well as a visual assessment, an objective color measurement should be performed on all colors of a job to ensure consistency and acceptability to a standard. Spectrophotometers are used to measure the amount of light reflection in the visible color spectrum. These spectral curves are much like fingerprints of a color. They provide a numeric representation that eliminates the subjective factors associated with visual assessment. It is possible to have a metameric color match when the two colors being compared use different pigments. A metameric match occurs when two colors match under one set of lighting conditions but not under another. For example, the colors can match when viewed in a light booth under standard light (D50) but will not match under incandescent lighting. The measurement of color by a spectrophotometer allows for identification of metameric color matches by reading color under various lighting conditions.

Ink Strength or Opacity

The transparency or opaqueness of a color should also be compared to a standard. The level of transparency becomes important when printing on nonopaque substrates, over high gloss or metallic substrates, and in

79 (opposite page) FTA Press Characterization Target.



80 Strong vs. weak ink test. Color strength is often assessed visually and subjectively. A densitometer or spectrophotometer can also be used to monitor the strength of the ink.

resulting colors from multiple ink traps. Opacity is commonly assessed visually. The level of opacity in a white ink can be determined objectively by the use of an opacimeter. The level of strength that an ink print exhibits can also affect its color. Certain colors will actually appear a different shade as the color becomes weak or strong vs. a standard. An example of this would be a Rubine-based color match (*Figure* 80). As the ink strength becomes weaker, the color appears to be more yellow. Color strength is often assessed visually and subjectively. A densitometer or spectrophotometer can also be used to monitor the strength of the ink. A weaker ink will have a lower density and different, lighter color.

Before color adjustments are made press side, correct strength should be obtained. This will avoid the possible addition of colors that can make the match difficult to control and can result in metamerism.

Scratch Test

A quick test for scratch resistance during start-up and press run can identify some potential problems easily and quickly. If an ink contains wax additives and the container of ink was not mixed properly, it is possible the scratch resistance will be poor. The test is performed by taking the back of the fingernail and dragging it across the surface of the print. The scratch resistance comparison vs. standard is necessary, due to the highly subjective method involved (*Figure* 81). If ink is removed vs. standard, the situation should be investigated.

Print Register

When running more than one color on a job, each color must be printed in close positional relationship to the other colors on the job. This relationship is called register. If the press causes the substrate to stretch beyond acceptable limits or oven temperatures are too high and cause the substrate to shrink, register can go out of acceptable limits. Both of these problems are usually correctable by press adjustments.

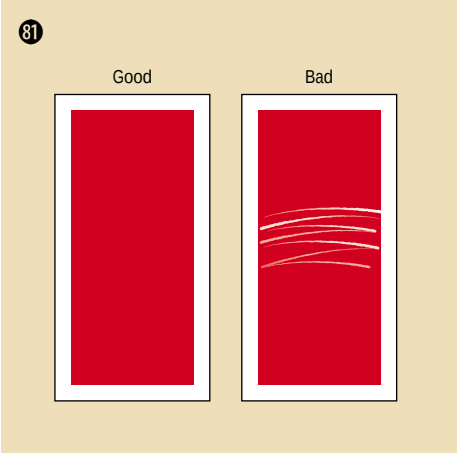
A job can also be out of register if the mounting of the plates on the plate cylinder is not done properly. If the register at the left lead edge of the print is in register and the right trail edge is out of register, it is likely that one of the plates may be mounted incorrectly. When a job is out of register due to plate-mounting problems, the plates will need to be remounted to correct the problem.

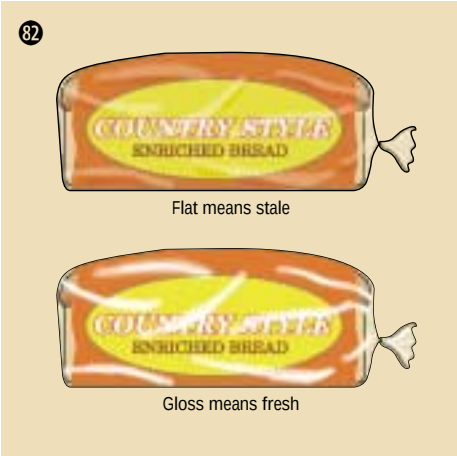
Ink Gloss

Gloss is a measure of the degree of reflectance on the surface of the print (*Figure* 82). The gloss level of a print is most commonly measured visually versus a standard. There is a move toward the use of a glossmeter to eliminate the subjective visual interpretation and to allow for numeric determination of gloss. If the gloss level is unacceptable, it may be an indication that the ink printed has not been mixed properly. This can cause an inconsistent level of slip additives in the ink container. The higher level of these additives can decrease gloss.

Ink Crinkle

On flexible packaging materials, such as polyethylene, polypropylene, polyester, etc.,





inks must also have acceptable flexibility. Poor flexibility on these substrates can result in ink flaking off the package as it is handled. Prints are most commonly checked for flexibility by putting about an inch of print material between the thumb and forefinger of each hand and quickly rotating the prints several times. This is a very subjective test. The number of times the prints are rotated and the degree of force in that rotation will affect the results. It is therefore beneficial to do this test with a known acceptable print and compare those results to the production print (*Figure* 83). There are also instruments available for determining the degree of ink flexibility. These instruments provide a much more consistent method of testing to allow for greater repeatability.

Lamination Green Bonds

When a job is laminated, it is important that bond levels be checked off the press to ensure that the process is in control. When adhesive lamination is done, bonds typically improve over time as the adhesive cures. Bond levels are determined by taking a 1-inch wide strip of laminated material and measuring the force needed to split the two laminated films apart. It is also important to note where the failure of the bond occurs. The point of delamination can indicate if the ink, adhesive, film, or application method is the cause of low bonds. The ultimate goal is to obtain stock destruction.

Coefficient of Friction

Certain packages require a specific level of slip on the outside and often the inside of the package. The inside slip level is important for high speed filling operations, where the product must go into the package. An inclined plane or an AGR are two common instruments used to measure the Coefficient Of Friction of a surface. Tests are usually done at the start of a production run and checked at regular intervals during the run to be sure the process is in control.

Rub

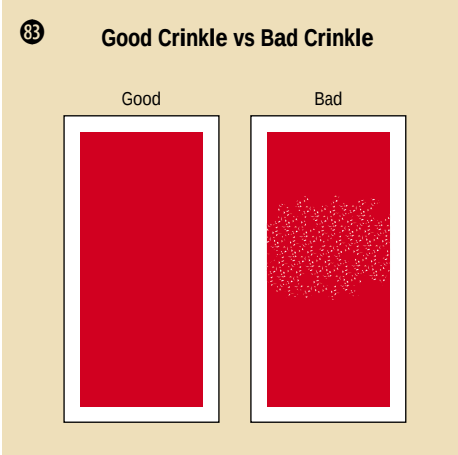
When rub resistance is required, it is common to test the rub resistance of the print either against itself or against another surface the print will be in contact with (*Figure* 84). The test is carried out using a Sutherland rub tester as described in Chapter 1. This test is performed with a certain amount of weight applied to the print for a set number of strokes/rubs in contact with either the print or the expected contact surface. In addition to the Sutherland rub tester, there are other instruments that can be used to test rub resistance, depending on the shipping and storage conditions a package will be exposed to. It is not unusual for optimum rub resistance properties to develop over several hours.

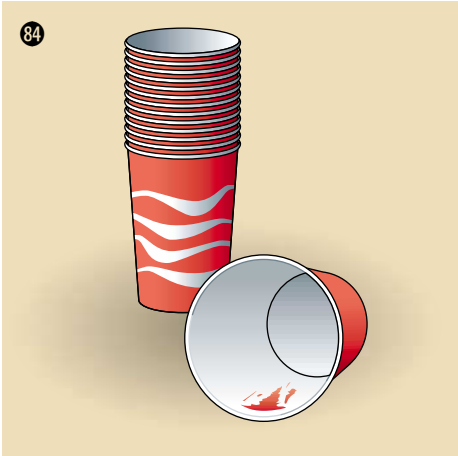
81 Good scratch vs. bad scratch test. If an ink contains wax additives and the container of ink was not mixed properly, it is possible the scratch resistance will be poor.

82 Flat vs. gloss ink. If the gloss level is unacceptable, it may be an indication that the ink printed has not been mixed properly.

83 Good crinkle vs. bad crinkle. For flexible packaging materials, inks must also have acceptable flexibility. Poor flexibility on these substrates can result in ink flaking off the package as it is handled.

84 It is common to test the rub resistance of the print against itself or against another surface the print will be in contact with.





Water Resistance

If a print is expected to be in contact with water, the inks must be designed to resist any bleeding or removal during this exposure. This is especially important for water inks; however, solvent inks may be of concern also. The degree that an ink will bleed in water is largely a function of the colorant used. If an incorrect pigment was used to tone the ink press side, the resulting print may bleed when exposed to water. This can happen with both solvent- and water-based inks. Test methods for water resistance are specific to the particular application involved. They must be agreed to by all parties involved in the process.

Water-based inks have their own concerns when it comes to water resistance. Commercial water-borne inks are not soluble in water, but rather in amine and water. If a job is printed and the amine is not removed through drying, or if too much or the wrong amine was added to an ink, the printed material may resolubilize when exposed to water. Generally, water resistance improves with time when water-based inks are printed. With the increased use of water-borne inks, some printers have set up tests off press to check for water resistance. This is done by wiping the print a number of times with a wet tissue. The pressure and amount of water used, as well as the number of wipes made will all affect the results. Once these three variables are controlled, this test can be a good indicator that the inks were applied and dried properly.

Other Conditions

It would be difficult to anticipate all possible conditions that may require press side testing. It is perhaps best to realize that any job should be carefully reviewed to determine which testing is feasible to be done press side. This can be determined by using a team approach to review what conditions the package will be exposed to and how the package is designed to perform.

SUBSTRATES

If a printer was asked what one thing he would like to see from his ink company, he would likely answer "one ink which works on all the substrates" (*Figure* 85). There are many ink systems out there, because there are many substrates printed flexographically, which is why the process is so popular. Each substrate has unique characteristics which require different formulations of inks in order to get the end-use properties desired in the final package. Common substrates that inks are specifically formulated to print on are papers and paperboards, polyethylenes, foils, cellophanes, vinyls, polypropylenes, PVCs, coextruded films, polyesters, metal-

85 Paper, paperboard, corrugated board, polyethylene, vinyl, cellophane, polypropylene, PVC film and foil represent several of the different classifications of substrates that be utilized in the flexographic printing process.

lized films and more being introduced to the process. Each of these substrates has variations, depending upon manufacturer and production processes. Each variation could require a different ink system, or maybe a slight modification to an existing ink.

It is important to remember that as substrates vary, the inks often have to vary with them. For example, if a printer is using a polyester film and switches to another polyester, which is supposed to be the same, there is a chance that the same ink will not work equally well on both substrates. The ink industry saw this problem recently. Polyester film suddenly became difficult to obtain in one part of the world. Some printers bought overseas products which were supposedly equal to what they had previously purchased. It was realized that this was not the case, when their standard polyester ink systems did not work properly on the imported substrate. In some cases, before the ink companies could formulate an ink to work on the imported material, the polyester shortage was over and printers could again purchase the material they originally used. The point to remember is that if someone asks you what type of ink should be used on a specific polypropylene film, don't be too quick to respond unless you are familiar with that exact substrate.

Substrate's Effect on Color

When color matching, it is very important to match the color of the ink applied to the substrate on which it will be printed. The

color of the substrate can greatly affect the appearance of the ink. For example, if the same red ink were to be printed on a range of substrates; clear film, white opaque film, white paper, and brown kraft paper, the color produced would appear to be quite different on each of the substrates. This is because inks are transparent, some more than others. Therefore, the color under the ink layer will show through the ink, changing the appearance of the ink.

If inks were not transparent but instead 100% opaque, what substrate was used would not matter, but these inks could not be used for process printing. Process printing relies upon overlap, or trap, of one color over another to create a very large number of other colors and shades. The subsequent trap colors can only be achieved if the inks are transparent. Process printing is covered in another volume, but it is important to realize that with transparent inks, the color of the substrate under the ink will alter the appearance of that ink

INK-VALUE DETERMINATION

Ink is a significant cost in printing – often as much as 5% to 10% of the sales dollar. The value of ink as a decorative and functional coating is easily measured in terms of specifications, such as spectrophotometric curves, gloss values and bond strength numbers. The cost of actually using the ink in specific jobs must be predicted and optimized. Exact knowledge of costs gives the printer a competitive edge because jobs with a below target profitability can be reviewed and corrected. Many printers conduct individual job costing within individual commodities allowing previously averaged variables, such as ink type and coverage, to be accounted for in detail.

Knowledge of ink value is often gathered through a combination of historical data, laboratory gravimetric techniques, rule-of-thumb formulas and precise material balance studies on production runs.

Laboratory Method

This method is extremely accurate in predicting ink costs for nonabsorbent surfaces. A proof of the ink being tested is made on an appropriate stock and ink coating weight is taken and used in the formula to compute ink costs.

$$C = \frac{100CW\left[IC + (PS \times SC)\right]}{IS}$$

Where:

C = Applied Cost, $/ream

CW = Dry Coating Weight, lbs./ream

IC = Ink Cost, $/lbs.

PS = Press Solvent Added, lbs./ink lbs.

SC = Solvent Cost, $/lbs.

IS = Fresh Ink, % solids content

This method does not predict the costs caused by fugitive solvent losses. The key to accuracy in this method is ensuring that the proofing method, used for coating weight determination and color specification of the proof, matches the production print exactly.

Historical Data

A formula can be developed by using data gathered over time. For example, a rough estimate of ink consumption can be determined using this equation:

$$I = R \times \%\ Coverage \times 0.02$$

Where:

I = Weight of fresh ink needed in lbs.

R = Number of reams printed

This formula can be further refined based on individual factors in specific jobs.

There are several formulas that have been developed for ink consumption estimation over the years and proven to work well, such as:

$$I = \frac{N \times A \times T \times Sa \times Sg}{250{,}000 \div W}$$

Where:

I = Weight of fresh ink needed, lbs.

N = Number of impressions

A = Area of ink coverage per impression (0 to 1)

T = Average Halftone %

Sa = Substrate absorbency
(film and foil = 1)
(paper and board = 1.5 to 2.0)

Sg = Specific gravity of the ink

W = Waste

Material Balance

The concept of material balance is that all ink and solvent are weighed in and out of the press and an exact count of printed impressions is taken. This is potentially the most accurate method for determining the value of ink consumption because tests are conducted under actual conditions. Unless all press variables are monitored carefully, misleading data can easily be generated. Many printers overcome the natural variability of these processes in mileage tests over extended periods, allowing the variables to be averaged out over several shifts or days.

APPLICATION VARIABLES

The biggest problem in ink mileage estimation is ink viscosity control. For example, in a solvent-based ink system, using roll-to-roll metering, a one second change in viscosity from 17 to 18 seconds measured using a #2 Zahn cup can reduce the mileage by 25%. Similarly, an increase in viscosity from 16 to 17 seconds can increase consumption by 50%. Therefore, viscosity control can not be ignored in a well run pressroom.

Variables in ink coating weight are prevalent on two-roll metering systems. It is not unusual to see variations of 1.2 lbs. to 1.5 lbs. per ream on white inks throughout a run using roll-to-roll metering. High pressures in the ink metering nip may cause variations of as much as 10% more ink being applied at the center of the web compared to the edge.

On ink-metering systems with doctor blades, extra cost is incurred when extender is constantly added to the ink to achieve color. A better cost strategy would be to install anilox rolls with lower specific volumes, printing a thinner ink film, thus eliminating the use of extender.

As a result of ink penetrating the substrate during drying, paper consumes more ink than film. Variations in paper absorbency cause variations in ink consumption.

Value Enhancement

Having considered how ink mileage can be increased and some of the variables that occur, we can conclude that ink consumption can be optimized in various ways.

The printer may be able to detect a visual color difference on a job that equates to a 10% variation in coating weight of an opaque pigment ink. In transparent colors the coating weight may vary by 50% before being visually detected. The eye alone is not always the best instrument to use in a cost abatement program. Reflectance values, measured by instruments, are by far the most reliable source of control data.

In film printing, because white ink often represents perhaps 50% of total ink consumption, an investment in the controls could pay dividends, especially when the amount of overuse is isolated. Most operators ‘play it safe’ and run the white ink with excess ink film or at the upper limit of the opacity specification. For example, an opacity specification of 53% to 56% covers a range that is barely visibly discernable, but printing at 66% opacity will increase ink consumption by 50%. To control ink consumption, lead-to-lead blocking and lower solvent retention, the limits of opacity need to be maintained by the use of an opacimeter or a

coating weight determination.

Color matches should be figured using applied cost and not cost per pound of ink. Establishing the applied cost may take more time but the payback will be seen rapidly. Typically, colors matched or re-matched for low cost are those used on high coverage or high volume items, therefore the greatest cost saving impact is seen.

When purchasing inks, the best value is in high-strength inks. These are highly pigmented and, while the cost per pound is higher than conventional inks, this can be more than offset by increased mileage.

Appendix A

ANILOX CELL VOLUMES*

LINE SCREEN (PER INCH)	LOW (BCM)	OPTIMUM (BCM)	HIGH (BCM)
120	11.10	12.60	13.50
140	9.00	10.50	12.00
165	7.00	8.50	10.00
180	6.00	7.50	9.00
200	5.50	6.80	8.10
220	5.10	6.30	7.60
240	4.80	6.00	7.30
250	4.70	5.80	7.00
260	4.60	5.70	6.70
280	4.40	5.20	6.10
300	4.10	4.80	5.60
330	3.90	4.60	5.30
360	3.60	4.30	5.00
400	3.00	3.70	4.40
440	2.90	3.40	4.00
500	2.80	3.20	3.70
550	2.60	3.00	3.50
600	2.10	2.50	3.00
660	1.90	2.30	2.80
700	1.80	2.20	2.60
800	1.50	1.80	2.10
900	1.20	1.45	1.70
1000	1.10	1.25	1.40
1200	0.90	0.95	1.00

SUGGESTED USE:

Heavy Lines and Solids	120–330 lpi
Line and Type	200–400 lpi
Vignettes	360–550 lpi
Process	500–1200 lpi

* *Reprinted with permission from Harper. Based on interferometric measurements. Specific values may differ with different measurement techniques.*

Appendix B

PRESS LOG BOOK

Date _____ Customer _____ Personnel _____ Title _____ Job # _____

Start _____ Location _____

Finish _____

Job Description _____ Total Construction _____

SUBSTRATE _____
MANUFACTURER _____
CODE _____
DESCRIPTION _____
WETTING TENSION _____
PRINT SURFACE _____ DYNES/CM
TOTAL QUANTITY PRINTED _____

PRESS NUMBER _____
MANUFACTURER _____
TYPE _____
NUMBER COLORS _____
NORMAL SPEED _____
TRIAL SPEED _____
WEB WIDTH _____
CI DRUM TEMP _____

DRYER B/C SETTING ____ READING ____
O/H1 SETTING ____ READING ____
O/H2 SETTING ____ READING ____
CHILL ROLL TEMP. 1ST ____ 2ND ____
WEB TEMP TEMP. ____ % HUMIDITY ____

CONDITIONS
PRESSROOM _____
OUTDOOR _____

DECK	INK			REDUCER		FOUNTAIN		ANILOX								FLAT	
COLOR	#	MFG.	BATCH	COMPO-SITION	LBS/100LBS VIRGIN INK	VISC. (CUP)	TEMP.	LINE	MFG.	TOOL	COND-ITION	VOLUME	RUBBER ROLL/HARD	NIP PRRESSURE	BLADE TYPE	COMP	#
1																	
2																	
3																	
4																	
5																	
6																	

Appendix C

PRESS INK RECORD

JOB PRESS DATE

	INK	INK ID#	ANILOX CELL COUNT	CELL VOL (BCM)
STATION 1				
STATION 2				
STATION 3				
STATION 4				
STATION 5				
STATION 6				

DENSITY BAR

SPECIAL INFORMATION

Appendix D

pH/VISCOSITY RECORD

JOB _____ PRESS _____ DATE _____

	STATION 1	STATION 2	STATION 3	STATION 4	STATION 5	STATION 6
TIME						
pH/VISCOSITY						
TIME						
pH/VISCOSITY						
TIME						
pH/VISCOSITY						
TIME						
pH/VISCOSITY						
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pH/VISCOSITY						
TIME						
pH/VISCOSITY						

Appendix E

MIXED INK AND BATCH ASSIGNMENT LOG

DATE _____ **COLOR** _____ **MIXED BY** _____

BASE COLOR	BATCH #	QUANTITY

UNIT OF MEASURE _____

BATCH NUMBER ASSIGNED _____

(Must be on label)

COMMENTS

Appendix F

VISCOSITY CONVERSION GUIDE

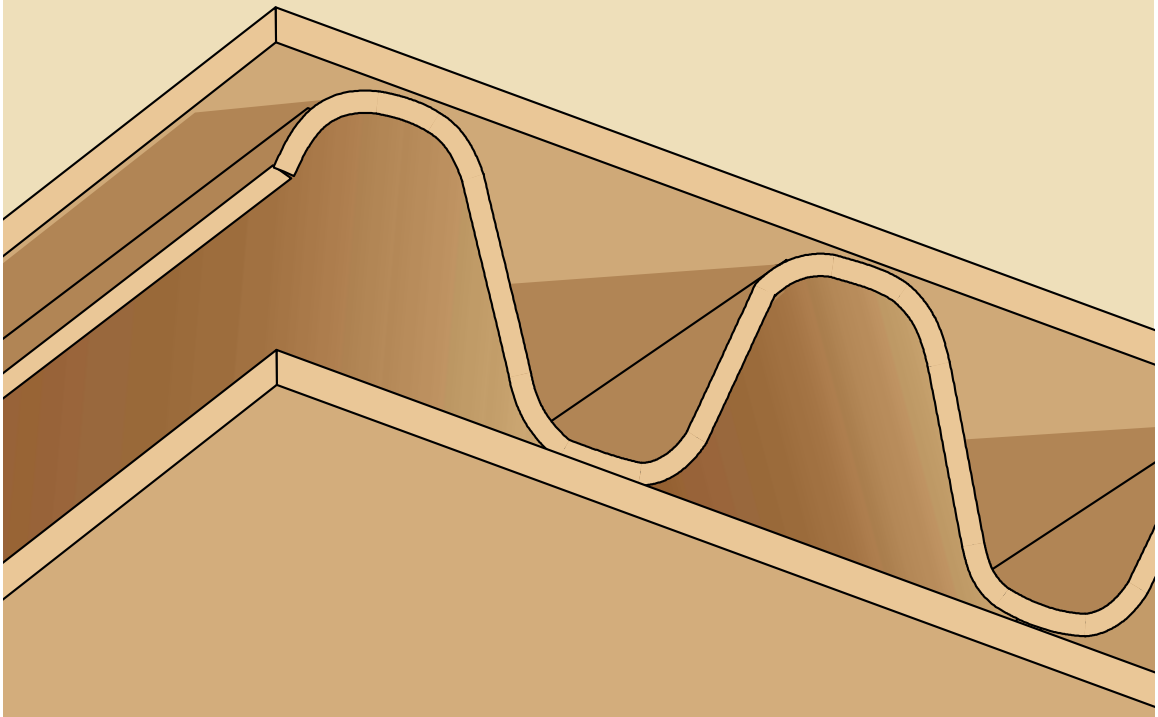
NUMBERS FOR ZAHN AND SHELL CUPS ARE IN SECONDS

	ZAHN			SHELL			
CENTIPOSE	**#1**	**#2**	**#3**	**#1**	**#2**	**#3**	**#4**
1				17			
2				21			
3				26			
5				35			
8	31			46	18		
10	32			57	22		
15	35				30		
20	38	18			39		
25	42	19			47	19	
30	45	20			56	22	
40	52	22				29	
50	60	25				35	
60	68	28				42	18
70		30				48	21
80		34				55	24
90		38					27
100		43	17				30
125		53	19				37
150		63	22				45
175		72	25				52
200			27				60

CAUTION: These numbers are guides only. Actual comparisons will differ.

CHAPTER 2

Substrates



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Introduction

A substrate is a material defined by Webster's New World Dictionary as "a medium or a substance which supports another; a foundation." In printing, the substrate supports the ink film that carries the message needed to describe the internal contents of a package or give an advertised message.

Substrates for flexography are varied, depending on the end use of the material. There is almost no material that cannot be printed by the flexo process – from tiny paper toothpick wrappers, to plastic coverings for mattresses, to metal foils. A major challenge for the flexographer is understanding the substrate material to be printed because each has special requirements.

Primary topics covered in this volume include: an explanation of the different substrates; how they differ in their production; printing characteristics; and guidelines on how they need to be handled.

New substrates are always being added, while existing ones are constantly improved upon in response to new needs. Substrates are divided into five major groups:

- Paper and Paperboard
- Corrugated
- Laminates
- Foils
- Films

Some classes of substrates have gone through further development, driven by changes in market demand, and the advent of recycling.

The flexographer needs to be aware that the materials are usually produced to meet end-use requirements and not necessarily those of the printing process. This is beginning to change with the demand for higher print quality. In some cases specialized inks need to be used, or the current inks have to be altered. Drying ovens are necessary in some cases. In the past 10 years, the use of water-based inks has become prevalent on paper substrates and even on some plastic films.

The objective of this chapter is to educate the printer about the properties of various substrates. Information presented is designed to make it possible and convenient for the printer to ensure that each material meets its proper specification before, as well as after, it is printed.

Common materials are listed under the five main groups. A brief description of the material manufacturing process is offered. Comments about the characteristics and problems associated with the substrate that are frequently encountered by the flexographer are provided.

Paper and Paperboard

Paper is one of the oldest substrates used for printing and has gone through many changes as materials and environmental concerns have influenced production. It is believed that man first invented paper about 200 B.C., but the earliest known record attributes the development and production to the Chinese, beginning early in the second century A.D. This paper was made using bark, hemp and rags as the chief ingredients.

The Chinese continued to refine their paper-making skills and developed starch sizing in the second half of the eighth century. Starch aids in keeping the fibers bonded together and holds the ink out at the surface to prevent blurring the printed image. The development of paper with sizing was continued in the Middle East and later in Spain and in Sicily. Most paper was made by hand until the 18th century when the Fourdrinier brothers developed the first practical paper machine.

The Fourdrinier machine formed a continuous strip of paper instead of the single-sheet production of the hand-made paper. This innovation facilitated the further development of printing presses. A second milestone was marked though the use of wood pulp for paper production. Prior to wood pulp, the chief ingredient in papermaking was rags. The new plentiful and renewable ingredient supported increased large-scale production to meet the rapidly growing demands for printed material.

As more people were educated, the demand for knowledge grew. The rising readership of newspapers and books resulted in other new developments: advertising and mass distribution. These in turn necessitated new methods for wrapping and packaging merchandise for delivery to consumers.

MANUFACTURING PROCESS

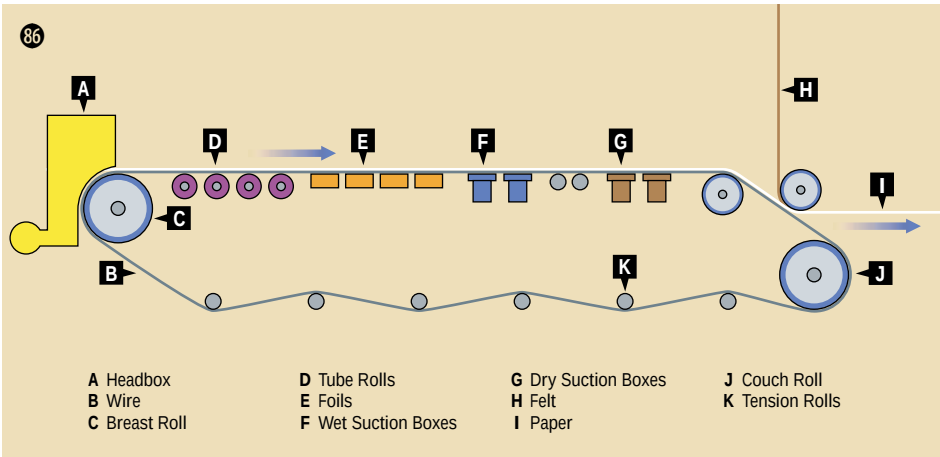
Paper can account for anywhere from 40% to 60% of the cost of a final printed job, so it is important to understand the manufacturing process. The original Fourdrinier invention is still in use today on most paper machines. Every piece of equipment can be broken down into three sections: the wet-end, the press section and the drying section.

From the wet end, or headbox, a dilute slurry of fiber and additives consisting of about 99% water is deposited onto an endless moving wire where most of the water is drained away. Further water is removed by perforated suction boxes beneath the wire.

The fragile wet web is transferred to the press section where a supporting wool or synthetic fabric felt passes the paper through wringers and suction rolls to the drying section. There, heated cylinders reduce moisture to the desired finished level. Paper caliper and surface smoothness are established by passing the web between a calender stack of steel rolls. Finally, the paper is wound onto a huge reel at the dry end of the paper machine.

Additional steps might include adding pigmented coating(s) to one or both sides of the web, rewinding to remove defects, slitting the master reel to the desired roll width and diameter, or other post-production enhancements. *Figure* 86 shows the wet end of the paper machine.

86 At the wet end a paper manufacturing process, a dilute slurry of fiber and additives consisting mostly of water is deposited onto an endless moving wire where most of the water will be drained away.



The ideal printing paper would be one that has identical characteristics on both sides. Paper traditionally has had a characteristic two-sidedness, or top side of the sheet, known as the felt side, and the bottom of the sheet, or the wire side. The difference between sides could be determined visually by means of the screen mark left on the wire or bottom side during sheet forming.

Newer paper machines with twin wires make the two-sidedness less apparent. The two-sidedness is most apparent in the difference in ink receptivity due to the inconsistencies in the concentration of "fines" or small fibers and fillers. The felt side is more closed because the fillers are concentrated on the top of the sheet, while the wire or bottom of the sheet is more open due to the drainage of water through the fibers forming on the wire. The use of retention aids and newer machines have helped to eliminate some of the top-to-bottom differences in mechanically produced paper.

Production of Wood Pulp

There are four main types of pulping methods: mechanical, chemical, semichemical and thermomechanical.

In the mechanical or groundwood method, logs are pressed against huge revolving grindstones to defiber the wood, and the pulp is flushed from the stones with streams of water. This pulp is made up of short, stiff fibers which have little strength properties. Paper made from this pulp is the least expensive because none of the lignin, resins or impurities have been removed and as a result the paper will darken very readily. Newsprint is a common example of a high groundwood paper but even this product needs the addition of longer, chemically treated fibers to provide sufficient strength for processing in high-speed printing presses and folders.

Chemical processes for producing wood pulp provide papers that are stronger and more impurity free than the groundwood process. Continuous batch digesters produce papers that are more permanent. There are two types of chemical pulping, sulfate (or kraft) and sulfite. The sulfate process yields a wider variety of products which are stronger than those from the sulfite process. Hence, the sulfate process is more commonly used. Semichemical pulps are sometimes used in varying proportions with chemical fibers to provide bulk or other desirable combinations at the lowest cost. All chemically separated fibers are longer, stronger and free from the resinous contaminates in the wood itself. Papers with no groundwood fibers are known as "free sheets" (groundwood free). Free sheets are used for business papers,

87 The magnified view of paper shows the mat combination fo hardwood and softwood fibers. This blend determines the desired finished product requirements.

forms, envelopes and book grades.

The newest types of pulping are thermomechanical (TMP) and bleached chemi-thermomechanical (BCTMP). Mechanical pulping causes damage to the fibers that results in fiber bundles and requires the addition of chemical pulp to provide strength. Thermomechanical pulping produces groundwood with a better yield and higher strength. This pulp can be used for newsprint without the addition of chemical pulp.

After pulping, the fibers are bleached with a variety of chemicals such as chlorine, chlorine dioxide or sodium hypochlorite. The latest bleaching technology involves the use of oxygen with the chlorine. Bleaching removes color caused by lignin and other impurities that can affect the quality of the paper. Bleaching does reduce the strength of the fibers. The last step is refining or beating, which frays the fibers and improves their ability to bind to one another when a sheet is formed.

Paper Fibers

Paper can be described as a mat made from a combination of hardwood and softwood fibers, the blend of which is determined by the desired finished product requirements (*Figure* 87). Softwood fibers are longer and add strength to the paper while the shorter hardwood fibers fill in the voids between the long fibers and give greater smoothness. Depending on whether strength and economy or appearance and printability are the criteria, different combinations of fiber blends will be used.

Colored papers are produced by the addition of dyes to the slurry in the stock preparation section or headbox (wet end of the paper machine) prior to the wire. These papers are expensive and must be made in large quantities due to the expense of paper machine changeovers.

Today, due to warehousing costs, the concept of "just-in-time" inventory is popular. White paper can be inventoried and, as needed, can be tinted on the felt and/or wire side using flexography in line to produce the desired quantity of colored paper or board.

Recycled Fiber/Paper

The use of wood fiber made paper production inexpensive process. A side effect of the paper industry's enormous production capacity was the solid-waste crisis of the late 1980s. Paper is the most abundant item in landfills. Although paper is biodegradable, this process does not happen quickly. The problem is that existing landfills are closing every day. It was estimated in the 1980s that 50% of these landfills would close by the year 2000. To resolve this problem, paper is now recycled.

Recycled paper is manufactured according to United States Environmental Protection Agency (EPA) guidelines. The guidelines are not specific for each paper and can include:

- mill broke, which is paper waste generated in the paper mill prior to the completion of the paper making process;
- pre-consumer, which includes converting waste and trimmings prior to finished product; and
- post-consumer waste (or paper that has been printed and de-inked before use).

Paper made from recycled fiber does not

differ very much from that made from virgin fiber. Some characteristics like formation, smoothness and opacity can be improved due to increased pliability of de-inked fibers. Brightness can suffer, but this can be improved with the addition of virgin fiber and optical brighteners. Recycled papers print comparably to virgin paper with the added bonus that they tend to curl less and have greater dimensional stability.

Fillers

Paper contains non-fibrous materials called fillers. Fillers such as clay, titanium dioxide or calcium carbonate are added to modify absorbency, hardness, smoothness, printability, durability, weight and handling characteristics of paper. Binders like gum, methyl cellulose, starch or resins are added to help hold the fibers together, to increase stiffness, and to reduce dust and lint. Papers need fillers to produce higher ink holdout resulting in less dot gain since, the ink can be kept on the surface and not be absorbed into the fiber's structure.

PAPER PROPERTIES

There are no obvious distinctions in the definition between paper and paperboard. The major difference lies in the caliper. Generally, papers are either coarse or fine. Coarse are the kraft papers, and fine are the bleached, smoother papers.

Paper is classified based on its end use and the term used for this description is called grade. Each grade is formulated differently so its characteristics are appropriate for the ink that will be applied and the equipment on which it will be run. Paper performs best when used for its intended purpose, but some papers are considered dual purpose. A good paper is one that prints and converts successfully. Finished paper properties can be broken down into several classifications:

- structural or mechanical;
- surface finish and appearance; and
- chemical.

These properties apply to both paper and paperboard. However, the method for their determination may differ. The following is meant as a brief definition and does not nec-

REAM WEIGHT CONVERSION FACTORS

PAPER	BASIC SIZE (IN)	REAM AREA (FT^2)	BASIS WEIGHT TO GRAMMAGE	GRAMMAGE TO BASIS WEIGHT
Linerboard		1,000	4.883	0.205
Writing, Printing, Computer, Bond	17 x 22	1299	3.760	0.266
Cover	20 x 26	1806	2.704	0.370
Cardboard	22 x 28	2139	2.283	0.438
Bristol, Tag	22.5 x 28.5	2227	2.193	0.456
Paperboard, News, Wrapping, Bag, Tissue	24 x 36	3000	1.628	0.614
Book, Text, Offset	25 x 38	3299	1.480	0.676
Index				
Newsboard	26 x 38	3431	1.423	0.703

Note: All values except paperboard based on a 500-sheet ream.

Table 18

essarily describe the test method or go into great detail of the method.

See *Appendix A* for the listing of TAPPI (Technical Association of the Pulp and Paper Industry) test methods according to substrate type: paper, paperboard and corrugated board.

Structural or Mechanical Properties

Basis Weight. Basis weight is the weight in pounds of a ream (usually 500 sheets) of paper at a given sheet size (usually the basic size for a given grade). These 500 sheets also represent an area of paper. For example, 500 sheets of 25" x 38" is equal to 3,300 square feet of paper. Therefore, the basis weight can be converted to a weight per unit area or pounds per square foot. Today, due to the International Organization for Standardization (ISO) requirements, the recommended expression of basis weight is in grammage (metric unit of weight). In metric measure, paper size or area is expressed in square meters and the weight per unit area is expressed as grams per square meter (g/m^2).

Table 18 lists some common ream sizes and their conversion factors to grammage or metric units. For example, a 17" x 22", 20# bond paper is equivalent to 75.2 g/m^2 (20 x 3.760).

CONVERSION VALUES

1 lb = 453.6 g	1 gm = 0.002205 lb
1 ft. = 12 in	1 in = 0.08333 ft
1 ft^2 = 144 in^2	1 in^2 = 0.006944 ft^2
1 m = 100 cm	1 cm = 0.1 m
= 39.27 in	1 in = 0.0254 m
= 3.281 ft	1 ft = 0.3048 m
1 m^2 = 10,000 cm^2	1 cm^2 = 0.0001 m^2
= 10.76 ft^2	1 ft^2 = 0.0929 m^2
= 1,550 in^2	1 in^2 = 0.00645 m^2

KEY:

lb = pound	**ft** = foot
g = gram	**in** = inch
m = meter	**in^2** = square inches
cm = centimeter	**ft^2** = square feet
m^2 = square meter	
cm^2 = square centimeters	

Table 19

Table 19 lists some useful conversion values and *Table 20* shows the metric "A" and "B" sizes.

Bulk. Bulk is another way of describing the thickness of a sheet. Bulk is also expressed as the number of pages (two pages per sheet or the number of sheets multiplied by two) needed to reach one inch of thickness. It is an important factor where a volume of paper

METRIC "A" AND "B" PAPER SIZES

"A" SIZE	LENGTH (MM)	WIDTH (MM)	LENGTH (IN)	WIDTH (IN)	"B" SIZE	LENGTH (MM)	WIDTH (MM)	LENGTH (IN)	WIDTH (IN)
A0	1,189	841	46.819	33.106	**B0**	1,414	1,000	55.669	39.364
A1	841	595	33.106	23.410	**B1**	1,000	707	39.364	27.835
A2	595	420	23.410	16.553	**B2**	707	500	27.835	19.682
A3	420	297	16.553	11.705	**B3**	500	354	19.682	13.917
A4	297	210	11.705	8.277	**B4**	354	250	13.917	9.841
A5	210	149	8.277	5.852	**B5**	250	177	9.841	6.959
A6	149	105	5.852	4.138	**B6**	177	125	6.959	4.921
A7	105	74	4.138	2.926	**B7**	125	88	4.921	3.479

Table 20

will be converted into a product that must fit into a specified container for shipping. This is important for books, envelopes and business forms.

Burst. Burst is a measure of a combination of properties, like tensile and stretch, up to the point of rupture. Burst differs from tensile strength in that the force used for the failure is in a circular direction, while tensile is in one direction only. Packaging paper must meet minimum bursting-strength requirements.

Caliper. Caliper is a measurement of the thickness of a single sheet of paper, paperboard or combined board measured with a micrometer under a static load for a minimum specified time. The unit of measurement is thousandths of an inch, or mils. Caliper is important because wide variations can cause the final print impression to be uneven. Caliper and smoothness are inversely related. Higher caliper papers tend to be rougher while lower calipers tend to be smoother. Caliper affects both stiffness and bulk. Heavier-weight papers and paperboard have calipers expressed in points (each point is equal to 0.001".)

Curl. Curl is non-flat paper caused by changes in moisture content or physical stress and may take many forms. Due to changing relative humidity, and ultimately paper moisture, stresses in the paper may become unbalanced and a curl will develop. As a general rule, fibers expand (contract) about three times more in diameter than in length with increased (decreased) moisture. A paper's wire side, with a higher concentration of fiber, is more reactive to moisture changes than the filler-rich felt side. Reel curl may occur near a roll core with paper wound too tightly and take on a permanent set in this position.

Density. Density is the value obtained by dividing basis weight, expressed as mass per unit area, by the caliper. Paper that is compact and tightly formed will have a higher density value.

Dimensional Stability. Dimensional stability is the ability of a paper to hold its original size or constant dimension in all directions when exposed to physical stress or variable moisture. This is a very important property especially where unit-print stations are used and more moisture is added by water-based ink at each unit. Papers with poor dimensional stability will not hold color-to-color register and may result in a poor, blurred print.

Folding Endurance. Folding endurance is a paper's ability to withstand repeated flexing or folding and bending. The test is usually run in both the machine direction and cross-machine direction of the paper. Government documents like wills and maps need high folding endurance. Papers have greater strength in the cross-machine direction. Paperboard uses a different procedure to measure this property and the result indicates the suitability of the paperboard for conversion into folding cartons without a scoreline.

Formation. Formation is the uniformity of the fiber distribution in the paper. There are a number of instruments that measure formation. The higher the number, the more uniform the sheet. The values are reported as flocs (hills) and voids (valleys). Flocs are densified fiber bundles and voids are areas with less fiber. Calendering can level out the surface of the paper but the internal structure that has the compacted fibers of the flocs will absorb ink less than the adjacent voids producing a non-uniform, mottled or blotchy print. Applying more pressure during printing cannot overcome the non-uniform or blotchy print since the floc structure is throughout the sheet and will appear equally on both sides of the paper. In process work, the print will appear grainy especially when working with higher line screens.

Grain Direction. Grain direction is essentially how the fibers lay or align when they are deposited on the wire in the papermaking process. "Grain long" refers to the machine direction with most of the fibers oriented somewhat parallel to this direction or the

long edge of a web or sheet. "Grain short" describes paper or paperboard sheets with fiber orientation parallel to the shortest dimension. Grain affects many properties such as tear, stiffness and fold. Paper expands when exposed to moisture and most often the effect will be noticed in the cross-machine or cross-grain direction. Paper will tear most readily and is stiffest in the machine direction. Paper folds most easily parallel to the grain, but fold strength (number of folds before tearing) is best across the grain.

Internal Bond. Internal bond is another method for measuring the failure point of paper. Unlike burst where the force is equal in all directions, the internal bond is a measure along the z-axis. It is an indicator of the force required to delaminate or split apart the internal fiber structure when the force is applied perpendicular to the paper surface.

Porosity. Porosity is a measure of the resistance to air flow through the sheet under pressure. Porosity is an indicator of absorbency (penetration of oil and water) and hence the amount of ink that penetrates into the surface. Porosity also relates to the hardness of the paper surface.

Stiffness. Stiffness is the flexing resistance of paper, or its ability to resist an applied bending force. This property is important in converting operations and requires high values for sorting and folding applications. High stiffness is also needed where optical character readers are used and in envelope manufacturing which requires the transport of the paper through converting machinery. Less stiffness is necessary for printing papers, napkins and paper toweling. Stiffness increases with basis weight and caliper.

Stretch. Stretch is an indicator of the ability of the paper to elongate under tension and to conform to a desired contour. Web tension must be adequate to form a good roll without distorting the paper. Web tension on the press must enable the paper surface to travel at the same surface speed as the plate and impression cylinders. Paper stretch is determined during the test for tensile strength. Paper will stretch a given amount before failure.

Tear. Tear is simply the resistance of a paper to tear. It is increased by fiber-refining and is decreased by most fillers. Good tear properties are essential for papers like tag, cover, bond, kraft wrapping and bag. Any paper that will be subject to repeated handling needs to have a high tear resistance. Papers are most resistant to tear in the cross-grain direction.

Tensile Energy Absorption. Tensile energy absorption, or TEA, is the ability of paper and board to absorb energy and indicates durability. Papers like multiwall sack are subject to repetitive strain and stress.

Tensile Strength. Tensile strength is a measure of the breaking strength of paper (the force per unit area required to break a specimen). Strength is determined by the fiber pulping process and not the thickness. Tensile strength is indicative of the potential resistance of a web to break during printing. Tensile strength is higher in the grain long or machine direction.

Surface Finish and Appearance Properties

Brightness. Brightness is a commonly used industry standard for measurement of blue (457 nm) light reflectance, usually directional. The standard brightness scale is based on the reflectance of magnesium oxide, which is rated as 100% on the brightness scale. The brightness of a paper will determine the intensity of printed color. Brightness can be affected by the addition of optical brighteners that will absorb invisible ultraviolet light and emit it in the violet to blue region of the spectrum. Brightness is affected by the fillers and pigments added during manufacture regardless of the paper color. Lower brightness is desirable where text is printed because glare will cause eye strain.

Color. The color of paper, as perceived by the human eye, is dependent on the light that illu-

88 Excessive moisture will cause welts and wavy edges making further converting difficult.

minates the paper. Paper will absorb some wavelengths and reflect others. If it absorbs all the wavelengths of white light while reflecting none, then it will be black paper. Most brilliant color reproductions are obtained on papers with high-balanced reflectance.

Friction Resistance. Friction resistance is sometimes referred to as coefficient of friction (COF). The coefficient of friction is expressed in both static and kinetic forms. The static term is related to the force required to initiate movement between two surfaces. The kinetic is the force required to sustain uniform movement. This is an important property for any printing paper and also for converting operations. Modifiers like waxes are added to increase the ease with which papers will move across each other. Paperboard cartons, file folders and multiwall shipping bags must have sufficient skid resistance to prevent problems during transport. In some cases colloidal silica is added as an anti-skid treatment.

Gloss. Gloss is the surface quality of the paper which reflects light like a mirror and gives it a shiny appearance. It is measured by an instrument that illuminates a sheet at a particular angle (usually 75°) and detects light reflected at the same angle. It is used for coated and uncoated paper and paperboard. The smoother a paper surface, the more light is reflected in this mirror-like manner. Printed ink gloss is somewhat dependent on paper gloss. A 20° measurement is preferred for high gloss, cast coated, lacquered and highly varnished papers. Neither method is a measure of image reflecting quality.

Opacity. Opacity is the property of the paper that obstructs light transmission. Opacity is influenced by the degree of fiber refining. Increased refining increases the fiber bonding and decreases the amount of voids in the paper reducing light transmission. The use of fillers in the paper also helps to increase the hiding power or opacity of the paper.

Smoothness. Smoothness is the surface finish or texture of the paper's face and is influenced by the fillers, coating, supercalendering and sizing. There are a number of instruments for determining smoothness, so it is important to understand which method is being used and reported. In general most of the instruments are air leak methods and the lower the number, the smoother the sheet.

88

Chemical Properties

Fiber Content. Papers are made primarily of both softwoods (fibers from conifers or pine trees) and hardwoods (fibers from deciduous trees that lose their leaves). An appropriate combination is necessary to obtain the proper balance between strength and surface finish for specific paper grades. Recycled and reclaimed fibers are also used exclusively or in part for certain grades of both paper and paperboard.

Moisture. Papers are manufactured to a specified moisture content. This moisture will have a direct bearing on how much ink the paper will absorb during printing. Papers are made of cellulose fibers that will absorb or lose moisture very readily. Handling of paper before printing is critical because paper picks up ambient moisture from the air. A very moist sheet will require more ink and will need many press adjustments to keep proper registration. Press rooms need to

89 A plate plugged with fibers poorly bound to the paper.

have adequate humidity control for proper performance of papers. Different grades of paper have different points of equilibrium where fibers neither give up, nor take on, moisture. Dry substrates may be more susceptible to press web breaks because many flexographic presses pull the web through the press rather than drive it through the many nip points. Excessive moisture will cause welts and wavy edges making further converting difficult (*Figure* 88).

pH. The measure of whether a paper is alkaline or acid is expressed as pH. The pH value determines the paper's permanence. Acid papers with values lower than pH 7 have the shortest life, while papers with pH values greater than 7 have maximum longevity.

Sizing. Sizing refers to one or more chemicals added during papermaking to improve the substrate's end-use performance. There are two types of sizing: internal and surface. Internal sizing is mixed in the pulp at the wet end of the paper machine. Surface sizing involves applying a very light continuous film of starch or other materials to one or both sides of the web with a size press which is usually located about two-thirds of the way down the dryer section of the paper machine.

Benefits of sizing include an increase in the ability of cellulose fibers to bond to each other, which reduces the potential for internal delamination and surface linting. Sizing also increases the resistance of paper to absorbing liquids such as water, ink, grease or blood. It improves ink holdout by slowing the rate of ink absorption into the fiber structure which otherwise might contribute to unwanted wicking, feathering, chalking and print density loss. Surface smoothness, surface strength, Mullen burst strength, tensile strength and stiffness are enhanced by surface sizing. *Figure* 89 shows a plate plugged with fibers which were poorly bound to the paper.

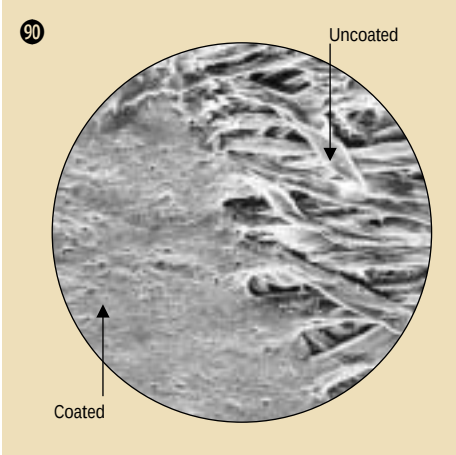
Wet Strength. Wet strength is important for any paper that will be exposed to outdoor weather conditions. Wet strength is obtained by the addition of resins in the papermaking furnish that increases fiber bonding.

Graphics. Conversion to a paper substrate offers the important advantage of superior graphic capabilities. The finish of the paper can be altered to meet the customer need. A printer is not limited to the use of kraft but can obtain semibleached or full-bleached kraft for improved graphic appearance. Printing on these papers requires following recommendations similar to those for plain or coated papers.

Alkaline/Acid Paper

Paper is classified as acid or alkaline depending upon the papermaking process used. The pH of the paper identifies this difference. The factor pH is measured on a scale of 1 to 14 with values less than 7 indicating greater acidity and above 7 greater alkalinity.

Paper is traditionally manufactured on the acidic side (pH 4.0–5.5) because of the rosin sizing and alum that are used as fixing agents to waterproof the paper. Clay is the filler commonly used for acid paper, and while it improves opacity it is not very bright. Titanium dioxide (TiO_2) is added to improve brightness. The use of clay has to be carefully controlled because excess clay can weaken the sheet. Titanium dioxide is expensive and abrasive. It also must be controlled because it



90 A magnified view of the fiber structure in coated and uncoated paper.

can dull slitter knives more quickly in converting operations. Acid papers can eventually yellow and become brittle due to small amounts of residual acid attacking the fibers.

Alkaline papers are manufactured in the pH range of 7 to 8. This is considered essentially neutral. The seemingly small difference between the pH values are deceptive because the scale is logarithmic, meaning each increment is 10 times greater than the last. Calcium carbonate is the primary filler for alkaline paper and this improves the appearance and brightness without the addition of titanium dioxide. Calcium carbonate can be abrasive in its natural form, but paper makers use a chemically manufactured precipitated form (PCC) of the material. The advantages of alkaline paper include higher natural brightness, which gives greater printed ink contrast; improved bulk, for better handling; greater stiffness to enhance runability; and improved archival qualities. The United States Government has required that all its documents must be printed on alkaline paper.

Acid and alkaline papers print equally well by flexography.

Coated Papers

A large portion of papers printed by flexo, such as label stock, some liner board and gift wrap, are coated (*Figure* 90). The primary reasons to coat a paper are to enhance the appearance and to improve the printing surface. Coatings also provide functional qualities such as water resistance, grease proofing and heat sealability. The paper acts as a base for the coating., which improves the surface of the paper by filling in the inherent micro spaces created by the fibers overlaying each other. It also improves the print formation by making the flocs (hills or dark areas of densified fiber) and voids (valleys, areas with less fiber) produced during the manufacture of paper less apparent. A more uniform surface gives more consistent print density, gloss and print smoothness. Coatings must allow the escape of water-vapor during printing, especially with heavy ink coverage. The higher a basis weight and coating thickness the greater the risk of the paper blistering when drying, especially at web temperatures above 212° F.

The coating is generally applied on the paper machine after the size press. Sizing helps hold the coating on the surface of the fibers. Coatings are comprised of pigments (clay or calcium carbonate), a binder (starch or latex), flow modifiers (carboxyl methyl cellulose), brighteners and whiteners. Coated paper is then super-calendered either on- or off-machine to give the final degree of surface finish. A super-calender is a stack of rolls that are a combination of alternating hard cotton rolls and steel rolls which polish the surface of the sheet. The number of nips through which the paper passes determines the final gloss, smoothness and caliper. Coatings can be produced in a number of finishes from matte to enamel. Paper finish will determine the final ink absorbency, gloss and drying rate. The color of the coating will determine the amount of “snap” or contrast between the ink and the paper surface.

Problems encountered with coated papers can take a number of forms. A mottled appearance in the unprinted coating may produce a mottled print. Imperfections in

the coating surface such as pits, scratches and streaks will negatively affect the finished print, especially in full ink-coverage areas where voids will be noticeable but will also negatively affect process work. Lower gloss finishes can produce wet-ink rub issues. The printing of high gloss papers needs care in the selection of ink due to drying and ink- trapping issues resulting from the higher ink holdout. Excess ink moisture and some solvent-based inks can soften the coating binders, so care should be taken to match the paper and ink to the job and end-use requirements.

Roll Quality

Most paper printed by the flexographic method is in rolls, but some paperboard and corrugated grades are printed as sheets. While all of the previously discussed paper properties are applicable to rolls, the quality or construction of the roll is an additional important issue. Due to advances in on-line paper machine technology, variations in basis weight and caliper are rare.

Paper immediately off the paper machine is referred to as a log. The log is slit down to the proper size for the end-use customer. Rewinding and slitting of the rolls into the ordered size can result in a number of problems, especially if the slitters are worn or the rewind is not at the proper tension. Poor roll quality can adversely affect converting productivity.

Rolls should have uniform tension across the grain, face or outer surface. Poorly wound rolls will result in bounce and tension disturbances that can affect print register. This bounce can also result in uneven unwind and can cause the web to break. Poor splicing may result in web breaks. Cracked or damaged edges on a roll may result in web breaks. Creases and wrinkles may result from baggy rolls. Linting can result from dull slitter knives and cause dirty print due to fibers being liberated and accumulating on the plate and in the ink.

If the roll is not smooth, or appears to be ragged on the edges, it can be checked by running a dark cloth over the edge. If an accumulation of white debris is evident, it is advisable not to use the roll. The printer/converter should always save the roll identification label to report roll condition to the manufacturer.

Determining the amount of paper needed for a specific job or number of labels has become easier. Most manufacturers now list the linear footage for each roll, but sometimes this information may be missing. Basis weight affects the size of the roll and linear footage. Lower basis weight paper will have more linear footage than a heavier weight paper.

The formula to determine the number of feet in a roll is as follows:

$$\text{LINEAR FEET} = \frac{\text{WEIGHT OF ROLL (LBS)} \times \text{BASIC SIZE (L}\times\text{W)} \times 41.667}{\text{WIDTH OF ROLL (IN)} \times \text{BASIS WEIGHT}}$$

Example: Book paper basis size is 25" x 38", 55#, 40" wide, 2,000 lb. roll

$$\text{LINEAR FEET} = \frac{2{,}000 \times 25 \times 38 \times 41.667}{40 \times 55} = 35{,}985 \text{ feet}$$

Basis weight may vary up to 5% above or below the advertised weight for that particular grade. If the actual basis weight is higher, the footage will be slightly under; if the actual basis weight is lower, then more footage will be available. Most rolls are not run to the very end due to problems with roll-set curl, so a minimal thickness of paper is usually left on the butt roll when splicing to a full roll.

PAPER AND ROLL STORAGE/HANDLING

Paper is shipped in a moisture-proof wrapping to maintain its production target moisture. Cold paper should be brought into the

pressroom and sufficient time allowed for the roll to come to the same temperature as the environment. Pressroom humidity is important when printing paper. Paper performs best when the relative humidity is less than 8% drier or wetter than that of the paper. Paper is hygroscopic, meaning it will absorb or lose moisture. Once the paper has picked up or lost moisture it is impossible to change back to the original manufactured moisture content. Some performance characteristics of the paper will be lost by the change in moisture. To avoid problems with dimensional stability, curl, register problems and dot gain, it is advisable not to unwrap a roll of paper until ready to put it on press. A partially used roll should always be wrapped again to avoid changes in the paper properties. Paperboard behaves in the same manner. The degree of moisture change in paperboard is dependent on fiber type, condition of fiber (degree of recycle) and structure.

Rolls should be handled carefully. Dropping a roll can crush the cores, making it difficult to put on the press shaft. Damaged cores can also result in tension variation that translates into print misregister, repeat-length abnormalities and slower press production. Bumping a roll with a fork-lift can damage many layers of paper in the roll, making it unusable. Rolls should always be moved with a clamp truck.

PAPER FINISHES

There are basically two types of paper finishes, uncoated and coated. Uncoated papers can vary greatly in appearance from a very smooth and shiny surface to an antique finish that has a rough, distinctive texture. In contrast, coated papers have a smooth finish and are classified by their gloss or shininess.

Uncoated Paper Finishes

Antique, Eggshell and Vellum. Refers to uncoated papers with a rough, distinct surface texture. Antique is the roughest, followed by eggshell with a pitted texture and vellum as the smoothest.

Machine and English. Differs from the antique finishes by having a smoother, more polished surface.

Felt. Made by having the felt mark transferred to the paper and is partly dried to imitate handmade paper.

Laid. Paper which has a fine crisscross of vertical and horizontal lines.

Embossed. This finish is applied after the paper is off the machine. These papers are made by passing the paper through two rolls that stamp a three-dimensional pattern into the paper.

Supercalendered. This paper is characterized by a smooth and shiny finish.

Coated Paper Finishes

Enamel Coated. The highest or heaviest coated paper which is highly supercalendered, generally to a 75° gloss of 60% or higher.

Dull Coated. This paper is lightly supercalendered to have a low gloss (typically 30% to 40% at 75°) and is very good for readability.

Matte Coated. A fully coated, nonsupercalendered finish that has virtually no gloss (below 25% at 75°), but tends to be more prone to poor ink-rub resistance, due to the large rough-surfaced pigments used to scatter light and reduce gloss.

Embossed Coated. This paper is coated, then embossed with a three-dimensional pattern, producing a textured surface having a slightly lower gloss.

Cast Coated. Paper which has its pigmented coating dried, while held against a highly polished surface similar to a glossy photograph. Cast-coated papers are usually measured with a 20° glossmeter rather than an 75° instrument normally used to characterize other pigmented-coated papers.

Coated One Side (C1S). Widely used for labels, the uncoated side is compatible with adhesives.

PAPERBOARD

There is no strict definition distinguishing paperboard from paper. Paperboard is simply referred to as board and is a major raw material in packaging. It is distinguished from paper by physical properties like stiffness and thickness. Since the structure consists of cellulose fibers, it has the same strength-to-weight ratio as paper. Board includes boxboard, chipboard, container board and solid fiber. It can be used for folding cartons, containers for liquids, or converted into drums for transportation of bulk chemicals. The structure of paperboard is determined by its end use. Structure can be single-ply or two to eight thinner plies. Multiple plies allow for the use of different types of fibers in each ply. Bonding of the fibers between the plies is extremely important because deterioration in strength during processing is undesirable. The combination of ingredients produces a paper product that is strong enough to protect heavy or large materials during shipping.

The main difference between paper and paperboard is caliper. Generally, substrates with a thickness of 0.012" (12 points or 305 microns) or more are paperboards; thinner structures are considered paper. Other differences are in the description of the components that make up the board. An example is the top side of the board. It is called the felt side for paper, but is often referred to as the liner side in board. The liner is usually a ply or layer of good quality fiber applied to the top side, which ultimately will be printed. The underliner is the layer in between the two external layers. Triplex boards consist of three different types of fiber plies. Multiplex boards have more than three layers. Paperboard, due to its higher thickness, has greater stiffness. When converting paperboard, scoring is sometimes necessary to avoid cracking or breaking the internal structure of the sheet. A flexographer must consider the side of the board to be printed since the finish, whether coated or uncoated, will affect ink drying and printed color.

Paperboard is usually opaque due to its greater thickness. To obtain good printing characteristics, paperboard will have a bleached chemical pulp for the liner. This also improves the appearance of the final product. Darker plies are usually used for the interior.

Printing and Handling

Like paper, paperboard is surface-sized or pigment-coated for good printability. Like paper, paperboard will absorb moisture and change its dimensions. The degree of change depends on the fibrous structure. Paperboard will often be glued and so the surface structure must be absorbent. Often the liner side of the board will be printed and the back side glued. Some grades of paperboard are known as double-lined; in this case the two faces of the web are both of high quality.

Types of Board

Can Board. A paperboard used for composite fiber drums. The cans can be used for a variety of liquids and powders.

Carton Board. A paperboard of various compositions used for the manufacture of folding cartons.

Chip Board. A board made from waste paper, and used for low-grade packaging and book board.

Coated Board. Paperboards of various grades that have a coating for high quality graphics.

Cup/Plate Stock. High stiffness paperboard containing one or more plies of virgin bleached pulp suitable for converting to paper cups or plates. The stock may be polyethylene coated before flexo printing or wax coated after printing.

Double-lined Board. A board which is lined on both sides; the outer surfaces are lined with bleached pulp. Used for high quality packaging of food and cosmetics.

Fluting Medium. A board made from semi-chemical hardwood pulp or waste paper that

is fluted and combined with liner board to produce corrugated board.

Food Board. A hardsized board for water resistance. Used for food packaging.

Frozen-food Board. Single- or multi-ply board with resistance to high moisture and water vapor. This usually is a coated board for high quality graphics.

Kraft-lined Chipboard. A board with an unbleached kraft liner on a wastepaper base.

Kraft Linerboard. A strong packaging paperboard with two-ply construction made from virgin kraft pulp. The top ply is added by a second headbox. Used in combination with a fluted medium for corrugated boxes.

Lined Board. A multi-ply board with a liner ply.

Liquid Packaging Board. Also called milk-carton board, this strong board is usually plastic coated.

Solid Bleached Sulfate. High quality board usually made with 100% bleached kraft pulp and coated on one or both sides to enhance process color printing.

Solid Unbleached Sulfate. Unbleached chemical pulp provides an exceptionally strong board with very good tear and burst resistance; frequently coated white on one side for printing.

White-lined Board. A board with bleached pulp liner and the remainder composed of a mixture of chemical and mechanical pulp. Used for food packaging.

LABEL STOCK

Label stock is very diverse and can include paper, laminates, metallic foils, plastic and synthetic substrates. It can be divided into groups like coated and uncoated, pressure sensitive or heat sensitive, gummed or self-adhesive. Plain paper labels are used extensively but generally are coated on the printing side so an adhesive can be applied to the back side of the paper. This type of label is used for large-volume items like soft drinks, wines and canned foods. These papers have a tendency to curl when printed. It is advisable to wet the back or uncoated side during printing, if an adhesive has not been applied, to help eliminate the curl tendency.

MULTIWALL BAGS

The first U.S. patent for paper-sack making machines was granted in the 1860s, when, due to the Civil War, paper replaced the difficult-to-obtain cotton sacks. Multiwall bags replaced the use of cotton sacks to ship flour and grains to distant cities. Further expansion of this type of shipping method was fueled by the shortages created by World War II. During this time the use of the multiwall bag came into wide usage. The development of a wide range of special papers to control moisture and insect infestation, plus the ability to tailor-make the shipping container to any required strength to fit difficult handling, gave a big boost to this industry. The major advantages of paper-shipping sacks are low tare weight, flexibility, ease of filling and handling, low cost, minimum storage, biodegradability and good graphics.

ENVELOPE PAPER

Envelopes are made from many paper grades, depending on end use and printing requirements. The grades can vary from bleached to unbleached kraft, to fine paper, to some label stocks. In some cases, synthetic paper is used for heavy shipping requirements. The ink must be specified for the type of paper. Most envelopes are printed in-line by the flexographic method, although a portion are still printed by sheetfed offset and later die cut into blanks. In some cases, the blanks are cut, then flexo-printed and folded.

Papers used for envelopes must have good dimensional stability, bulk and stiffness to allow for manufacture at high speed with good printability. Paper moisture is critical when heavy ink coverage is used because

excess moisture will cause the die cutting to become ragged and the sheet to lose stiffness. Formation is important when printing halftones because the higher the line screen used for the art work, the more the nonuniformity of the paper formation will be enhanced.

GLASSINE PAPER

The primary use of glassine paper is in the flexible packaging and specialty applications. It is highly dense and resistant to the passage of oil, grease and air. These properties are developed through a damp supercalendering process which produces a dense, smooth, glossy paper. The glassine sheet is an ideal substrate for heat-seal materials and barrier coatings. Polyvinylidene chloride, polyethylene, silicone, hot melts and waxes all have been applied successfully to glassine paper. Glassine paper can be modified to accept almost any ink on virtually any press. It has been used in envelopes, candy wrappers, liners for cereal and cracker boxes, potato chip bags, pie bags, medical packaging, safety jar seals, pouches, soap wrappers and photographics. Glassine can be modified for virtually any printing or strength requirements.

Physical Properties

Originally, glassine paper was highly transparent (low opacity), but exhibited low paper strength. Today glassine covers a wide range of levels in strength, color and opacity. Typically, softwood pulps of the kraft and sulfite process constitute the raw material. Depending on color requirements, the fiber may be bleached, unbleached or semi-bleached. Bleached hardwood krafts have been used, but only in small quantities because of adverse strength and refining properties.

Abrasion while in suspension during refining is used to increase the fibers' surface area. Hydroxyl groups are exposed on the fiber surface to provide sites for hydrogen bonding. Natural grease and air resistance is indicative of the amount of fiber contact developed in refining. Damp supercalendering makes the sheet denser to increase gloss and boost resistance to grease and air passage.

Glassine paper contains no fillers and is translucent (low opacity). These grades can be made at varying levels of opacity, depending on weight and end use. Various pouches, envelopes and bags are currently being printed on this unfilled or bleached glassine.

In pigment-filled glassine paper, a filler (an inert pigment such as titanium dioxide) is added to block the flow of light through the sheet. Opacity is highly desirable for candy bar wrappers and potato chip bags to filter out ultraviolet light. Opaque glassine paper varies in weight, grease and air resistance, opacity, gloss and application requirements.

Table 21 summarizes some of the physical properties of glassine paper.

PHYSICAL PROPERTIES OF GLASSINE

GLASSINE	BASIS WEIGHT (#/3000 FT^2)	GLOSS (%)	OPACITY (%)	TEAR (G)	SMOOTHNESS (ML/MIN)
Lt. Choc. Glassine	25	35–45	70–80	18–22	under 125
Candy Bar Wrap	25	45–55	55–70	18–22	under 125
Bleached Glassine	25	35–55	20–30	16–20	under 125

Table 21

Printing and Handling Characteristics

Glassine paper is handled differently from other substrates, mainly because the fibers of the highly refined sheets are very reactive to moisture. Many printers and converters use water-based inks and coatings because of the volatile organic compound (VOC) regulations. However, improvements in wet-end chemistry, refining and surface treatment has produced glassine paper of greater dimensional stability, so it is possible to obtain glassine paper that will do just as well as other substrates using solvent-based inks.

When converting glassine, the paper should not be allowed to lose any more than a minimum of its original moisture. Loss of moisture can cause brittleness and weaken web strength. As the paper loses moisture below the supplied content, a small amount of shrinkage should be expected.

TISSUE

Tissues are a special category of substrates which run the gamut from semitransparent to totally opaque. They may be made very weak and soft or surprisingly strong and hard. Tissue is almost always characteristically fairly thin, unless combined in multiple plies by embossing or adhesives. Tissue-making paper machines are among the fastest in the industry with production speeds up to 5,000 ft/min. Tissue formed on a Fourdrinier wire is further dried in a press section and against a huge (typically about 18' in diameter) heated Yankee drum. Paper towels and napkins are among tissue commonly printed by flexography using water-based ink. Producing tissue with fiber strength to resist linting during printing and maintain fluffy softness desired in the end product is a technical balancing act for the papermaker.

Corrugated Board

Corrugated packaging is the most popular and cost-effective packaging method for the transportation of manufactured goods today. Corrugated board's main purpose is to protect its contents by cushioning. It's very high strength-to-weight ratio allows this material to be strong despite its light weight.

BOARD CONSTRUCTION

Corrugated material is a composite made from paperboard components of the liner, which is the outside face, and the medium, which is the internal fluted structure that gives the board its strength There are different types of board construction as shown in *Figure* 91.

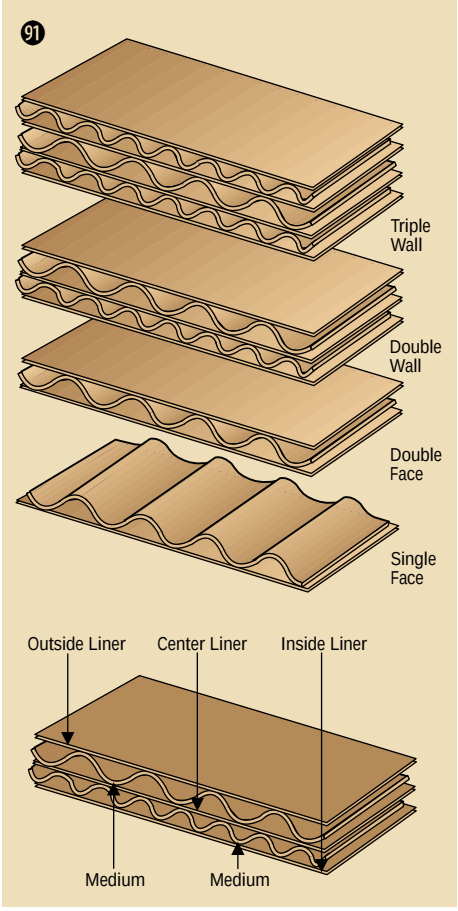
The Medium

The medium is generally made up of shorter fibers and is more flexible than the liner. It is usually made of hardwood fibers from deciduous trees and is made by the sulfite process. Resin is added to the pulp to improve wet strength. It also has a lot of stretch to it, allowing the paperboard to be fluted without cracking. Flutes are the characteristic that give the combined board its rigidity and strength with low weight and density. The fluting provides the stiffness and the resistance to crushing in the corrugated box.

Looking at the magnified view of the medium in *Figure* 92, it can be seen that there are a lot of spaces or voids in the fiber construction of the medium. These void areas receive the adhesive and serve as the anchor point for the bond between the liner and the medium. Because the medium is normally sandwiched between two layers of liner, there is no real concern for sheet appearance

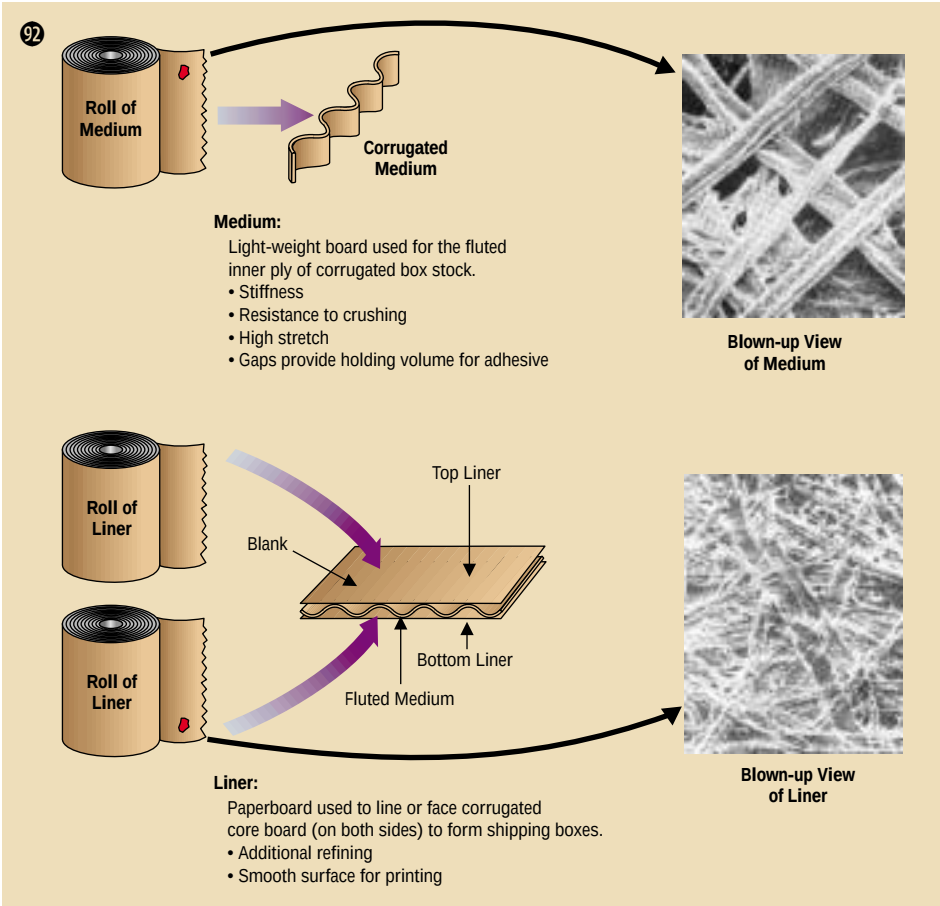
The Liner

The outside face is made of natural kraft. This kraft paper is made primarily of softwood from coniferous (evergreen or pine) trees. The pulp is made by the sulfate process from wood chips. The kraft fiber can be bleached to lighten dark components.



91 The different types of corrugated board and its construction.

92 A magnified view of the medium shows voids in the fiber construction. These void areas receive the adhesive and serve as the anchor point for the bond between the liner and the medium.



After washing and refining, the paper is made on a specialized Fourdrinier machine. The difference between this machine and normal paper machines is the use of two headboxes. About 80% of the fiber first deposited on the wire is less refined and stronger. The remaining fiber is more refined and smoother and is applied to the felt (top or finished) side of the sheet.

Two types of finishes are possible, wet finish or dry finish. The wet finish has a coating of starch applied before the calender and is smoother than the dry finish, which is uncalendered.

Mottled white liner board is made by the same method but has both kraft and bleached kraft in its composition. The top layer of bleached kraft is not enough to make a perfectly white layer but is sufficient to give an improved imaging surface for packaging applications, thus the mottled appearance and name.

Combined Board Construction

At the corrugator, the roll stocks of both medium and liner are converted into combined corrugated board and cut into sheets, which are also known as blanks. Corrugated board is manufactured in a number of constructions (*see Figure* 91). The simplest form, known as single-face, is used for wrapping fragile items, but not for making shipping containers. Double-face is the most common construction and uses a fluted medium sandwiched between two layers of liner. The double-wall and triple-wall configurations provide

much stronger and stiffer corrugated boards.

The terms “inside liner” and “outside liner” refer to the orientation of the liner with respect to the shipping container. Sometimes, a better-quality liner is used on the outside surface for improved printing. Today there are perhaps as many as 50 different specifications for the outside printing surface of the facing liner, from plain kraft to high-holdout bleached and coated material.

One of the major concerns of the box manufacturer, which also has a major effect on the printer, is the type and integrity of the board construction. Presuming that the bond is made properly between the medium and the liner, the most important factor in the value of the corrugated container is the integrity of the flutes. The flutes provide the necessary flat crush strength of the box; they provide the resiliency that absorbs the shocks of shipping and handling. It is the fluting concept that created the corrugated box industry. The flutes provide the protection to the contents of the corrugated container. If the flutes fail to support their proper load, the box fails to meet its primary function – protection.

The A-flute has the highest flute height, with a greater space between each flute. Corrugated board constructed with the A-flute is susceptible to crushing and is not suitable for heavier products. The other flutes have more and smaller flutes per foot *Table 22)*. This construction enables the corrugated packages to withstand a crushing force and still protect their contents. Smaller flutes, such as F, N and micro flutes, have been developed for the small-container market, and provide a much smoother printing surface.

DEFECTS

There are many different defects that can be generated during the corrugating process. These defects can affect the production rate of the corrugated boxes at the flexo-folder-gluer, as well as the print quality of boxes being produced. A good flexo post-print operator must inspect the corrugated board as it comes to the machine, and must be able to recognize defects before feeding them into the flexo unit. This inspection eliminates waste and saves press down time.

Most of the combined board defects fall into these major areas:

- flute integrity;
- caliper;
- washboarding;
- blank size; and
- warped board.

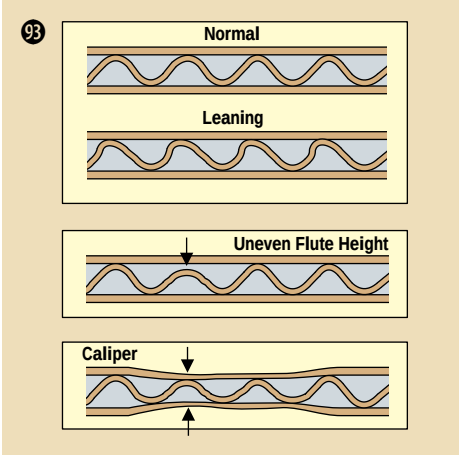
Flute Integrity

A major defect of corrugated board, and one that all operators should be aware of, is flute integrity. The construction of the flute and the bonding to the linerboard play a large role in the production of quality boxes. Some of the flute problems created at the corrugator include leaning, uneven heights, and crushed flutes, which affect board caliper (*Figure* 93).

TYPICAL FLUTE SPECIFICATIONS

FLUTE DESIGN	FLUTES/ LINEAR FOOT	HEIGHT OF FLUTE
K	24.6	0.260
A - Standard	35.4	0.177
A - Optional	37.7	0.158
C - Standard	39.4	0.142
C - Optional	38.6	0.140
B - Standard	46.9	0.098
B - Optional	46.9	0.097
E - Macro	84.7	0.053
E - Micro	89.9	0.044
F	128.1	0.030
N - Standard	170.0	0.020
N - Optional	140.0	0.020

Table 22



93 The construction of the flute and its bond to the linerboard plays a large role in the production of quality boxes. Some of the flute problems created at the corrugator include leaning, uneven heights and crushed flutes, which affect board caliper.

94 Washboarding is a physical fault in which the liners, instead of forming a flat, smooth outer surface, partly follow the contours of the fluted medium to produce alternate ridges and valleys

Leaning flutes fail to provide sufficient flat crush. Insufficient flute heights cause problems with bonding, or if they do bond, they cause low spots in the board, places where printing plates cannot touch without crushing other flutes.

Crushed flutes are flutes that have been smashed, resulting in the failure of the box to hold its contents or to stack properly. Crushing also results in low caliper and missing print areas.

Caliper

Caliper is the measured thickness of the board. The caliper differs with a change of flute size and with the grade of paperboard used in construction of the board. The flexo operator must always check the board caliper of each order. Blanks have to fit properly through the feed gates (not too tightly, or so loosely that more than one blank can pass through at one time). As the blanks proceed through the machine, they are pulled by rolls and pull bands that have high coefficients of friction. It is necessary for the rolls and pull bands to apply a slight pressure on the blank so that they maintain control of the blank as it is pulled through the machine. If there is too little pressure applied to them, the rolls and pull bands lose control of the blanks, which results in skewed or misfed blanks into the next section of the machine. When the board goes into the printing section, excessive pressure on the board embosses the printing, making it unsightly and, at the same time, crushing the flutes.

Washboarding

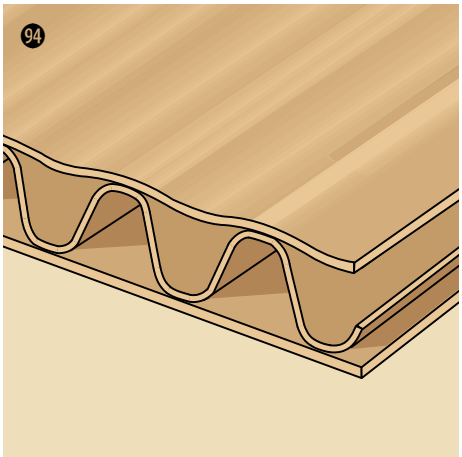
Washboarding is a physical fault in which the liners, instead of forming a flat, smooth outer surface, partly follow the contours of the fluted medium to produce alternate ridges and valleys (*Figure* 94). The lighter the weight of liner used, the more likely that washboarding will be present.

Washboarding makes printing very difficult because of the uneven surface. Washboarding makes it necessary to increase printing-plate impression, which crushes the board with resulting loss of caliper, flat crush and print quality.

Blank Size

Board length is very important for reducing waste, eliminating problems in the flexo-folder-gluer, in die cutting, and for box-making accuracy. Boards that are cut too long at the corrugator result in waste. The waste comes from the scrap that is trimmed off at the flexo-folder-gluer or die cutting machines. Boards that are too short will skew in the flexo unit, causing jams in the machine. Short boards in a flexo-folder-gluer do not form good boxes because the glue tab will not overlap the side panel properly, thus the tab will not hold and the box will not form properly.

There are two causes of short boards. The obvious one is that the board is cut too short at the corrugator. The other is improper curing. When a board comes off the corrugator, it is still warm and contains moisture, feeling much like a loaf of bread that just came out of the oven. A hot board also affects ink transfer and drying in the printing units. It is better to wait and let the boards “cure” in the “Work in Progress” area before using them. Waiting allows the boards to normalize and



cool down to room temperature. As the warm, moist boards cool, they tend to shrink.

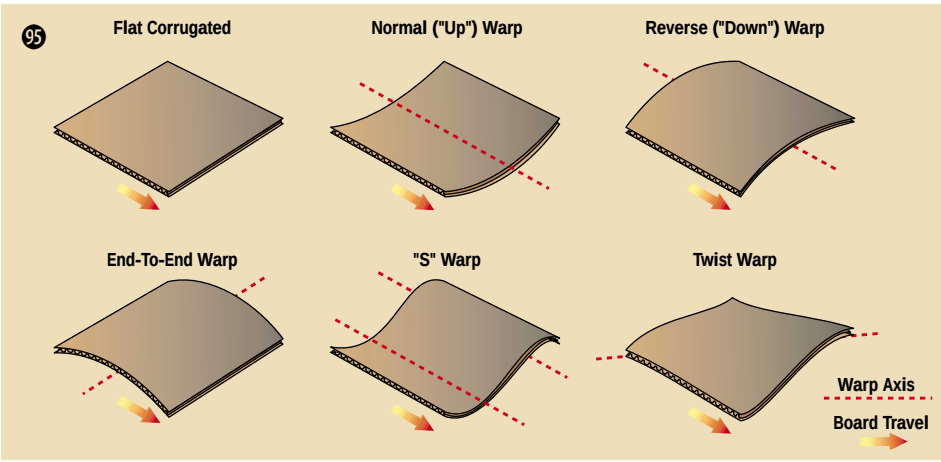
Warped Board

Warped board (*Figure* 95) in corrugated postprinting, variability of the substrate is the greatest of any industry. As described earlier, double- or even triple-wall combinations of flutes can be manufactured. The outermost liner (the double-backer liner) is the one that receives the printing. Therefore, depending on the flute profile chosen in postprinting (single-wall, double-wall, etc.), the printer is compelled to compromise to account for caliper variations, wash boarding, surface pH variation in the area where the corrugator starch is applied and excessive warp on sometimes incredibly stiff sheets.

Since there are no exact specifications as to the composition of the printing liner other than mechanical strength characteristics, the printing surface can be extremely absorbent or high-holdout, or it can be extremely hard or very soft. Since the fluting material also follows rules that have nothing to do with printability of the liners it supports, postprinting presents many challenges.

So, what is the best corrugated substrate to print on flexographically? There are many desirable quality considerations, some of which are:

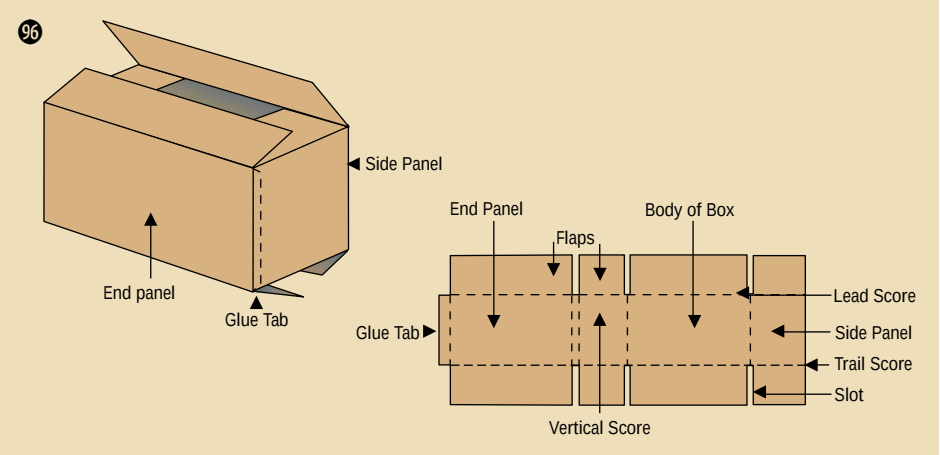
- caliper of print liner a minimum #38 (38 lb./1,000 ft.^{2});
- smoothness of the finish (highly calendered);
- medium clay-coating or solid-bleached sulfite;
- absence of loose fibers;
- medium to smallest flute profile (B down to N);
- good quality medium-minimum #24 (24 lbs./1,000 ft.^{2});
- flat sheets;
- caliper-correct sheets;
- no washboarding;
- consistency in hue and brightness;



94 When corrugated liners exhibit this "ridging" effect, it becomes necessary to compensate for the uneven surface by increasing printing-plate impression. This crushes the board, yielding other unfavorable results: loss of caliper and print quality.

95 Variability of corrugated substrates accounts for different warpness.

96 The regular slotted carton (RSC) is the standard form of shipping container with top and bottom flaps



- dust-free sheets; and
- controlled moisture content.

The wish list of the printer could go on and on, but the corrugated board and box manufacturer has economical constraints and even the preferences mentioned here hardly ever exist together in a corrugated plant. The quality-conscious postprinters of today deserve a lot of credit for past and current achievements.

BOX CONSTRUCTION

There are many different types and styles of boxes as well as special construction displays produced in the corrugated postprint industry. These box constructions may be broken down into two major categories: slotted cartons, lids and trays, which are generally produced on an in-line flexo-folder-gluing machine; and special folded boxes and displays which require die cutting.

Slotted Cartons

The regular slotted carton (RSC) is the standard form of shipping container with top and bottom flaps. *Figure* 96 shows how the leading and trailing slots have been cut into the blank sheet to form the box flaps. End- and vertical-scores are impressed into the blank to assist in folding the flaps. In this instance, the lead and trail scores are impressed into the blank at the corrugator and the vertical scores are impressed on the flexo-folder-gluer. The glue tab is cut into the blank for attaching the end panel to the side panel.

Other types of containers produced on the flexo-folder-gluer include the half-slotted container (HSC) and trays, which are produced two at a time. The majority of flexo-folder-gluer machines have limited die-cutting capabilities.

Die-cut Blanks and Containers

Corrugated materials that require die cutting are generally produced on a sheet-fed corrugated flexo printer equipped with either a rotary or a platen die-cutting station. The die-cut station may be in-line or off-line with the printing. Off-line die cutting is preferred when printing high quality multicolor graphics and halftone process screens.

Laminates

The primary label is important in packaging decoration because: it differentiates the product from its competitors, creates perceived value to the consumer and fights for attention on the shelf at the store. Pressure-sensitive coated films and paper serve this growing market.

PRESSURE-SENSITIVE COATED FILMS

The packaging-decoration market is a $3-billion market that continues to grow. Within this market, pressure-sensitive film is the fastest growing segment. In 1996, heat-transfer technology accounted for less than 5% of the packaging-decoration market, as did shrink-sleeve and in-mold labeling. Pressure-sensitive represented 40% of the market, while wet glue made up the remaining 60%

Pressure-sensitive film for packaging decoration improves the overall aesthetics and durability of the labeled container. It looks as good on the day the finished product is used, as on the day it was purchased. It is also a response to the advances made in printing and application technologies. It contributes to lower total applied cost of the package. In beverage applications, it also fits in with environmental concerns. The label can be made of the same material as the bottle, so that the entire package is recyclable.

The outlook for pressure-sensitive primary labels in the personal care category is for medium growth. The market has seen an emergence of commodity products and a need for high performance coupled with low cost. Growth opportunities lie in secondary labeling, package reduction, couponing and private brands.

The outlook for the household chemical market is higher than in personal care, with an anticipated growth in the foreign markets. Opportunities lie in the thinking that clear containers are good, and in the push for recycling/refilling.

The food and beverage market continues to see growing use of pressure-sensitive films because this is a relatively mature industry. Growth is in the glass packaging/clear containers, private brands and product line extensions.

The pharmaceutical market is currently growing slowly, but will increase due to the aging population. Opportunities will be found in tamper-evident packaging, the need for more information to be provided with the product, and in shelf competition.

FACESTOCKS

Currently, 90% of the films used in packaging decoration are vinyl, polyester, polystyrene, polyethylene and polypropylene. Films are available either corona-treated, print-treated or top-coated to give the printer ease in ink selection regardless of the type of film.

Polyvinyl Chloride (Vinyl)

Two different processes are used to manufacture vinyl films for pressure-sensitive applications: calendering and casting. Both processes use the same basic raw materials: polyvinyl chloride resin, plasticizer (for flexibility), UV stabilizers (for outdoor use), antioxidants (for film processing), and colorants. It is the additives that are migratory

and will bloom to the surface and can make printing difficult. Shelf life of the vinyl is dependent upon the quality of these additives, and storage conditions.

Calendered Vinyl has an outdoor life of one to five years, and is typically available in thicknesses of 3 to 10 mils. Vinyl has high tear resistance, good dimensional stability, and is a squeezable film. Unfortunately, it is prone to label shrinkage (especially if conditions approach the temperature at which it was calendered). It is fairly expensive, and has low stiffness, which can cause dispensing issues. Because of the way it is processed, vinyl has a high tensile strength and lower elongation in the machine direction than in the transverse direction. This attribute can manifest itself in end-use applications, or on-press, especially if exposed to high temperatures.

Cast Vinyl has an outdoor life of five to seven years, and is available only in thicknesses of 1.5 to 3.0 mils. Its biggest advantage over calendered vinyl is its ability to conform over rivets, making it ideal for large signage applications. Unfortunately, it is more expensive than calendered vinyl.

Nontop-coated vinyl can be printed only using solvent-based and UV-curable inks. Screen inks typically have the heaviest ink laydowns, and therefore contain the highest amount of solvents or monomers. In order to be printed flexographically, as well as via letterpress and offset, vinyl has to be top-coated. The topcoat is a low-solids coating applied to the film, analogous to a primer coat.

Polyester

Polyester is manufactured with polyethylene terephthalate resin (to impart toughness to the film) and colorants, such as titanium dioxide. It is manufactured by the cast tentering method, which gives the film its biaxial orientation as well as its high tensile strength in both the machine and the transverse direction.

Clear polyester has an outdoor life of two to three years, and is available in thicknesses ranging from 1.5 to 7.0 mils. Polyester is a very stiff film, which makes it easy to dispense, is dimensionally stable (because of the cast/tentering) and has high solvent and temperature resistance. It is not a conformable film (cannot be used in squeezable applications) and is very expensive.

The solvent resistance, which permits polyester to be utilized in harsh environments, makes it very difficult to print. Nontopcoated polyester is printable only with solvent based inks. If it is topcoated, it can be printed with water-based and UV-curable inks as well.

Polystyrene

Polystyrene is produced with crystalline polystyrene resin or rubber-modified polystyrene (to give it some flexibility), and is available as clear, clear matte, white matte, or metallized. It is usually produced in the same way as polyester and consequently can react similarly in its end use or on press.

Polystyrene is not intended for outdoor use, and is available in the 2- to 10-mil thickness range. It is a very economical film that can be competitive with paper. Its inherent stiffness makes it easy to die cut and dispense. Unfortunately, it is solvent-sensitive, and has low-heat and tear-resistance.

Without some type of surface modification, be it corona treatment or topcoat, it is usually printed only with solvent-based ink systems. After the surface is modified, it can be printed with water-based and UV-curable systems as well.

Polyethylene

Polyethylene historically has been manufactured by the blown-bubble method. It has a limited outdoor life and is available in a wide range of colors, typically in thicknesses of 2 to 4 mils. It has high tear resistance, a smooth surface, and is very conformable.

The clarity is poor and it can be difficult to die cut and dispense.

Without surface treatment, polyethylene has a surface energy of approximately 32 dynes which make it difficult for inks to wet out on, let alone adhere to. After applying a topcoat, it is printable via screen, flexo, offset and letterpress.

Polypropylene

The most talked about film in the polyolefin family is biaxially-oriented polypropylene (BOPP). It is an indoor film typically manufactured at 2-mil thickness. It has excellent optical clarity and high solvent resistance, but can be difficult to die cut.

Considerable time has been spent in developing topcoats for polypropylene that can survive end-use requirements, including pasteurization, as well as compatibility with UV flexo inks.

PRESSURE-SENSITIVE ADHESIVE SYSTEMS

Adhesives must have the proper balance of tack, peel and shear properties necessary for the intended end use. Tack is a measure of how quickly an adhesive wets and establishes surface contact to the material being bonded. Peel is a measure of the force required to break the bond between the adhesive and the surface to which it is applied. Shear is the measure of the adhesive's inner cohesive strength.

The ideal adhesive will offer short-term repositionability (up to 24 hours after application), moderate term removability (24–72 hours) and long-term permanency (beyond 72 hours). This allows for rework opportunities either on-line or off-line in the event of misapplied labels. This is a lot to ask of an adhesive system considering the variety of resins used in bottle manufacturing, their respective surface energies, and the tear resistance of the films previously discussed.

High-speed automatic label application requires moderate to high initial tack to prevent labels from falling off during the application cycle. Moderate-to-high shear properties are important for squeezable containers to prevent tunneling of the label during deformation of the labeled container.

For the increasingly popular no-label look, the adhesive must have water-like clarity (the liner selection is also a contributor in this application). For many applications, the adhesive must also be resistant to water and humidity. In newer applications, the same adhesive may need to be able to tolerate wide temperature requirements from pasteurization temperature to water immersions.

Most high-performance adhesives for pressure-sensitive labeling use solvent-based acrylic chemistry. Recent advances in adhesive technology, plus environmental concerns, allow for the successful use of high-performance emulsion acrylics in many applications. Rubber-based adhesives find their place with opaque label materials and with low-surface energy containers.

Choosing a Release Liner

A release liner has four basic functions:

- carry other label components through the converting process;
- protect the adhesive;
- provide a die cutting base; and
- act as the label dispensing system.

Historically, the choices for release liners were extremely limited. Bleached, calendered kraft papers in the 40# to 50# basis weight range with silicone coating on one side were practically universal in use. With demand for a stronger, more tear-resistant liner, plus the increase in no-label look applications, a 150-gauge polyester liner was developed. Today, options include biaxially oriented polypropylene and extrusion-coated natural kraft paper.

PRESSURE-SENSITIVE PAPER

Paper-based, pressure-sensitive laminates are the second most popular substrate used in printing. After label die-cutting tools appeared in the mid-1930s, the category began to expand from simple price stickers to sophisticated, converted products that have met the decorating and marking needs of practically all segments of the industrial, commercial, consumer and medical markets.

Better paper stocks with outstanding flexographic printing capabilities, a broad range of adhesives to adhere to a wide variety of materials and release liner technology for high-speed converting and processing have all helped make these materials popular. Among the markets that prefer them are consumer product primary labels, inventory control and order-picking systems, printed stickers, coupon promotional labels and many other familiar devices.

From about $500 million a decade ago, the value of converted pressure-sensitive papers sold today exceeds $1.6 billion. They are produced in roll form and supplied to flexo printers sheeted, in uncut master rolls or in specified roll widths. Master rolls can be up to 78" wide, and selling price is based on cost per msi (thousand square inches).

Pressure-sensitive paper substrates are limited to 78" in roll width, up to 15,000' in roll length, with core diameters of 3" to 6". Gloss, semi-gloss and matte finishes of tag stocks, fluorescent, colored papers, in addition to latex impregnated, laminated and solid foils, metallized papers and thermal-sensitive imaging stocks are all suitable for flexographic printing.

Physical Properties

Substrate thickness is usually measured in mils and, depending on the material, can range from 2.5 mils to 10 mils. Basis weight is calculated in pounds per ream (25" x 38", 500 sheets) and varies by material type from 30 lbs. to 150 lbs. per ream.

Flexibility and gloss are the strength of these substrates, with a facestock's luster ranging from matte to high gloss. Smoothness can have a big impact on print quality with smoother sheets usually providing more uniform ink coverage. For applications that call for computer imprinting and smudge resistance, a rougher, uncoated sheet, or one with smudgeproof coating is best. Low-surface-strength facestocks are most efficient where label destructibility is needed, but the substrate must be strong enough to withstand converting. When choosing a facestock, the label shape, web width, converting equipment, pressure-sensitive adhesives and release liners should be considered.

Standard paper stocks can't take much exposure to moisture without a clear coating of varnish or over-laminate. Of the paper facestocks, those which are latex and resin impregnated have the best moisture resistance. Generally, uncoated facestocks or those with smudge-proof coatings are more suitable for computer applications. The degree of smudge resistance can be influenced by the type of imaging method, the printer and the type of ink ribbon or toner required.

Printing and Converting Characteristics

The paper facestocks used in pressure-sensitive work have many of the printing characteristics of other paper substrates. Because the whole pressure-sensitive construction, including facestocks, adhesive and release liner, is handled by flexo equipment, it is important to look at how each component relates to the final converting step of die cutting and stripping. As mentioned before, the facestock has a number of traits that determine the quality of printing and contribute to the performance of the whole construction. Key properties, which determine the ability to die cut and strip any material, include tensile strength, tear and elongation.

The facestock's coating is extremely important to the printer because it dictates ink receptivity, holdout and character definition. Coatings can be used to change properties such as opacity and gloss, and can have a direct effect on die life. If coatings are abrasive, dies wear out faster. Some papers are filled with abrasive materials that can affect paper strength. For example, a true 40# to 45# basis weight sheet of paper can be turned into a 60# glossy facestock by using a coating. In this case, the coating accounts for a good deal of the basis weight. The bottom line is the direct effect on internal properties, die cutting and stripping.

The release liner is just as important in label production as printing quality and die performance. Most liners are made from a bleached, supercalendered kraft paper. Other popular materials are unbleached brown kraft and film liners ranging from extruded films to coextruded combinations. All liners are designed to withstand die cutting and automatic label dispensing.

Along with internal strength, two other critical features of the release liner are needed for the successful manufacture of printed labels. Density is needed to withstand the die strike and to maintain the proper holdout of the silicone-release coating. Insufficient holdout can cause release problems where the liner and facestock do not readily separate. This condition can hinder diecutting and stripping. Another vital factor is liner thickness. Uniform thickness ensures that the die will make a clean cut through the facestock and adhesive coating without fracturing the release coating or cutting into the release liner.

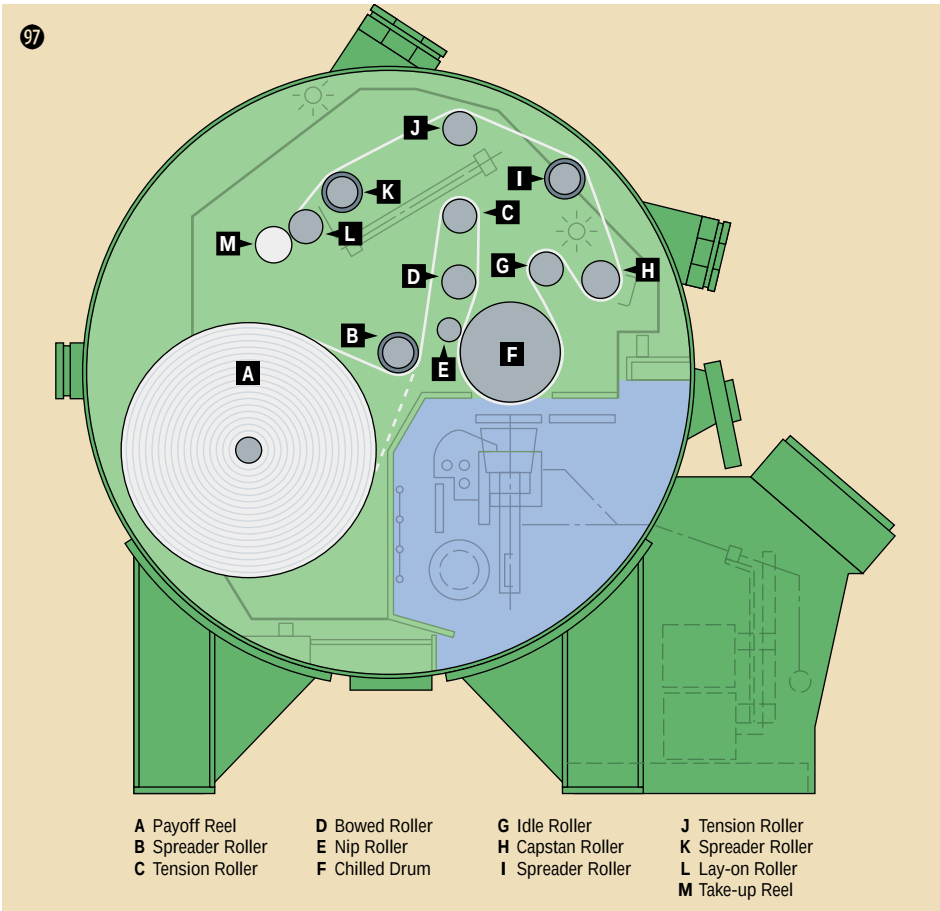
Rotary dies are tooled to the following liner thicknesses: 40# liner is usually 2.4 mils thick with a given tolerance of 0.3 mil; 50# liner is normally 3.5 mils thick with the same tolerance. The release coating is critical to pressure-sensitive construction and relates directly to converting performance. The characteristics of silicone-release coatings are determined by a complicated chemistry formulated to provide a specific range of release that is often dictated by the construction and the application itself. These coatings are designed to withstand normal die impact, but can fracture under a die that has been improperly made or adjusted. Fracturing the liner with too deep a die cut will expose paper fibers in the liner and allow the adhesive to flow in. The result is a label partially bonded to the liner.

Primers are sometimes used with facestocks to prevent certain adhesives from migrating through the paper and for sealing the open pores of some papers to provide better anchorage for the adhesive. Properly applied primer coatings generally are not a factor in printing or converting quality. A number of adhesives are available for permanent, removable, cold-temperature and specialty printed labels. These can be solvent-based, emulsion or hot melt.

Foils

Foils are produced using vacuum metallizing. In this process, a thin layer of metal, usually aluminum, is placed on a substrate, typically a flexible film or paper. This is done in a vacuum chamber, usually by resistance-heated evaporation sources (*Figure* 97). This highly reflective coating is used for the aesthetic and barrier traits the aluminum can provide. Among the users for these metallized materials are thermal insulation, labels and decals, capacitors and a variety of decorations. One of the largest single markets is flexible packaging where shelf appeal and barrier properties are important.

Ordinarily, metallizing machines are cylindrical vacuum chambers that can process substrates up to 120" wide. Reel diameters are as high as 40" (OD). Because the metallizing process takes place in a vacuum chamber, it happens one reel at a time and, for economic reasons, as large a reel as pos-



97 Foil, a thin layer of metal on top of a substrate, is produced in a vacuum chamber.

sible is used. This is the reason for the trend in recent years toward machines that can handle wider substrates and larger reels.

METALLIZED FILM

In the metallizing process, reel diameter is limited and turret rewinds and unwinds can't be incorporated in the vacuum chamber. For these reasons, it is more economical on a per unit area basis to metallize thin films. The usual cost for metallized 48-gauge polyester for flexible packaging is under $0.055/msi, where msi stands for one thousand square inches.

Physical Properties

The aluminum layer on metallized film is so thin, usually 20 microns, that the mechanical properties of the film aren't changed. In other words, metallized packaging film, such as OPP, is just as flexible as the unmetallized type.

Metallizing a plastic film is a very economical way to enhance its barrier properties, and the amount of metal used can vary. The amount usually is measured and controlled by monitoring the film's opacity in optical density units. The barrier property depends on the metal's thickness or optical density. At a typical packaging density of 2, oxygen permeability through 48-gauge polyester is improved by a factor of 100 by metallizing. On coextruded OPP, the improvement would ordinarily be a factor of 80 to 3. Similarly, improvements by a factor of 100 can be achieved in moisture permeability on 48-gauge polyester. For light-barrier properties, both visible and UV transmission is reduced to less than 1%.

Printing and Handling Characteristics

Much of the metallized film used in printing is a laminate, with the metal layer sandwiched in the middle. In this case, the actual printing occurs on the unmetallized surface and the inks to be used should be the right ones for that substrate (OPP, polyester, etc.). In cases where printing on metallized surface is required, standard inks normally can be used, although some metallized substrates (paper and some grades of OPP) can have a surface "poisoning" effect that will harm ink adhesion, unless printing is done shortly after metallizing. Usually the metallized substrates are primed to provide a stable surface with good printing characteristics.

METALLIZED PAPER

Since it was introduced commercially in North America, metallized paper has made significant advances in food and beverage labeling and packaging. It is being used to label nearly every type of glass and metal container and is starting to find application as a packaging material. Prime label applications include liquor, wine, wine coolers, beer, paint cans, soap wrappers and personal care products.

Following rapid growth in the 1980s, the metallized paper industry began a period of consolidation. The primary markets continue to be giftwrap, glue-applied labels, pressure-sensitive laminators and bags. Market size in 1995 was estimated at 85–90 million pounds.

Physical Properties

Packaging engineers like metallized paper because of its printing, finishing and application advantages over foil laminates. The paper quality determines the labeling advantages. Manufacturing metallized paper is complicated, from the substrate selection to final remoisturing. These papers provide the top quality appearance of foil with the production efficiency of plain paper. Physical properties are summarized in *Table 23*.

Printers especially like the fact that metallized paper lies flat during printing and resists mechanical and humidity-induced

PHYSICAL PROPERTIES OF METALLIZED PAPER

END USE	BASIS WEIGHT #/REAM[a]	BASIS WEIGHT g/m^2	CALIPER MIL	TENSILE MD[b]	TENSILE CD[c]	STIFFNESS MD[b]	STIFFNESS CD[c]	MULLEN PAL
Giftwrap	35	57	2.1	2	29	66	40	12
General label	43	70	2.7	27	40	74	41	14
General label	58	94	3.2	32	60	150	22	22
High Gloss	56	91	3.4	34	0	150	23	23

[a] Ream of 500 sheets, 24" x 36"
[b] Machine direction.
[c] Cross-machine direction.

Table 23

curl. Foil laminates often curl and jam press and production lines with misfeeds and flagged labels. Metallized paper's tendency to lie flat also boosts press speed and die cutting efficiency to similar levels as those of plain paper. The same holds true at high-speed labeling lines.

Printing Characteristics

Most metallized papers have a print coat, which make them compatible with both solvent- and water-based inks. Plain-paper inks need little adjustment to print metallized papers; they even strip and dry as easily as with plain paper. Because of the advantages outlined above, metallized paper can be introduced into the pressroom without the learning curve that usually accompanies an unfamiliar substrate.

CLEAR METAL

The metallizing industry has made significant strides in producing high-barrier, "clear" films. Both SIO_x and ALO_x films have been finding new market applications. SIO_x films have been used in several high-end medical applications.

Films

Films represent a large and diverse class of substrates used in the flexographic packaging industry. These clear, plastic substrates fall into four classes: polyvinyl chloride, polyester, polypropylene and polyethylene.

POLYVINYL CHLORIDE (PVC)

PVC is a unique and popular packaging material because of its ability to accept and respond to a range of additives. This film is commonly referred to as vinyl. It can be blown, cast, or extruded. Thicknesses of sheets range from 0.0004" to greater than 0.004". The films are inherently odorless, tasteless, chemical resistant and waterproof. In the early years of use they were seen primarily as cheaper alternatives to textiles. Today, vinyl films are versatile and cost effective for uses including wall covering, blister packaging, tapes and labels, waterbeds and floppy-disk jackets.

The ingredients used to manufacture vinyl depend on the intended application. PVC resins are the major component of the films and are made by polymerizing vinyl chloride monomer using suspension, emulsion or bulk polymerization. Plasticizers are the major additive and impart flexibility. Food packaging requires the use of an FDA-approved plasticizer. The next ingredients are heat stabilizers whose functions are to prevent discoloration during processing. Further additives are lubricants and esters of multifunctional alcohols, which impart antifog and antistatic properties. Additives or fillers,like talc or clay, as well as amides, are added for slip and antiblock properties. Pigments are added for color.

Physical Properties

For printing, especially labels and decals, most vinyl films are made by calendering. This process is best suited for high-volume production and requires excellent surface quality and uniform thickness control. It can produce films up to 84" in width. For thicknesses below 0.002" casting is used. Casting works best for small volume specialty applications requiring excellent clarity, low strain and uniform strength in both directions. Although vinyl films have a broad flexibility range, the typical physical properties are tensile strength of 3,400 to 5,000 psi, elongation of 50% to 200%, and Sheffield smoothness of less than 10 on the face side.

Printing and Handling Characteristics

The ability to print with both solvent- and water-based inks without surface treatment has figured prominently in both meat and poultry packaging. A recent development has been the imprinting of a safe-handling label mandated by the USDA, on the film itself. This ensures 100% compliance at the store level on all packages of raw meat.

Although not always necessary, a primer coat may be used in some applications. Corona treating of vinyl films to improve surface tension is available but not widely used.

POLYESTER

The unique mechanical, thermal and chemical traits of bi-oriented polyester (polyethyl-

ene terephthalate or PET) film is making it more and more the substrate of choice in many flexographic applications. When a substrate must be tear-resistant, stable in heat and humidity, retain sheet flatness and clarity, and have a good moisture and or oxygen barrier, polyester film is the right choice, whether the printed result is a throw-away package or a long-life graphic.

Once a product with generic types, PET film today has many forms designed for specific end uses. These forms may feature a particular surface chemistry, roughness, clarity or slip. Also, there are special variations, such as matte, heat sealable, thermoformable, shrinkable, low shrink and barrier-coated.

The primary uses for polyester film include: photography (X-ray, aerial, phototool), magnetic recording (computer, audio, instrumentation, video) and reprographics (duplicating microfilm, engineering, layout), but packaging and printing uses are the fastest-growing. Most photographic PET base and some magnetic and reprographic base is produced by plants belonging to the coating firm. Virtually all other uses are supplied by industrial film producers. (*Table 24*).

Standard area yield factors for polyester film are shown in *Table 25*. Thicknesses above and below this range are common in some end uses, especially electrical and magnetic recording. Thicknesses listed are the ones commonly used in flexographic printing.

Roll widths of 60" to 70" are common in many end uses and roll diameters are very often 24" to 28", with weights of 1,200 lbs. to 2,000 lbs. With flexo applications, smaller rolls are more common, with 6" diameter cores virtually the standard, though 10" is often supplied for other uses.

END USES OF PET FILM IN U.S. ESTIMATED

APPLICATION	% OF CONSUMPTION
Photographic	26.7
Magnetic Recording	15.2
Reprographics	13.4
Packaging, including metallized	11.5
Printing/labels/release coating	3.8
Electrical	3.2
Glazing/specialty vacuum coating	3.2
Transfer printing/roll leaf	2.7
Pressure-sensitive Tape	2.5
Building Products	2.5
General laminates/stationery	1.9
Miscellaneous	13.4
TOTAL	**100**

Table 24

AREA YIELD FACTORS FOR POLYESTER FILMS

	AREA YIELD	
GAUGE/MICRONS	IN^2/LB	M^2/K
48/12	41,250	58.7
75/19	26,400	37.6
92/23	21,500	30.6
142/36	13,900	19.8
200/50	9,900	14.1
300/75	6,600	9.4
400/100	4,950	7.0
500/125	3,960	5.6
700/175	2,830	4.0

Table 25

Physical Properties

Depending on the requirements, PET film can be manufactured with a variety of physical properties, as shown in *Table 26*. Special films such as formable or heat-sealable may have different properties, and the manufacturer can supply data on these. Unless otherwise indicated, all values in *Table 27* are at 73° F (23° C) and 50% humidity.

Printing Characteristics

Polyester film's chemical stability comes from its basic polymer, polyethylene tereph-

PHYSICAL PROPERTIES OF PET FILM

PHYSICAL PROPERTY	NORNAL RANGE
Tensile Strength, at Break	20,000 psi maximum
Elongation at Break	150% maximum
Shrinkage	
Low Shrink	less than 1%*
Standard	1-5 Maximum*
Shrinkable	Over 30%**

WATER VAPOR AND OXYGEN PERMEABILITY	THICKNESS (GAUGE)			
Maximum Uncreased, Uncoated	**48.0**	**75.0**	**92.0**	**142.0**
Water-vapor Transmission (g/100 in^2/24 hours)	3.5	3.0	2.5	2.0
Oxygen Transmission (cc/100 in^2/24 hours)	10.0	8.0	5.0	3.0

* *150° C, air unrestrained, 30 mins.*
** *100° C, water, 1 min.*

Table 26

thalate (PET), a polymerized ester normally formed in a condensation reaction of ethylene with terephthalic acid or dimethyl terephthalate. The natural chemical inertness of this polymer is further enhanced by two-way stretching (bi-orientation) and high-temperature crystallization. Orientation increases tensile strength, flexibility, tear strength and pinhole resistance, while crystallization boosts thermal stability and barrier properties.

Chemical inertness, one of PET film's major strengths, makes it hard to coat and print because of solvent and water resistance. Manufacturers have attacked this problem by changing the surface chemistry without hindering the thermal and mechanical characteristics. While these changes do not make PET film as easy to print on as some other substrates, they do give the printer a wider choice in both inks and processing conditions.

The earliest of these surface modifications was corona treatment to allow easier wet-out. Next came resin treatments that worked well with solvent-ink systems but resisted water-based inks. Very recently, polymer treatments were developed to allow the use of water- and alcohol- ink systems. These surface modified films are shown in *Table 28*.

While PET film's physical traits make it ideal for flexo printing, some precautions are in order, especially if press operators are used to running paper or more extensible films, such as vinyl or polyethylene. For example, the film has a residual shrink tendency that increases alarmingly as the temperature rises. Needless to say, this can affect such processing parameters as neckdown and tension. In addition, rising temperature greatly reduces tensile strength. This can cause the film to stretch under press tension, affecting register and promoting wrinkles and creases. PET film is quite stable at processing temperatures up to 180° F. But once into the 180° F to

SURFACE-MODIFIED FILMS

GROUP	DYNES	COMMENT
Plain Film	40-43	Polyester Inks. Primer/Top coats required.
Resin Treated	43-45	Solvent-based Inks. Primer/top coats not required: treatment does not fade with time.
Corona Treated	50-54	Water/Alcohol inks. Mild solvents;treatment fades with time.
Polymer Treated	58-63	Water-based inks. Primer/top coat not required; treatment does not fade with time.

Table 27

98 Polypropylene usage in the United States.

220° F range, the film goes into an expansion-to-shrinkage transition that can cause unpredictable web-handling problems.

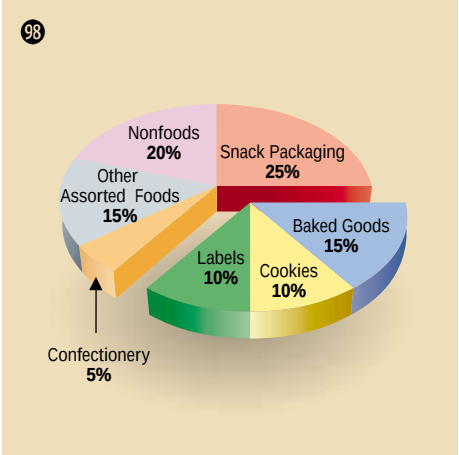
POLYPROPYLENE

This section will focus on oriented polypropylene or OPP film. The volume of non-oriented polypropylene film used is about one fourth that of OPP film. It replaces low-density polyethylene (LDPE) film in applications for which its better clarity, stiffness and barrier properties justify the extra cost. Non-oriented polypropylene film, sometimes called cast-polypropylene film, has physical properties and printing characteristics similar to those of LDPE film. The inks and printing practices used with cast-polypropylene film are the same as those for LDPE (see section on LDPE for details.)

Estimated world usage of oriented polypropylene (OPP) for 1997 was approximately 4 billion pounds, with 20% of it being consumed in North America, 31% in Western Europe and 38% in the Asian-Pacific Region. The largest portion of the 800-million pound North American market is snack packaging (25%). Other major areas include baked goods (15%), cookies (10%), labels (10%), confectionery (5%), other assorted foods (15%) and nonfoods (20%) (*Figure* 98).

Polypropylene film changed little between 1960 and 1980. But in recent years. many new products have appeared and OPP film has expanded into a large family of materials, some of which call for special printing considerations.

Recent additions to this family include a number of composite films in which OPP is the core, with thin, functional layers of various polymer resins coextruded or applied by coating. Opaque films, which have a foam-like structure, and metallized films are two relatively new additions that have achieved substantial volume. For a view of polypropylene film beyond what this section covers,



the reader is referred to The Encyclopedia of Polymer Science and Engineering, Volume 3.

The yield of 1 mil (0.001") OPP film is 30,600 square inches per pound, compared with 19,500 square inches per pound with cellophane. PP's specific gravity of 0.91 g/cc, the lowest among plastic films, accounts for a yield significantly higher than that of any other clear, oriented plastic film. PP resin's high yield and relatively low cost per pound make it the most cost-effective film of its kind for flexible packaging. Depending on thickness and structure, it ranges from $0.05 to $0.10 per 1,000 square inches.

OPP film is available in thicknesses from 40 to 400 gauge (0.0004" to 0.004"). Essentially, all printed OPP film ranges in thickness from 0.00045" to 0.0012" (0.45 to 1.2 mil). OPP film is sold by the pound, and comes on 3" or 6" inside diameter cores. Widths depend on the type of film. Several types are available from tenter lines that yield widths of about 200".

Physical Properties

Most of today's OPP film is clear, biaxially oriented, slightly formulated homopolymer not significantly different from when it was first introduced in 1960.

Polypropylene's physical characteristics come from the catalyst and reaction conditions used to produce it. They determine

whether the polypropylene chains will be highly symmetrical and, therefore, highly crystalline and easily oriented. An asymmetrical chain will crystallize only slightly and will not be capable of high orientation or great strength.

Orientation, OPP film's distinguishing trait, means that its long, chain-like molecules have been aligned in the machine and transverse directions. In a linear orientation, the aligned molecular chains form highly symmetrical matrices known as crystalline spherulites, fitting together in a multilayer, repeating configuration of juxtaposed chains to create great cohesion. This keeps the ranks closed and resists the penetration of solvents and certain vapors, including water vapor, giving OPP film its excellent barrier properties.

Orientation also accounts for other good characteristics. The high directional-tensile strength and modulus of a crystalline-oriented film, compared with unoriented film, is analogous to that of a woven fabric compared to the same mass of fibers in a random pile. In addition, orientation provides better clarity and low-temperature flexibility.

Orientation may be equal in both planar directions, giving equal tensile properties, as

TYPICAL PHYSICAL PROPERTIES OF OPP FILM

MECHANICAL/OPTICAL PROPERTIES	UNBALANCED TENTER PROCESS OPP FILM	BALANCE (TUBULAR PROCESS) BOPP FILM
Haze, %	2.0	1.0
Gloss, %	85.0	80.0
Tensile Strength, psi (kg/cm^2)		
MD[a]	22,000 (1,500)	30,000 (2,100)
TD[b]	43,000 (3,000)	30,000 (2,100)
Elongation at Break, %		
MD[a]	165	85
TD[b]	50	85
Tensile Modulus, psi (kg/cm^2)		
MD[a]	280,000 (20,000)	380,000 (27,000)
TD[b]	490,000 (34,000)	380,000 (27,000)
Elmendorf Tear, g/mil	4–6	4–6
Coefficient of Friction[c]		
Film to film	0.25	0.25
General Properties		
Water Absorption (%)	<0.005	
Low-Temperature Usefulness (°C)	–60	
Chemical Properties		
WVTR for 1 mil (g/100 in^2, g/m^2)		
Grease Resistance	Excellent	
Oil Resistance	Excellent	

[a] *Machine Direction*
[b] *Transverse or Cross-machine Direction*
[c] *Slip-modified Film*

Table 28

is typical for tubular-process OPP film, usually known as balanced (BOPP) film. It might be unbalanced and relatively weaker in the machine direction but stronger in the transverse direction, as is usually the case with tenter-produced OPP film.

Table 28 shows the typical tensile properties of OPP film. Of special interest when it comes to printing is the tensile modulus. The machine-direction modulus is a direct measure of a film's resistance to elongation, a significant trait in continuous web printing.

Printing Characteristics

Any discussion of printing of OPP film with flexography has to include both bulk composition, physical properties and surface characteristics. The surface characteristics are important because they determine whether or not a particular ink will wet-out and adhere, while bulk film properties matter because they affect print quality from the aspect of web handling.

Polupropylene is made by polymerizing the unsaturated hydrocarbon gas propylene. The result is polypropylene, a saturated hydrocarbon structure of the class of polymers called polyolefins. Like other saturated hydrocarbon substances, polypropylene has very low polarity and very low reactivity. Its surface-wetting tension (sometimes called surface energy) is low, 29 dynes per centimeter. This inertness means that wetting and ink adhesion will not occur unless the surface energy is increased. Usually, this is done by corona, high-voltage discharge treatment and, to a lesser extent, by flame treatment.

The energy intensity and technique used in surface treatment are critical for successfully printing OPP film. For general purpose printing, a surface treatment equal to 2.5 to 3 watt minutes of corona discharge per square foot of film is required. Film manufacturers will do this to boost the surface energy from 29 to 45+ dynes per centimeter on freshly treated film. This treatment will fade down to about the 40 dynes per centimeter level. Converters can increase the dyne level on already-treated OPP by corona treating in-line, but the effect is only temporary. If done improperly, converters (and suppliers) can also cause backside treatment, which can be disastrous for applications which require a non-treated surface such as cold-seal release applications.

OPP films can contain migratory slip- and anti-blocking agents. These tend to bloom to the surface, mask the surface treatment and give misleading, low-wetting tension readings. Solvent inks usually get through these contaminants easily, while water-based inks will not, without the addition of some cutting solvent (5% alcohol). Ink adhesion is typically a function of the film's surface chemistry beneath any migratory additives which bloom to the surface.

Variations in surface composition include coextruded or coated layers of ethylene-propylene copolymer, acrylic polymers and aluminum. In printing characteristics, polyolefin copolymers are similar to polypropylene, but they are usually more receptive to corona treatment than homopolymer polypropylene.

Acrylic surfaces have wetting tension higher than that of the polyoefins and show an advantage in ink adhesion (but a disadvantage in retaining ink solvents, requiring extra care in drying).

Metallized surfaces adhere well when clean. But they are so reactive that the surface may be contaminated by contact with the other side of the film, particularly if it contains any organic substance of low molecular weight. For consistently good printability, the metal surface should be treated in line, using, for example, a bare-roll corona treater.

Just as important a consideration in printing OPP film is resistance to machine-direction elongation. After the surface energy deficiency of OPP was remedied, the tendency of OPP film to stretch in the machine direction was the next major obstacle. Converters found

TENSILE MODULUS VALUES/RESISTANCE TO ELONGATION

FILM TYPE	TENSILE MODULUS[a], PSI MACHINE DIRECTION	LOAD, IN POUNDS, TO STRETCH A 1" WIDE, 1 MIL THICK FILM TO ELONGATION OF 100%	1%	0.63%
LDPE	50,000	50	0.50	0.32
PP (cast)	95,000	95	0.95	0.60
OPP (tenter process)	280,000	280	2.80	1.76
BOPP (Balanced tubularProcess)	80,000	380	3.80	2.39
Cellophane	620,000	620	6.20	3.91
Polyester	500,000	500	5.00	3.15

[a] *Defined as load required to stretch a 1" wide by 1" thick piece of material to 100% elongation.*

Table 29

that while they could use tensions of a few pounds per inch of web width when printing cellophane, they had to learn to control web tensions to as low as 0.25 to 0.5 pounds per inch and still maintain good web spreading and flatness when printing OPP film.

As temperature goes up, OPP film's resistance to elongation goes down, just as with other thermoplastic materials. At temperatures of about 140° F (typically reached in converting) a 1 mil thick OPP film under 0.5 lb. per inch tension would stretch about 0.6%, the maximum allowable elongation for good registration.

The tensile modulus (not the tensile strength) reflects the film's resistance to elongation. The tensile modulus has been defined as the value of the load required to stretch a 1" wide by 1" thick piece of material to 100% elongation. The tensile modulus is the initial slope of the load vs. elongation curve and is measured in units of pounds per square inch (psi). For a film, converting a 380,000 psi modulus (such as for the machine direction of BOPP film) to the tension load that would apply to a 1 mil thickness, yields a value of 380 lbs. for 100% elongation per 1-inch width film (as shown in *Table 29*). Note that tenter-process film stretches more easily in the machine direction and would require only a 280 lb. load for the 100% elongation, 2.8 lb. for 1% elongation. This value would occur at the initial part of the curve of the stress-strain relationship and can be relied on as physically meaningful. Increasing the temperature or tension, or reducing the film thickness, would mean higher elongation for a given tension load.

Comparison of various films' machine direction modulus values, as in *Table 29*, indicates the relative tendencies of OPP film and other flexible packaging films to stretch in the machine direction. This comparison should bring home the importance of controlling tension in printing them. *Table 30* shows common off roll weights.

OPP FILM WEIGHT/INCH OF ROLL WIDTH

CORE DIAMETER INSIDE (IN)	CORE DIAMETER OUTSIDE (IN)	ROLL DIAMETER (IN)	WEIGHT IN LBS. PER INCH OF WIDTH
3.0	3.75	11.0	2.7
3.0	3.75	15.0	5.5
6.0	6.75	12.5	2.8
6.0	6.75	16.0	5.4
6.0	6.75	19.0	8.1
6.0	6.75	21.0	10.0

Table 30

99 Polyethylene usage in the United States.

POLYETHYLENE

Polyethylene (PE) is the most common film used in the United States (*Figure* 99) . The first PE resin was made in Great Britain, but during the 1940s it appeared in the United States, with Union Carbide being the first manufacturer. PE's applications are too numerous to list but range from tape and dry cleaner bags to exotic multilayer boil-in-the-bag laminations and coextrusions.

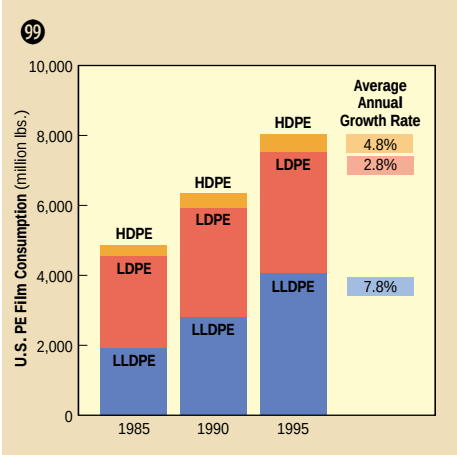
New resins and in turn, new films, are appearing on the market quickly and constantly. Ideas generated by resin producers, film producers, and film users and converters have expanded the roster of available films. New resins, such as those using the new catalyst technology metallocene, have greatly expanded the universe of polyethylene films.

A short review of polyethylene resins should be helpful in understanding the many different film types available today. *Table 31* shows three main families of polyethylene. These can be further broken down as follows:

Low-density Polyethylene (LDPE). The first polyethylene commercially manufactured was low-density polyethylene (LDPE). LDPE is also referred to as high-pressure polyethylene, or branched polyethylene. These names are derived from the type of reactor and the appearance of the molecules. LDPE is made in a high-pressure reactor (pressures upwards of 40,000 psi) and has an ethylene backbone with many branches as shown in *Figure* 100. LDPE can be copoylmerized with at least four commercially available comonomers:

- vinyl acetate (EVA);
- methyl acetate (EMA or EMAC[a]);
- acrylic or methacrylic acid comonomers (EAA or EMAA); and
- ionomer or ionically crosslinked PE (Surlyn[b]).

[a] Registered trademark of Chevron
[b] Registered trademark of DuPont



THREE MAIN FAMILIES OF PE FILMS

	LDPE[a]	LLDPE[b]	HDPE[c]
Melt index (g/10min)	0.2–70	0.2–50	0.01–80
Density (g/cc)	0.91–0.935	0.916–0.94	0.940–0.965
Short chain branching	10–30	10–-30	<10
Short chain branching length	C1–C4	C2C4 or C6	C2 or C4
Long chain branching(no./molecule)	30	0	0
Crystalline melting point (° C)	180	122	130

[1] *LDPE (low density PE): Best clarity; highest tear; lowest stiffness*
[2] *LLDPE (linear low density PE): Higher stiffness, greater puncture resistance; improves down gauging potential.*
[3] *HDPE (high density PE): Highest stiffness, low impact and tear, highest tensile, best barrier.*

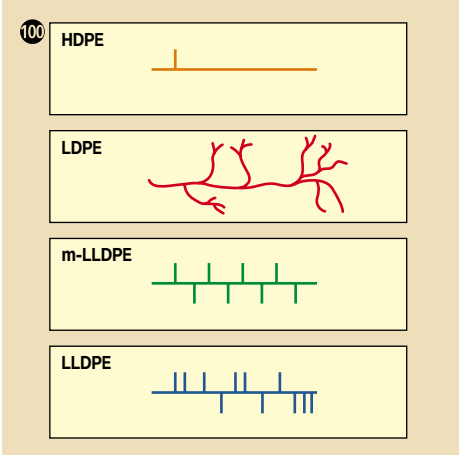
Table 31

High-density Polyethylene (HDPE). First introduced in 1957, HDPE is the first "linear" polyethylene. HDPE is characterized by densities above 0.935 g/cc. This higher density provides stiffness, toughness, good environmental stress-crack resistance (ESCR) and low-temperature properties. HDPE has found wide use in many film markets, such as merchandise bags, cereal/cracker box liner, extrusions for improved barrier and grocery sacks.

Linear Low-density Polyethylene (LLDPE). The next oldest linear film, LLDPE, first appearing widely in 1980, though grades were available commercially as far back as the 1960s. Its density is generally 0.916 to 0.940 g/cc). LLDPE has the same high-density backbone but is characterized by the side chains as shown in *Figure* 100.

Manufacturers can make up these side chains from any number of different alpha olefin copolymers, but commercially the butene (four-carbon chain), hexene (six-carbon chain), and octene (eight-carbon chain) LLDPE resins are used. Typical comonomer content in 0.920 g/cc density LLDPE resins, a workhorse film grade is 8% to 10%. Properties vary with the type of alpha olefin used. Overall, properties improve with increase in short-chain branch length. This means there is an increase in the tear strength, tensile strength and impact strength when going from butene to hexene to octene.

Metallocene Polyethylene (mLLDPE). mLLDPE is the latest in the linear polyethylenes to arrive, with commercial production starting in the 1990s. These resins derive their name from the unique nature of the catalyst used in their manufacture. The catalyst uses various metals such as zirconium or other transition metals to produce a uniform or homogeneous resin, since the catalyst has only a single site for the polymerization to take place. "Single site" is another name for metallocene resins. These resins can range in density from below 0.860 g/cc to 0.960 g/cc and above, allowing them to possess the properties of all the previously mentioned resins. The main advantage of mLLDPE is that as the density decreases the melting point also decreases. This is unlike LLDPE, where density has minimal or no effect on melting point. Another advantage is the lower odor and fewer extractables. These resins also can incorporate many different alpha olefins, but those generally available are the butene, hexene and octene comonomers.



100 Polyethylene families.

Physical Properties

Armed with the multitude of resins available, film producers multiply the various possibilities by blending and coextruding all of the above. In addition, film manufacturers add color, slip, anti-block, antifog agents, anti-stats and/or a variety of other items to modify physical or surface properties. Other variables include two- to nine-layer coextrusion, orientation and mechanical finishes, such as embossed or matte patterns.

Various polyethylene resins/films do not have a constant selling price. Each year, one or more resins are in tight supply and cause dramatic shifts in relative cost. Factors affecting film price include, resin, additives, gauge, surface pattern, production rate, roll

TYPICAL FILM PROPERTIES

PROPERTY	LLDPE CAST	LDPE CAST	LLDPE BLOWN	LDPE BLWON
Additives (ppm)				
Slip	750	750	750	750
Anti-block	4,000	5,000	4,000	5,000
Melt Index	1	2	1	0.3
Density index	0.918	0.925	0.918	0.921
Gauge (mil)	1.0	7.0	2.0	2.0
Haze (%)	4.3	3.5	11	1.7
Gloss 45° (%)	84	87	67	75
Tensile Strength (psi)				
MD[a]	6,400	4,700	5,700	3,500
TD[b]	2,200	2,200	5,700	3,400
Elongation (%)				
MD[a]	462	457	970	400
TD[b]	550	535	1,080	800
1% Secant modulus (psi)				
MD[a]	42,000	47,000	33,000	28,000
TD[b]	44,000	48,000	40,000	31,000
Elmendorf Tear (g)				
MD[a]	19	219	430	200
TD[b]	501	112	560	260
Dart impact (g)	93	47	260	230

[1] Machine Direction
[2] Transverse or Cross-machine Direction

PROPERTY	LDPE	HDPE	PP
Density	0.91–0.925	0.941–0.965	906
Tensile Strength (psi)	600–2,300	3,100-5,500	4,300–5,500
Elongation (%)	90–800	20–1,000	200–700
Impact Izod	High	5–20	5–2
Resistance to heat (¡F)	180–212	250	225–300
Water Absorption (%)	<0.15	<0.01	<0.01–0.03

Table 32

configuration and width/diameter of rolls.

Down-gauging has had a major influence during the last 10 years. In most applications, down-gauging has been accomplished by using different formulations incorporating linear low-density PE (LLDPE) (equal stiffness and tear at a lower gauge).

Typical yields can be calculated from the formula:

$$\text{YIELD } (\text{IN}^2/\text{LB}) = \frac{27{,}690}{\text{DENSITY (GM/CC)} \times \text{CALIPER (MILS)}}$$

For example: a 2 mil white pigmented film with a density of 0.96 has a calculated yield:

$$\text{YIELD } (\text{in}^2/\text{lb}) = \frac{27{,}690}{0.96 \times 2} = 14{,}422 \text{ in}^2/\text{lb}$$

Typical film manufacturers produce a wide

variety of products. Some key traits are clarity (haze/gloss), sealing (initiation temperature/hot tack), tensile (at yield point/ultimate/machine direction/transverse direction), stiffness (machine and transverse secant modulus), barrier (moisture, MVTR/oxygen, OTR/air) and surface additives.

Polyethylene films do not have the clarity of a polypropylene-cast film, but have comparable prices. LDPE gloss can approach 85% and 3%–5% haze, versus 90% or higher gloss and 1.5% haze for polypropylene. *Table 32* lists some typical film properties.

General resin types are linear LLDPE, HDPE, LDPE, mLLDPE, random copolymer polypropylene (RCPPP), and homopolymer polypropylene (HPPP). *Table 33* shows their ranking from worst to best for clarity, stiffness and sealing under equal circumstances.

Additives have a major impact on a film's physical characteristics and surface properties. Films should have only those additives required for a specific application. Common additives include:

Slip Agents – Erucamide and other fatty amides. Slip agents lower the coefficient of friction (COF). A lower COF means the film will have a higher "slip" film. These additives migrate to the surface and at a given parts per million (ppm) additive-loading a 2-mil film will have twice the amount of slip agent on the surface than a 1-mil film. Negative aspects include slip-agent buildup on the surface causing a "greasy" feel. The slip agent appears as a waxy powder which can build up on equipment when processing and prevent inks or adhesives from adhering to the film.

Anti-block – SiO_2. Anti-block prevents blocking (sticking) of adjacent layers of film. Anti-block lowers COF similar to slip but usually only to a COF of about 0.4. Low-density ethyl vinyl acetate (EVAs) and other comonomers require higher levels of slip and anti-block. anti-block works by microscopically roughing the surface so it can make a less smooth surface for printing.

RANKING RESIN TYPES

Clarity: **Best**

HDPE-LLDPE- LDPE-mLLDPE-RCPP-HPPP

Stiffness: **Stiffest**

mLLDPE-LDPE-LLDPE-RCPP-HPP-HDPE

Sealing:

mLLDPE - LDPE - LLDPE - HDPE - RCPP -HPP

99° **108° C** **160° C**

Table 33

Pigments. The primary pigment used for white film is titanium dioxide. There is a whole range of organic and inorganic pigments used to color film. Many of these pigments, when supplied in a concentrate, to the film producer, may have various dispersion aids or lubricants to help disperse the pigment. These dispersion aids may affect printability.

Other Additives. These include ultraviolet stabilizers, ultraviolet absorbers, antifogs, antioxidants, processing aids, chill-roll release, foaming agents, flame retardants, optical brighteners, delusterants, degradable additives, clarifiers and antistats.

Printing and Handling Characteristics

The film surfaces of polyethylene are notably indifferent to the adhesion of inks or coatings, and since the first introduction of polyethylene to the packaging film market, this has been a hindrance. First the films need to be "treated" before coating or printing.

An electronic "corona" discharge is the primary form of treatment. There is also flame treating and plasma treating. It is commonly thought that treating "oxidizes" or reorients the electrons on the surface or forms carbonyl groups or another chemical change. In "The Science and Technology of Polymer Films", edited by Orville J. Sweeting, the author

shows that the mechanism was "micropitting of the surface". Whatever the mechanism, we know the surface energy, measured in dynes/cm, is increased after treatment. This higher surface energy allows inks and coatings to wet-out the surface.

Common treat levels range from 36 to 42 dynes/cm, depending on the application. Untreated polyethylene has an inherent treat level of 31 as compared to polypropylene with a 29 dyne/cm treat level. The measurement of treat levels is done by a wetting tension method (ASTM, D2578-67). Other methods used to measure treat level are: adhesion-ratio test, ink pick-off test and measuring the angle water or other solvents make with the surface.

Films with additives need more power (or slower speeds) to reach the same treat levels as film without additives. An insufficient treat can cause poor or spotty adhesion, trapping of colors over each other and ghosting. Over-treating can cause blocking, reduce seal strength and cause poor printing by the possible formation of low-molecular-weight degradation products.

Handling requirements for polyethylene films can be summarized in two words: Be Gentle. Marks from handling rolls can cause films to tear in end-use processing. Storing film in hot conditions can cause blocking and sunlight can break down polyethylene.

To get a rough estimate of the tension required to run polyethylene films, the secant modulus and the film thickness is required. The secant modulus is simply the force required to stretch the film 1%.

Example: Use a typical secant modulus for polyethylene film in the machine direction of 25,000. With a 1% stretch, the web tension on a 2-mil film needs to be

$$25{,}000 \times 0.002 \times 0.01 = 0.5 \text{ lbs/in of web width}$$

or **0.5 lb/in of web width**

For a 40" web, the total web tension would be

$$40 \times 0.5 = 20 \text{ lbs.}$$

Converters print many millions of pounds of polyethylene each year, but for applications requiring top-quality print with exacting register standards, polyethylene is usually not the substrate of choice. In many packaging applications, polyester or oriented polypropylene is reverse printed and then laminated with polyethylene to lock in the print and give excellent protection to the printed image, in addition to, making the film heat-sealable. Polyethylene is used in many printed applications, but often not as the printed film.

CELLOPHANE

Cellophane is a thin, flexible and transparent material used for packaging applications. It is not truly a film in the sense that it is composed of chemical compounds. Cellophane is both a bio-degradable and renewable resource of regenerated cellulose film, derived from purified wood pulp, known as "dissolving pulp".

The use of cellophane followed the growth of the flexible packaging industry. For 30 years it dominated the industry because it offered the marketplace a wide variety of properties that produced a product at reasonable cost. Once the base sheet is produced, it is coated either with polyvinylidene chloride copolymer (PVDC) or nitrocellulose, which adds heat sealability, machineability and barrier properties. Uncoated cellophanes are sold mostly for industrial uses, such as pressure-sensitive tape base, fiberglass and rubber mold-release membranes, and roll-leaf applications. The advent of plastic films, such as polyethylene and polypropylene, eroded the use of cellophane.

Physical Properties

The physical properties of cellophane are very similar to all types of film and are only differentiated according to coatings and reinforcing structure and thickness. Many film

types, designed for specific applications, are produced. Regenerated cellulose, the base sheet for all mono-web cellophanes, varies in thickness for different basis weights. Other variations in the base sheet include the amount and/or type of plasticizer added for durability, stiffness and dimensional stability. The most widely used film is plain uncoated, used for producing pressure-sensitive tapes and where high-quality printing is desired. The uncoated film prints readily, with almost any type of flexographic ink, because it absorbs liquids.

Each family of cellophane films has similar properties. Except for the two reinforced ones (one of which is metallized polyester and the other a white, opaque polypropylene core), all of them are clear. The nitrocellulose films range from 16,000 to 18,000 psi tensile strength in machine direction and 8,000 to 9,000 psi in transverse direction. Elongation ranges from 15% to 25% in machine direction and 30% to 45% in the transverse direction. Heat-sealable coatings have a wide sealing range that usually requires temperatures of 200° F to 350° F, depending on machine speed and pressure. As a rule, these films will run on any machine that can handle a flexible packaging substrate. The coefficient of friction ranges from 0.30 to 0.35 (US) to 0.25 to 0.30 (UK). Water-vapor transmission rate (WVTR) for the moisture-proof films averages 0.05 gm per 100 in^2 per 24 hours, while the breathable "L" types range between 30 to 50 gm/100 in^2 per 24 hours. Oxygen permeability stays around 2 cc/100 in^2 per 24 hours per atm for most two-sided coated nitrocellulose films. *Table 34* shows the cellophane yields for different gauges.

Printing Characteristics

All cellophanes lend themselves to flexographic printing and samples are routinely given to ink manufacturers for testing. They can make specific suggestions for their use. Air velocity, exhaust and web temperature are prime factors to consider when printing cellophane. Maximum air velocity should be used and the exhaust should be at least 15% to 20% greater than the air volume entering the system.

When web temperature is excessive, there may be locking in the roll even if the film has cooled to room temperature before rewinding. Overheating may also cause PVDC-coated cellophane to stretch during printing and completely or partially return to its original shape (snap back). This can cause the repeat to vary, making it hard for the end user to properly control the packaging equipment cutoff. When the film then tries to return to its original shape, rolls that were wound soft on the press later become hard. This can cause ghosting, offsetting and blocking. Web temperature should be measured as soon as the film comes out of the overhead oven.

CELLOPHANE YIELDS

CELLOPHANE

GAUGE	IN^2/POUND	MIL THICKNESS
116	11,600	1.7
140	14,000	1.4
160	16,000	1.2
180	18,000	1.1
195	19,500	1.0
210	21,000	0.9
220	22,000	0.9
230	23,000	0.8
250	25,000	0.8

REINFORCED CELLOPHANE

GAUGE	IN^2/POUND	MIL THICKNESS
118	11,800	1.6
122	12,200	1.6
123	12,300	1.7

Table 34

Appendix A

TAPPI TEST METHODS: PAPER

PROPERTY	TEST METHOD	PROPERTY	TEST METHOD
Air Permeability	T 251, T 547	Grammage	T 410
Air Resistance	T 460, T 536	Ink Absorbency	T 431
Bending Stiffness	T 535	Internal Tearing Resistance	T 414
Bonding Strength	T 541	Liquid Penetration Resistance	T 530
Brightness	T 452	Moisture Content	T 208, T 412
Bulking Number	T 500	Opacity	T 425
Bursting Strength	T 403	Optical Properties	T 442
Coefficient of Friction	T 542	pH	T 428
Coefficient of Static Friction	T 503	Pick Resistance	T 459
Color	T 527	Smoothness	T 538, T 479
Color Matching	T 515	Spectral Gloss (20°)	T 653
Curl	T 520	Spectral Gloss	T 480
Degree of Curl/Sizing	T 466	Stiffness/Bending Stiffness	T 451, T 489, T 535
Diffuse Opacity	T 519	Stretch	T 495
Edge Tearing Resistance	T 470	Surface pH	T 529
Elongation	T 404	Surface Strength	T 459
Equilibrium Moisture Content	T 550	Tearing Strength	T 496
Fiber Analysis	T 401	Tensile Strength	T404
Folding Endurance	T 423	Thickness	T411, T 551
Gloss	T 653	Wet Strength	T 456

TAPPI TEST METHODS: PAPERBOARD

PROPERTY	TEST METHOD	PROPERTY	TEST METHOD
Abrasion Resistance	T 476	Internal Bond Strength	T 541
Air Permeability	T 547	Moisture	T 412
Bending Strength	T 495	Ring Crush	T 818
Bonding Strength	T 541	Smoothness	T 538
Brightness	T 452	Stiffness	T 451, T 489, T 543
Bursting Strength	T 807	Stretch	T 495
Colorimetry	T 524	Tearing Strength	T 414, T 496
Fiber Analysis	T 401	Tensile Strength	T 494
Gloss	T 653	Thickness	T411, T 551
Grammage	T 410	Wet Strength	T 456

TAPPI TEST METHODS: CORRUGATED

PROPERTY	TEST METHOD	PROPERTY	TEST METHOD
Bursting Strength	T 810	Fluted-crush Test	T 824
Coefficient of Static Friction (horizontal-plane method)	T 816	Ply Separation	T 812
Coefficient of Static Friction (inclined-plane method)	T 815	Puncture Resistance	T 803
Compressive Strength	T 811	Grammage	T 545
Flat-crush Test	T 808	Folding Endurance	T 512
Flat-crush Test (ridged-support method)	T 825	Edgewise Compressive Strength	T 811
Flat-crush of Corrugated Medium	T 809	Compression Test	T 802
Flexural Stiffness	T 820	Impact Resistance	T 801
		Vibration Test	T 817
		Water Resistance	T 805

Reference:
Technical Association of the Pulp and Paper Industry, TAPPI Test Methods, 1997.

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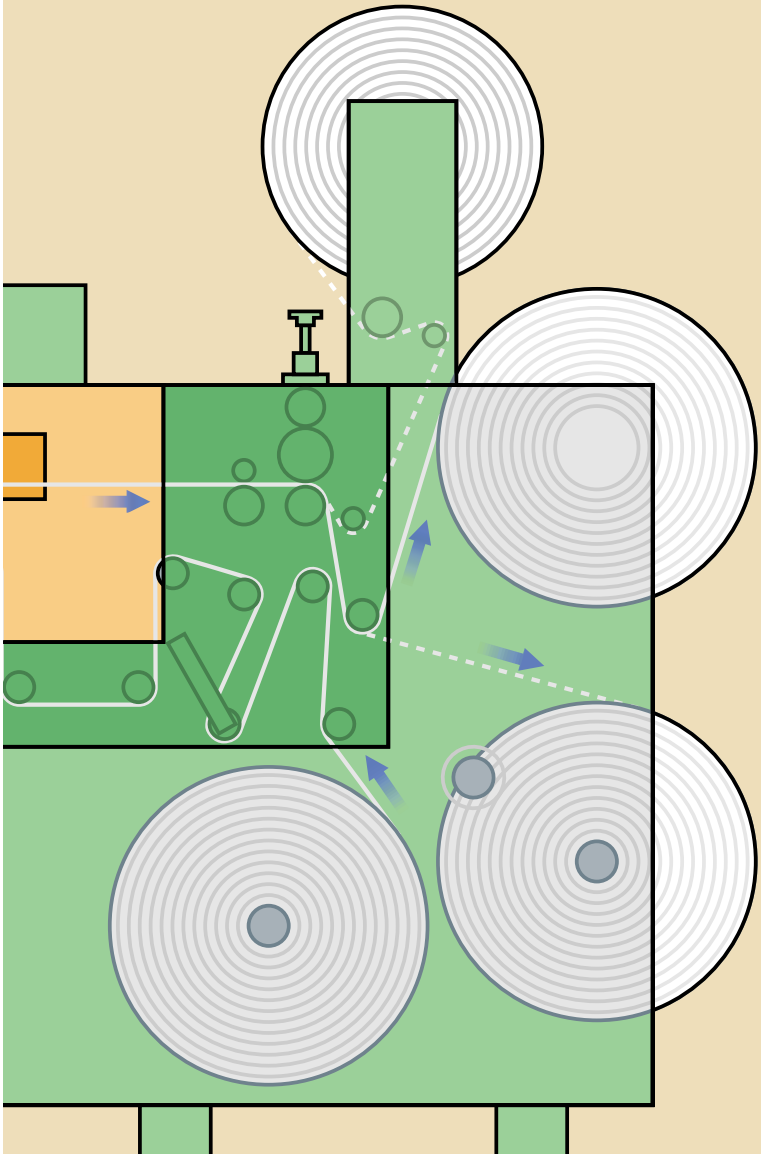

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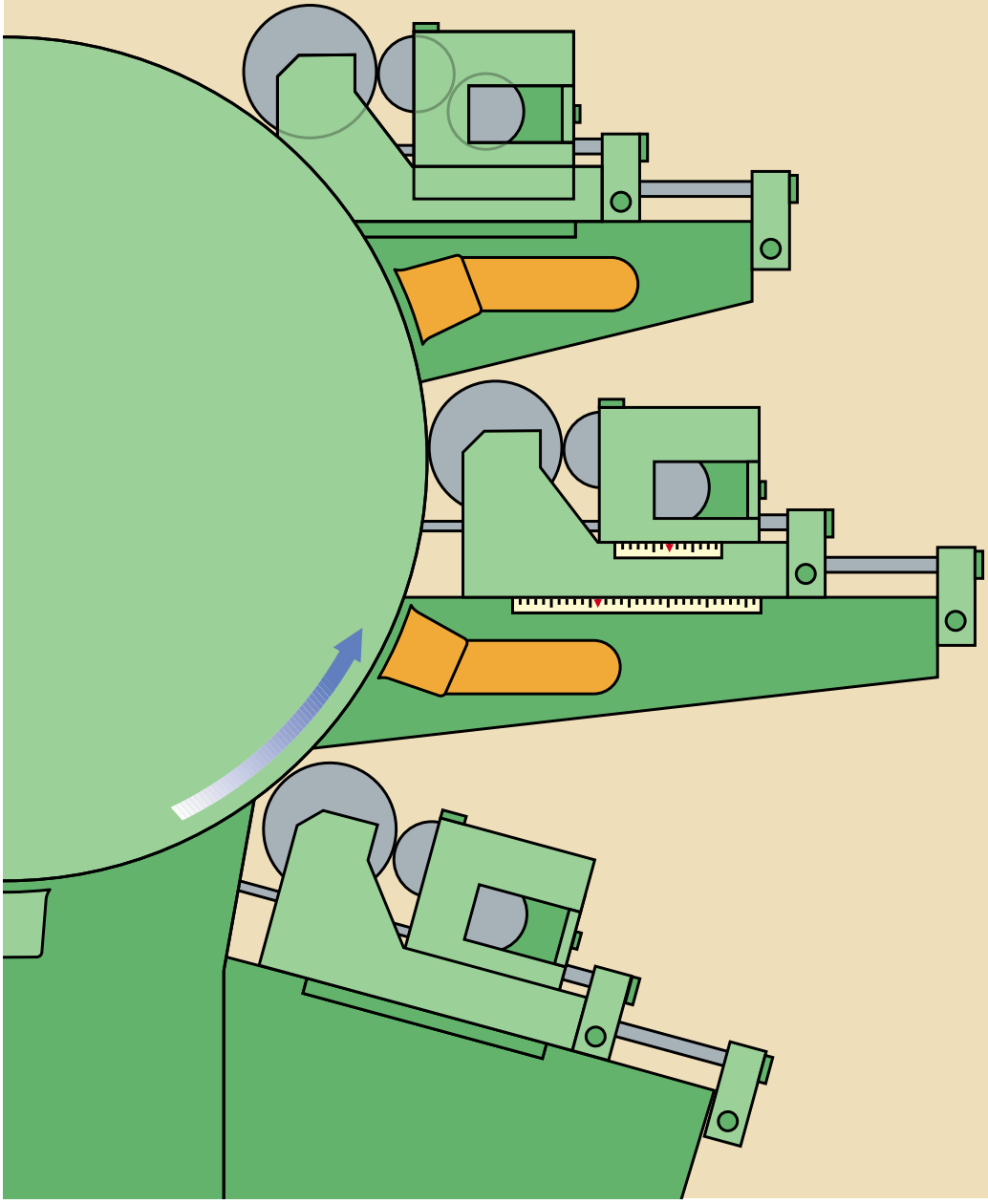
CHAPTER 1

Presses & Press Equipment



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Introduction

There are so many kinds of presses, auxiliary equipment and in-line operations that it's virtually impossible to review all the available combinations. However, each of these subjects will be reviewed sufficiently to provide an understanding of flexo printing presses and their related equipment.

In recent years, more and more flexo presses have been supplied with in-line operations, such as laminating and/or coating, die cutting, etc. Therefore, an understanding of how these operations are incorporated into the press is beneficial. Do not confuse in-line operations with in-line presses. In-line presses are just that – a specific variety of printing press as described elsewhere in this chapter. In-line operations are applications other than printing that are performed on other equipment that has been combined with the press. A separate section in this chapter has been devoted to in-line processing with the narrow web press. There is also a complete chapter devoted to the corrugated post-print operation.

Historically, the flexographic web printing industry has been broken down into two basic web configurations: wide web and narrow web. Web widths range from 6" on a small adhesive label press, to over 150" on a newspaper press. The break point between the definition of narrow web and wide web has been in the range of 20" to 24". That is to say, web widths up to 24" may be considered narrow web and web widths over 20" may be considered wide web, leaving an area for dispute. The term "mid-web presses" has come into usage for a class of presses that, although not strictly defined, has a web width that lies somewhere in the range between 20" and 47". For this publication, narrow web is defined as being web widths up to 20". Anything above 20" is considered wide web.

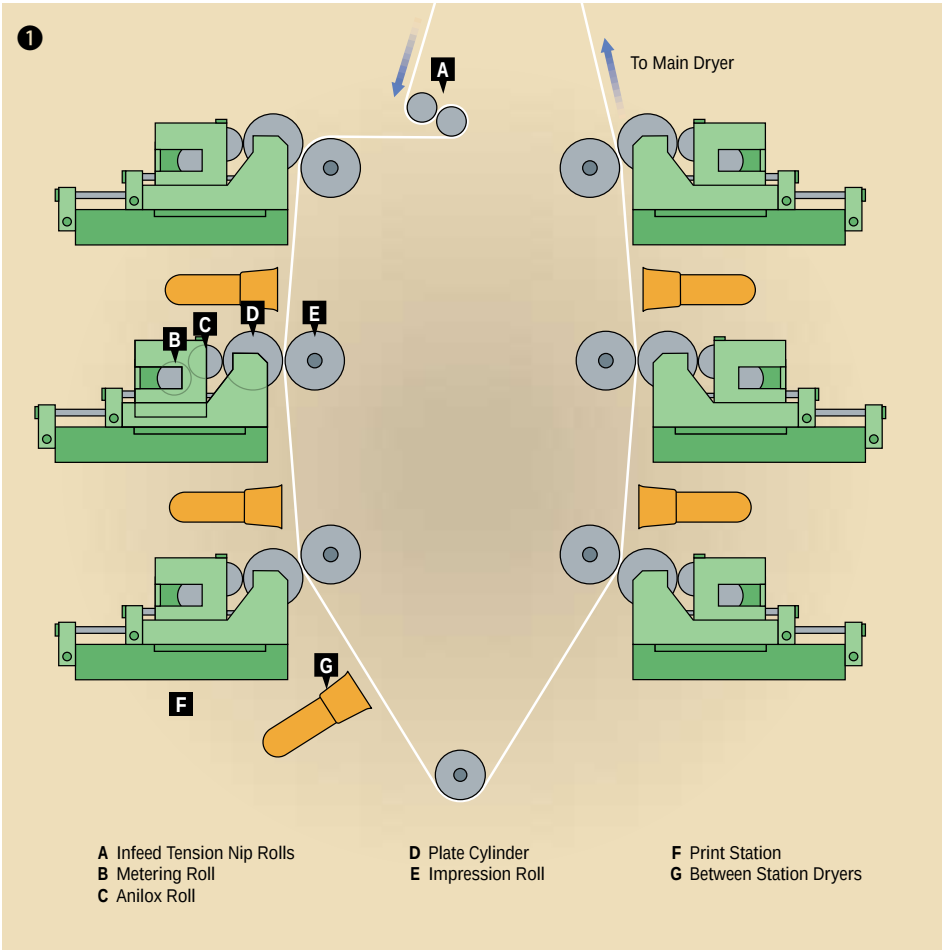
The flexo web press has four major components: the unwind with in-feed, the printing section, the dryer and the rewinder with out-feed. The auxiliary equipment, such as web guides, web viewers, powder spray units, air shafts, etc., are also important in the overall operation of the flexo press. There are many models and designs of this equipment and each component will be covered in detail in other chapters.

Wide-Web Presses

There are three basic types of wide web flexographic printing presses: stack, central impression cylinder and the in-line press. Generally, these presses are used for printing flexible packaging materials, but they also do narrow web, corrugated and publication printing operations. Regardless of the end product, the printing principles remain fundamentally the same.

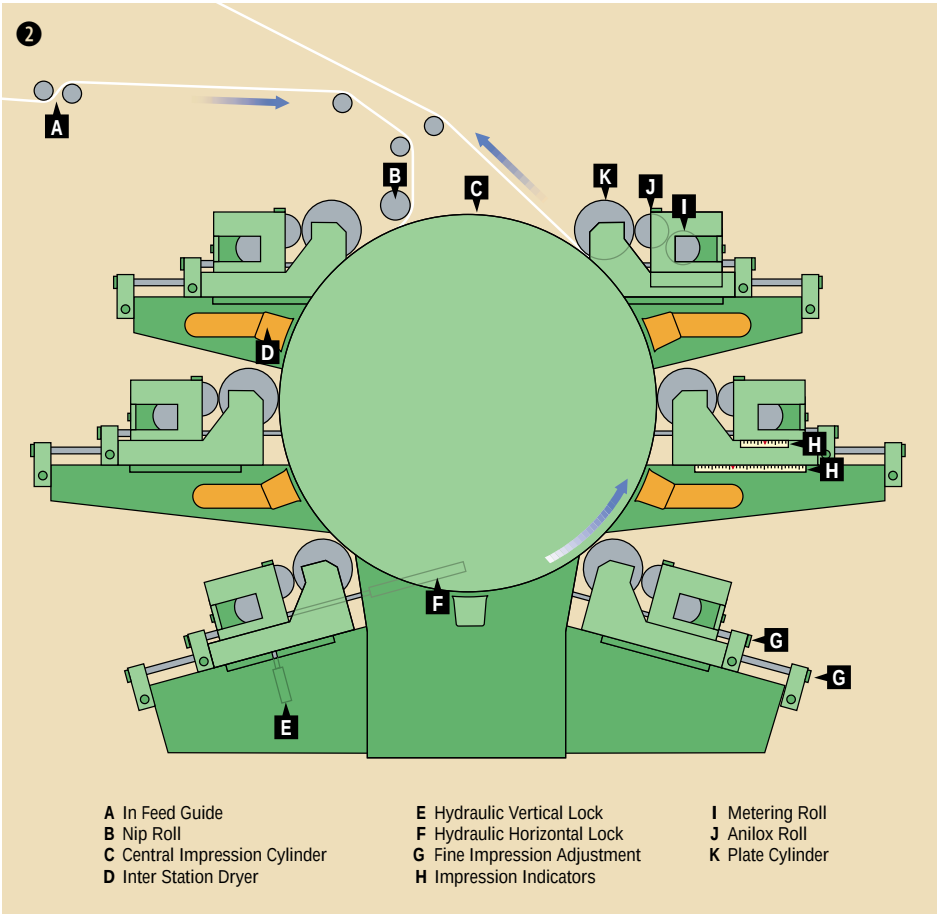
THE STACK PRESS

In the stack press (*Figure* ❶), individual color stations (sometimes called sections or decks) are stacked one over the other on one or both sides of a main press frame. Each color station is driven through gear trains supported by the main press frame. Stack presses are made with one to eight color stations, although the most common configuration is a six-color press.



❶ A typical 6-color wide-web stack press, where individual color stations are stacked one over the other on one or both sides of a main press frame.

❷ A typical six-color central impression press supports all of its color stations around a single impression cylinder.



Stack presses have three main advantages. First, the operator can usually reverse the web to allow both sides to be printed during one pass through the press. Various web-threading arrangements allow complete ink drying before the reverse side is printed, provided enough drying capacity is designed into the area where the web passes between the two series of stations. The second advantage is the color-station accessibility, which facilitates changeover, wash-up, etc. The third advantage is the ability to print large repeats.

The stack press has proved useful in many applications and has been used to print on almost every type of substrate. It does have limitations that don't make it completely acceptable for some applications. When printing substrates that are extensible or of extremely thin gauges, the stack press is generally restricted to color registrations that do not require greater accuracy than ±0.0312". When heavier gauge materials are being printed, such as papers, laminated film structures and others that can tolerate fairly high web tension values, the stack press can profitably produce commercially acceptable registered products.

The stack press lends itself well to applications such as printing in-line with other types of machinery. These add-ons may include extruders, bag machines, sheeters, laminators or other equipment.

With some special color-station designs, it's possible to have 360° register on each station and independent engaging and disengaging to allow the remaining part of the

machine to operate. The stack press also has been used both as a coating and tinting (all-over coloring) machine. Since each color station is independent from the others, it is easy to mechanically arrange various rotations of the inking parts. It is also possible to change the web lead to flood coat a sheet, or print coatings in a standard fashion. These techniques have been applied in the pre-printing of corrugated liner material.

THE CENTRAL IMPRESSION PRESS

The central impression press, sometimes called a drum, common impression or CI press, supports all of its color stations around a single steel impression cylinder mounted in the main press frame. (*Figure* ❷). The impression cylinder supports the web, which is thereby "locked" to the cylinder as it passes all color stations. This configuration helps prevent register shift from color to color.

Since the greatest advantage of the central impression cylinder press is its ability to hold excellent register, it has become the mainstay of the converting industry. Also, with graphic designs becoming more complicated and the demand for process printing remaining steady, the positive register ability of the CI press makes it suitable for all types of substrates. The most common press in use today is still the six-color central impression press, although this is being superceded by the eight-color CI press. Even ten-color CI presses are being now built.

Impression cylinders of various diameters have been used. At first, four-color presses were the most common, and they generally used 30- or 36-diameter impression cylinders. To get better speed and allow room for interstation drying, impression cylinders up to 60" were used for four-color presses. The first six-color central impression cylinder presses used 83" diameter cylinders. The latest eight-color central impression presses have cylinders up to 94" in diameter. As drying techniques have improved and the distance required for drying between colors has decreased, smaller impression cylinders have come back into use. The most common eight-color single impression cylinder press today has an 89" (2.26 meter) diameter cylinder.

Thanks to advances in between-color drying, the adage that "larger cylinder presses usually offer higher speeds" no longer applies. In general, however, it is still possible to get longer printing repeat lengths on the larger impression cylinder presses than those of smaller design.

The central impression press has found limited use when it comes to printing both sides of a web during one pass through the press, most commonly in tubular film printing.

Development of the CI Press

Beginning in late 1989, major technological advances were made regarding construction of wide web CI presses.

The first significant change was making the individual printing deck a single piece casting. The previous manufacturing technique utilized a pair of machined side frames joined together by two or more bolts on transverses. The new development required major advances in machine tool design and construction. However, it was immediately apparent that a single piece cast deck provided a more stable platform from which to print.

Simultaneous with the development of single piece cast decks was the elimination of all the hydraulics on these presses, replaced by digital electronic and pneumatic controls. This change eliminated the messy hydraulic operation and maintenance problems associated in the past with hydraulically actuated printing decks.

Further enhancement to these decks was brought about with the use of prismatic linear recirculating ball guides, which are permanently lubricated and preloaded, allowing movement of the printing deck only in the

direction of the x-axis. Previous hydraulic deck designs required the printing deck to move in all three directions, i.e., along the x, y and z axes in order to move the printing decks forward and back, on and off impression, and in or out of gear engagement.

Inherent in hydraulic deck construction is the need for additional gaps between the various metal pieces in order to allow for this movement. Each additional gap between the metal pieces, and movement along all three axes allows for more movement of the printing deck, and in turn more potential for registration errors and inaccurate impression setting. The electronic decks allow movement along only one axis, and therefore have a more stable platform and a lower centerline of the plate and anilox rolls relative to the printing decks. These modifications result in better print quality at higher speeds, which is a distinct advantage on jobs that previously were not able to run as fast on hydraulic decks.

The new electronic decks were further enhanced by using true closed-loop digital stepping motors with built in encoders, feeding back actual deck positions to the host computer now controlling the printing decks. This digital control enables the operator to set or reproduce previous impression and register settings on the decks with a high degree of accuracy and virtually 100% reliability, something that is not possible with hydraulic decks and their inherently looser construction.

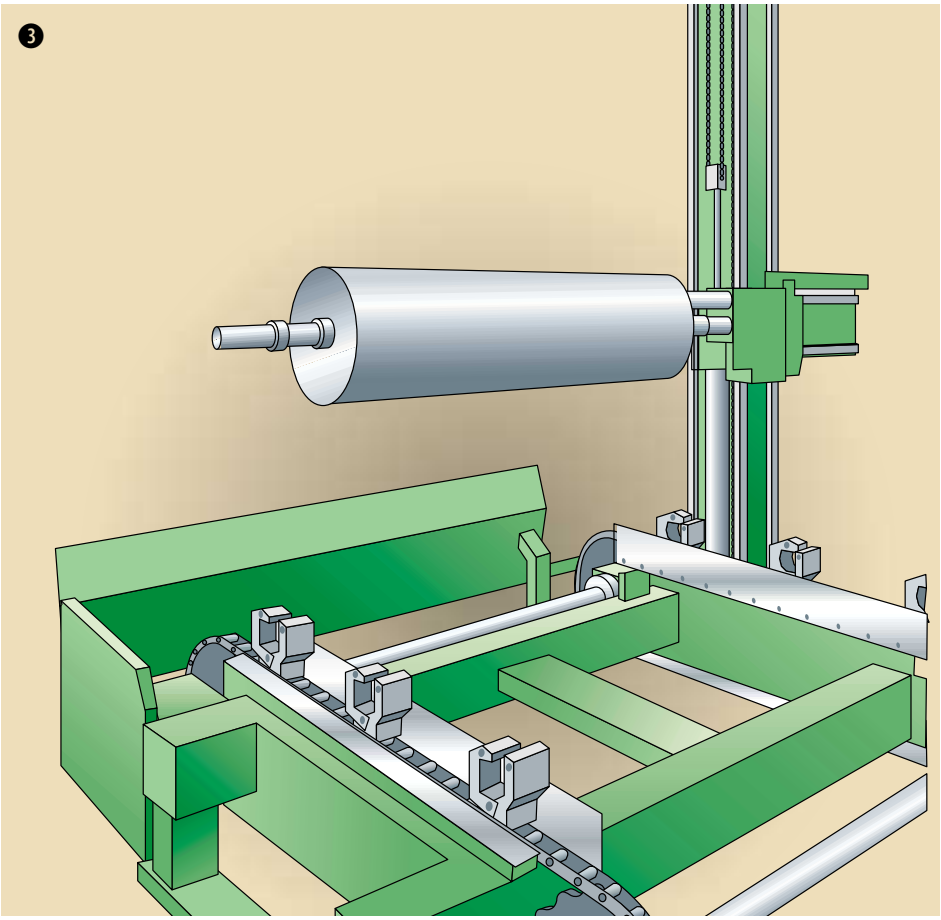
Modern CI presses also have fully automatic plate cylinder-to-bull-gear-engagement register systems. The best systems automatically rotate each plate cylinder and its repeat gear into initial register and engagement position relative to each other, and then into engagement with the bull gear to within ±0.0002" initial register accuracy, without pulling any material through the press.

First developed during the late 1980s and incorporated by virtually all wide-web press manufacturers today, was the addition of robotic cylinder loading/unloading systems for both the plate and anilox rolls (*Figure* ❸). The addition of these robotic loading systems significantly reduces the potential for damage to the press, anilox rolls, plate cylinders and personnel, while speeding up overall changeover times. Today, most wide-web presses are ordered with a robotic cylinder system.

These robotic cylinder loading systems have gone through a number of iterations by various manufacturers; however, as of this writing most robotic cylinder systems are virtually 100% reliable.

Chambered doctor blades with automatic wash-up systems, coupled with the advances of electronic printing decks and robotic cylinder handling systems, have led to the development of modern CI flexo presses controlled via a central operator console. The various press components – including unwind, in-feed draw, printing deck movement, register correction, drying system temperature settings, air flows, out-feed chill-roll draw settings, slitter settings and winder settings – are all integrated into the main operator console with direct digital connections. The central console further reduces makeready times by allowing operators to automatically preset all these settings quickly and easily for later recall of similar or same jobs, or to use as a template for a family of jobs.

With the development of electronic printing decks, robotic cylinder loading systems, on press wash-up systems and automatic gear engagement, it is now also possible for press manufacturers to provide a safe system for allowing operators to make ready unused printing decks while the press is running at full press speed. These free deck safe systems have proven to be economically viable for those customers running three-, four- or five-color jobs. However, with six colors or more, the above-mentioned features allow jobs to be changed fast enough while the press is stopped, so as not to require the free deck makeready system.



❸ Modern wide-web presses are almost always ordered with a robotic cylinder loading/unloading system, which helps in reducing potential damage to the press, anilox rolls and plate cylinders, as well as personnel.

In recent years flexo has achieved print quality comparable to gravure, and as a result, more and more work from the gravure sector is moving to flexo. This increase in print quality has driven the development of the 10-color CI press, since most gravure jobs are up to 10 colors.

Central Impression Drum

Drum construction in a central impression press can be of double-wall steel or cast iron. In either case the drum will be temperature-controlled by a heating/cooling device. As markets have advanced in flexography, and the product expected from a CI press has improved to a high degree of excellence, press manufacturers have been compelled to hold more demanding tolerances in regard to the CI drum. Very commonly employed today is the use of digitally controlled heating/cooling elements, which hold drum temperature within a range of ±1° F. This close tolerance is a necessary element in the printing excellence being demanded of press manufacturers and converters today. If the press experiences variation in drum temperature, which causes CI drum size variation, the operator will be continually attempting to compensate, causing missed impressions or over-impression.

The CI cylinder, independent of its method of construction, must be manufactured to meet high Total Indicated Runout (TIR) characteristics. It is very common today that specifications on a new press dictate that the drum not exceed 0.0003" TIR. Ideally, the

drum will be held to a lower actual number if possible. Realizing that the TIR of the drum will only be as good as the supporting journal and bearings, manufacturers of presses are demanding the use of printer-quality roller bearings with a TIR of around 0.0002". The use of custom hand-fit bronze bushings, which were very prevalent in the past, is losing favor with manufacturers today. The bronze bushings must be constantly lubricated, usually with a lube pump. The advantage of printer-quality roller bearings manufactured to acceptable tolerances is that they can be lubricated in a similar manner to a gearbox (enclosed oil bath or grease pack).

IN-LINE PRESS

The in-line press is the third commonly used type of wide-web press. Its color stations are separate, complete units horizontally mounted one to the other, and may be driven by a common line-shaft. In-line presses can be manufactured with any number of colors. This type of press can be easily designed to handle various web widths, from narrow to extremely wide, since a single frame need not support all colors. The in-line press is commonly used in folding carton, corrugated post print and multi-wall bag operations, as well as in other special applications.

In-line presses are also common in narrow web widths for printing pressure-sensitive and standard label stocks, where they offer the advantages of quick setup and accessibility. This design is also used in those specialized areas where a specific product line may need a press designed for short runs.

The in-line press has the versatility to print on both sides of a given web by either turning the web over with the turning bar system or using alternate threading. They can be used to flood-coat where all-over coloring of absorbent materials is required.

FOLDING CARTON PRESS

Folding cartons have been printed by flexo for many years, but it has only been in the past 10 years that the industry has started using state-of-the-art central impression presses for this application. Pizza cartons illustrate the type of work that was originally relegated to the flexo process. The ability to print multi-colors in close register on wide webs, however, has made the process more attractive to other point-of-purchase folding carton applications.

Normally the folding carton press is tied in to an in-line process that would include cutter-crease or platen die-cutting operations. In the past, most cutter-creasing operations were mated only with roto-gravure or sheet fed offset presses. With the improved quality of flexographic printing, the use of water base or UV inks, and the lower cost of equipment, converters can no longer ignore the option of printing high quality folding cartons flexographically.

Folding carton equipment differs as a result of the substrate. Heavy board roll stock is used, which requires higher tension levels, larger idle rolls and more sophisticated splicing and control units. The unwind section must handle 72" diameter rolls and automatically splice them without an overlap (butt splicing). Idle rolls must be of a large enough diameter to eliminate the risk of weakening the board fiber bond or creasing the board.

From the unwind through the cooling drum and to the out-feed unit, the press operator is dealing with the usual tension zones and a constantly moving web. From this point on to the cutter creaser or platen die-cut section, the motion is intermittent (stop and go). Web control is critical to both print and die-cut register, as the printing must be on a smooth flowing, tensioned web, and the die-cutting on a stationary, relaxed web. Electronic print sensors register the image on the web to the die cutter.

PLATE CYLINDERS

The plate cylinder shaft and cylinder wall may be of integral construction similar to the roll body of the fountain roll and anilox roll, or of a de-mountable type. Whether integral or demountable, it must be very accurate. Its total TIR should not exceed 0.001" for line work, and 0.0005" for fine screen or process work (some feel this should be reduced to 0.00025" for process printing), when turned on its bearing journals. Further, it should be made with a taper not to exceed 0.0002" for every 12" of face length, and should be dynamically balanced to operate smoothly at high press speeds.

Also, the roll diameter should be of such a size that when the stickyback and rubber or photopolymer plate is applied, the printing plate will run at the proper gear pitch line. Most wide-web flexographic presses are equipped with either 0.25 circular pitch or 10 diametrical pitch gearing. European presses have metric pitch gearing. For more details on gears *see pages 132-141*.

Demountable Plate Cylinders

There are several different types of demountable plate cylinders. They are commonly used where a converter may have several different flexographic presses of about the same width, but which require different types or lengths of journal. So it's possible to make demountable plate cylinder shafts for each press. Otherwise, it would be necessary to have complete sets of cylinders for each different press because the cylinder shaft and gearing would not necessarily fit each press.

What plate system to use sometimes becomes a question of cost. The tolerances for demountable plate cylinders and shafts must necessarily be the same as those for integral-constructed cylinders. Cylinders and shafts must be well maintained. Each time a new cylinder is taken off or put on a plate-cylinder shaft, its seating arrangement should be checked for damage. When operating a demountable system, it is essential to check the concentricity of the plate cylinder each time it is reattached to a cylinder shaft to make sure it is within the proper operating tolerances.

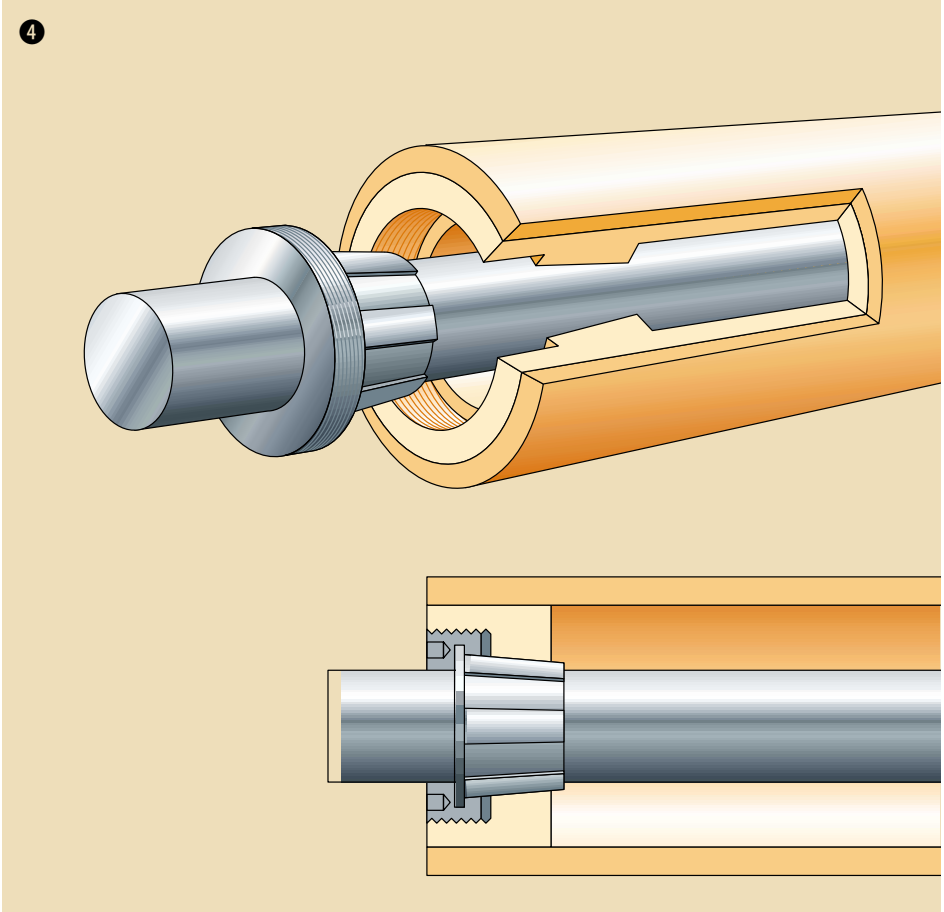
There are a few common ways of attaching demountable cylinders to shafts. One type of cylinder lends itself to having its end wall heated so it will expand and slide over the shaft. Upon cooling, the cylinder wall will shrink into position. Another type of demountable cylinder has a threaded opening on the end wall (*Figure* ❹). The shaft is also threaded and, when tightened with a spanner wrench, the cylinder and shaft lock together. Another type is locked into position with a pressure system using a grease gun that fits in the shaft. Still another type is fastened with screws, activating a "hydraulic" system.

Whatever system you use, the requirements for consistency, taper, balance and concentricity must be maintained for proper printing. Demountable plate cylinders take up less storage space, but they do require extra time to reshaft for each new job.

SIDE AND CIRCUMFERENTIAL REGISTER CONTROL

A number of devices are available to the operator to adjust side and circumferential registration. Most common is a mechanical apparatus, such as a hand-wheel, which when connected to the plate cylinder, will cause the plate cylinder to be laterally moved. Circumferential register can also be accomplished with a simple hand-wheel by allowing the plate cylinder and associated gearing to be connected to a helical gear. The male spline clamped to the plate cylinder journal in conjunction with a female spline will allow the plate cylinder gear to slide forward and back on the male spline to affect the circumferential register without affecting the side register of the plate cylinder.

A number of hydraulic or electrical



❹ Demountable plate cylinders help provide consistency, taper, concentricity and balance during printing. This type, a robotic cylinder, has a threaded opening on the end wall. The shaft is also threaded and, when tightened with a spanner wrench, it locks into the cylinder.

devices can be designed and installed to allow the operator not only convenient access to the register controls but a degree of automation. Normal use of automatic deck positioning systems allows for the possibility of automatically centering both side and circumferential register devices. With properly positioned plates, the automatic deck positioning system provides the operator, upon rack-in and gear mesh, a properly registered print job very close to acceptable quality without further adjustment.

The motor-operated type of registration system, whether hydraulic or electric, can be furnished with the capability to be pulsed – that is, upon activation of a pushbutton or switch, the units will be programmed to move a certain increment. Incremental movement is a great asset, especially for a high-quality process print where fine register capability is paramount. By providing the capabilities for pulse registration, the operator has the ability to adjust and fine-tune registration from a remote area, such as a web viewer or video monitor. The above capability saves lost motion, which equates directly to higher quality print with less waste.

Narrow-Web Presses

Narrow-web flexo has most recently been defined as any web width less than 20" (508 mm). While this is an arbitrary designation, it will serve as a definition for this chapter. The vast majority of narrow-web presses, however, are 16" (406 mm) or less, and most are 10" (254 mm) or smaller. However, changing market conditions and the need for greater productivity have created a definite trend toward the use of wider presses. Web widths of 10" (254 mm) and 13" (330 mm) have supplanted the old standards of 6" (152 mm) to 8" (203 mm) web widths. Presses with 18" (457 mm) to 20" (508 mm) web widths are becoming more common.

Narrow-web flexography is also characterized as a rotary process with multiple in-line converting functions. Variable print, or repeat length, capability is a critical feature in the markets served by narrow-web equipment. With alternate printing processes, varying repeat is often accomplished with an intermittent web motion. The elegant simplicity of the flexo ink system, low-cost plate cylinders, and the ease and cost effectiveness of processing plates in a variety of sizes, make an intermittent or platen type of system unnecessary on narrow-web flexo presses. Plate cylinders are easily and economically changed on narrow-web presses, providing the ability to alter the repeat length while maintaining rotary printing. Typical narrow-web flexo presses have a print repeat range from approximately 4" (101 mm) to 24" (609 mm) in 0.125" (3 mm) increments.

It is rare for a narrow-web flexo press to be limited to simply printing. Typical applications will include some form of in-line converting operation, such as die-cutting, slitting or laminating. The ability of narrow web presses to do multiple operations in-line at high speeds provides tremendous production efficiencies and cost savings to users. The converting operations performed on narrow-web presses are also usually accomplished by rotary means. However, platen, or flatbed, die-cutting can be used, and foil for stamping can also be fed intermittently.

DEVELOPMENT AND GROWTH

The origin of narrow-web flexography is usually placed in the period immediately after WW II. At that time, Mark Andrews Sr. (1904-1980), the founder of Mark Andy, Inc., made his first presses for printing on the then new product, “Scotch Tape.” Others may have made similar equipment prior to this but, unquestionably, Andrews was the first to begin the sustained manufacture and marketing of narrow-web flexo presses. Flexo then was still called the “aniline” process, named for the aniline dies in the inks. These initial presses were designed to sit on a workbench or table and were used for making labels from self-wound, self-adhesive tapes. Web widths were 2" to 4" (50 mm to 100 mm).

Andrews is also credited with another innovation that has shaped the narrow web flexo industry: the development of rotary die-cutting and its integration into narrow-web presses. Initially, these rotary dies were used for perforating tapes. As pressure-sensitive roll label markets emerged, the entrepreneurs building that industry recognized the

advantage and cost effectiveness of in-line printing and die-cutting on narrow-web flexo equipment. These early innovators forged a bond between pressure-sensitive roll labels, flexographic printing and in-line rotary die-cutting that has facilitated and forced growth and advancement within each of the technologies and built them into world class disciplines.

The explosive growth of pressure-sensitive labels (estimated to have a value of $10 billion in North America by the year 2000) has fueled the growth and development of narrow-web flexography. However, narrow-web presses are used for a vast variety of products in addition to pressure sensitive labels. Many of these products are other forms of product identification or promotion such as tags, in-mold labels, sleeves and cartons. Lottery pieces and tickets for everything from sporting events to transportation and turnpike usage are common narrow web applications. Medical and pharmaceutical packaging is produced on narrow-web presses, as are foil and paper lids. Increasingly, narrow-web presses are used for manufacturing folding cartons and flexible packaging.

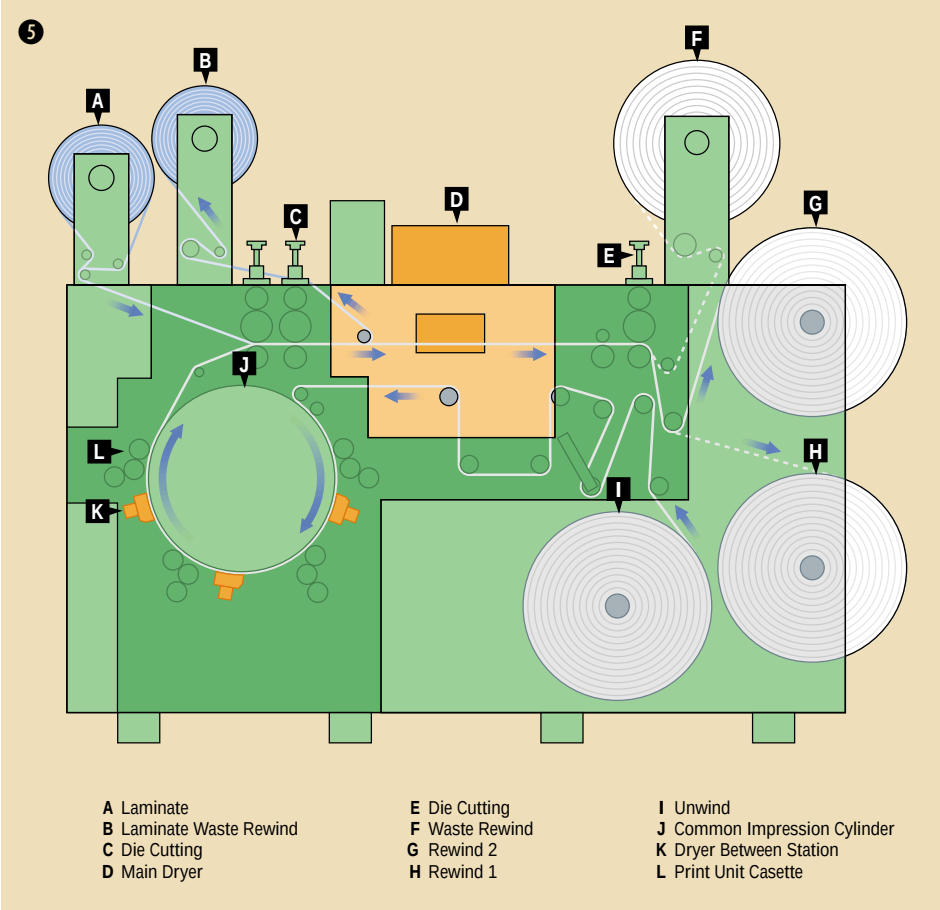
Advantages

Narrow-web flexography has many advantages that make its economics very compelling in a world of higher quality, cost-effective productivity, and shorter, more frequent runs. In-line processing reduces the time and costs associated with multiple processing steps, such as those that occur with the sheet-fed offset manufacturing of folding cartons. This advantage is reinforced with the multitude of tasks that can be combined on narrow-web presses. These tasks range from corona treatment to multiple forms of graphic imaging, including variable data, overprint varnishes and laminates. In-line die-cutting, hole punching, perforating, creasing, embossing and folding can also be done on narrow-web flexo presses. Multiple webs can be processed, married together and delivered in roll, sheet or stacked formats. The multiplex character of narrow-web presses gives their users a strong cost advantage on a wide variety of products.

In addition to the time and labor saved by performing multiple operations on a narrow-web flexo press, material waste is also reduced. The spoilage associated with handling and moving of the work in process is eliminated, as is the scrap generated by multiple setups in the manufacturing process. Since the material is typically the largest cost element in the finished product, waste reduction can have a tremendous impact on profitability.

Another advantage of narrow-web flexo presses is their ability to be set up and changed-over quickly. Part of this efficiency is due to the nature of flexo printing compared to other technologies, and part is inherent from being smaller than their wide-web counterparts. Narrow-web press manufacturers have also made setup and changeover efficiency a key element of their designs. This concerted effort by press designers has dramatically reduced the time required to set up narrow web presses, even as the complexity and difficulty of the work performed on them has increased. Sophisticated change out and clean up procedures are increasingly utilized by converters to achieve maximum productivity of their equipment. These innovations have led to makeready times of 10 minutes or less for changing from one six color job to another, on state-of-the-art narrow web presses. This quick changeover includes plate rolls, ink fountains, anilox rolls, metering system, material and die changes.

The final element that gives narrow-web flexo a significant advantage over competing technologies is the quality being produced by narrow-web converters. Advances in prepress, plate, anilox, ink and press technologies have been eagerly embraced by narrow-



5 A typical narrow-web four-color CI press. Among the features that make it popular is its relatively low cost, small footprint, and easy-to-use controls and accessories.

web converters and combined into a world class printing technology. While each printing process has its own unique set of strengths and weaknesses, flexo has made tremendous progress in overcoming its weaknesses and further advancing its strengths. As a consequence, process work of 200 and 225 lpi is now being printed on narrow-web flexo presses, while solids are richer and smoother than ever before.

TYPES OF NARROW-WEB PRESSES

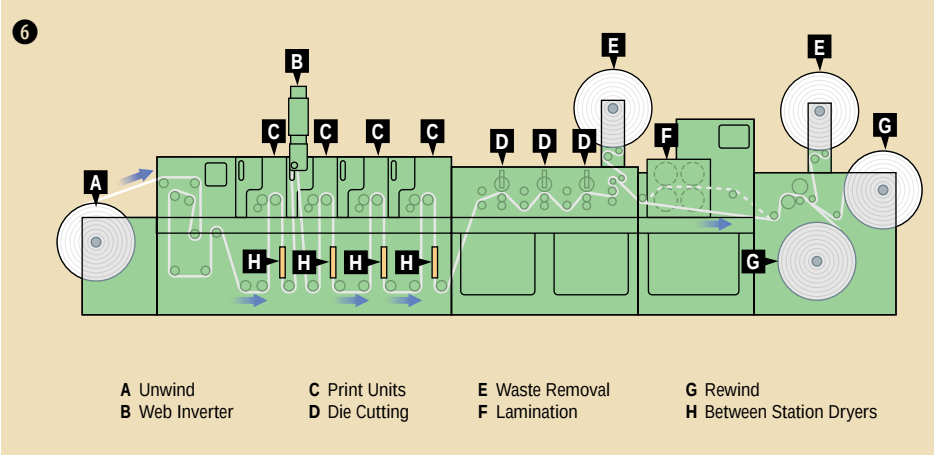
There are four basic design styles of narrow-web presses: central impression, in-line, stack and platform. These presses are distinguished from one another in the first instance by their web paths, as determined by the spatial orientation of their printing stations. From this difference, a number of other characteristics are derived.

Central Impression Presses

The earliest narrow-web flexo label presses were central impression, and this design has remained popular through the years. Narrow-web central impression presses, like their wide-web counterparts, are characterized by the location of all the printing units around a common impression drum (*Figure* 5). Unlike wide-web central impression presses, the typical narrow-web CI press is three or four colors. Satellite stations, not located on the central drum, can be added to obtain five- or six-color capability.

Narrow-web central impression presses

❻ In a typical narrow-web in-line press, printing stations are configured horizontally, providing versatility and accessiblity to the printing stations.



are relatively inexpensive and take up a small amount of floor space. They typically do not have sophisticated controls and accessories, making them easy to operate and maintain. These characteristics make the design popular with smaller and start-up companies, as well as with larger converters needing additional capacity for low-end work. This style of press is also often used for training in educational institutions.

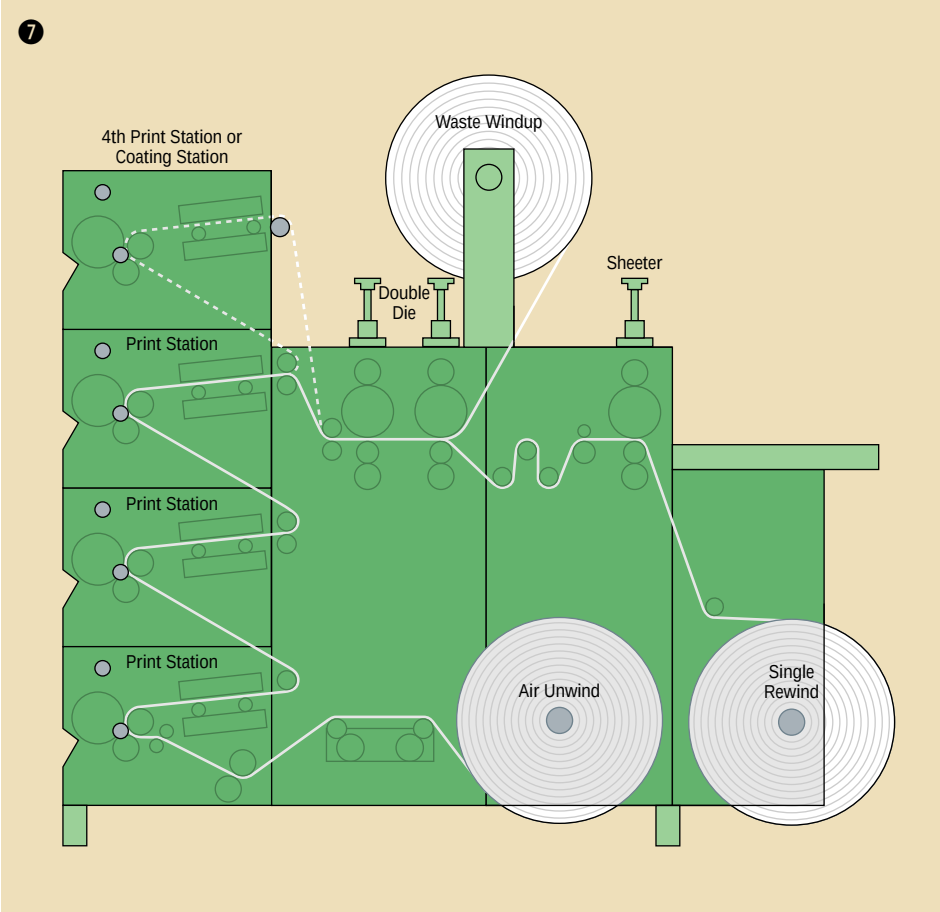
Because the web is captured on a common cylinder and not subject to tension fluctuations as it is transported from station to station, central impression presses hold excellent color to color register. They are well suited for printing difficult to control materials, such as tapes, highly extensible films and cloth.

The typical narrow-web central impression press has a web width range of 6" (152 mm) to 20" (508 mm). This narrow width, and the limited number of colors on typical narrow-web CI presses, have restricted their use in the flexible packaging market. However, in response to changes in the flexible packaging market and its need for equipment better suited for shorter run lengths, traditional wide-web press manufacturers have introduced narrower versions of their wide-web central impression presses. These presses are typically six to eight colors and have a web width of 16" (406 mm) to 24" (609 mm). While falling within the range defined as narrow web, the design of these presses is heavily influenced by their wide-web origins, and the reader is directed to the wide web chapter for more information on them.

In-line Presses

In-line presses, as their name implies, have their printing stations oriented horizontally to one another (*Figure* ❻). Each printing station has its own impression cylinder. These presses are appreciably longer than central impression presses, but are also more versatile and provide the operator with greater accessibility to the printing stations. More than 75% of the narrow-web presses sold today are in-line designs.

In-line presses are manufactured in a full range of web widths, from 7" (178 mm) to 24" (609 mm). They are often modular, i.e., designed to allow the buyer to specify the number of print stations required, and, if necessary, to add stations at a later date. The number of print stations on an average in-line press has increased over the years. Six to eight colors are now typical, but 12 or more is not uncommon. Even on the largest in-line presses, register tolerance is typically less than ±0.005" (0.13 mm) over a specified number of repeats.



❼ A typical four-color narrow-web stack press, also known as a vertical in-line press, can be configured with as many as eight print stations.

The range of available web widths, and the number of print and converting positions possible with in-line style presses, make them very adaptable to a wide variety of uses and markets. Their open, accessible design allows many accessories to be added to them for specialized requirements. Thus, most of the narrow-web flexo presses used for folding cartons, flexible packaging, lottery tickets and coupon applications, are of the in-line design.

There are many design variations within the category of in-line presses. Some are cantilevered, i.e., without a framework on the operator's side of the press, while others are fully framed. All in-line presses have to transport the web from one station, or module, to another. However, the web path to accomplish this may vary dramatically, depending on the location of the interstation dryers. Likewise, the level and sophistication of the press controls range from basic manual, mechanical functions to nearly fully automated presses.

Stack Presses

Narrow-web stack presses are characterized by the vertical relationship of their print stations, and they are sometimes referred to as "vertical in-line" presses (*Figure* ❼). Stack presses can also have the print stations oriented in an inverted "U." Like the central impression press, the stack press takes up a small amount of floor space. Like the in-line press, the stack press has individual impression rollers. Stack presses are

usually manufactured with four, six or eight print stations.

In the narrow web industry, due to the need for larger registration tolerances on stack presses, they have not been as popular as in-line and central impression presses. However, stack presses do provide a good solution to the converter with restricted space and requiring more flexibility than can be obtained with a central impression press. Also, there is more distance for drying between print stations on narrow-web stack presses than on CI presses. This additional drying time allows some job layouts to run at a higher speed on a stack press than on a central impression press.

Platform Presses

Platform presses are a recent development in narrow-web flexo. Unlike CI, in-line and stack presses, a platform press is not distinguished from other presses by its web path. Instead, platform presses are unique in their ability to move processing and converting functions from one location to another. Narrow-web flexo is characterized, in part, by its ability to perform multiple printing and converting functions. Other narrow-web presses allow the converter to define the position of various functions of the in-line process at the time of manufacture, but they are then, essentially, fixed in location. Platform presses take this attribute to the next level by allowing the converter to quickly rearrange the press to the most effective in-line process configuration to efficiently run the job at hand.

Platform presses are oriented in an in-line fashion. In addition to allowing printing and converting functions to be repositioned, platform presses often will combine a number of printing technologies, which can also be positioned where needed. Rotary screen, lithographic offset and foil stamping are common printing technologies that may be combined with flexo on platform presses.

The need for platform presses arises from three fundamental market developments. First is the increasing variety and complexity of products produced by narrow-web converters. Fixed position presses, either in generic or specialized formats, are difficult to adapt to these rapidly developing and changing requirements. A second catalyst for the development of platform presses comes from heightened and changing graphic requirements. Flexography has dramatically increased the range of graphics that it can reproduce. However, the graphic design of some labels and packaging can be most efficiently reproduced only by combining a number of printing technologies. As narrow-web presses are used to produce labels and packaging for an increasingly broad array of products, the need for combining print technologies will increase.

The final development leading to platform presses is the increase in pricing pressures among converters, which has in turn caused a need for efficient production techniques to control and contain costs. It has also led to more customized equipment needs as converters develop unique and profitable products for niche market opportunities. Platform presses provide “on the fly” customization to meet these changing requirements.

PRODUCTS PRINTED

The flexibility of narrow-web presses, the economics of single-stage production and the ingenuity of narrow-web converters have resulted in a tremendous variety of products being produced on narrow-web equipment. Nearly any product substrate with a thickness between 0.001" (0.025mm) and 0.024" (0.6mm) that can start as one or more rolls of material, is a candidate for conversion on a narrow-web press. Some examples include:

Folding Cartons. This product can be printed, creased, blanked out and delivered in a sin-

gle pass on narrow-web presses. Other examples of similar applications are paper cups and sidewalls for dairy product containers.

Business Forms and Form/Label Combinations. To produce form/label combinations, a dual unwind is required together with some form of adhesive applicator.

Lids and Closures. Foil lids for juices and yogurt cups, for example, can be converted on narrow-web equipment. Likewise, paperboard lids, such as for ice cream containers, can be produced in a single pass on narrow-web presses. These lids often include a laminated viewing window that requires blanking out the window, applying a patterned adhesive, laminating and then diecutting the laminate. As with folding cartons, the foil and paperboard lids are blanked out and delivered on a conveyor or stacker.

Tickets. A variety of tickets can be converted on narrow-web equipment. Depending on the use of the ticket, these may require high-quality graphics, as for sport and entertainment venues, or precision-cut lengths for automatic dispensing of turnpike tickets. Lottery tickets require multiple print and coating stations and the use of special inks. Increasingly, security and anti-counterfeit features are incorporated into tickets for authentication and tracking.

Tags. The retail industry uses a tremendous number of tags in a variety of forms, including hang tags, static-cling tags and pressure-sensitive tags. All of these can be produced on narrow-web presses.

Flexible Packaging. Wraps for beverage containers and other products are printed roll to roll on narrow web presses, as is packaging for food products. Tubes, such as those used for toothpaste and gel containers, are also produced on narrow web equipment.

Coupons and Information Booklets. Instant redeemable coupons and extended information booklets are increasingly popular promotional and information vehicles. They require multiple unwinds, the ability to print and die-cut the webs individually, and the application of adhesives. All of this is done in a single pass on narrow-web presses.

Pressure-Sensitive Labels. The most common use of narrow-web presses is to produce pressure-sensitive labels. These products are used for product promotion and identification (prime labels), ingredient and usage instructions (secondary labels), material tracking and control, and promotional pieces, to name just a few examples.

Self-wound, Self-adhesive Tapes. Tapes are used for promotion and identification of a number of products, including tires, metal rods and conductive wires.

Other. Other uses growing in popularity include medical and pharmaceutical packaging, in-mold labels, and shelf markers and shelf talkers.

THE NARROW WEB PROCESS

Since most narrow-web presses are in-line presses, we will use that design, generally, for the purposes of describing the components of narrow-web equipment. The description will also be, for the most part, of a generic press for pressure-sensitive labels. The primary elements of these presses are:

- unwind;
- in-feed and tension control;
- print stations;
- drying and curing;
- die-cut stations;
- waste removal; and
- delivery.

Unwind

The unwind of a modern narrow-web press can, generally, handle rolls up to 1,000 lbs. or 40" (101 cm) in diameter. A roll loader will often be built into the press to assist in handling large rolls. A splicing platform and web guide are also usually included in the unwind module. The web guide may be a manual

device, but more typically is automatic. Automatic web guides may be hydraulic or pneumatic and may use an optic, sonic or pneumatic sensor.

Unwind Tension. An unwind brake is used to apply tension to the web as it is unwound from the roll. The braking device, which may be pneumatic, magnetic or electric, is mechanically coupled to the unwind core-holder to restrict its rotation. The brake may apply either a constant, fixed force, or it may vary the force to obtain a constant tension. Constant-torque systems, which apply a fixed force, are efficient only with smaller diameter rolls, such as those less than 15" (38 cm) in diameter. Since the braking force is generally applied at the core-holder, the force required to obtain a given tension is greater at larger diameters than at smaller diameters. Consequently, if large diameter rolls are used with constant-torque brakes, the press operator must periodically adjust the brake as the roll diameter changes. Constant-torque systems are usually used only on small central impression presses with limited roll sizes, and in situations where the printing and converting accuracy is not critical.

Constant-tension systems continually adjust the torque of the brake as the roll diameter changes. This can be done either by sensing the diameter of the roll or by measuring tension changes. Sonic and optical sensors are the most common methods used on narrow-web presses to monitor roll diameter. In some cases, a follower roller maintains physical contact with the roll of material. Tension-responsive systems are also commonly used on narrow-web presses. These systems may employ a load cell to measure absolute web tension, or a dancer system that uses a counterbalance measure of tension. The typical narrow-web dancer system will be pneumatically loaded against the tension created by the unwind brake. An advantage of the dancer system is that it will accumulate and release material if necessary, such as with irregularly wound rolls or during speed changes.

Unwind stands capable of handling rolls greater than 40" (101 cm) in diameter can be used with narrow web presses. These stands are often supplied with presses purchased for folding carton applications. In some instances, these larger roll stands will incorporate multiple unwind stands with automatic splicing to provide continuous, nonstop production. Automatic splice stands are also used for high-volume label production. These stands must make butt-splices to avoid damage to dies, while allowing continuous winding of the die-cut waste matrix. Multiple unwind modules without automatic splicing are also commonly used on narrow-web presses for applications that require lamination of multiple webs, including coupons and form/label combinations.

In-feed and Tension Control

Some narrow-web presses use only the tension created by the unwind brake to control the web as it enters the process area. However, most have some form of in-feed pacing in addition to an unwind tension system. The in-feed pacing system will have a driven roller and a rubber nip roller. In some cases, the system will also have a tension monitoring device and regulating controls. Those systems without a monitoring and control loop are called “open loop” systems. The driven roller in these systems will have a fixed velocity relative to press speed. “Closed loop” systems, those with a monitoring and control system, allow a press operator to select a web-tension level that is to be maintained. This is done with an electronic feedback system, which monitors the tension of the web and compares it to the selected tension level. Depending on the system, a constant tension is maintained by varying the velocity of the driven roller or of the braking torque applied to it.

Some narrow-web presses can vary the velocity of both the in-feed and the exit pacing rollers. This capability allows the press operator to alter tension while maintaining a constant amount of material passing through the press on each revolution. Some applications, such as EDP labels, require an exact, specified throw length, or spacing of the labels and feed holes. The capability to alter tension without affecting throw length is very important to converters of these products.

In-feed pacing systems are used to create an initial web tension and to control the web as it enters the press. Maintaining tension through the press is the function of the exit-pacing roller, and, to a lesser extent, all of the driven rollers in the press. Web control is obtained on all web presses through tension. However, as the web passes through the press and over rollers, it loses energy due to friction, inertia and deformation. These energy losses reduce web tension. To balance the energy losses and maintain adequate tension through the press, the exit-pacing roller will, typically, have a higher velocity than the other rollers in the press. Some press designs will have a slight, but precise, gradation of the velocity of all driven rollers. The gradient can be introduced by minute changes to the diameter of the rollers to alter their surface speed, or by use of servo motors to regulate roller velocity.

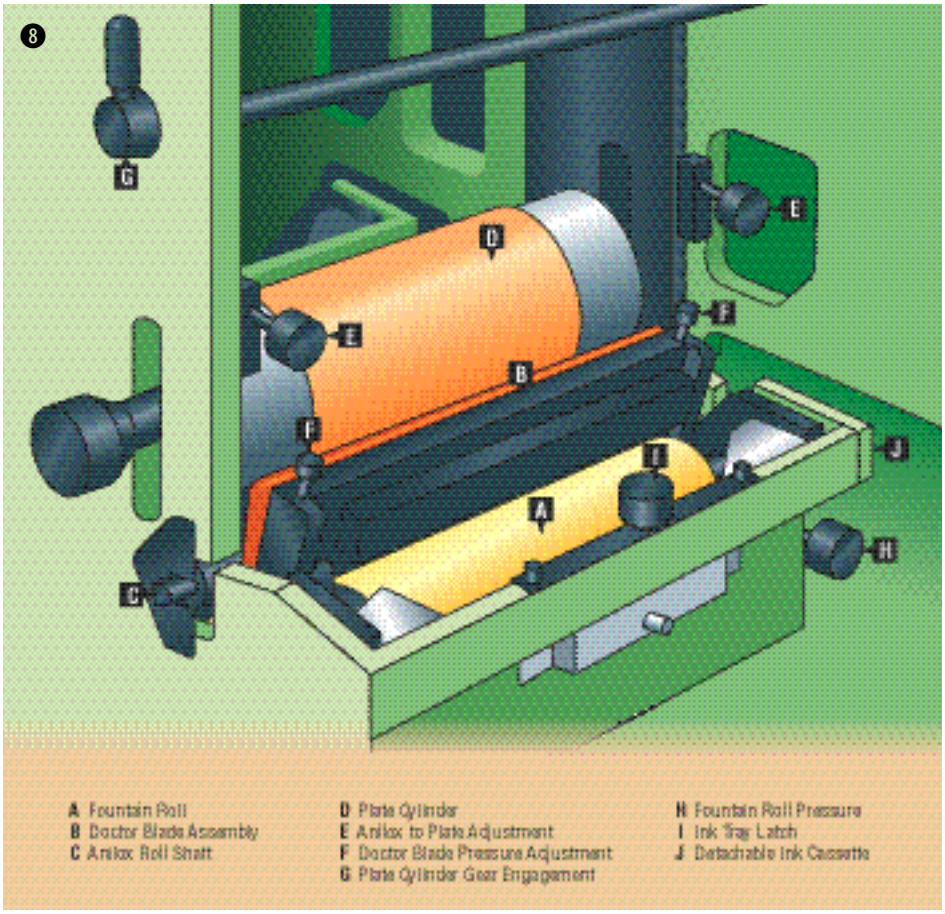
Print Stations

As with any flexo press, narrow-web presses use an anilox roll to control the amount of ink applied to the printing plate. Many narrow-web presses are supplied with laser-engraved ceramic anilox rolls, although mechanically engraved chrome rolls are also used. Metering of the ink film is typically done with a reverse-angle doctor blade in a two-roll system. In these systems, the fountain roller is used to flood the anilox roll with ink. The rubber fountain, or doctor, roller may be driven at a one-to-one ratio to the press speed, or at a slower ratio. If desired, the fountain roller, instead of the doctor blade, may be used to meter the ink. Some narrow-web presses are designed to use only a doctor blade and do not have a metering roller. Either conventional reverse-angle doctor blades or chambered doctor blade systems are used in these cases.

Repeat Lengths. Narrow-web presses do not have a fixed print repeat. A typical narrow web press will have a repeat range of approximately 5" to 24" (127 mm-610 mm). Also, narrow-web presses print on a wide range of materials with varying thickness. As a consequence, narrow-web presses must allow precise adjustment of plate cylinders with a wide range of diameters, to materials of varying caliper. This is typically done with “adjusting arms” that move perpendicular to the point at which the plate cylinder contacts the anilox and impression rollers. The plate cylinder is captured in the adjusting arms with journals or by a rod passing through the plate cylinder bearings. The movement of the adjusting arms must be sufficient to accommodate the full repeat length range. In addition to this coarse positioning of the plate cylinder, finite adjustments are provided to establish precise pressure settings between the printing plate and the anilox roll, and between the plate and the web. This can be done either by adjustment of the position of the plate cylinder relative to ink and web, or by positioning the plate cylinder to the web and adjusting the anilox roll position to the plate. Regardless of the method used, the mechanism must be rigid to avoid plate-roll bounce and to maintain the pressure settings throughout the run. *Figure* ❽ shows a typical narrow-web print station.

Registration Adjustment. Because the repeat length is variable on narrow-web presses, there is not a constant relationship that establishes close linear register position between stations. Consequently, narrow-web presses provide for both coarse and fine reg-

❽ A typical narrow-web print station layout.



ister adjustments. Coarse register adjustments are made in a number of ways on narrow-web presses. The most common is by disengaging the gear of the plate cylinder from its drive gear and rotating the plate cylinder. Another method is to use a high-speed motor to rotate the plate cylinder. This method is sometimes used for automatic preregister systems. With preregister systems, the operator positions all of the plate rolls at the equivalent of top-dead-center, and enters the repeat length information into a processor. The processor calculates the amount each plate cylinder needs to be rotated, or offset, to obtain a coarse register position.

Coarse positioning is used to register the print to within approximately one gear tooth, typically 0.125". Fine positioning, to establish precise register, may be a manual or an automatic function. Fine adjustments are usualy made through a worm gear to momentarily change the velocity of the plate cylinder or die. This adjustment results in a phase shift of the position of the tooling. The adjustment range may be a full 360°, or within a prescribed window.

Automatic Register Systems. Automatic register systems normally are used with 360° gearboxes, but they can also be used with systems with a restricted adjustment range. Two basic types of automatic register systems are used on narrow-web presses. One style is a mark-to-mark system. This style uses one or more optic sensors to “read” the position of a series of sequentially printed register marks. The other style of automatic register system

is a mark-to-pulse system. These systems are time based. A shaft encoder, which generates a series of high-frequency pulses, is used to precisely measure line-shaft revolution. Sensors at each print position detect register marks on the plate cylinders. The timing of the register marks are measured against the pulse chain to determine register. To avoid overreacting, both mark-to-mark and mark-to-pulse systems use an averaging algorithm to determine register error. If they did not, and transient errors were responded to, the system would quickly begin to chase itself.

On some narrow-web presses, register corrections affect web velocity and tension. This effect occurs when the plate roll and impression roll, or the die and anvil roll, have a common drive. In these situations, the momentary velocity change to the plate cylinder or die, done to effect a register correction, also creates a momentary velocity change to the impression roll or anvil roll. The transient disruption of tension usually will not result in a noticeable misregister on pressure-sensitive materials or on board stock. However, it can affect register on extensible film materials.

Drying and Curing

Narrow-web presses either dry or cure the ink after each print station. This interstation drying eliminates the need to wet-trap colors, and allows multiple converting and finishing operations to be done in-line. Drying of flexographic inks requires the removal, through evaporation or absorption, of a portion of the ink blend. Curing of UV flexo inks is a photochemical process, that is, a chemical reaction is initiated by the ultraviolet light and instantly proceeds to link the reactive components of the ink blend. Many narrow-web presses have both drying and curing capabilities at all or some of the print stations.

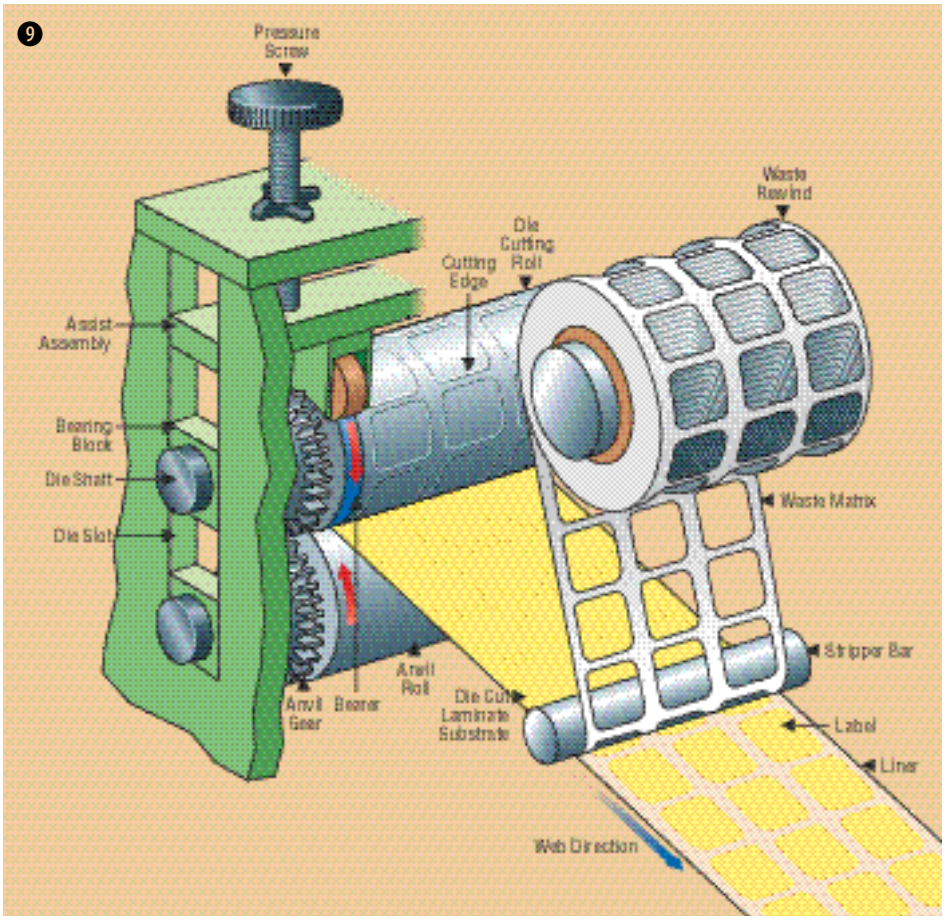
Drying on narrow-web equipment is done in chambers, or tunnels, located after each print position. The volatile components of the ink or coating are vaporized by heated, high velocity air directed at the web. Typically, the air is heated with electric heating elements. Some designs incorporate infrared (IR) lamps to radiate heat energy to the web. Occasionally, natural gas will be used to heat the air. The airflow in the tunnel must create turbulence around the wet ink. As it passes through the press, the web pulls a thin stream of air with it that forms a vapor barrier, which in turn prevents the evaporated particles from escaping from the ink. Turbulence is used to break down the vapor barrier.

Ultraviolet curing. For UV curing, ultraviolet radiation (light) must be generated. Ultraviolet light is usually generated with a mercury lamp. When the lamp is turned on, the mercury droplets are vaporized to a gaseous state. When excited to a gas form, mercury naturally emits radiation in the ultraviolet frequency. Either an electrical current or microwave radiation can be used to vaporize the mercury. Polished reflectors are used to direct the light at the web. For better, deeper or faster curing of some colors or of some specialty formulations, other materials may be added to the mercury in the lamp to alter the spectral “signature” or wavelength profile of the emitted light.

Laminating and Varnishing. Some products look better and are more durable with a glossy surface finish. This finish can be accomplished by laminating a film with a pressure- or heat-sensitive adhesive to the web, or by applying an overprint varnish. Most converters use varnish, since it is generally considered cheaper than laminating. Ultra-violet curable varnishes are particularly popular because of their durability and gloss.

When laminating, either a self-wound or liner-backed material can be used. If the laminating material has a liner, then this must be rewound on a waste spindle. The laminate film is applied to the web by pressure from a rubber roll in one of the die cutting stations. As well as giving gloss to the product, lami-

❾ A typical rotary die station consists of parallel slots milled in the front and rear frames of the press; a rotating, driven roller used as an anvil; a pressure assembly consisting of a pressure bridge and an assist assembly; and a waste matrix removal system.



nates and varnishes provide more durability and scuff resistance.

Die-cutting Stations

Narrow-web presses are converting systems that combine printing with die-cutting and other finishing operations. Die cutting requires extreme precision and exacting tolerances. Its mechanics have been compared to using an ax to cut wood to a prescribed depth repeatedly and consistently. The increased use of film materials for labels requires that the analogy be modified to include precisely cutting plastic as well as wood.

Typically, die cutting is done with rotary tools. However, flatbed die cutting is often used for folding cartons and in some international markets. Special male/female tools are also used for folding cartons and for foil lids. These applications require that the desired shape be fully cut out of the web. Since male/female tools provide a shear cutting action, as opposed to the crush or bursting action obtained with standard rotary and steel rule dies, less force is required and a cleaner cut is produced. Die life is also greater with male/female systems.

A typical rotary die station (*Figure* ❾) consists of parallel slots milled in the front and rear frames of the press; a rotating, driven roller used as an anvil; a pressure assembly consisting of a pressure bridge and an assist assembly; and a waste matrix removal system. Removable bearing blocks are placed on the journals of the die to position and maintain it in the parallel slots.

The rotary die is typically engraved in the desired pattern from high-grade steel. In some cases, electronic discharge machining, EDM, is used to create the cutting shapes. This process uses an electrical spark to erode material from the steel roll. It creates a very durable cutting edge and is used for long-run applications and when through-cutting to the anvil. Thin steel, etched plates or "flexible dies" are also used for die cutting. These flexible dies are mounted on magnetic cylinders of the appropriate circumference to match the desired repeat length. The cost of the magnetic cylinders has limited the use of this form of die cutting because a separate cylinder is required for each repeat size. This method is used most frequently for EDP labels and stickers and other applications that have a small number of standard shapes.

Bearers are also machined on the die. The height of the engraved cutting area relative to the bearers determines the depth of the cut. Different dies are usually required for different liner materials. However, special anvil rolls are sometimes used to allow the same die to be used with a variety of liners. These anvils have a different diameter on the main body of the roll than in the area of the roll contacted by the die bearers. This difference in diameter changes the relationship of the bearers and cutting blades to the material being cut. These special anvil rolls are called "stepped anvils." Usually these are fixed dimensions and one anvil is substituted for another as the liner material is changed. Anvil rolls have also been introduced that allow the operator to adjust the depth of the cut without changing the anvil roll.

The anvil rolls must be rigid enough to resist deflecting under the force created by the die-cutting operation. They must be mounted in bearings adequate for the load and the station frames must be rigid. The pressure assembly must also be rigid and must not compress or deflect. Many press designs incorporate a pressure beam or a roller beneath the anvil to increase the structural integrity of the die station and to assist in carrying the load. Increasingly, die pressure systems are used to observe the force on both bearer areas and to obtain quantified data for SPC or other quality programs.

Die-cutting Basics

Because of the many factors that affect the outcome of what is broadly termed die cutting, the process remains more art than science. What may in certain situations be a solution to a problem may, in other circumstances, make the problem worse. For example, in some cases, waste removal (stripping) problems caused by a difficult adhesive release may be improved by heating the web, but a thin plastic substrate will be difficult to die cut if it is overheated.

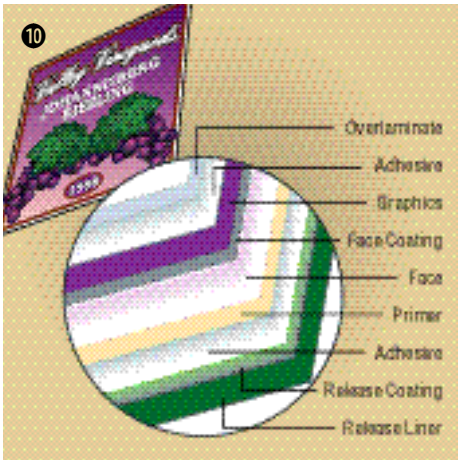
Die cutting on narrow-web presses is very much like using an old fashioned cookie cutter on a thin layer of dough. In the case of flatbed die cutting, forward speed of the web and the die are matched by slowing or stopping the web and/or moving the die in an orbital pattern as the web slows.

Since, in flatbed cutting, all the cutting edges contact the web at the same time, various approaches are used to reduce the extreme pressures involved. The dies are either kept small or, in some presses, the amount of cutting edge in contact is reduced by using a moving anvil roller under the web to create the cutting action.

To get a picture of the rotary application, imagine our cookie cutter being wrapped around a cylinder, with the cylinder's surface speed matched to the speed of the web.

While the entire process is properly called "die cutting," it would be well to remember that it really is a two-fold activity. One step is the cutting of a material to a predetermined shape, and the other is the removal or separation of the product from the waste or the waste from the product.

While die cutting is a large factor in the



❶❶ This cross-section of a pressure-sensitive laminate shows the layer where the adhesive bonds the release liner, which provides the additional strength needed to resist the stress of subsequent waste rewinding.

success or failure of the entire converting operation, the interaction of the various parts of the converting process (printing, drying or over-laminating) often causes the difficulties. The components of this interaction are: the specifications for the products to be produced, whether it is tags, labels or specialty items; the capability and condition of the press and auxiliary equipment, such as an air compressor; the environment in which the process will take place; and the condition, adequacy and quality of the die being used. Individual components, such as the material to be converted or the die, frequently meet specifications of their own, but when used in combination and influenced by other parts of the process, may have to change to attain needed or expected production rates.

The die station anvil is another significant influence on the results of the cutting process. Of the three variables that interact during the cutting process – the liner, the die and the anvil – the anvil is the easiest to inspect and maintain. It must be perfectly round and smooth, and its die-supporting surface has to be concentric to its axis of rotation.

Even though anvils are made of steel and hardened, like all components, they will wear with use. Unfortunately, this wear is neither uniform nor predictable. As with all cylinders on a press, frequent detailed inspection of anvils with appropriate measuring instruments is advisable. It is preferable to take some of these measurements while the load is applied to the system, so that eccentricities caused by faulty gears, bearings or supporting components can also be detected.

To best understand rotary die cutting action, particularly with lines perpendicular to the length of the web, think of the process as driving an ax into a piece of wood. The sharper the blow and the more rugged the support, the more likely it is to produce a thorough cut. The lighter the ax or the weaker the force of the blow, the more likely it is to glance off the target and not penetrate sufficiently to do its job.

Consider this definition of narrow-web die cutting: "the process of cutting a prescribed shape in register while printing on diverse substrates moving at high speeds, without adversely affecting the integrity of the carrier and while separating waste." It is a simple enough statement for a process that can be very frustrating when problems crop up. Additional details about the key aspects of die cutting are discussed below.

Substrate Influence

The two most important traits to consider when die cutting are the substrate's ability to be die cut with a wedge-like tool, as in rotary die cutting, and sufficient strength in the part that becomes waste, to resist the stress of subsequent waste rewinding. In the case of pressure-sensitive laminates (*Figure* ❶❶), the adhesive bond to the release liner, called the release factor, adds significantly to the strength requirements of the waste portion, as does the product's configuration. To a lesser degree, the impact tear strength of the waste material is also important, since the removal and rewind process tension often is irregular.

Many materials besides paper are now used in converting on narrow-web flexo presses. Some of these materials are readily

affected by environmental conditions when it comes to being die cut and having waste removed. For example, some thin plastic films are affected by heat and/or ink solvents, making them extrude under the die edge instead of parting.

The liner of a pressure-sensitive laminate, sometimes called the carrier sheet, is as important to the die-cutting process as the label material itself. Since the liner, along with the anvil roller, becomes the surface supporting the die-cutting action, it is important that it be uniform in all characteristics throughout the lot, particularly in thickness and compressibility.

For many years, paper coated with a thin layer of silicone to allow easy removal of the adhesive was the material of choice for liners. As the variety of label materials grew and the demands on the strength and performance of the liner increased, plastic liners or composites also came to be used.

It is paradoxical that the liner on a pressure-sensitive laminate is ultimately discarded as waste, but during its life serves many critical functions in the manufacture and application of pressure-sensitive labels. The liner function starts as a release-coated web to which adhesive and label-face stock are merged. Its next job is to provide a way to store the label material until it is placed on the press unwind, at which point it becomes a carrier for the face stock, transporting it to the various printing, coating and over-laminating stations. When the web reaches the die-cutting station, the liner functions as part of the anvil against which the die cutting is done. The liner then carries the die-cut label as a conveyor through the waste-removing station and onto the end of the press, where it takes on a storage function again, either in fan-folded, sheeted or roll form. Before being disposed of, the liner performs its last significant task, that of providing a way to remove the label for transfer to its product or other end use.

In many cases, the label is transferred to its intended surface with automatic dispensing equipment that relies a great deal on the liner's ability to release the label and withstand the high stresses of this dispensing process. It is at this point that the quality of the die-cutting process and its effect on line integrity are most critical.

Since many pressure-sensitive labels are automatically dispensed and applied in high speed packaging lines, it is important that while die cutting, the liner's integrity be preserved. If the die cuts too deeply, it may damage the liner's release coating and sometimes even the base material. Depending on the location and severity of this damage, fouling of the application equipment can occur and cause interruptions of the production line. Frequent and diligent monitoring of the die-cutting process will prevent this downtime.

The most prevalent method of quality assurance for liner integrity is visual inspection of the liner after removing the die-cut parts from randomly selected portions of the web. To enhance this difficult, very subjective evaluation, a dye or diluted ink solution is spread over the release-coated side of the liner, where it will penetrate and highlight areas where the coating has been damaged.

When it comes to quality, there are widely varying standards for what to accept and what to reject. It is crucial that the standards are agreed upon between the customer and the producer and clearly defined to the press staff before each production run.

Since the quality of the label's liner is such a critical part of the product's utility, the matching of the die's specification to the liner thickness is critical. A great deal of the potential success or failure of the die-cutting process depends on the ability to maintain tight control over the consistency of the thickness (caliper) and compressibility of the liner so the die can be produced to work with a predetermined liner specification. Unexpected variations in the die or the liner are

the most frequent causes for production problems and resulting delays.

Cutting Modes

There are two basic modes of rotary die cutting:

- Partway-through cutting, usually done to the liner, without damaging it, when the substrate is a multiple-layer laminate,
- Through-cutting, sometimes called "steel-to-steel" cutting, cuts through the whole web thickness.

Combinations of the two modes are sometimes used with the same die, which is called a two-height or multi(ple)-height tool.

Other cutting modes sometimes are used in narrow-web presses. For example, slitting a straight cut along the web can be done in several modes: with a through-cutting (steel-to-steel) lineal rotating die against an anvil, using razor blades held by a press attachment against the web (substrate) as it moves along; or with rotating shearing rings whose edges overlap like scissors to sever the web. On narrow-web presses, shear cutting across the web is very rare, except in small-hole cutting with special male/female attachments. This example is yet another variation of the basic cutting modes.

Prescribed Shapes

The easiest shape to define, specify and die cut is a straight line along the web's travel direction. While it may seem that a straight line in any direction would be equally simple, that is not the case in rotary die cutting. Straight line cutting across the web (perpendicular to web travel direction), causes significant reactive stresses on the die support members and the total die station, including the anvil. These stresses can be very significant as the length of cut across the web approaches the full web-width capacity of the press.

Examples of simple, across-the-web cutting are a cross perforation used on computer labels and buttcut labels, such as bumper stickers. Circles are considered the easiest shape to die cut because of the absence of across-the-web straight lines, but there can be a problem with waste removal.

There are many aspects of a product's shape that affect the ease of waste removal. Unfortunately, the converter is frequently not given enough of a chance to affect the final design. In addition to long, straight-across-the-web lines, other hurdles to successful waste removal without tearing the substrate include small corner radii (under 1"), abrupt changes in outline configurations and reverse indentations in the product outline.

Specialized Tooling

There are two manufacturing processes that generate the cutting edges on rotary dies. One uses conventional machining, sometimes called engraving because the cutters are so small. The other uses electrical discharge machining: the controlled erosion of material with an electric spark. Whatever the process, the crucial results are shape, included angle, sharpness and consistency of cutting edge height in relation to the bearer.

Besides the conventional rotary die produced from a steel bar with raised cutting edges and machined to conform to the press, there are also now in use thin, sheet-steel etched dies mounted to magnetic cylinders. But their use is limited by the availability of varying repeats of costly magnetic cylinders.

In addition to shape-cutting rotary dies, other special tools used in the die-cutting stations of narrow-web presses are described below.

Removable Blade Crosscut Tools. These tools cut straight across the web and by changeing blades, allow the removal and replacement of the cutting edge as it wears. These tools also allow a change from straight cut to various interrupted cuts, called perforations, and changes in cut spacing.

Adjustable lineal cutting and scoring tools. These tools permit across-the-web position adjustment of the lineal cut, while the press is stopped. After loosening a set screw, the cutting blade is repositioned and then relocked. Often, these tools come with extra blades and some perforating wheels. When repaired, all parts originally supplied with them must be refurbished at the same time.

Pinfeed hole-cutting tools. For use with pressure-sensitive laminates, these tools are available as either fixed-position or adjustable across-the-web tooling. Usually, they are installed in the anvil position of the die station, cutting the liner up against the face material, and allowing removal of the small liner waste on the pressure-sensitive waste matrix.

For some other applications, where small holes are required in the liner, such as feed slots for some labeling equipment, the same principle as for pinfeed hole cutting can be used. Frequently, the die labeling is then no longer adjustable but is dedicated to that application.

Air-assisted dies. When cutting through a single-layered substrate or all the way through a multilayered web, compressed air is frequently used to keep the die clean and help separate waste from web. Air-assisted dies are made with air passages leading from the cutting cavities to the hollow center of the tool, which is connected to a compressed-air source. Waste accumulating in the cavities is a common culprit in die damage.

Two kinds of air-assisted dies are in wide use today: the standard air-eject, with all passages open at the same time; and dies incorporating a unique valving system that uses air more efficiently to greatly boost the capabilities of air-assisted tooling while reducing some of the disadvantages.

To further help with waste collection and removal, industrial vacuums, brushes and various other mechanical devices are employed.

Male/female tooling. This tooling is employed on web presses if product quantities are large enough to amortize the cost. The rotary attachments use two large, geared rings running opposed to one another with the web between them (Figure ⓫). The lower ring usually carries the female or die portion and the upper carries the punch, which penetrates the substrate and forces waste into the die. Cutting is achieved by a shearing action. Usually, waste is removed from the lower ring with a vacuum, creating the most positive cutting and waste removal system in rotary die cutting. A flat die-cutting attachment is sometimes available for reciprocating male/female cutting, depending on press or unit design.

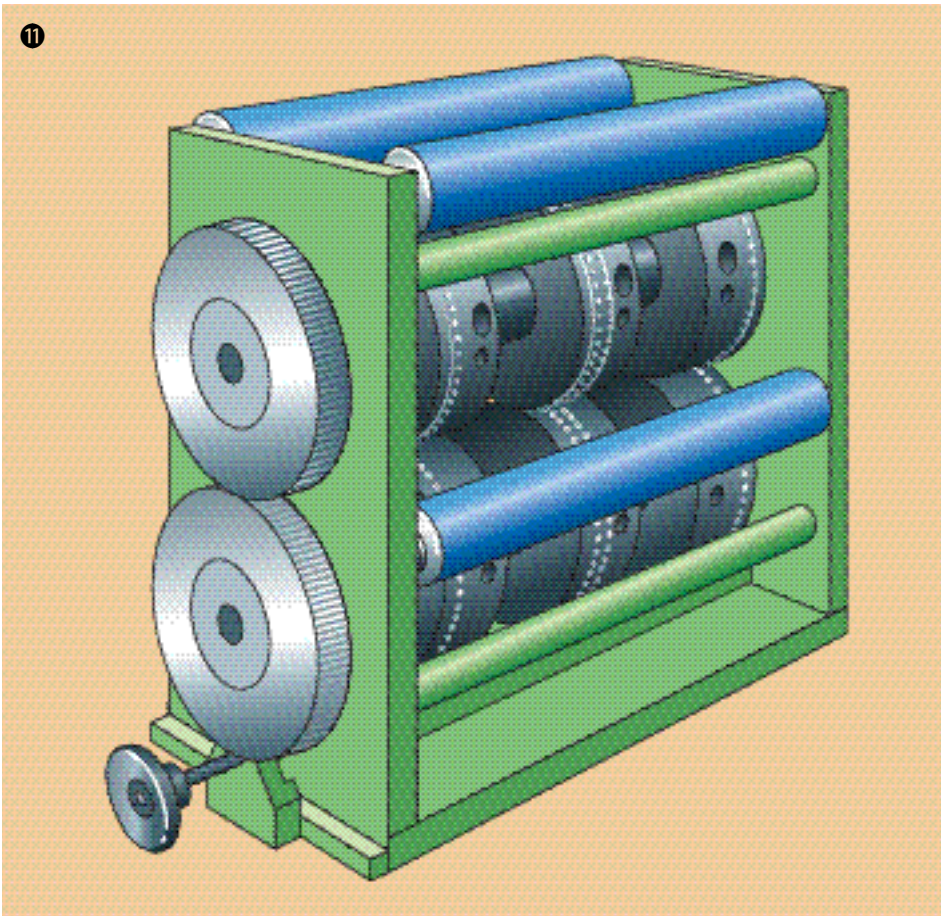
Care and Handling of Rotary Tooling

Rotary dies represent a major investment. They are very expensive, perishable tools and can be resharpened several times. Their service life is directly related to the substances being cut, the ink through which cuts are made, and the care the tool gets. Given the precision nature of these tools, even storage habits have to be considered in preventing damage.

It is sad but true that die repair is mandated more often by mishandling or damage in storage rather than by wear. Much has already been written about ways to avoid die damage. The essentials can be reduced to common sense practices that apply to any machine part.

Shafts and bearers should be clean and well-lubricated. Die surfaces must be kept clean and protected from unexpected sources of damage, such as rings or belt buckles worn by the operator. Keeping the die protected while stored, installed in the press or otherwise handled should become a routine pressroom practice.

Die wear caused by use is expected. The die should be checked after each run to



⓫ A typical rotary male/female punching unit, where the lower ring usually carries the female or die portion and the upper carries the punch. The gears run opposed to one another, with the web between them, penetrating the substrate and forcing waste into the die. Cutting is achieved by a shearing action.

decide if resharpening is required before putting the die into storage, so it will be ready to work well the next time.

Problem Areas

The rotary die-cutting process appears quite simple under casual observation but in fact relies heavily on the quality of tools, converting materials, the condition of the die station and the press. In addition to control and maintenance of appropriate web tension, the press must be able to keep the web from weaving, thus avoiding what can be one of the major sources of die damage – tracking of the web under the bearers.

The die-cutting process relies on the web being under tension while supported by the anvil. This anvil must be rigidly supported against deflection because the forces during die cutting change greatly as the cutting edges move from along-the-web to across-the-web cuts. If the die isn't correctly loaded, the die bearers and the cutting edge may separate from the anvil, thus losing the critical positioning of the cutting edge in relation to the anvil. This separation, referred to as die liftoff, is often found to be the source of diecutting difficulties that can't be diagnosed by measuring the die, the straightness of the anvil and the liner in use.

A similarly difficult-to-diagnose problem is caused by die flexing and sometimes both die and anvil flexing. In this situation, the bearers do not necessarily leave the anvil surface, but the forces during cutting are great enough to bend the die, causing a movement

of the cutting edge away from the anvil along the center of the across-the-web cuts.

In early models of narrow-web presses, the problems of die flexing, anvil flexing and die liftoff were accentuated by the method used to position and load the die against the anvil; it was done by applying the load over the shafts through bearing blocks. In modern presses, anvil diameters and shaft support bearings have been increased considerably, and the method of loading the die employs an assist system that applies the pressure directly against the die bearers while using the die shafts only to locate the die in the required position to the anvil.

A frequently asked question about die wage is: What is the correct operating load for a die? There is no specific force that can be stated, since the load varies with the amount of cutting edge across the web, the material to be cut and the sharpness of the die. The best way to define the correct load is to say that just enough pressure should be applied to keep the die bearers from separating from the anvil during any part of the die's revolution.

Various devices for measuring the load being applied to the die have been developed and are useful in training and developing operator skills. It is very important that the load applied to each bearer be equal, since uneven loading can be even more detrimental than incorrect total load. In the absence of load-measuring devices, backing off and reapplying load while observing the cutting action of the die and looking for evenness of cut across the web can indicate whether a die is loaded correctly. It is important to remember that as a die-cutting station is used, it warms up and various parts expand at different rates. It is critical for extending die life and reducing overloading on various parts of the system, particularly bearings, that during the warm-up period, die load is readjusted to reduce excessive loading caused by thermal expansion.

When a rotary die is positioned in the die station, axes of the die and anvil must be perfectly parallel to each other and perpendicular to the web. Use of worn or non-symmetrical bearing blocks can cause lack of parallelism, which results in changes in the cutting depth of the die, incorrect placement of the desired label shape on the web and premature die failure.

During the life of a rotary die, the bearers are very seldom the exact size that its gear and particular anvil circumference require for exactly matching die bearer surface speed to that of the anvil. Therefore a slippage between the die bearer and the anvil surface on which it rides has to occur. To minimize the effects of this differential movement, it is imperative that the surfaces of the hewer and the anvil be kept clean and well lubricated. Many narrow-web presses do this cleaning and lubrication by installing wipers. Wipers are pieces of felt or similar material that ride against the anvil and/or die, wiping away paper dust and other debris, and depositing oil on the wiped surface. These wipers require constant attention to replenish their oil and to remove the accumulated debris they pick up.

Waste Removal

Die cutting creates a waste matrix that must be removed and accumulated for disposal. With pressure-sensitive labels, the waste matrix is a portion of the face stock and adhesive. Frequently, an edge trim of the liner is made with a scoring unit and this portion of the liner is also removed with the waste matrix. The most common removal and disposal method for this waste is to strip it from the material and to wind it on a core-holder. The waste rewind unit consists of an idler roll for stripping the waste; a capstan roll driven through a clutch to pull the matrix at a constant tension; and a clutched core-holder on which to wind the waste. A turret system may be used for waste winding

for continuous operation, as can a vacuum removal system. These systems also incorporate the stripping idler and capstan roll. The waste-rewind components are intended to keep the waste matrix moving at the speed of the web without hesitation or excessive pull. Frequently, a driven capstan roll is provided to assure uniform pull on the waste matrix as the rewound waste roll changes size during the cycle. The waste rewind drive has a clutch to allow for the torque variation caused by the size change as it drives a core holder and lock.

Many experts consider the geometry of the point of waste-from-web separation a very critical factor in overcoming waste removal problems. Therefore, to allow for the relationship between the web, the die anvil and the point of waste separation to be optimized, both diameter and position of the idling roll of the waste removal section and the position of the stripping bar must be adjustable.

The waste created in die cutting folding cartons, lids, in-mold labels and other products that are fully cut out of the web, is handled differently than a pressure-sensitive waste matrix. Die cutting of these products occurs in the sheeting position of the press, and the die cut pieces are fed into a conveyor or stacker. The waste matrix is the unused portion of the full web and not simply a portion of the face stock, as with a pressure-sensitive construction. If the waste is a continuous matrix, it will typically be rewound on a standard product rewind. In some cases, the shape of the product prevents a continuous waste matrix from being formed. When this occurs, the waste is vacuumed away. The vacuum system may be used with a pin-removal system to physically capture the waste for deposit into the vacuum tube.

In addition to shape-cutting rotary dies, there are a number of special tools that are used to sheet, perforate, score and add holes to the web. These tools sometimes are mounted on special platforms in the press, but are more often used in a die station.

Removable blade crosscut tools are used to through-cut, perforate or score across the web. The blades used for the different operations can be easily interchanged and replaced when worn. Typically, the tool is made with multiple positions around the roll for mounting of the blades. By adding or removing blades in these positions, the spacing of the cuts may be altered.

Lineal cutting and scoring tools cut, score and perforate the web in the direction of its travel. Through-cutting systems are normally located in a dedicated position on the press and are crush-cutting circular knives. These systems can also be used for perforating the web. Shear-cutting systems are also available for through-cutting. These may be mounted either in a die slot or in a dedicated position, depending on the press design. Lineal-scoring tools are used to cut or perforate only part way through a web, for example, to cut through the liner but not the face stock of a pressure sensitive web. These tools usually are positioned to cut or perforate from the bottom side of the web. They may be placed in a die slot, but frequently are mounted with brackets directly to the press frames.

Hole-cutting tools are used to create feed slots or other holes in the web. These tools can be placed in a die slot and used to cut through the liner material of a pressure-sensitive web. The liner waste is then removed with the waste matrix. More typically, line hole punching is done with a male/female unit mounted in a special platform on the press. The waste from these systems is vacuumed away. Air assist dies are sometimes used for through-punching the web. These tools use compressed air to eject the waste chaff from the die.

Product Delivery and Collection

The most common delivery system on narrow-web presses is to rewind the product.

The press is typically equipped with one or two spindles capable of rewinding rolls to a diameter of 30" to 40" (762 mm to 1016 mm). These spindles are independently driven. Depending on the control mechanism, the product will be wound under a constant torque, a constant tension or a controlled taper tension. Turret rewinds are also available for continuous operation.

Another means of delivery is in a sheeted form, known as sheeting. Narrow-web presses have a die slot located immediately after the exit nip and pacing rollers. Typically, a rotary crosscut tool is placed in this position to cut the product to the desired length. Through-cutting tools are also used in this position to cut the product into special shapes. The individual pieces are collected in either a stacker or a conveyor for easy bundling and removal. A stacker will gather the items in a vertical stack. A conveyor will shingle the pieces horizontally. The stacker or conveyor must be located immediately adjacent to the cutting tool. After the web is cut, only its momentum carries the piece to the delivery unit. After the product is in the stacker or conveyor, an acceleration section transports the individual pieces and creates a slight gap between them.

The delivery of cut-to-shape folding cartons often requires a specialized system. The unique shape of the cartons, and the need to minimize waste, create situations where multiple shapes are interleaved or “nested.” xTo create individual stacks in these cases, it is necessary to laterally separate the cartons, or to “de-nest” them. The stackers and conveyors used for this process are highly specialized. Unique delivery systems are also incorporated into the flat bed die-cutters used to shape cut folding cartons. These delivery systems must have the capability to remove both the waste and the cartons from the die cutter, as well as to de-nest them.

Narrow-web presses can also be equipped to deliver the product as a fan-folded stack. With this delivery system, a perforated web is fed into a fan-folding and conveying system, which is timed to the press speed either mechanically or electronically. Fan-folding is commonly used for EDP labels and for pharmaceutical labels.

Tension Systems

While this discussion on web tension applies mostly to flexographic presses, it is also relevant for coaters, laminators, slitters, winders, sheeters and other machines familiar to the flexographer.

Web-tension control is a very important function of any web-process machine because it determines, in large part, the machine's production efficiency and the product's quality. Inadequate tension control can severely limit the performance of new machines. And modern tension controls, retrofitted to older machines in good condition, can raise performance to equal or sometimes beyond that of the newest machines.

Web breaks and wrap-ups around driven rolls *(*caused by slack web*)* are only the most obvious consequences of inadequate tension control. Here are some others:

- loss of color-to-color registration while running at speed, splicing or changing speed;
- deformation of web due to stretching or wrinkling;
- print-length variations; interleaving of slit webs; web shifts side-to-side;
- curling or wrinkling of laminating webs;
- variation of coating thickness;
- unwind or rewind core crushing;
- reduction of machine speed to accommodate web-handling problems or sheet length;
- excessive waste of web material; inability to run a wide range of web thicknesses, widths or materials;
- the need for excessive labor to operate the machine; and
- in general, poor productivity and high waste.

Many of these problems are simply accepted as normal and are not usually attributed to web tension, as they should be. However, anyone who experiences these problems and recognizes the relationship can improve efficiency, and profits, by using better tension-control methods.

TENSION ZONES

A typical flexographic press has more than one tension zone. This separation exists because the process in any individual zone may require a different tension level or pattern than the processes in other zones.

A tension zone is that length of web that extends from one tension-affecting device (TAD) to the next. Typical tension-affecting devices are: unwind or rewind core shaft with attached motor, clutch or brake; driven rolls; braked rolls; nip rolls where at least one roll is driven or braked; drag bars; and any other device that may add or subtract a significant amount of tension to or from the web. Printing, coating or slitting stations are not normally considered to be tension-affecting devices, even though driven rolls are involved because the web is not gripped firmly. An exception is the gravure printing station, which uses a high-pressure nip and driven rolls. The following describes the different tension zones.

Unwind Tension Zone

Constant tension from full roll to core is desirable here. Any significant deviation

from constant tension may be reflected in the next tension zone, causing problems there. The unwind tension level should be equal to or less than the tension used while winding the roll. Greater tension can cause the roll to tighten on itself and telescope. This problem is more serious with smooth, low friction materials than with rough or sticky webs.

Extensible webs, such as polyethylene and unsupported vinyl, are run with much lower tension than nonextensible webs, such as paper or foil, to prevent wrinkling, stretching and reduction of width.

Intermediate Tension Zone

Constant tension is also desirable here, but the level may be higher or lower than the unwind tension. The process, the web material, and its thickness and width usually determine the correct tension. Extensible films must be run with low tension to prevent stretching, which causes short print lengths and curling upon release of tension.

Rewind Tension Zone

Either constant or tapered tension is used in this zone. The choice is determined by the web material, the buildup ratio (full roll diameter divided by core diameter) and the tension capability of the rewind drive. Usually, buildup ratios (full roll:core size) of more than 5:1 require tapered tension, which refers to a tension profile having less tension at the full roll than at the core. A profile having a decrease of 40%, for example, is said to have 40% taper; full roll tension is 60% of core tension.

The rewind-tension profile is almost always dictated by the necessity to produce a good quality rewound roll rather than by prior processes in the machine. But this priority is only possible if the rewind tension zone is effectively isolated from the tension in the preceding zone by an efficient nip-roll system. If the nip is not a good isolator, rewind tension will affect tension in the preceding zone and the rewind-tension profile may have to be adjusted to accommodate its requirements, consequently roll quality may suffer.

Low-friction web materials, such as plastics and high gloss paper, are normally wound with high taper, 50% or more, while extensible webs are wound with low taper or constant tension. Webs requiring high tension and large buildup ratios need high taper to keep from exceeding the capability of the rewind drive. For example, a roll wound with 50% taper requires half the horsepower of the same roll wound with constant tension.

Table 1 lists some common converting materials and some typical tensions for them. The values shown come from practice rather than theory, so they may be different from those listed in charts from other sources. However, they closely represent tensions actually used by converters.

Tension is often used to correct web-handling problems. For example, the web may have a loose edge, so the machine operator increases tension to stretch the web and eliminate the looseness. Or the web may not track properly through the machine so, once again, tension is increased to correct the problem. Unfortunately, this adjustment may create other problems such as web breakage, stretching, wrinkling and print-length variation. It would be more beneficial to correct the cause of the web-handling problems than to create more problems by increasing tension.

TENSION DRIVES

Tension dirves fall into two catergories: motors or brakes and clutches.

Motors

Both alternating current (AC) and direct current (DC) motors can be used as tension drives. Direct current motors may be used in all tension zones, but they are most common in the intermediate tension zone and least

TYPICAL TENSION FOR WEB MATERIALS

MATERIAL	TENSION (per mil per inch of width)
Acetate	.50 lb.
Foil (aluminum)	.50 lb.
Foil (copper)	.50 lb.
Cellophane	.75 lb.
Nylon	.25 lb.
Polyethylene	.12 lb.
Polyester	.75 lb.
Polypropylene	.25 lb.
Polystyrene	1.00 lb.
Saran	.15 lb.
Vinyl	.05 lb.
Paper*	**(per inch of width)**
15 lb.	.40 lb.
20 lb.	.50 lb.
30 lb.	.75 lb.
40 lb.	1.25 lb.
60 lb.	2.00 lb.
80 lb.	3.00 lb.
100 lb.	4.00 lb.

**based on 3,000 sq. ft. ream*

Paperboard	(per inch of width)
8 pt.	3.0 lb.
12 pt.	4.0 lb.
15 pt.	4.5 lb.
20 pt.	5.5 lb.
25 pt.	6.5 lb.
30 pt.	8.0 lb.

Table 1

often used in the unwind zone, where the additional expense and complication of a regenerative controller as compared with a brake controller can not usually be justified. In the rewind zone, when the roll approaches maximum diameter and the DC motor operates at high torque and low speeds, auxiliary blowers are needed to cool the motors.

The commutators and brushes may suffer overheating and burning if the motor is left stationary under high torque output, conditions which exist when the machine is stopped for a while and full tension is maintained. However, in spite of these shortcomings, DC motors are commonly used because they have the following advantages: they are usually smaller than eddy current clutch/AC motor units of the same horsepower; their dynamic response is faster than any clutch; their minimum torque output is quite small, which permits operation at low tensions; and they are more energy-efficient than a clutch.

Alternating-current motors are gaining popularity for use in intermediate tension zones. Their advantages are low cost and low maintenance (no commutators, slip rings or brushes). But the controllers that operate the motors are quite complicated and are not available for large horsepower units, and furthermore torque output tends to be jerky at low speeds. DC motors are the choice for intermediate tension zones and eddy current clutches, or for rewinds. The trend is toward dual-disk pneumatic brakes for unwind tension development because of their wide torque range and high heat capacity.

Brakes and Clutches

Brakes are usually used to create tension in the unwind zone. There are several different kinds, including manually actuated friction devices, pneumatic brakes with either single or dual disks, electric friction brakes and electric magnetic-particle brakes.

It is hard to imagine any case where a manually actuated friction brake would be the best choice, except possibly on laboratory test machines, small pilot lines or inexpensive, low-production machinery. Pneumatic brakes, whether air cooled or water cooled, can dissipate much more heat than electric types. They also have a wider torque range, especially those that have been designed specifically for tension control (constant slip) applications. So they are most desirable when high speeds, high torque and wide ten-

sion ranges are involved. In addition, most pneumatic tension brakes are available with linings having several different coefficients of friction. They can be installed in combinations on the same brake and also have multiple cylinders that can be turned on or off as needed to produce the desired torque. These brakes also produce the lowest minimum torque of any brake, which makes them most desirable for low-tension applications.

Electric friction brakes are usually cheaper than pneumatic brakes and are simpler to apply because no compressed air is needed. But they have limited torque range and can dissipate only a fraction of the heat. They may also squeak because of the metal-to-metal rubbing contact necessary to complete the magnetic circuit. Minimum torque tends to be high because of residual magnetism and drag.

Electric magnetic-particle brakes are different because they have no surface-to-surface rubbing contact. Instead, they produce torque by forming linkages of particles, similar to iron filings, in the gap between the rotating and stationary members. The particles arrange themselves in the gap along the magnetic flux lines produced by the electric current in the coil of the brake. Strength of the linkages (and therefore torque) varies with strength of the field, which is determined by the current.

Magnetic-particle brakes are well suited for very-slow-to-moderate-speed applications. Torque output at slow speed is very smooth because the stick/slip condition caused by rubbing contact in other types of brakes is missing. They are also completely sealed, preventing wear products from being released to the environment. Compared with pneumatic brakes, their minimum torque is high and heat dissipation ability low.

The clutch versions of the brakes listed above are sometimes used to create tension in the rewind zone. The comments made for the brakes also apply to the clutches.

Eddy-current clutches are another type of non-contact, variable-torque electric clutch. They are available in sizes ranging from less than 1 horsepower to over 100 horsepower, with an attached AC motor. They are typically used on rewinds because of their high heat-dissipation capability and smooth torque output. Also, they can be easily controlled by a simple, variable-voltage power supply and can remain “parked” at full torque output for long periods without damage.

Tension Control Systems

Brakes, clutches and motors can only create tension and therefore a method is needed to adjust the torque of these devices in order to produce the correct web tension. There are only two tension control systems: the machine operator or some kind of automatic controller.

MANUAL SYSTEMS

Manual tension-control systems require the machine operator to judge the tension in the web and make appropriate adjustments to the brake, clutch, or motor torque or speed by hand. Such systems are called "open loop" because the torque or speed output does not depend on what is happening in the machine, only on the person making the adjustments. Skill, experience and constant adjusting are required to achieve a satisfactory result. The machine operator is the tension controller and the quality of control depends on that person's judgment, skill and attentiveness. The machine operator must compensate for changes in machine, speed, roll diameter, brake and web characteristics, and quality, with nothing more to help him than his best guess and experience.

Consequently, manual tension-control systems provide tension profiles that are very erratic, and change from roll to roll over time and from operator to operator. Manual control is best used in slow machines having small diameter unwind and rewind rolls where product quality and material waste are not important.

Roll Diameter Followers

Roll followers are an improvement on manual control systems. There are three basic types: follower arms, sonic range finders and diameter computers. All measure the diameter of the unwind or rewind roll and adjust the brake or clutch torque as it changes. Torque adjustment is the basic function of any unwind and is proportional to diameter change according to the formula:

$$\text{TORQUE} = \frac{\text{TENSION} \times \text{DIAMETER}}{2}$$

This torque adjustment process is sometimes mistakenly called "taper tension," but the correct term is "taper torque." Taper tension refers to the rewinding tension control

Roll followers are not true tension controllers. The machine operator manually sets tension, and the roll follower only compensates for roll diameter variation. There is no compensation for speed changes, brake fade or other factors affecting web tension. Follower arms have a roller or wheel on the end of a lever arm attached to a rotary position sensor. The wheel rides on the roll surface and the arm rotates as the roll diameter changes. The sensor detects the arm movement and signals the controller to adjust brake or clutch torque accordingly.

The follower arm is the simplest and least expensive type of roll follower. But it has two disadvantages. First, it requires touching the stock roll surface, which is not always desirable, and it gets in the way of loading and unloading rolls. Second, setting torque is more difficult than with the other types.

Roll followers eliminate the constant readjustment required by manual systems and

free the machine operator for other tasks. However, they share some of the disadvantages of manual systems.

There is no compensation possible for speed changes, brake fade, temperature and humidity variation, web characteristic variation, and other factors affecting tension. With a roll follower system, setting correct tension remains difficult, as this is done manually by guessing.

Non-Contact Roll Diameter Followers

Sonic range-finders operate by bouncing sound waves off the roll surface and measuring the time it takes to make the trip. Most systems use the same sonic transmitter/receiver unit found in Polaroid cameras. As the roll diameter changes, the range-finder control unit adjusts brake or clutch torque accordingly to maintain roughly constant tension.

Diameter computers use tachometer generators or pulse generators to measure roll rpm and web speed. The two speeds are then electronically divided to produce an output voltage that varies directly with the roll diameter. As with other types of roll followers, the diameter signal is fed to a control unit that adjusts brake or clutch torque to maintain more or less constant tension.

Range finders and diameter computers are mechanically and electronically more complicated and expensive but do not require touching the roll and don't get in the way of loading and unloading the rolls.

INTERMEDIATE TENSION OR DRAW SYSTEMS

"Draw" controls are used only in intermediate zones. The nip rolls at the upstream end of the zone are slaved to the main drive either mechanically or electrically. The nip is oversped a small amount, stretching the web and creating tension (or draw) in the zone.

The most common mechanical draw system has a continuously variable speed transmission driving the nip with a shaft from the main drive gear train. The transmission's output speed is adjusted manually with a hand wheel. The speed range is quite small, usually ±0.5% of the input speed.

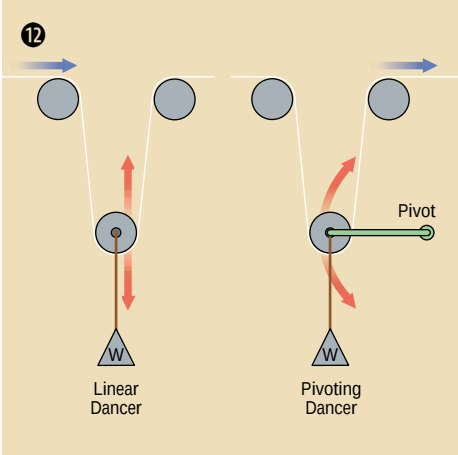
Electrical draw systems eliminate the need for a driveshaft. Instead, a speed-regulated DC motor drives the nip following a speed-reference signal from the main drive. The draw is accomplished by an operator adjustment that over-speeds the nip motor. Using digital techniques, very precise speed control is possible, with a draw accuracy of .05% or better.

The correct draw is arrived at by trial and error and, for best results, must be reset each time a change is made in web thickness, width, speed or material. Moisture content of paper webs must also be considered and the draw adjusted accordingly. Excessive draw will cause web breaks, stretching and wrinkling. Inadequate draw results in folding and wander or sideways drift.

AUTOMATIC CONTROLS

Automatic control systems relieve the operator of the need for constant manual adjustments of the tension level. While they do not require a great deal of skill and experience, their greatest benefit is vastly improved tension control.

There are several kinds of automatic tension-control systems, each with its own advantages and disadvantages. However, keep in mind that no automatic system will eliminate tension problems caused by mechanical deficiencies or poor-quality web material. The effects of bad bearings, bent shafts, worn gears and bad machine design can not be negated simply by installing an automatic tension-control system, no matter how sophisticated. To get the most from an automatic system, the machines must be



⓬ A dancer roll is an idler roll that is free to move in a straight line or arc under the influence of web tension. A counter-force is created to oppose the tension force, and a sensor is connected to the dancer to detect its position.

properly designed and in good condition, particularly when low tensions and extensible or low-friction webs are involved.

Dancer Roll Systems

A dancer is an idler roll that is free to move in a straight line or arc under the influence of web tension (*Figure* ⓬). A counter-force created by a weight or air cylinder opposes the tension force, and a sensor is connected to the dancer to detect its position. The position signal is fed to a regulator, where it's compared to a desired-position signal, usually representing the mid-point of the dancer travel, set by the machine operator. In theory, the counter-force is equal to about twice the desired web tension, and the dancer will maintain position in the middle of its travel as long as this condition exists. If tension increases, the dancer will rise, moving the sensor and signaling the controller to reduce torque, allowing the dancer to return to its original position. If tension decreases, the opposite sequence occurs. Tension is determined by adding or removing weights to the roll, or by varying air pressure to a loading cylinder according to a chart set up to show the relationship between pressure and tension.

Dancers are mechanically complicated and require at least two other properly positioned idler rolls (one before and one after the dancer) to operate. These rolls require extra space in the machine. A properly designed dancer is lightweight so it can react quickly, but strong so it won't deflect and steer the web to either side. Its mechanism must also be designed with very low friction in its moving parts so it can react to small changes in tension. Motion dampers, such as shock absorbers, should never be used to stabilize its movement because they degrade the dancer's sensitivity and response time, causing excessive tension fluctuations.

Dancers usually begin to have difficulty maintaining control at web speeds over 500 feet per minute because of the inherent friction and inertia of the dancer itself and the relatively low gain (sensitivity) of its controller. Low tensions and wide tension ranges are a problem for dancers, again because of friction, inertia and low gain. The dancer roll will oscillate or "hunt" along its travel path, causing tension variations, web length variation and shifting to the side. If the hunting is severe, the dancer may reach the ends of its travel and causes web breaks or slack in the web, resulting in wrap-arounds. This disrupts the printing, coating or other process taking place in the machine and causes waste and loss of quality. The typical cures for hunting are to mechanically dampen the dancer's movement or bypass the dancer and operate manually. The result is degradation of tension control, which results in waste, reduced productivity and poor product quality. Dancer systems are most suitable for moderate web speeds and narrow tension ranges.

Disadvantages of Dancer-roll Systems. Dancers are actually position controllers, not tension controllers. Tension plays an incidental part in the operation of the system. Dancer systems do not measure or display tension. Dancers must move to operate, therefore they always disturb and change the length of web in their tension zone. This

movement may actually cause some of the problems associated with inadequate tension control.

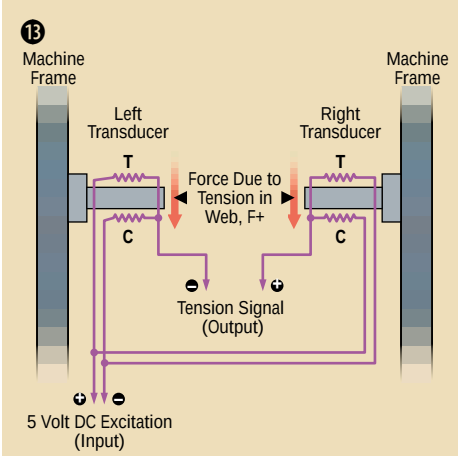
Tension Transducer Systems

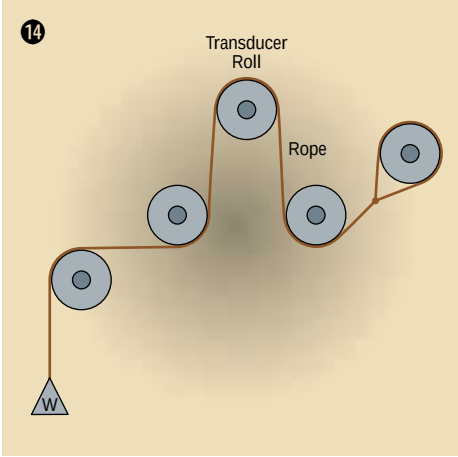
Tension transducer systems are specially designed force transducers that measure actual web tension. They are normally used in pairs, installed on each end of an ordinary idler roll. Most transducers use either strain gauges or variable inductors to develop a voltage proportional to tension and are accurate to within 1%. Sometimes a single transducer is used, but accuracy is very poor because transducer output becomes dependent on web width, the placement of the web relative to the transducer, and the location of the tightest part of the web, which can change continuously throughout a roll of material.

Dual transducer systems are not subject to these factors because the transducers are electrically connected so that their outputs are averaged (*Figure* ⓭).

Transducer output is displayed on an analog or digital meter. The most useful arrangement has a meter that is calibrated to display actual total web tension expressed in pounds, ounces, grams, newtons or any other suitable unit. Sometimes the meter is calibrated to read 0% to 100% of some arbitrarily assigned maximum tension value. This arrangement is clumsy because the maximum tension must be remembered and then multiplied by the meter reading to determine the actual tension. The only advantage is for the manufacturer, who has to make only one type of meter scale.

Meter calibration is very simple and quick (*Figure* ⓮). Required equipment comprises a small screwdriver, a rope and a known weight of at least 20% of the meter full scale. To calibrate: Turn the power on, turn the "zero" adjustment on the circuit card so the meter reads zero. Run the rope over the transducer roll in exactly the same path the web follows, and tie one end in the machine.





⓭ In a dual transducer system, the transducers are electronically connected so their outputs are averaged.

⓮ To calibrate a transducer output meter, a rope is run over the roll in the same path the web follows. A weight is attached to one end of the rope, and the meter is adjusted until it matches the value of the weight.

Attach the known weight to the other end and let it hang free. Turn the "calibrate" adjustment on the circuit card so the meter reads the same as the weight.

Transducers are made in many different sizes, load ratings and mounting styles. Transducers are selected in a two-step procedure. First, decide which mounting style is best for the particular use. Second, determine the load rating. The appropriate load rating depends on the weight of the idler roll mounted in the transducers, web tension and wrap angle. These factors are considered in simple mathematical formulae to arrive at the correct load rating. Unlike dancers, transducers take up no extra space and don't need specially located rolls.

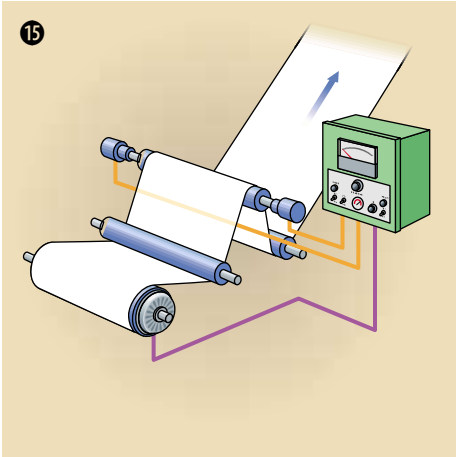
The analogue indicator is the simplest kind

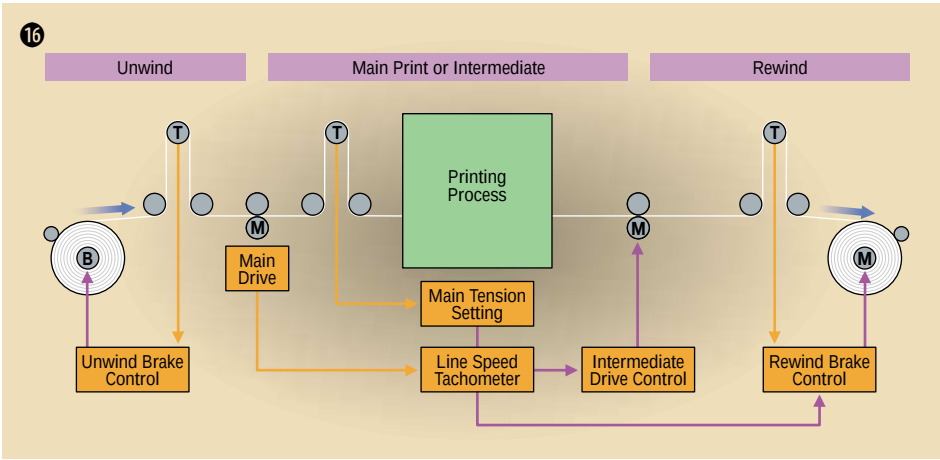
of transducer system. It consists of a pair of transducers; an enclosure with a display meter on the front, containing a circuit card to excite the transducers and amplify their output; and a pair of interconnecting cables. The circuit card usually has voltage and current outputs that are proportional to tension and can be fed directly to variable-speed drives, recorders or computers.

The transducer system does not directly control tension by itself. Controllers also indicate tension but, in addition to being displayed on the meter, the tension signal is fed to a regulator circuit where it is compared against a desired tension signal set by the machine operator. The regulator outputs a voltage or current to a servo valve, motor, brake or clutch to automatically control tension in a "closed loop" control scheme. Closed loop tension systems are very accurate because actual web tension is measured continuously and compared against the desired tension set by the operator. The regulator circuit automatically adjusts its output to eliminate any difference between actual and desired tensions. The term "closed loop" comes from the fact that the output of the system (tension in this case) is fed back to the input. The output forms a continuous path through the regulator and back to the input, circulating endlessly in an unbroken loop.

There are two kinds of transducer systems: full control and tension trim. Full-control systems have torque outputs completely determined by the transducer signal (*Figure* ⓯). If tension is very high, output will go to zero. This type of control system is used on unwinds and rewinds but not in the intermediate zone.

Tension trim systems operate in intermediate zones and use the transducer signal to vary the motor, clutch or brake torque within a narrow range, typically ±10% of operating level, which is determined by another signal, usually speed (*Figure* ⓰). The transducer signal allows the system to control tension and will automatically compensate for variations in speed, drive accuracy and web thickness to maintain proper tension.





⓯ Full control transducer systems have torque oututs completely determined by the transducer signal.

⓰ In this tension control system, the transducer signal allows the system to control tension and will automatically compensate for variations in speed, drive accuracy and web thickness to maintain proper tension.

Another type of tension trim system is used on rewinds. The transducer signal is again used to control torque within a narrow range, but the operating torque level is determined by roll diameter as well as speed. The diameter is calculated by a roll follower as described earlier.

Tension control is of primary importance in the processing of continuous webs. Better quality and profits are possible through improvements in tension control. Manual systems and roll followers are the cheapest in terms of purchase cost, but sophisticated controls involving measurement of tension allow faster operating speeds and consistent results with reduced waste and less labor cost.

Advantages of Transducers over Dancer-Roll Systems. The transducer's ability to measure actual web tension is the single biggest difference from all other types of tension controls, and it provides the transducer system tremendous advantages. The most obvious of these advantages is the analog meter or digital display. No other system offers a display of actual web tension. It eliminates all the guesswork.

The next advantage is accuracy. The closed tension loop enables the controller to automatically and quickly compensate for factors affecting tension, including changes of speed, roll diameter, web characteristics and brake fade. The result is a typical system accuracy of 2% to 3%. The third advantage is ease of use. Setting tension is simple; just watch the meter while turning the tension set knob and stop when it displays the desired reading. No further operator involvement, skill or experience is needed.

Another advantage is consistency. The high accuracy, automatic compensation and ease of tension-setting allow the operator to run the same tension roll after roll and to easily repeat the correct tension for each job at any time. An additional advantage is the ability of transducer systems to operate successfully over a wide range of tensions. This latitude is made possible by the negligible movement, low inertia, accuracy and sensitivity of the transducers themselves. Ranges of 25:1 are possible. In fact, it is not unusual for the range to be limited by the motor, clutch or brake, rather than by the tension equipment.

Unwind Equipment

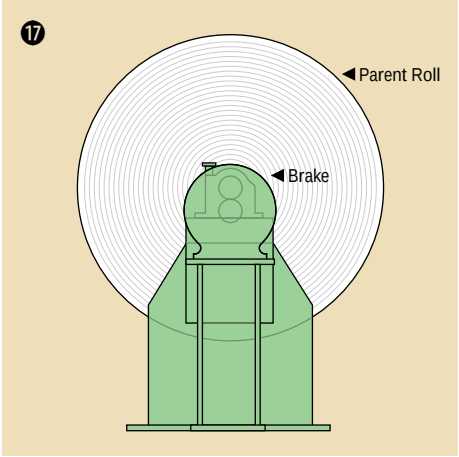
The unwind stand, which can be simple or complex, plays an important part in the proper operation of the press. There are two general groups of unwind stands: single-position and flying-splice stands. Most single roll and older drop-splice unwind stands are non-driven, while most modern flying-splice unwinds are of the driven type. A brief discussion later will cover both center-shaft and surface-drive types.

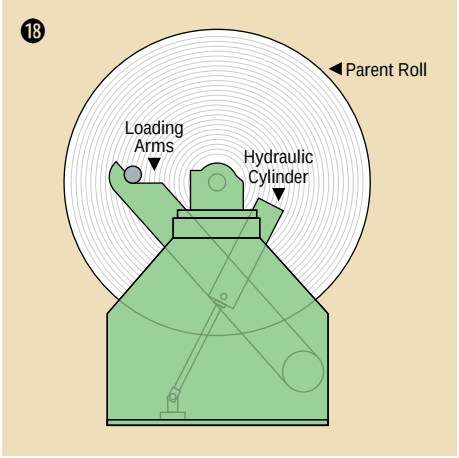
SINGLE-POSITION UNWIND

The simplest and most common type of unwind stand is the single-position stand. It can be manufactured to handle a great variety of roll widths and diameters (*Figure* ⓱). To make the stand more usable, designers normally incorporate a side shift adjustment so the core shaft may be moved by the operator either way from its center position. This adjustment allows the operator to relocate the web without having to shift the roll on the core shaft. For wide, large-diameter rolls, a loading apparatus may be used. Hydraulic arms may be added to the stand to facilitate the loading of rolls (*Figure* ⓲). Other arrangements, such as overhead hoists or tram rails, have found applications.

The most important function of an unwind stand is uniform tension control during the unwinding of the material to the printing sections. Also, the unwind stand can be automatically guided to provide lateral web position control at the press in-feed. The second most common single-position unwind stand is the shaftless type (*Figure* ⓳). This stand uses the roll core as a support for the material. The advantage of this system is that the operator does not have to shaft and unshaft rolls of material. Even with pneumatic shafts, this chore becomes quite difficult when handling wide rolls. A further sophistication of a shaftless stand is the self-loading type (*Figure* ⓴).

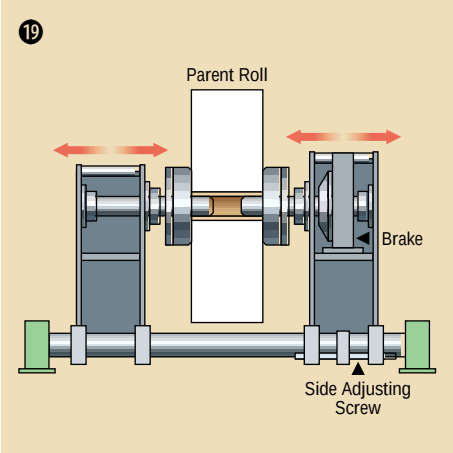
In general, single-position roll stands are used where large diameter mill rolls contain sufficient footage to keep the press running for a reasonable time between changes.

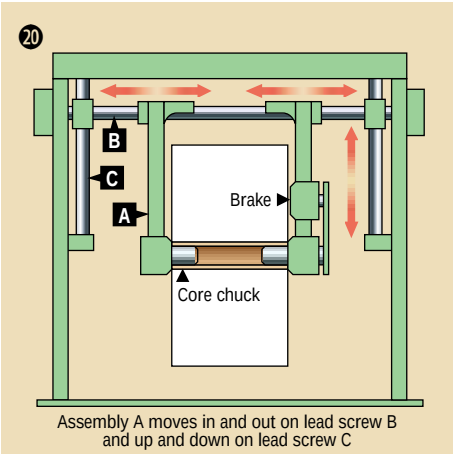


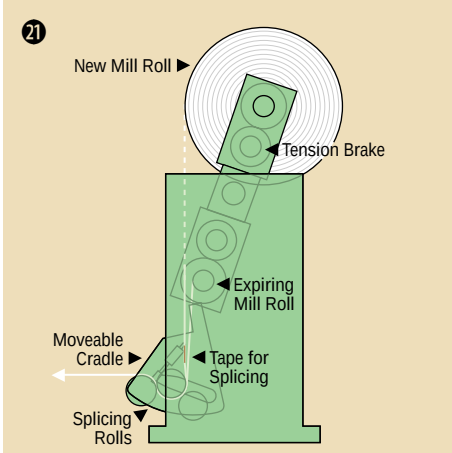


⓱ The single-position unwind is the most common type of unnwind stand.

⓲ Single-position unwind with loading arms facilitates the loading of rolls.







When changes become frequent, consideration must be given to flying-splice systems, which, although more expensive, increase the printing output.

FLYING-SPLICE UNWIND

There are many types of flying-splice stands available. They are classified with respect to their roll diameters. Flying-splice stands for the packaging industry generally are capable of handling up to 24" or, in some cases, 32" diameter rolls. Other stands for handling heavier laminates and paper are available with diameters up to 60". It is not uncommon to see flying-splice stands capable of handling 72" diameter rolls where fairly heavy board stock is being run.

Figure 21 illustrates a typical 24" diameter, simple drop-splice unwind stand for common packaging materials such as polyethylene and other extensible films.

In this sketch, note that this simple unwind is semi-automatic in operation since it requires the operator to "drop" the splice into the splicing rolls. Drop splices are made by placing the pre-taped, leading edge of the new roll into the pneumatic or hydraulically-loaded marriage rolls that press the tape onto the expiring web. Operator skill is required to determine the precise moment to make the splice, in order to keep the tail of the expiring roll to a minimum. The operator also has to index the turret into the proper splicing position. Most modern stands are made to accept both "underwound" and "overwound" rolls. Indexing the turrets can be done with either electric or hydraulic motors.

Larger roll diameters and the demand for more uniform color throughout the roll lead to a need to drive the full roll during splicing. Rolls weighing 500 lbs. to 800 lbs. are very difficult to move, making a successful "drop" splice at running speeds where matching web sped is required virtually impossible.

An improvement in this type of stand is to drive the new roll of material so that it is traveling at the same linear speed as the expiring roll. The new roll can be driven

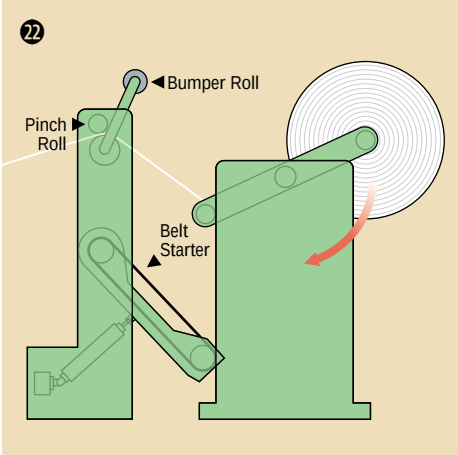
19 The shaftless unwind uses the roll core as a support tor the material and is the second most common single-position unwind because the operator does not have to shaft and unshatf rolls of material.

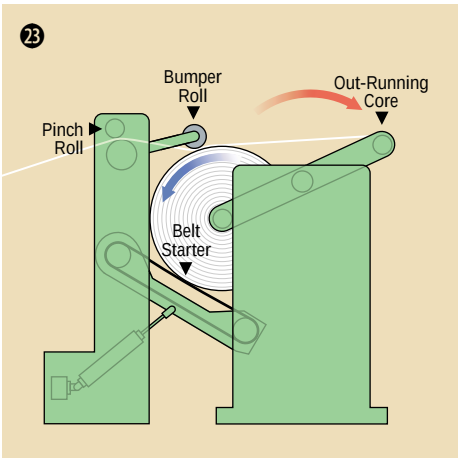
20 A more sophisticated shaftless unwind self-loads the material.

21 Flying splice unwind is a simple unwind, semi-automatic in its operation, since it requires the operator to "drop" the splice into the splicing rolls.

㉒ Splicing operation where the turret is in loading position.

㉓ Splicing operation where the turret is in splicing position. Contact with the belt starter brings the new roll up to speed.





with a center-shaft or surface-drive system. In the center-shaft system, the new roll is accelerated to the proper splicing speed by an adjustable speed drive, which is usually a direct current (DC) motor or an alternating current (AC) eddy current drive. A hand-held or machine-mounted tachometer controls the drive motor to properly match the new web speed with the expiring web speed.

In the surface-drive method, an air cylinder pushes a drive belt into engagement with the new roll surface. The belt is driven by mechanical means at line speed. In order to accelerate the roll smoothly, a pneumatic clutch gradually engages the belt.

The splicing operation in either case is normally the same. The leading edge of the new roll is pre-taped, and held in place by two or three pieces of "breakaway tape" to keep it from unwinding as the parent roll is brought up to speed. When the roll reaches the proper speed, an air-loaded rubber roll forces the expiring web against the new parent roll. As the pre-taped leading edge of the new roll comes in contact with the expiring web, the breakaway tape releases and the transfer is completed. As with the "drop" method, the transfer is at the operator's discretion and the amount of tail left on the expiring web depends on the operator's skill. *Figures* ㉒ and ㉓ describe the automatic splicing sequence for an "over" splice.

This type of unwind splicing can be automated by using a knife to cut the expiring web after the transfer is made. In this case, the knife may be mounted on the same pivot arm that holds the rubber bumper roll. There is usually a delay between the actuation of the bumper roll and the knife. This delay is to ensure that contact has been made with the pre-taped leading edge of the new roll before cutting.

This automated system eliminates some of the operator's responsibility. It will leave a minimum tail equal to the circumference of the new parent roll. The amount of tail can be minimized by adding an electric eye to the system to sense the position of the pre-taped leading edge of the parent roll and, at the proper time, signal the actuation of the bumper roll and the splicing knife. Of course, this type of unit is more expensive.

Although it is possible to obtain shaftless flying-splice unwind stands, these units are usually too expensive to be considered on most flexographic press applications. They are commonly used where a large mill roll of board stock is to be run. There are also significant differences in unwind stands for rolls up to 72" in diameter when compared with others described, with respect to the splicing method.

In the case of board, a double thickness

of an extremely heavy material can ruin the flexo printing plates. Therefore, a butt splice must be made instead of the previously described lap splices. Butt splices can be made either manually or automatically. For manual splices, an accumulator or festoon in a two-position unwind is required. While one roll is in operation, the second unwind is being loaded with a new roll. When the expiring roll reaches its end, the leading edge of the new roll is manually taped while the press continues to be fed by a web that has been stored. The amount of web to be stored in the accumulator or festoon is determined by the web speed and the time needed to make the manual butt splice.

There is equipment available for making automatic butt splices. This splice is generally formed in three operations. At the time of splicing, the new web is fed through a set of rolls; both webs are cut to give square edges and are then positioned end to end. In this position, they travel to the next set of rolls, where splicing tape is applied to both sides of the web. From this point, they travel to the next set of rolls, which are marriage rolls, to ensure that the tape applied at the previous operation is securely bonded. The web then travels its normal path.

UNWIND TENSION SYSTEMS

In general, there are two basic types of unwind tension control systems. Each type can use the same tension-sensing devices. The most common tension control is the unwind braking device employing air, electric or manually adjustable brakes. The other system uses either air, electric or hydraulic motors to drive the unwind shaft to release a predetermined amount of material into a tension-sensing device.

Unwind tension control is necessary for good register. Control is especially necessary on stack and central impression presses. Sufficient unwind web-tension must be applied to maintain an even flow of material into the printing section. Further, the tension value must not be so high that it can cause slippage in the in-feed draw roll section, or so low that there is not sufficient tension to properly track the web. Materials that require the least tension (in pounds per lineal inch) are the most difficult to handle. In general, when unwinding materials, the tension values are roughly half the intermediate and rewind tensions. *Table 2* lists some common converting materials and some typical unwind tensions for them.

In the unwind braking system, the braking power is decreased as the material unwinds. A controlling device such as a dancer or a load cell may be used to automatically regulate any type of brake.

The braking system has some control problems when the product of the tension range and roll diameter buildup exceeds 100-to-1. Problems occur when:

$$\text{TENSION DIFFERENCE} \times \text{ROLL DIAMETER DIFFERENCE} > 100$$

Where:

$$\text{TENSION DIFFERENCE} = \text{MAXIMUM TENSION} - \text{MINIMUM TENSION}$$

$$\text{ROLL DIAMETER DIFFERENCE} = \text{MAXIMUM ROLL DIAMETER} - \text{CORE DIAMETER}$$

On narrow webs where low tension values must be held, overcoming core-shaft inertia and gearing-friction loads may take away all of the brake's sensitivity and hinder its proper control of web tension. Further, if the press speed is high and the core shaft and brake gearing have a high inertia value, then as the roll diameter decreases, the brake may be turned to a zero setting. Even at a zero setting, the tension value in the web can still be too high, thereby stretching the web to overcome the high inertia value.

The second most common unwind-tension

㉔ A typical weight-loader or pneumatically loaded dancer system.

TYPICAL UNWIND TENSION FOR WEB MATERIALS

MATERIAL	TENSION (per mil per inch of width)
Acetate	0.25 lb.
Foil (aluminum)	0.25 lb.
Foil (copper)	0.25 lb.
Cellophane	0.375 lb.
Nylon	0.125 lb.
Polyethylene	0.06 lb.
Polyester	0.375 lb.
Polypropylene	0.125 lb.
Polystyrene	0.50 lb.
Saran	0.075 lb.
Vinyl	0.025 lb.
Paper*	**(per inch of width)**
15 lb.	0.20 lb.
20 lb.	0.25 lb.
30 lb.	0.375 lb.
40 lb.	0.625 lb.
60 lb.	1.00 lb.
80 lb.	1.50 lb.
100 lb.	2.00 lb.

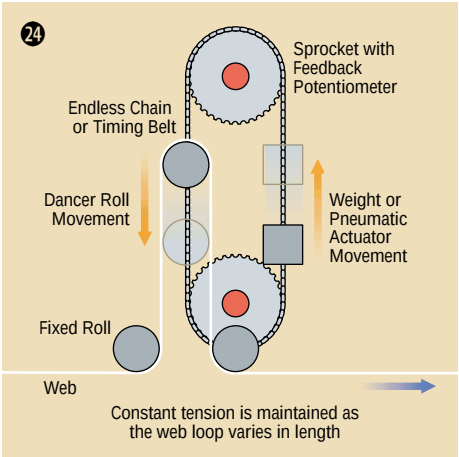
**based on 3,000 sq. ft. ream*

Paperboard	(per inch of width)
8 pt.	1.5 lb.
12 pt.	2.0 lb.
15 pt.	2.25 lb.
20 pt.	2.75 lb.
25 pt.	3.25 lb.
30 pt.	4.0 lb.

For laminated webs, sum the tensions for the individual webs and add 0.10 lb. per inch of width

Table 2

system is the driven type. A DC motor drives the parent roll shaft, feeding the material into a control system. The feedback signals from a tension device control the motor speed, thus maintaining preset tensions. The horsepower required to drive the unwind roll by the driven method is basically the same formula as used when calculating the horsepower for rewind drives, except that



the roll inertia is a factor to be considered. However, the tension values are in the range of 50% of the rewind values, therefore horsepower requirements are lower.

One basic controlling system is a dancer roll, which has a force applied to it by weights, air cylinders or load cells to establish a predetermined loading of the web. While the machine is running, the roll is expiring and decreasing in diameter. As the diameter decreases, the movement of the web arm becomes shorter. This means that the basic braking force applied initially to the roll to counteract the dancer system is no longer in balance. As the roll decreases in size, the braking force becomes larger in value and applies more tension to the web. This unbalanced condition changes the dancer-roll position and adjusts the electric brake rheostat, or an air-control valve in the case of air brakes. The controls decrease the braking force sufficiently to once again put the system in balance, maintaining the initial tension value. With heavy rolls, it may be necessary to have an auxiliary control circuit for stopping the mill roll as the press stops. This control can be called an anti-flood device.

Figure ㉔ shows a typical weight-loader or pneumatically loaded dancer system. Another type used is a load-cell controlled

tension system. The load cell or tension transducer system is widely used for controlling unwind tensions. It has the disadvantage of being a short-stroke dancer, so it does not have the storage capacity to absorb the shock of splicing. For this reason load cell systems are normally used with single-position unwind stands or with automatic splicing units, which drive the full roll to prevent the shock load that occurs with a manual drop-type splice. The load cell arrangement works on the strain-gauge principle as previously described (*Figure* ⓯). Web tension applies a force to the idler roll which, in turn, is transmitted to the load cell. The most minute change in tension causes the strain gauge to change its electrical signal output. This signal is amplified and then sent to the unwind brakes to adjust their braking power. Similar devices are available that, by very small movements, create air-pressure signals that are amplified and transmitted back to either air or electric brakes.

The basic purpose of the unwind braking system is to apply just enough holdback force to the expiring roll to maintain a constant tension into the printing section.

IN-FEED UNIT

The function of the in-feed is to present the web to the print section at a constant feed rate and tension. It is normally located prior to the first print deck on a stack press or in-line press and is usually a three-roll system comprised of two driven steel rollers and a rubber pressure roller that is air or hydraulically loaded. The in-feed pulls the web from the unwind roll and helps establish the first tension zone in the press. Tension in the unwind section is established by braking the unwind roll. The in-feed also serves to isolate the tension in the print section from the unwind tension and becomes the nip point for a new tension zone through the print and drying sections.

On central impression presses, the CI drum becomes the pulling element and the rubber-covered nip roll, which secures the web to the drum, the in-feed. Because of the amount of web wrap (about 85% of the drum's circumference), it is only necessary to secure the web to the drum to have constant feed.

The in-feed plays a vital role in maintaining tension and in controlling register. Forgetting to activate the nip roller has created more than its share of problems. Also to be considered is the hardness of the rubber roller and the amount of pressure used. Most press manufacturers will specify hardness, but lacking any specifics, one has to rely on experience or trial and error.

Also associated with the in-feed is a spreader roll, which functions to present a smooth, wrinkle free web to the print section. There are a variety of opinions as to the type of spreader to use or whether one is really necessary. A spreader roll is normally a factory option.

Many converters believe a bowed roll or "banana" roll is the wisest choice. The bowed roll will be driven either by a belt with an adjustable pulley, or in some cases, will have the luxury of an independent DC drive. If a bowed roll is the preferred choice, the consensus of opinion is that a roll should be of such a design as to enable the operator to vary the bow. This option allows the operator optimum control to facilitate eliminating problems such as gauge bands. Less effective, but in many cases preferred, is a non-driven spiral, grooved roll constructed of rubber, aluminum or steel that is designed to spread the web. The action of the spirals, which are cut from the center to the end of the roll, has the same effect but not as dramatic as a bowed roll, and is available at a lower cost.

OUT-FEED UNIT AND/ OR COOLING DRUM

The function of the cooling drum unit par-

allels the function of the in-feed. It provides an even, constant pull through the print section and also serves to isolate the print section tension zone from the rewind tension zone. It consists of one or more chill rolls with a rubber-covered nip roll to secure the web to the chill roll and prevent slippage. The drive is variable through a variable-speed unit or, on the latest presses, by means of an independent DC drive motor.

Earlier presses drove the chill roll mechanically at a fixed rate of over-speed. These drives were speed sensitive and could not handle a variety of substrates. The variable speed mechanical drive was then developed, which allowed the operator to adjust the tension to accommodate the various substrates, or those that had some imperfections. The most recent development is the DC drive, which gives automatic control over a wide range of tensions. Again, experience becomes vital in setting the tension in this zone, but once the experience is gained it can be repeated. It is only necessary to input the desired tension; the automatic controller then goes to work. The biggest problem encountered in this area is failure to lower the nip roll, resulting in misregister and other negative-tension problems.

Rewind Equipment

There are two basic classifications for rewinding equipment: center and surface winding. Some single-roll rewinds use a combination of center and surface drives. Flying-splice rewinders are normally of a center-wind type. Although there are automatic flying-splice surface winders, they are normally used in the paper industry.

SURFACE WINDERS

Surface rewinding units use the surface of a moving roll to impart rotation, by frictional contact, to the roll being wound. There are two surface rewind designs common to the industry.

Double Drum

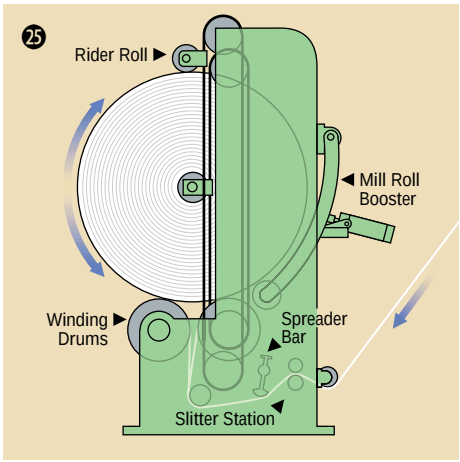
The double-drum rewind is the most common type of surface rewinder and is described in *Figure* ㉕. It uses two rolls of equal diameter to drive the web. The rewind unit is usually driven by a variable-speed drive to set the basic tension pattern. Normally, one roll is also driven slightly faster than the other to provide a differential surface speed, creating a hard roll. The winding drive rolls can also be fluted to reduce wrinkling and give additional roll hardness. As shown in the illustration, the printed roll can be wound with the printed surface in or out, depending on the method of threading. The center of the roll, the core shaft, moves vertically upward as the roll diameter builds. The increasing weight of the roll on the winding drums assists in obtaining a tightly wound roll.

A rider roll can be supplied with a double-drum rewind unit. The rider roll rests on top of the roll being wound, and can be pneumatically or hydraulically loaded to provide a greater nip pressure between the roll and the winding drums. The pressure of a rider roll should be gradually lessened during the rewinding cycle to provide more uniform pressure.

Hydraulic or pneumatic loading of the roll core shaft is another accepted method of increasing nip pressure. The hydraulic cylinders act to maintain a uniform or steadily decreasing pressure relationship between the roll being wound and the winding drums. Maintaining uniform pressure is easier to accomplish on a single-drum winder because the method of loading doesn't have to overcome or compensate for the increasing roll weight.

Single Drum

The single-drum rewind unit (*Figure* ㉖) uses the same surface-winding principles as the double-drum unit, but has a single



㉕ The double-drum rewind, the most common type of surface rewinder, uses two equal-diameter winding drums to drive the web.

drum to impart rotation. It is also driven with a variable-speed drive to set the basic tension pattern.

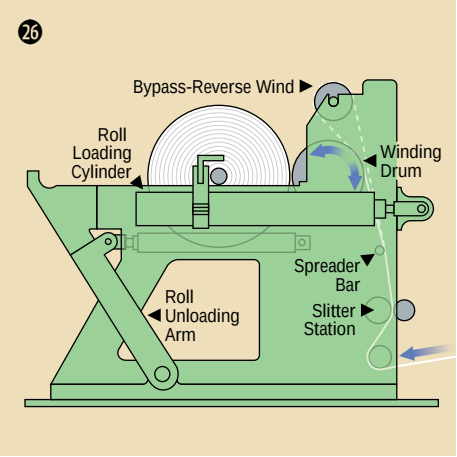
The roll being wound moves horizontally rather than vertically during buildup. Hydraulic or pneumatic pressure is applied to maintain a regulated roll pressure between the roll and the winding drum. This pressure can be varied to provide different roll densities and hardness. As in the double-drum rewind, the printing can be wound inside or out.

One of the main advantages of surface-rewinding equipment is the ability to obtain very dense and uniformly wound rolls with most grades of paper. Also, rewinding can be accomplished with less horsepower than required with center-winding equipment. More attention must be paid to minimum roll widths with a single-drum rewind because of shaft deflection. The minimum roll width is usually restricted to 80% of the maximum roll width.

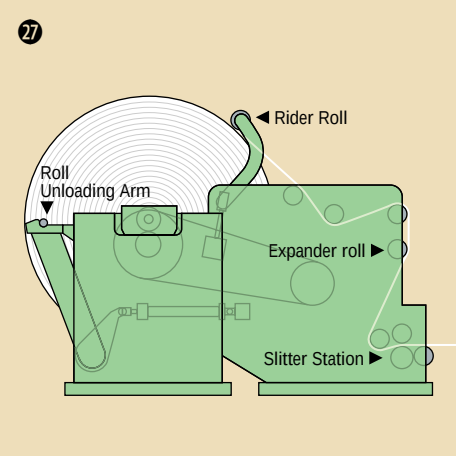
Because a rotating surface imparts motion to the sheet through friction contact, this equipment is generally limited to materials or products that don't have slippery surfaces, are not easily stretched, and can withstand some rubbing or scuffing action. A waxed sheet surface, for example, might be wound more effectively on center-winding equipment.

Either score- or shear-slitting units lend themselves readily to surface-winding methods. The slitting station is mounted before the winding drums to reduce the travel length of slit webs to ensure there will not be web interleaving.

Roll unloading equipment is available on both single- and double-drum rewinding units. Hydraulic or pneumatic means can be provided to either lower the roll out of the winding machine or to push the finished roll onto a loading platform or dolly.



26 The single-drum rewind unit uses the same surface-winding principles as the double-drum unit, but has a single winding drum to impart rotation.



27 A single-position center shaft rewind unit with web slitter. This common design employs one core shaft mounted in frames. The shaft is driven by an electric, mechanical, hydraulic or combination drive with some means of adjusting the drive speed to vary the roll hardness.

CENTER WINDERS

Center winding gets its rotary movement through the core shaft. The center-winding units are available both as core-shaft and as shaftless types. On flexo presses, the most common center-shaft winder is the core-shaft type.

A common center-shaft winder is the single-position type described in *Figure* 27. This design employs one core shaft mounted in frames. The shaft is driven by an electric, mechanical, hydraulic or combination drive with some means of adjusting the drive speed to vary the roll hardness. The single-position type must be stopped for roll changes. The rider roll is also driven on more modern designs.

A rider roll is frequently used in both single- and flying-splice center rewind units. Its purpose is to help get a hard and uniform fin-

ished product roll and to keep air from being trapped between the plies of material, which will prevent telescoping. In addition, flying-splice rewind units generally have secondary (or follower) rider rolls. These secondary rolls ride against the rolls throughout the rewinding and splicing sequence. When the rewind arms of the primary rider roll lose contact with a roll that is in the final state of being wound, the follower rider roll continues pressing against the full roll to prevent air entrapment and telescoping. The secondary rider rolls can be either spring, hydraulic or pneumatically loaded.

Flying Splice. The flying-splice rewind uses the same basic center-winding principle, but has two core shafts mounted on a turret. The drive and auxiliary equipment are more sophisticated and aim to splice at full operating speeds. Normally, each shaft is driven through a slipping clutch and/or separate, direct drive motors to permit speed control of each shaft. Center-shaft, flying-splice units have become the most popular and widely used winders today, especially in the processing of extensible films and packaging materials.

Unloading. Roll unloading equipment is available in the form of hydraulic or pneumatic roll-lowering arms for the single-position winder. Floor dollies or overhead hoists are normally used for unloading the rolls from either the center-shaft or flying-splice rewind units.

Slitting. Roll slitting on center winders has grown in use. Score and razor-blade slitting attachments are available as auxiliary equipment. Shear slitting is also used in some instances where materials call for it. A spreader bar, driven expander roll or slatted expander roll is used after slitting to prevent web interleaving.

Web Guide. Edge guiding on rewinds generally employs one of two approaches. One is to independently guide the web to the winding roll; the other is to side shift the rewinding unit to “chase” the web edge. If the winder is quite large, the provisions for shifting it may be relatively expensive compared with an independent guide ahead of a stationary rewind. Recently, on presses with web-scanning inspection devices ahead of the rewind unit, an independent web guide has been installed beneath the scanner viewing platform to maintain web alignment through the viewing section.

Splicing. Semi-automatic or automatic splicing attachments can be fitted to turret-type rewind units. The operator starts the splicing sequence by rotating the turret to a preset splicing position. When the core shaft is running at or close to the printed web speed, the operator manually makes a splice by cutting the web while simultaneously pushing it against the new, pre-glued or taped core. This same sequence has been fully automated, thanks to hydraulic or pneumatic cylinder-actuated cut-off mechanisms and electric sequence controls.

Large-roll diameter flying-splice units are required for additional footage when processing laminates. These units allow the handling of larger rolls and further reduce downtime. Along with the larger diameter rolls, core sizes are also increasing in order to keep the roll buildup ratio more in line with the capabilities of present rewind drives.

REWIND TENSION SYSTEMS

There are two basic tension-control systems: constant tension and taper tension. In a constant-tension rewind system, the tension in the sheet being wound is the same on the first wrap at the core as at the last wrap on the roll. In a taper system, the tension in the last wind of the roll is less than the tension in the web at the core. For instance, if a web experiences two pounds of tension per linear inch at the core and finishes winding the roll at one pound per linear inch, the tension experienced is referred to as a 2:1 taper.

A center rewind unit can offer either constant or taper tension. A drum rewind unit offers only constant tension. Since most flexographic presses use center-shaft rewind units, more attention will be given to these tension systems.

A good rewind tension system should be capable of winding rolls with straight edges and uniform density, while preserving the accuracy of register and repeat length in the print stations. To accomplish these requirements, the unit must be able to rapidly and accurately follow the acceleration and deceleration of the printing press, compensate for change in the diameter of the winding roll, and be able to make rapid speed transfers when used with flying-splice rewind units. The drive must be able to handle wide or narrow webs; flexible, stiff or stretchable materials; and, in some cases, perforated webs.

POWER REQUIREMENT

Specifying a rewind system and sizing the rewind motors is a job for the press designer. However, it is useful to know the parameters and how to apply them when adapting a press to suit a new substrate application. The following are some of the factors used to determine the rewind horsepower needed: line speed expressed in feet per minute; core tension expressed in pounds per web inch; web width expressed in inches; the mathematical horsepower constant; and the ratio of the full-roll diameter over the core diameter.

Two other factors should also be considered. The first is taper, which is selected core tension divided by full roll tension, if taper winding is required. The other is an experience factor, and this has to do with the windage and friction losses that are present in the various mechanical components of any particular rewind stand.

In setting up the various formulae to size a particular winder drive, the following parameters must be known:

- line speed (feet/minute);
- line acceleration or speed change over the time taken (feet/minute^2);
- core tension (pounds/inch);
- web width (inches);
- taper tension when used (core tension/full roll tension);
- core diameter (inches);
- full roll diameter (inches);
- full roll weight; and
- experience factor for rewind.

The general equation for determining the approximate rewind drive horsepower is:

$$\text{HORSE POWER} = \frac{2\pi \times \text{TORQUE} \times \text{REVOLUTIONS/MINUTE}}{33{,}000}$$

$$\text{WINDER TORQUE} = \text{TENSION} \times \text{WIDTH} \times \frac{\text{ROLL DIAMETER}}{2}$$

$$\text{CORE RPM} = \frac{\text{Line Speed}}{\pi \times \text{ROLL DIAMETER}}$$

Winding horsepower for a constant line speed therefore is directly proportional to web tension, web width and line speed and is independent of roll diameter. However, whenever line speed is changed, the inertia of the wound roll must be overcome either by a braking system to slow the roll or additional horsepower to accelerate.

$$\text{ROLL INERTIA} = \text{ROLL MASS} \times \left[\frac{\text{ROLL DIAMETER}^2 - \text{CORE DIAMETER}^2}{8}\right]$$

$$\text{ROLL ACCELERATION} = \frac{2 \times \text{LINE SPEED CHANGE}}{\text{ROLL DIAMETER}}$$

$$\text{INERTIA TORQUE} = \text{ROLL INERTIA} - \text{ROLL ACCELERATION}$$

For any given roll diameter and line speed acceleration, winding torque is proportional to the roll diameter, and roll acceleration is inversely proportional to the roll diameter. Therefore, the horsepower required to overcome the roll inertia torque on press start-up

or speed change depends largely on the time it takes to run the press up to speed and is proportional to the roll diameter.

Many materials wind best by taper tension; some wind best by constant tension. A representative list of materials and their suggested winding tensions and recommended winding method is shown in *Table 3*. A web wound by either method must be controlled by a sensing device.

Constant Tension

The most commonly used controller for a constant-tension winding system is a dancer roll. The dancer may be loaded by weights, air or a torque motor. A typical weight-loaded dancer system was previously described in the section on dancer rollers (*Figure* ㉔). Any movement of the dancer roll signals the rewind drive to speed up or slow down, maintaining a given dancer-roll position. Another method to control the rewind drive is a load cell transducer.

The rewind motor can either be a DC or a constant-speed AC motor fitted with an eddy-current clutch. Direct current motors are more expensive, but because of their superior performance, are now virtually standard on new equipment.

Taper Tension

The controller for a taper tension wind can be set up in several ways. One method is by an electronic controller using solid-state cir-

REWIND TENSION RANGES

MATERIAL	TENSION (lb per mil per inch of width)	PREFERRED WINDING METHOD	
Aluminum Foils	0.5 to 0.15	Taper	1.5 to 1
Cellophanes	0.5	Taper	1.25 to 1
Cellulose Acetate	0.25 to 0.5	Taper	1.25 to 1
Ethyl Cellulose	0.5	Taper	1.25 to 1
Glassine	1.0 to 2.0	Taper	1.1 to 1
Methyl Cellulose	0.5	Taper	1.25 to 1
Polyester	0.5 to 1.0	Constant or Taper	1.25 to 1
Polyethylene	0.2	Constant or Taper	1.25 to 1
Polypropylene	0.187 to 0.25	Constant or Taper	1.25 to 1
Polystyrene	1.0	Taper	
Rubber Hydrochloride	0.06 to 0.25	Constant	
Vinyl Chloride Copolymers	0.06 to 0.187	Constant	
Vinylindene Chloride Copolymers	0.06 to 0.187	Constant	
Paper & Laminates	(per inch of width)		
20#	0.5 to 1.0	Taper	1.5 to 1
40#	1.0 to 2.0	Taper	1.5 to 1
50#	1.25 to 2.5	Taper	1.5 to 1
60#	1.5 to 3.0	Taper	1.5 to 1
80#	2.0 to 4.0	Taper	2 to 1
85#	2.0 to 4.3	Taper	2 to 1

Table 3

cuitry. The controller receives two electrical signals from the main drive system. One signal must be proportional to line speed and the second proportional to acceleration.

The signal proportional to line speed is usually obtained from a tachometer generator mounted on the main drive. A signal proportional to the main drive acceleration is obtained from the main-drive control system. The controller regulates the winder drive shaft output horsepower, whether it be a DC motor or an eddy-current clutch. Adjustments are provided in the controller to allow tension to be decreased as the roll size increases, providing a taper tension. With this type of equipment a wide range of tension patterns may be obtained with a single-winder drive and controller.

The operator can vary the tension level to accommodate different material thickness and width combinations. The operator first sets a tension value; the regulator will decrease this value according to the taper pattern programmed into its system. It is possible to program several different tapers into the system and have an operator selector switch to choose the taper pattern desired during any given run. Since this type of rewind drive only develops torque, it does not know which portion goes into friction and windage and which portion goes to the web, hence the experience level of the press operator is important.

As mentioned in the rewind horsepower formula, the drive manufacturer must take operator experience into account in adjusting for windage and friction losses when sizing the rewind motor. In the previously discussed alternative dancer-roll system, the tension in the web is only a function of the loading of the dancer roll and, therefore, friction, windage and inertia do not affect the drive operation.

Another type of controller system is the force transducer (*Figure* ⓯). It is similar to the dancer-position drive, except that the dancer roll is replaced with a fixed roll coupled to a load cell arrangement, sometimes called a strain-gauge amplifier. This system has very precise and linear deflection-versus-load characteristics. Consequently, the deflection of this load cell is directly proportional to the web tension exerted upon it. A small deflection (0.001") can cover the entire tension range desired. This sensing system is therefore very responsive and accurate. It has the ability to readily adjust taper with an electrical potentiometer (operator's tension setter) and it provides a readout of the tension on a calibrated meter.

REWIND DRIVE CHARACTERISTICS

DRIVE TYPE	SINGLE MOTOR COST	DUAL MOTOR COST	CONTROL COMPLEXITY	TIE-IN W/ MAIN DRIVE	TENSION RANGE	ADJUSTMENT TAPER
TORQUE REGULATED (TR) (Taper Tension)	130%	210%	Medium	Yes	Medium[1]	Yes
DANCER POSITION (DP) (Constant Tension)	100%	180%	Low	No	Medium[2]	No
CELLULOSE ACETATE	170%	240%	High	Yes	Wide	Yes (in TR mode)
FORCE TRANSDUCER (Load Cell)	200%	330%	High	No	Wide[3]	Yes

[1] *Better at high end.* [2] *Better at low end.* [3] *Direct reading.*

Table 4

Since this system has no material storage, there is nothing to absorb the tension shocks resulting from out-of-round rolls, splicing, or other irregularities. Compensating systems are provided in its design to handle these conditions.

Table 4 sums up the characteristics of the drives that have been discussed. The dancer-position drive is used as a base point or the 100% reference line. For different drives, the relative cost, control complexity, tie-in with the main drive, tension range and adjustable taper have been compared.

The dancer-position system has low control complexity, medium tension range and does a good job of winding materials requiring low tensions. The taper-drive system has a medium tension range and does a better job of winding materials requiring higher tensions. It requires a tie-in with the main drive, has medium control complexity and costs more than the dancer-position system.

A combination system of both taper and dancer position is commonly used, allowing for a wider range of tension values. In this case, when winding heavier materials, the dancer roll is bypassed and the drive winds in the taper mode. When winding lighter materials, the dancer roll may be used and the control is then electrically transferred to the dancer-position mode.

The force transducer system has a wide tension range and features a direct tension readout. This system does not require a tie-in with the main drive and is readily adjustable to taper controls. The system rates a "medium" in complexity and expense.

Rewind drives, in the case of flying-splice systems, can be equipped with either single or dual motors. Dual motor drives have several benefits, and individual core-shaft electrical braking is available. No auxiliary core-shaft clutches are required, and it's easy to get a very efficient, high-speed transfer from the full roll to the empty core. On single-motor systems tied into flying-splice rewind units, it is necessary to use clutches to engage the drive motor to each of the core shafts. Although it is possible to speed match the empty core to the line speed by "slipping" the full-roll clutch, this method is not as reliable or as smooth as the two-motor system. For these reasons, two-motor systems are now standard on most modern equipment.

SURFACE-REWIND TENSION SYSTEMS

The tension system used in most surface rewind units is simpler than those just discussed. The double-drum or single-drum surface rewind is normally geared to the main drive so that the winding drums are driving at a speed proportional to the line speed. In order to establish a given tension, a variable-speed drive is usually employed. The operator adjusts the rewind to run faster than the press. The material slippage on the winding drums establishes the tension.

In certain applications, surface winders are driven by a follower-type DC or eddy-current, clutch-and-drive motor combination. Again, an operator sets the basic winding tension on one winding drum, while another drum continually tries to tighten the roll. The differential speed between winding drums is usually obtained by gearing arrangements. However, twin DC motors have been used. The operator can then select a different speed setting between the winding drums. This approach allows a wide range of roll hardness, depending on the difference in the speed settings of the two drums.

With a single-drum system, there is no differential or tightening effect. The winding tension is set by the operator through the mechanical or electrical speed controls.

Pneumatic Shafts and Chucks

Whenever there is a roll or web, regardless of the material, it has to be unwound and usually rewound. In most cases the roll has a core of some type, which could be paper/fiber, metal, plastic or wood, that has to be held securely to provide rewinding tension or braking torque. There are a variety of mandrels, shafts and chucks in use and most are mechanically or pneumatically operated.

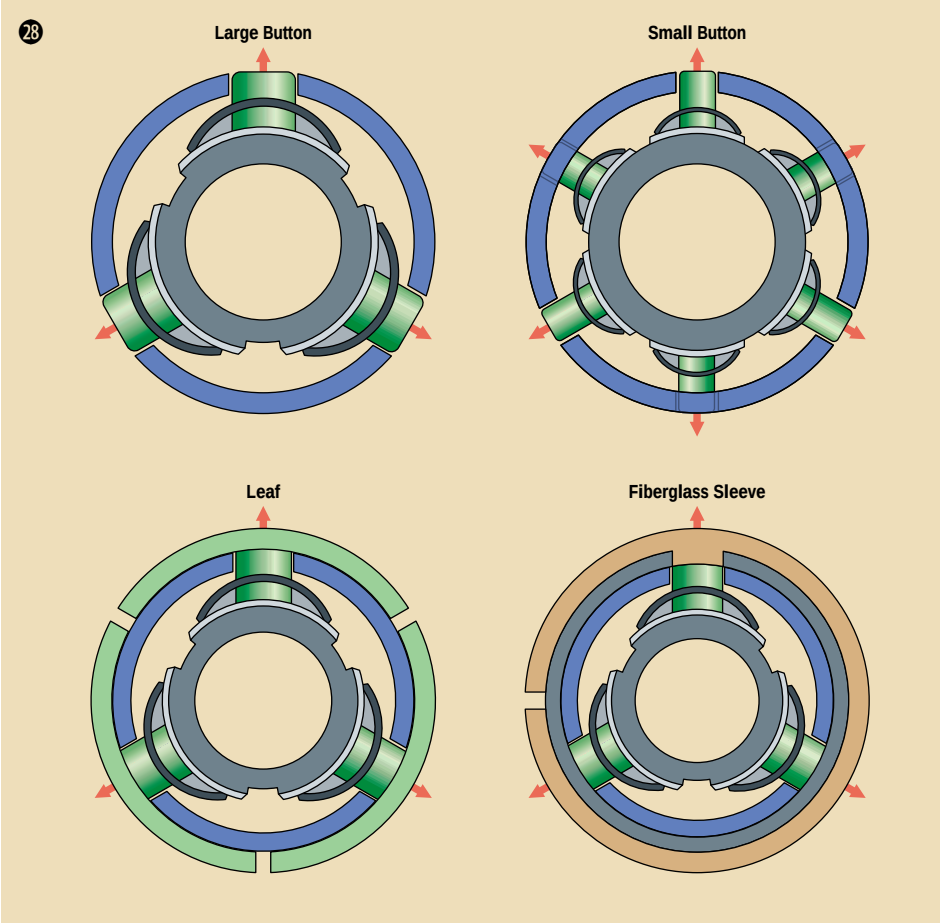
Mechanical shafts and chucks have been widely used for conventional web handling operations and are well-known in the field. Pneumatically-operated shafts and chucks, because of their simplicity and reliability, are accepted as standard by engineers, production supervisors and maintenance personnel knowledgeable in manufacturing and converting operations where web materials are being processed. This next section will explain the operation and application of pneumatic shafts – more commonly called air shafts – and chucks.

AIR SHAFTS

Air shafts are used for both conventional and more demanding applications. They offer many advantages over the older mechanical shafts mainly because of their light weight and simplicity of operation. In addition, a high strength-to-weight ratio results in minimum deflection, and the ability to maintain a full grip across the entire length of the core or roll face allows air shafts to handle very high torque. Narrower rolls can be handled because of low deflection from loads concentrated near the center. Low maintenance and easy in-plant repair procedures contribute to the popularity and extensive use of air shafts.

Although the air-shaft design is basically simple, a variety of styles are available and each shaft is custom-made to suit specific requirements of an application. Each of these types is designed around one basic principle, i.e., a metal tubular bar acts as the load-carrying member. The body of the shaft has a number of drilled holes or slots into which are fitted buttons or lugs backed with steel pressure flanges. Upon introduction of air into the shaft, an internal air bladder expands and forces the buttons or lugs radially outward until the inside diameter of the core is securely gripped along its full length. The internal air bladder is made of a tear-resistant neoprene or similar material and has bonded ends or metal fittings to form an airtight flexible chamber. Air pressure of approximately 80 psi is necessary to ensure that the outward thrust is sufficient to grip the core. When the air is released, the shaft deflates, causing the spring-loaded buttons or lugs to retract below the outside surface of the body and allow fast shaft removal.

There are five basic types of air shafts: large-button, lug, small-button, leaf and fiberglass-sleeve (*Figure* ㉘). The best applications are described in the following paragraphs.



28 Four of the five basic types of air shaffts. The large button type is best used with heavy duty winding and unwinding, while the small button type is bet used with multiple cores. The leaf type is effective in core-less windings, while the fiberglass-sleeve type is used an an altenative to the leaf type in light-weight applications.

Large Button Type. For rugged, heavy duty standard core winding or unwinding. Big buttons 0.625" in diameter are spaced 1.75" apart in multiple rows.

Lug Type. The lug type of air shaft is similar to the large-button type, but with bars 0.25" wide by 3" long instead of buttons.

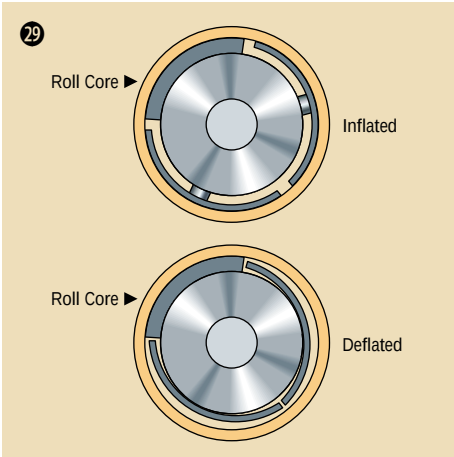
Small Button Type. For stacked or multiple cores when slitting and rewinding narrow webs. Small buttons 0.375" in diameter are spaced 0.75" apart in multiple rows. This shaft has the capability of gripping individual narrow cores stacked on the shaft even if the core tolerances vary from one core to the next.

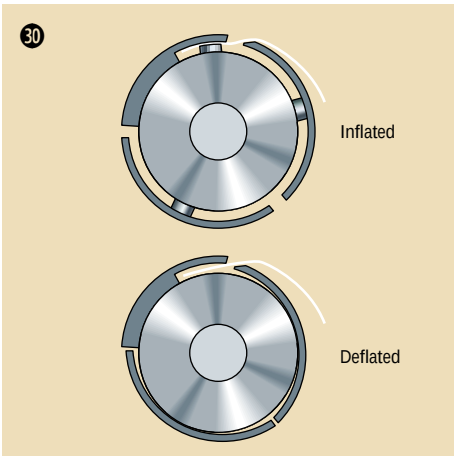
Leaf Type. For rugged heavy-duty coreless winding or where thin walled cores are used, this type provides a continuous gripping action throughout the entire expanding face, making it suitable for winding multiple rolls or rolls without cores.

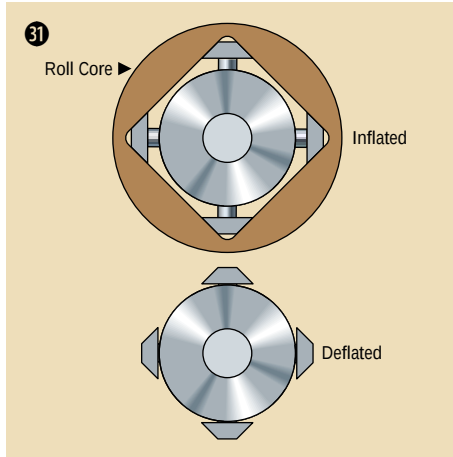
Fiberglass-Sleeve Type. A variation of the leaf type, this air shaft is used when light-handling weight is of prime importance. Two fiberglass sleeves used in lieu of leaves and in conjunction with a high tensile aluminum-shaft body account for the weight saving and make for a lightweight rugged unit.

SPECIAL AIR SHAFTS

There are many specially designed models of air shafts for specific requirements. Four unique and popular types are described







29 A fixed-leaf type special air shaft gives maximum concentricity in close-tolerance cores.

30 A trapper-leaf type special air shaft is used in coreless applications. This leaf type grips the leading edge of the web or webs through use of a bar or small button.

31 The unique design of the square type air shaft enables it to securely grip square bore cores.

below. However, thousands more have been built for just about every conceivable winding or unwind operation and it would be impossible to describe each one. Torque figures and additional engineering data are available from manufacturers. In general, air shafts have a superior performance record versus mechanical shafts.

Fixed Leaf Type. This shaft gives maximum concentricity in close-tolerance cores. One leaf is located and secured in the fixed position, its radius matching the inside diameter of the core (*Figure* 29). The remaining leaves expand and retract in the normal manner, supplying the gripping effects and forcing the core against the fixed radius of the leaf. The core is therefore securely held concentric with the shaft body in between the leaves and turned to a desired outside diameter (determined by the core) for a similar effect.

Trapper Leaf Type. In coreless applications, this leaf type grips the leading edge of the web or webs (*Figure* 30). One leaf is fixed in the expanded position with a bar (or small button) used to secure the web material against the underside of the fixed leaf when the shaft is inflated. The web is released when the shaft deflates, allowing its withdrawal from the finished wound coreless roll. Adhesive tape or any other method used to secure the web or webs for start-up is eliminated.

Square Shaft. The unique design of this type enables it to securely grip square bore cores. The pneumatic feature eliminates the clatter and vibration usually associated with this type of application in square bore, metal or wooden cores (*Figure* 31).

AIR CHUCKS

Pneumatic chucks offer many advantages over mechanical types. They insert easily into the core end and allow the introduction of air, resulting in a high-torque grip. When air is released, the chuck slides out easily without damage to the core ends. From an operator standpoint, the simple procedure

of inserting air pressure makes chucks easy to use and as with air shafts, contributes to their popularity and extensive use. Maintenance, when required, is extremely simple and easily carried out on site.

Air chucks are bored to fit over and clamp onto a variety of core bars, round or square, and in some cases are mounted on smaller air shafts.

Slitter Knife Mounting. These special shafts are designed and custom built to extremely close tolerances for mounting and driving slitter blades, individual hubs and other similar slitting equipment.

Web Guiding

The simplest approach to controlling a web is edge guiding. It is generally applicable in cases where it is desirable to maintain the edge in constant reference to the press and where the sensor can be repositioned in accordance with changing web widths. Control systems are available with capabilities for guiding on either edge, center guiding, or electric eye line guiding.

Sensing of the web edge is generally accomplished using a pneumatic detector that provides a low-pressure signal proportional to the web position. Photoelectric sensing is generally used only in those cases where guiding relative to a guideline registered with the printing is required to accommodate critical slitting requirements on the press.

Center guiding is used in situations where web widths vary during operation and it is therefore desirable to keep the material centered relative to the press, rather than referenced to one edge. This kind of guiding can be accomplished through the use of fixed sensors located on each side of the web, or through systems providing automatically adjusted sensors for continually following the web as its width varies. The choice between fixed and moving sensors depends upon the degree of web width variation.

The hardware for center-guide systems is more complex and the setup and operation are more complicated than the simple edge-guide system. However, in those cases where the benefits of center guiding are required, it can be a highly successful way of dealing with the printing requirement.

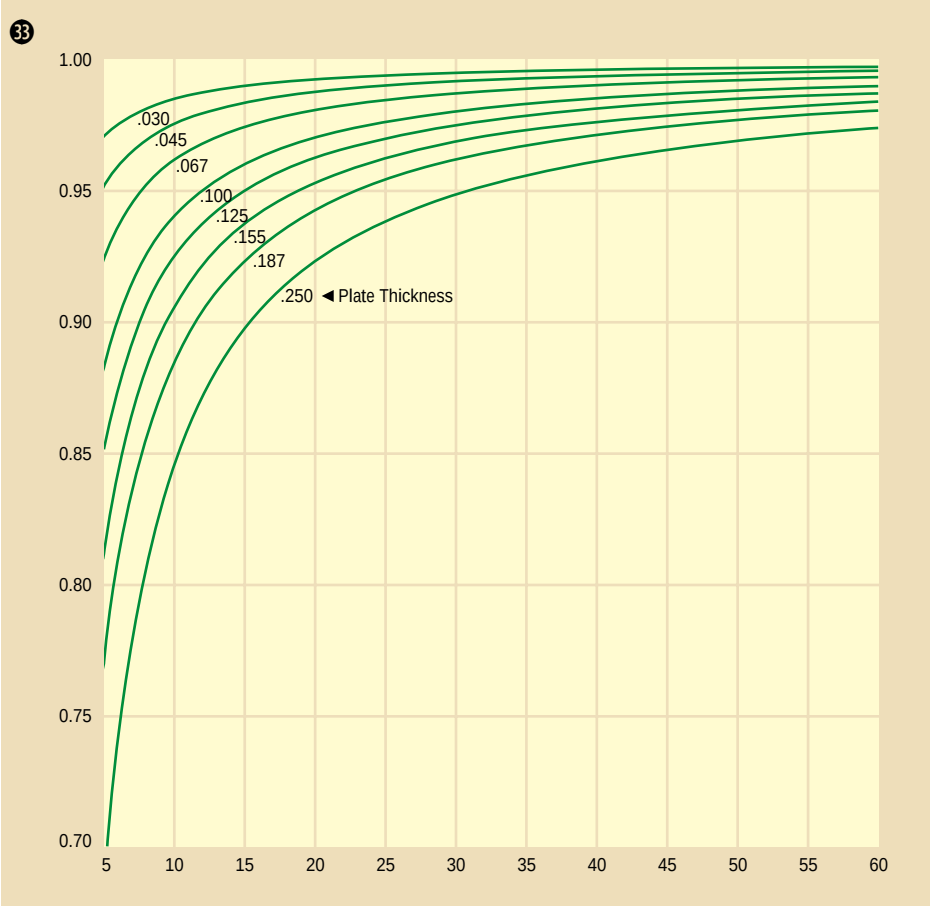
WEB GUIDES

The typical web guiding system consists of several components integrated into a closed control loop. *Figure* 32 illustrates a system showing the sensor, controller, hydraulic actuating cylinder and web. No particular type of guiding apparatus is shown in this illustration, since it depends on the specifics of the installation.

In the typical closed-loop condition control system, the set point, or command, is the prepositioning of the sensor on the press to determine the guide point. The sensor then produces error signals, which go to the controller. At the controller, the servo valve translates the low-level error signal into a high-level hydraulic output to the guide cylinder. The guide mechanism, in turn, produces an output. This output is a velocity differential across the web in response to the flow from the controller. This velocity differential is transmitted to the web through the guiding device, and the web is repositioned at the sensor, providing the necessary feedback.

32

32 This air-pressure hydraulic guiding system includes the sensor, controller, hydraulic actuating cylinder and web. Note no particular type of guiding apparatus is shown, since it depends on the specifics of the installation.

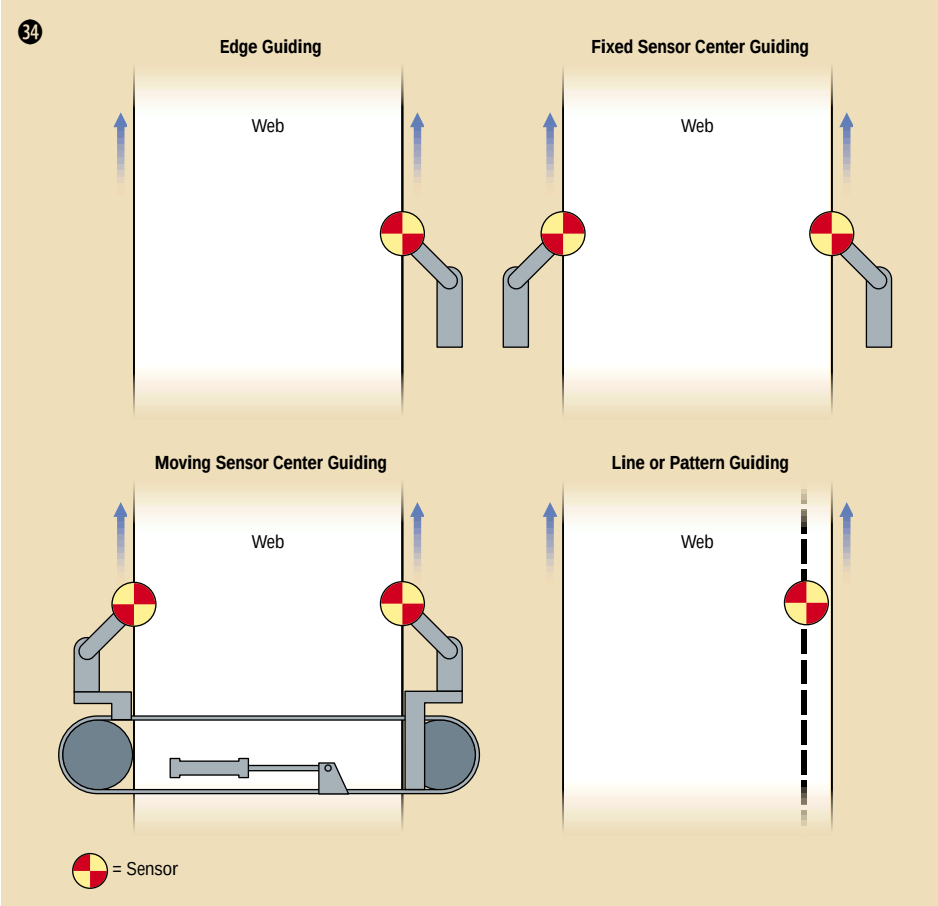


33 The four types of automatic guiding systems. All of these systems rely on a sensor to monitor web position and transmit any shifts to a servo valve (hydraulic systems) or a DC drive motor (mechanical systems).

It is important to note that the feedback to the sensor is through the web. Thus, the behavior of the web, in conjunction with the other components in the loop, is most important to the proper functioning of the control system. Not only are the characteristics of these individual components important, but the relationship of their characteristics must be carefully established to ensure proper system results. The accuracy of this feedback is particularly true where high press speeds require fast guiding system response and stability to achieve highly accurate web position control and registration.

Various auxiliary control systems are available for use with the automatic guiding systems. With intermediate guides, the most common auxiliary control system is a feature that allows the operator to disable the automatic guiding system and to center the intermediate guiding device in its travel. This feature is generally most useful in situations where the press must be re-threaded. With unwind and rewind guides, the most common auxiliary control system is a feature that enables the operator to manually control the system, as well as to operate in the automatic guiding mode. With this system, the operator can manually position the unwind or rewind stand during press setup and then switch the system into the normal automatic mode of operation when printing.

There are three locations on flexographic presses where guiding is normally applied at the unwind, prior to printing and at the rewind. Guiding at the in-feed section with



34 The four types of web-position control systems. Note the varying positions of the sensors.

either unwind guiding or intermediate guiding corrects for misalignment of mill roll position and such things as telescoped and poorly wound rolls.

Automatic Web Guiding Systems

There are four basic types of automatic control systems (*Figure* 33):

- pneumohydraulic;
- electrohydraulic;
- pneumomechanical; and
- electromechanical.

All of these systems are closed-loop, type 1, proportional control systems; this description means the correction output adjustment is opposite and in proportion to the error detected.

Hydraulic types. The two hydraulic types of automatic control systems function in a similar manner. A sensor monitors the lateral position of the web. The sensor signal is transmitted either directly to the power unit servo valve (pneumohydraulic systems) or to a signal processor, which then sends a signal to the power unit servo valve (electrohydraulic systems). Hydraulic output from the power unit through the servo valve, proportional to the lateral error of the web, positions the guide structure, which moves the web to the correct lateral position in the sensor. These systems are attractive for extremely heavy loads and harsh environments.

Mechanical types. The two mechanical types of control systems also function in a similar

manner. A sensor, either electronic for electromechanical systems or pneumatic for pneumomechanical systems, monitors the lateral position of the web. The sensor signal is either transmitted directly to the signal processor (electromechanical system) or is first converted from an air pressure signal to an electrical signal with a transducer (pneumomechanical system). The processor then sends a signal, proportional to the amount of error detected by the sensor, to the DC drive motor on the electromechanical actuator. The actuator positions the guide structure, which moves the web to the correct lateral position in the sensor.

These systems are especially attractive for applications demanding a high frequency response and where hydraulics are not desired.

Web Position Control

There are four types of web-position control systems (*Figure* ㉞):

Edge Guiding. The sensor detects the web edge and the guide system maintains this edge at the desired lateral position.

Fixed Sensor Center Guiding. Two sensors are held in a fixed position; they detect both edges of the web. The guide system maintains the centerline in an exact position and accommodates small web width variations.

Moving-Sensor Center Guiding. In applications where there are large web width variations during a production run, the sensors continuously reposition themselves automatically to detect both web edges and to maintain the centerline of the web in an exact position.

Line or Pattern Guiding. The sensor detects a printed line, pattern or some distinguishable feature on the web. The system then maintains the printed line, pattern or feature in an exact lateral position, regardless of the web edge position.

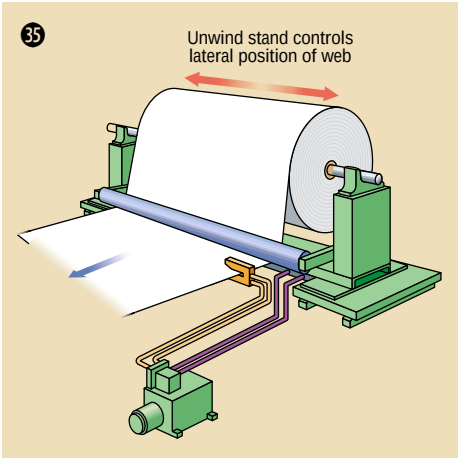
Sensor Installation

The sensor should be located in the exit span as close as possible to the exit guide roller and no farther downstream than one-half the exit span length. A dead-bar or idle roller can be used to stabilize the web and prevent the web from contacting the sensor. The dead-bar or idle roller should be positioned immediately downstream of the sensor and have a web wrap no greater than 10°. Sensor selection is based on material and system requirements.

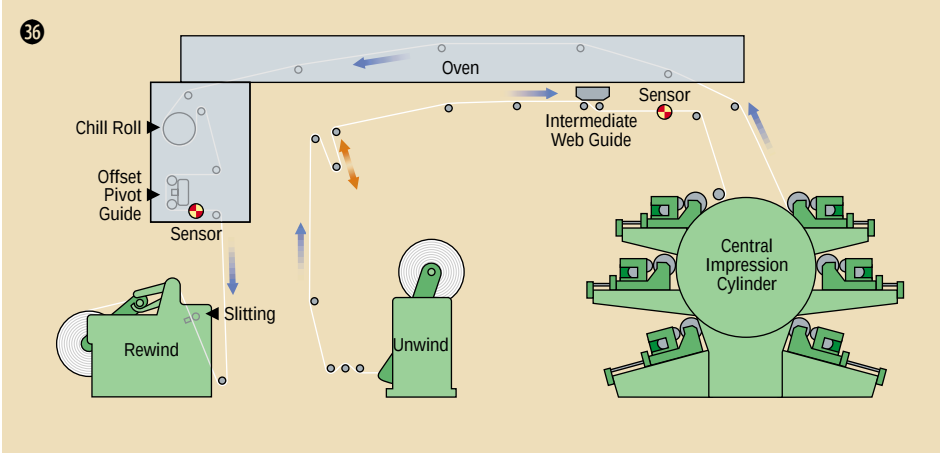
UNWIND GUIDING

A typical unwind installation can be seen in *Figure* ㉟. In this application, the unwinding roll of material is shifted laterally and the sensor is fixed so that the edge of the material is aligned to the desired position relative to the press. An idler roller should be provided to shift laterally with the unwind and provide for a constant plane at the point of sensing.

Since the web plane between the tangent to the unwinding roll and the first idler in the press is constantly changing, it is not practical to sense in this area. The use of the shifting idler establishes a fixed web plane suitable for sensing. Also, by shifting the idler with the unwind stand, the output from the controller to the cylinder is imparted to the web immediately in the vicinity of the sensor.



㉟ A typical unwind edge-guiding system. The unwinding roll of material is shifted laterally and the sensor is fixed so that the edge of the material is aligned to the desired position relative to the press.



36 Installing an intermediate web guide immediately ahead of the first print station, either in lieu of or in addition to, the unwind guide, there is a great distance between the unwind and the first print station.

This setup eliminates undesirable time lags before the sensor sees the output of the control cylinder.

Because of the mechanical configuration of most unwind stands and the masses likely to be involved, mechanical and hydraulic resonance considerations generally play an important part in designing a successful unwind guiding installation. Lateral bending of the uprights due to their flexibility, or flexing of the stretcher members of the stand often contribute to a relatively low spring rate and resultant low mechanical natural frequency. All shifting stands should be designed with the natural frequency of the controller in mind so that they are in the vicinity of two or three times the natural frequency of the controller.

Unwind guiding aligns the edge to a predetermined guide point. Depending on the sensor selected, unwind guiding sometimes requires a direct mounted or slave idler, or idler rolls, for proper operation. The idlers are required when using a sensor with a narrow gap or a line guide sensor. The idler maintains a constant plane for the material being guided. The unwind stand is generally positioned so there is less than one web width to the first fixed idler in the machine.

The operator positions a roll of material on the unwind stand. The operator then positions the sensor where he or she wishes the edge of the web to be positioned. In automatic mode, the unwind stand then shifts laterally, keeping the edge of the web at the guide point of the sensor.

The ideal location for the sensor is as close as possible to the shifting unwind (See *Figure* 35). This positioning will give the best dynamic performance and accuracy. Systems are available that allow the sensor to be located after the first fixed idler. These systems will guide the web, but at a reduced level of performance.

INTERMEDIATE WEB GUIDES

If there are long spans between the unwind and first print station, it may be desirable to install an intermediate web guide immediately ahead of the first print station, either in lieu of or in addition to the unwind guide (*Figure* 36). This intermediate guide can correct for any web position errors that may occur in spans between the unwind and the first print station.

Intermediate guiding devices generally fall into two categories. The first is a steering guide, which is a roller having accurate motion (in the plane of web travel) about an instant center located several web widths ahead of the guide. The second type of intermediate guide is a displacement guide, or off-

set-pivot guide, which is a two-roll assembly, the rollers of which are pivoted about a line tangent to the face of the entry roll.

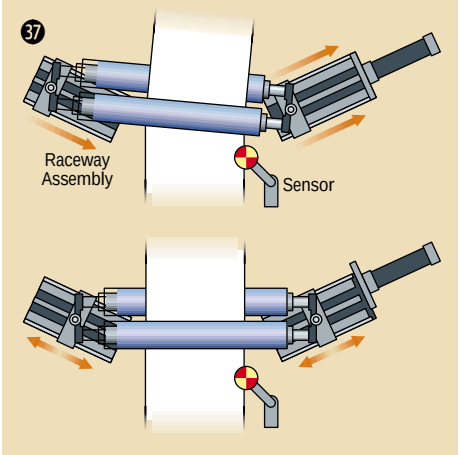
Steering Guides

Steering-type intermediate guides, as seen in *Figure* 37, have been used with great success for many years. A steering guide provides web position correction by bending the web through a long entering span. This type of application, however, requires a long, free entry span to distribute the stress distortions caused by the guide motion. The span requirement is also a function of the mechanical properties of the web.

When web materials of unusually high stiffness or very thin and extensible materials at very low tensions are encountered, it becomes desirable to employ offset pivot-type guides as opposed to steering guides to minimize the web stress distribution in limited-guide entry and exit spans. An offset-pivot guide with a large dimension between the two guide rollers requires only short entry- and exit-span dimensions. Therefore, it can be installed under the dryer bridge or below a viewing platform for the web scanner prior to the rewind. The range of material types to be run on a press and the press geometry and auxiliary equipment layout, combined with various guide arrangements and costs, determine the choice of specific guide types and locations.

Steering guides are mechanical devices using one or more rollers rotating about a remote center of rotation located upstream from the device. The center of rotation is also known as the instant center. The device steers the web in the entering span of the guide by changing the angle of the roll relative to the centerline of the machine. The angular change corrects steady-state errors, whereas the translation due to the remote instant center corrects transient errors.

The steering guide consists of a single or pair of fixed raceway bases and a moving structure. The moving structure, sometimes referred to as the pivot carrier, holds the roll and rotates about the remote center of rotation. The roller is attached to pivot brackets, which are attached to the pivot carrier.



37 Steering-type intermediate guides provide web position correction by bending the web through a long entering span.

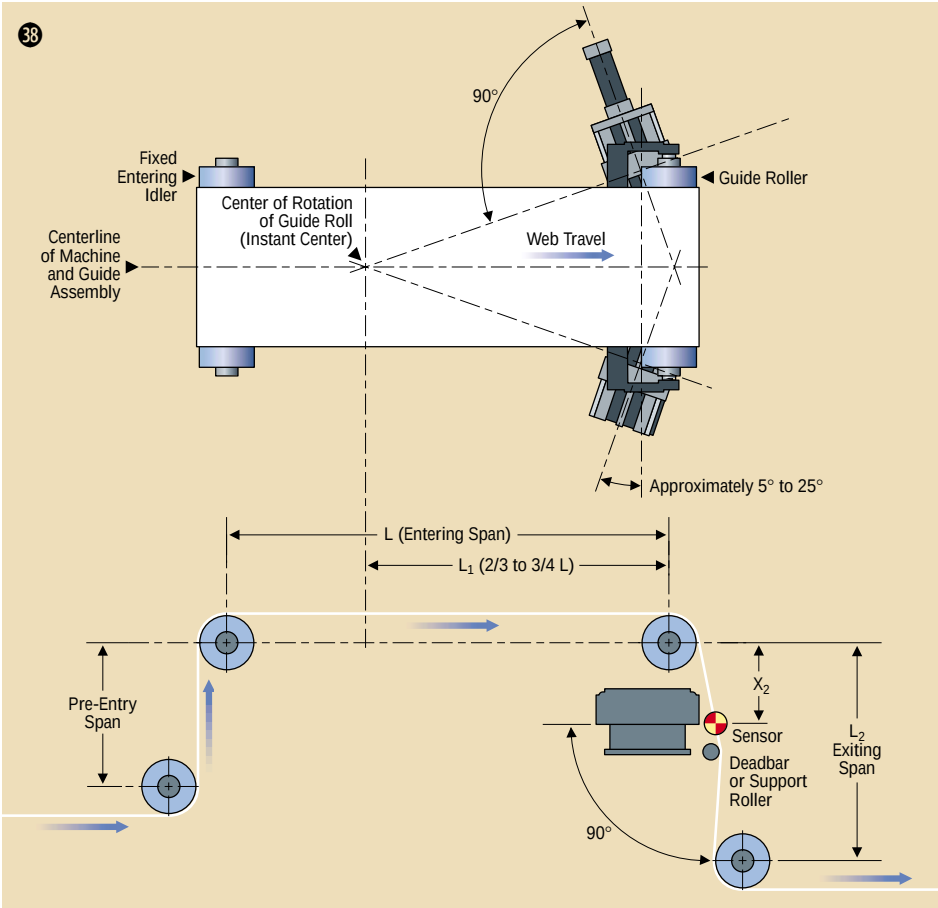
The center of rotation is generally located two-thirds to three-quarters the length of the entering span ahead of the guide roller. This location provides satisfactory dynamic characteristics. The angle of rotation of the guide roller is small, usually less than 3°. For most steering guides, the location of the center of rotation can be adjusted by positioning the base at the correct angle during installation.

The span immediately upstream of the guide is known as the entry span. The span upstream of the entry span is known as the pre-entry span. The relative length of these two spans is important and will be explained later. The last fixed roller prior to the guide roller is referred to as the entry roller.

Steering Guide Operation

The plane of motion of the steering guide is normally parallel to the plane of the entering span (*Figure* 38). If the web on the entry roller is displaced from the desired guide point, the pivot carrier rotates, causing the web to be repositioned to the desired guide point. As the pivot carrier rotates, the web is bent laterally. The greatest bending occurs

38 A typical installation for a steering guide operation.



as the web exits the entry roller. The exit is where the highest stress distortion occurs.

At the point of critical rotation, the stress on one edge will be zero. The stress on the other edge will be approximately 13 times the web's average stress. This lateral bending of the web, and the associated stress distortion, is the primary reason the steering guide requires a long entry span. If the rotation of the steering guide exceeds the critical angle, the stress on one edge can become negative, meaning it has a loose edge. The stress on the other edge increases to compensate for the loose edge. The net tension in the web will remain constant, but if less web width is under tension, then web stress becomes higher. The loose edge can result in troughs and/or wrinkles being formed in the web.

The web-entering span ideally should be parallel to the guide plane of motion. In a worst case scenario, the web plane of motion should be no greater than 30° off the guide plane of motion.

Instant Center Location. The location of the center of rotation is very important in obtaining stability in the control system. The center of rotation is ideally two-thirds to three-quarters the length of the entry span upstream of the guide roller. If the center of rotation is less than ideal, the guide becomes over-steered. The magnitude of over-steering is inversely related to the distance the center of rotation is located upstream. As over-steering increases, the guide control system becomes more and more unstable until the system oscillates

constantly, causing the guide to induce more error than it is correcting.

Entry Spans. The length of the pre-entry span should be shorter than the length of the entry span. If the pre-entry span is equal to the entry span or longer, the stress distortions in the entry span can transfer across the entry roller into the pre-entry span.

In the pre-entry span, stress distortions will cause a movement in the web, inducing error. The guide will then try to correct the greater error, causing even more error. The end result will be the guide bottoms trying to correct the amplified error. This chain of events is known as a pre-entry span condition. Keeping the pre-entry span shorter than the entry span prevents this problem. The lengths of the typical entering spans expressed in web widths for normal corrections are shown in *Table 5*.

The required correcting capabilities of a steering guide can be determined by the equation:

$$C = 9T(L/W)^2/tE$$

Where:

C = guide correction (inches, mm)
E = modulus of elasticity (psi, Newtons/mm^2)
L = length of entry span (inches, mm)
T = tension (pounds, Newtons)
t = web thickness (inches, mm)
W = maximum web width (inches, mm)

Web Plane. The plane of the web in the exit span of the steering guide ideally should be perpendicular to the guide plane of motion. This arrangement will keep the stresses in the exit span to acceptable levels. In this case, the web in the exit span is twisted.

In some cases, a steering guide with a straight through-pass is used. The plane of the exit span is then parallel to the guide plane of motion. These installations work, but with increased stress distortions in the exit span and loss of guide accuracy due to the bending of the web in the exit span. This loss of accuracy is known as residual error and can be as much as 20% of the incoming error, depending on the material and the length of the exit span.

The equation for exit span length limits the edge stress amplification to three times the average stress. This limit prevents possible web damage. As a rule, if material properties are not known or if the calculated exit span is less than one-half the web width, the exiting span should be greater than one-half the web width in length. This span reduces the possibility of the steering guide inducing wrinkles into the web.

In the case of stiff webs, the previous equations should be used to determine the minimum length of the entering and exiting spans.

Steering Guide Selection

To select the proper steering guide model, or to determine the actual steering load capacity of the guide, the following application parameters must be known:

- web wrap style;
- modulus of elasticity of the web material;
- maximum web width;
- maximum web tension;
- maximum web thickness;
- web error;
- roller diameter;
- roller face length;
- guide entry span; and
- exit span length.

To prevent the steering guide from inducing wrinkles in the web, it is recom-

ENTRY SPANS

MATERIAL	ENTRY SPAN IN WEB WIDTHS
WOVEN TEXTILES	1 to 2
PLASTIC FILMS	1.5 to 3
PAPER AND PAPERBOARD	2 to 5
METALS	10 to 390

Table 5

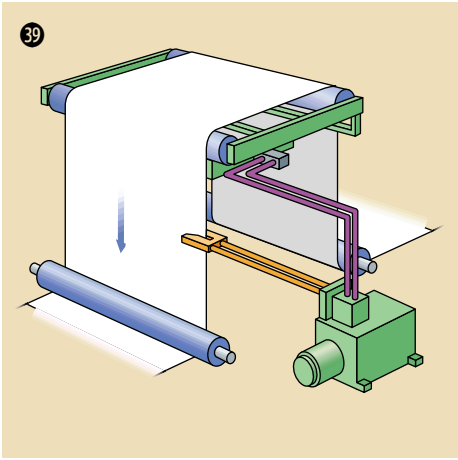
mended that the exit span be greater than one-half the maximum web width.

Offset Pivot Guides

An offset pivot guide (OPG), shown in *Figure* 39, is a mechanical device used to correct the lateral error in a web of material as it runs through a process. The OPG corrects the error by displacing the web between the entry span and the exit span of the guide. It is a displacement-type guide that provides web position correction with minimum entry and exit span requirements. Designed with parallel rollers, the guide pivots such that the web is twisted, thus minimizing web stress. This design allows an OPG to be used in the least amount of space.

The offset pivot guide consists of a fixed base and a pivoting structure with one or more rollers. The pivoting structure, referred to as a pivot carrier, rotates about a fixed, imaginary point called the pivot point. The angle of rotation is limited to 7.5° maximum. The point of rotation is ideally in the plane of the entry span or within 10% of the guide span of the entry span plane.

OPG Operation. If the web on the entering roller is displaced from the desired guide point, the pivot carrier will rotate, causing the web to be repositioned to the desired guide point. As the pivot carrier rotates, the web in the entering and exiting spans is twisted. This twisting causes the stress in the web to be redistributed so the stresses are higher at the web edges than in the center of the web.



39 The offset pivot guide is a mechanical device used to correct the lateral error in a web of material as it runs through a process. Economy of space is a major advamtage of an OPG.

The web should enter the OPG perpendicular to the plane of motion of the OPG. The plane of motion is the plane that the pivot carrier rotates in. Webs entering the OPG at angles other than perpendicular to the plane of motion cause an increase in stress distortions and detrimental steering effects in the web. These steering effects can cause instabilities in the guide control loop or lead to reduced guiding accuracy, as well as stress distortions that could damage the web.

When the pivot carrier is in a centered position, it does not influence the lateral position of the web because the rollers on the pivot carrier are parallel to the other rollers in the process line.

Different models of OPGs are available for different web widths, web tensions and roller diameters. The guide span (the distance from outside of the entering guide roller face to the outside of the exiting guide roller face) and the roller face lengths are a variable feature for each model. While the guide span should ideally be equal to the web width, it should never be less than one-half the web width.

As a rule, if the material properties are not known or if the calculated entry/exit span is less than one-half the web width, the entering and exiting spans should be made greater than one-half the web width in length. This precaution reduces the possibility of the OPG inducing wrinkles into the web.

OPG Selection. To select the proper OPG model and determine the guide angle, correct exit and entry spans, the following application parameters must be known:

- guide correction;
- modulus of elasticity;
- length of entry span ;
- maximum tension;

- web thickness;
- maximum web width ;
- roller diameter;
- roller face length;
- guide span;
- base mounting dimension; and
- wrap style and base mounting style.

The actual load capacity of an OPG depends greatly on the guide span, roller face length and wrap style.

REWIND GUIDING

Rewind guiding (*Figure* 40) is not truly lateral control of a web. Rewind guiding is actually a chasing control system. At the rewind, guiding is accomplished by attaching the sensor to the rewind stand and shifting the stand to chase the web as it comes from the press. In actuality, this is not web guiding at all but, rather, merely positioning the rewinding mandrel in such a way as to follow the normal wandering of the web so that its edge is maintained in fixed, lateral relationship to the rewinding mandrel at all times.

A fixed idler roller between the moving sensor and rewind stand isolates the web from stand motion and provides for a constant web plane at the point of sensing. The same considerations regarding mechanical and hydraulic resonant frequencies apply to rewind guiding as to unwind guiding. In addition, however, care must be exercised in designing the support for the sensor so there is sufficient rigidity to avoid flexure and mechanical resonance in this part of the equipment. Factors to consider in selecting an unwind/rewind stand are shown in *Table* 6.

Rewind Operation

The rewinding roll is positioned to align the edge of the rewind roll to the edge of the approaching web. The sensor is located just ahead of the last fixed idler in the machine and is typically attached to the rewind stand with a mechanical arm. The operator either manually or automatically positions the sensor at the edge of the web being chased. The sensor chases the edge of the web and, as a result, the rewind control system then causes the rewind stand to shift laterally as the web tracks laterally, resulting in a roll of material with a straight edge.

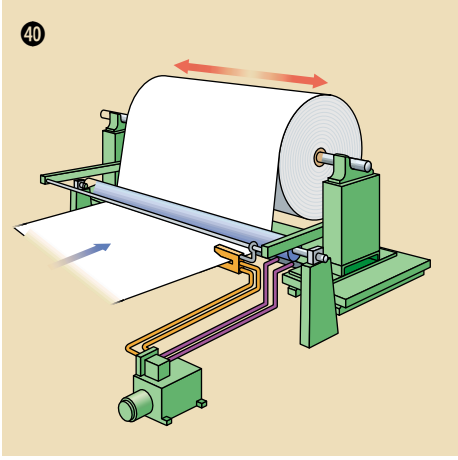
Systems are available that do not require the sensor to be mounted to an arm attached to the rewind stand. Instead, the sensor is

UNWIND/REWIND STAND SELECTION

To select the proper stand, the following application parameters must be known:

1. Web material.
2. Maximum web width.
3. Maximum tension.
4. Maximum lateral shift required.
5. Maximum line speed.
6. Maximum roll weight.
7. Maximum roll diameter.
8. Maximum weight of the stand.
9. Coefficient of friction for the slider bearings.

Table 6



40 In a typical rewind edge guiding, the rewinding mandrel is positioned in such a way as to follow the normal wandering of the web, so that its edge is maintained in a fixed, lateral relationship to the rewinding mandrel at all times.

electronically connected to the rewind stand. The rewind stand is generally positioned so there is approximately one web width from the last fixed idler.

In rewind guiding, if the sensor is located downstream of the last fixed idler or the web does not have sufficient frictional engagement with the last fixed idler, a roll with a ragged edge will be wound. Another problem often seen in rewound rolls is telescoped wraps. The guiding system is often blamed for this defect, when in reality, the roll was not wound with sufficient tension to prevent lateral slippage of one or more layers in the wound roll. This defect often occurs many layers deep in the wrap being applied, during winding or even days after the roll is removed.

Web Viewers

From the beginning of flexographic printing, press manufacturers have constantly made improvements in their designs and process techniques to reach higher optimum printing speeds for improved profitability. As web speeds increased, many process functions became more critical, requiring greater operator attention and skill to obtain maximum efficiency, quality assurance and waste control. As a result, web viewers were developed and made available to aid the press operator in fully utilizing the press potential.

As web speeds exceeded the 250 to 300 feet per minute (fpm) range, above which operators could no longer accurately inspect the printed web, web scanners became a necessity for quality assurance. Today, with the increased demand for more sophisticated print requirements, the selection of a suitable web viewer is of prime importance.

The degree of efficiency obtainable is greatly dependent upon the ability of the web viewer to provide a stable image of such quality that precise definition of detail, registration, etc., is readily visible at all printing speeds. When this stable image is accomplished, the operator can constantly monitor the print quality and make the necessary press adjustments, as well as observe the adjustment results, while the press is running at optimum web speeds. This, of course, minimizes material waste and press downtime.

STROBOSCOPE

The simplest web-viewing device is a stroboscope, similar to an automotive timing light. This device consists of a lamp and voltage pulse source, providing a brief instant flash with a frequency synchronous with the print repeat length. Being relatively simple in concept and structure, it is the least expensive option but has severe limitations as a suitable web viewer.

With a stroboscope, the viewing area is limited to the size of the lamp beam diameter, which varies with distances, of course. The distance also controls the degree of illumination and definition of print detail. Discounting operator discomfort and fatigue, image definition is also less than satisfactory. The lamp of the stroboscope is designed to flash in synchronization with the print repeat length, or multiples thereof, so that an identical portion of the web is constantly viewed. Therefore, frequency is dependent upon print repeat length versus web speed and will vary as either or both are changed.

At low speeds, the operator observes a brief instant flash, lacking the necessary dwell time to retain the image between flashes. As web speed increases, a frequency is reached where persistence of vision bridges the gap between flashes, providing the stroboscopic effect, or a stationary image. As the frequency approaches and exceeds approximately 25 cycles per second, the stationary effect is lost and the stroboscope begins to provide a constant illumination typical to the common light bulb. With these factors in mind, it is readily apparent that a web viewer with the stroboscopic concept is limited in performance.

OSCILLATING MIRROR

Another type of web scanner is a device

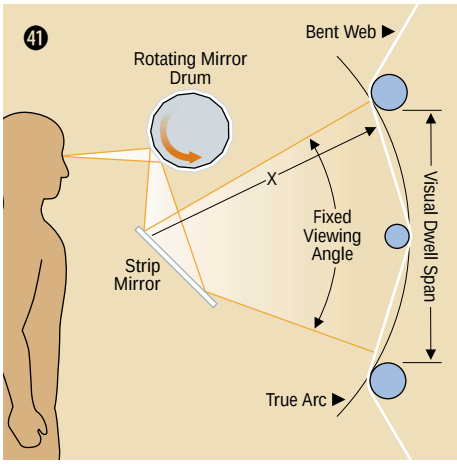
consisting of a rectangular mirror oscillating in synchronization with the print repeat length. In practice, the web viewer is mounted at a fixed distance from the web plane and the sweeping angle of the oscillating mirror is varied to accommodate the various print repeat lengths, or multiples thereof. The oscillating mirror is generally sized to view a web width of 18" to 20" and can be mounted on side-motion tracks to traverse web widths beyond its fixed viewing range.

Due to the width and height restrictions of the oscillating mirror, only a portion of the print repeat length is visible through the viewing area at a given time. As a result, the synchronous drive is equipped with a modulator so that the oscillating frequency can be regulated to cause the field of vision to drift through the entire print repeat length. Any portion of the print repeat length can be constantly viewed by simply reestablishing synchronization.

This type of web viewer has a definite advantage over the stroboscope concept. Auxiliary light fixtures constantly illuminate the web, rather than utilizing the flashing lamp, which eliminates the flickering effect and reduces operator fatigue. In addition, the visual dwell time is increased due to the angular movement of the oscillating mirror throughout the oscillating cycle, improving the operator's ability to define print detail.

The prime disadvantages for the oscillating mirror concept are its speed limitations and lack of image stability. Any mechanical device that utilizes reciprocating motion, regardless of its design quality, has many moving parts that are subject to speed limitations and rapid deterioration of precision fitting or surface wear. Since the oscillating frequency, or reciprocating motion, increases with speed and is further magnified as smaller repeat lengths are viewed, this concept is limited to viewing web repeats of moderate length (6"–12") and slower-moving webs.

For printing applications within the suited speed range of 100 to 300 fpm, there is another disadvantage that induces image instability and distortion. This problem is caused by the constant variation in optical distance between the flat web and oscillating mirror surface, as it sweeps through its angular movement. Obviously, the occurrence relative to oscillation frequency provides an additional need for the inspector to continually refocus on the image each time a print repeat length is viewed.



41 By "bending" the printed web over an idler roller to simulate an arc throughout the sweeping angle, the "bent-web" viewing feature eliminates the sweeping angle distortion during a straight-web threading orientation.

ROTATING DRUM MIRRORS

Figure 41 illustrates a third generation of web viewing equipment. This method uses a rotating drum of mirrors to offset the speed limitations inherent in the previously discussed web viewers.

The multisided drum of mirrors is rotated in synchronization with the viewed web segment of a given print repeat length. Each time a viewed web segment passes through the visual dwell span, one mirror of the rotating drum reflects the image until the next mirror picks up the identical area of the succeeding print repeat length. This process is repeated continuously as other mirrors rotate into position in synchronization with the print repeat. The series of images is then reflected to a separate strip mirror that is

cam-operated from the drum shaft, providing tracking through the visual dwell span.

The rotary drum web viewer generally has a fixed viewing width of 18" to 20". The basic viewer is normally mounted on an overhead track assembly with a sideways motion feature for traversing the total web width as required by the specific press design. Since the viewing angle of the rotary drum viewer is fixed, the track assembly must also have provisions for positioning the web viewer at various distances from the web. This capability allows the rotary drum position relative to the web to vary so that the visual dwell span is equal to the print repeat length being viewed.

"Bent-Web" Feature

Also shown in *Figure* 41 is the "bent-web" viewing feature. This feature was developed to eliminate the optical distance change that occurs as the viewed web segment sweeps though the visual dwell span when utilizing a straight-web threading orientation. The printed web is "bent" over an idler roller to provide the similarity of an arc throughout the sweeping angle. Although not a true arc, optical distance is relatively constant throughout the visual dwell span. This feature practically eliminates the sweeping angle distortion, providing image stability.

Relative to reciprocating motion, the "bent-web" technique reduces the transition of the cam profile enough that the strip mirror oscillation is practically zero. In operation, this technique, when combined with a rotating drum mirror concept, can provide suitable web scanning at speeds up to 2,000 fpm.

The "bent" idler located in the visual dwell span optically disappears at speeds over 250 to 300 fpm. The optical disappearance in the field of view is relative to the idler size. Therefore, idler diameters should be kept to 3" or less. Concentricity and balance of the bent idler are of prime importance to prevent web flutter and image instability.

Automatic Synchronization

The synchronous rotation of the mirror drum is achieved with two self-synchronizing motors. One self-synchronizing motor on the drive assembly, acting as a transmitter, is coupled to the print cylinder shaft or any other line shaft that has a ratio equivalent to one revolution of the print cylinder circumference. This self-synchronizing motor transmits voltage to the second self-synchronizing motor in the basic web-viewing unit driving the drum of mirrors. Synchronization is now achieved since one print repeat length equals one mirror movement of the drum rotation. By disrupting the synchronization phase manually with a hand-wheel, or automatically by a built-in electric drive, the viewed web segment can be varied throughout the entire print repeat length. This provides the operator with the ability to slowly scan any portion of the print repeat length.

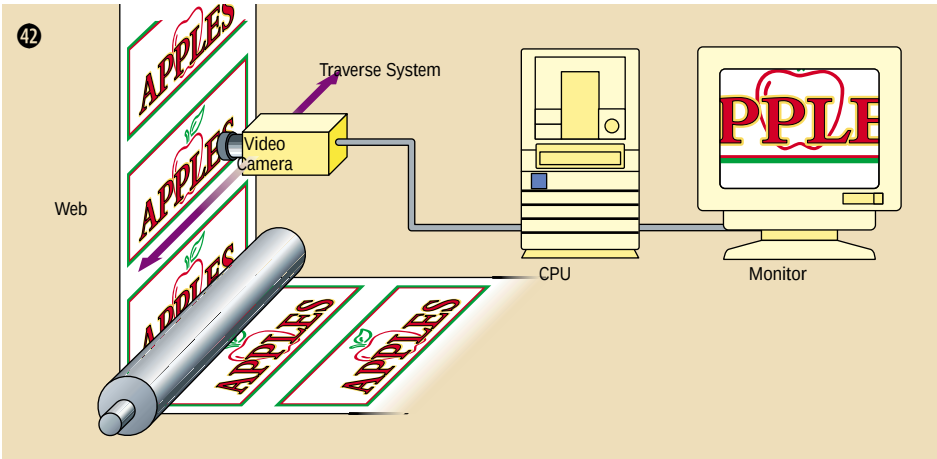
Lighting and Magnification

Suitable front light fixtures are required to provide constant illumination of the printed surface of the web. Fixtures should be positioned and properly baffled to avoid obstruction or glare throughout the viewing area. For applications where transparent or translucent materials are frequently printed, it is advantageous to utilize a rear lighting fixture for improved web illumination.

Due to the image stability of a rotating device, scopes are available for print magnification. In the range of five to ten power, critical inspection of minute details of fine type, texture and other quality details is feasible.

VIDEO SCANNING

In recent years, coinciding with the evolution to higher speeds, wider web widths, longer repeats, gravure-like quality, increased, number of colors and more on-press coating, the need for better visual inspection has become critical. Video scan-



42 A typical video inspection system consists of a camera assembly, camera positioning assembly, CPU and software, and press timing devices.

ning and video web inspection systems have filled this need, and are now the most popular form of online print inspection methods. They are available from basic viewing systems to automated defect detection systems. This discussion will focus primarily on basic viewing systems.

System Configuration

A typical video inspection system is shown in *Figure* 42 and consists of these four basic components:

- camera assembly
- camera positioning assembly
- CPU and software
- press timing devices

Camera Assembly. Typically, the camera assembly contains a high resolution RGB (red, green, blue) color camera. A motorized zoom lens and diopter, or close-up lens, together determine the overall magnification of the system. The zoom lens also controls the focus and iris. The iris controls the amount of light reflected into the camera and hence the brightness of the image. A strobe lighting system uses a xenon flash lamp that produces a high-intensity short-duration flash of light. This illuminates and provides stop-motion of the area for the camera to capture the image.

Camera-Positioner Assembly. This is typically available in three different configurations: manual, motorized and programmable. If a manual positioner is chosen, the positioner must be installed on the press so the operator has physical access to move the camera across the web (crossweb). Manual positioners are primarily used on narrow-web machines. Motorized positioners provide basic left-right jog capability. Programmable positioners offer multiple, user-programmable positions to be stored and then activated in a continuous loop.

The camera positioner needs to be installed after the last line operation that requires inspection. This is typically accomplished after the dryer, but before the last dancer assembly prior to rewind. Most inspection system suppliers do not supply the brackets that connect the positioner to the press frame as standard equipment. Many will provide these at an additional charge. The brackets and the chosen viewing area are critical to ensuring satisfactory viewing results.

The chosen viewing area must meet some minimal requirements. The distance from the web surface to the camera/lens is defined by the camera lens focal length. The focal length determines the height at which the camera positioner assembly is positioned above the web viewing area. This dimension should be

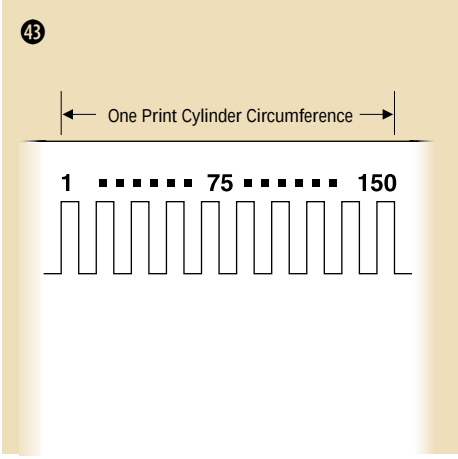
held from sideframe to sideframe to ensure that the viewed image remains in focus from one web edge to the other.

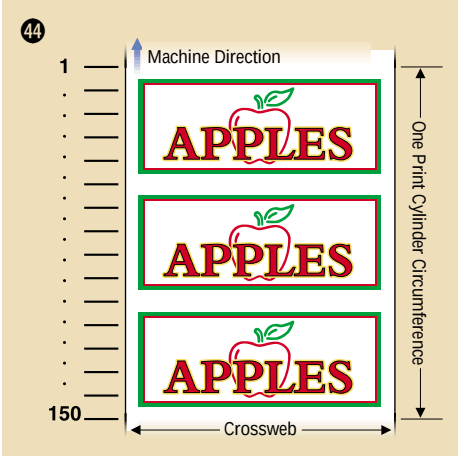
The web should be supported so that web-plane change is kept to a minimum. This may be accomplished by utilizing two idler rolls that are relatively close together. Another method would be to install the camera positioner assembly as close as possible to one idler roll that has approximately 90° of wrap, taking care that the camera viewing area does not extend beyond the curvature of the idler roll. If the web is allowed to experience excessive plane change, the viewed image may not remain in focus. Care should also be taken to ensure the centerline of the camera can be positioned over the web edge and that no interference is caused by the sideframes. When properly installed, the camera-positioner assembly will provide complete crossweb viewing capability.

CPU and Software. The CPU (central processing unit) contains the main computer system and its associated power supplies. Also contained in the CPU is the frame grabber, which "grabs" the image that is captured by the camera and converts it to a form that can be displayed on a high-resolution video monitor for inspection. The software gives the computer the instructions to follow. These include the basic instructions for capturing and displaying images and any advanced instructions such as automatic color monitoring, register monitoring or bar-code verification.

Signal Input Device. The signal input device is used to provide the inspection system with speed and timing information. There are many different types of signal input devices. The most commonly used sensors include proximity sensors, optical encoders and print mark sensors. The one to choose will depend on the specific application. Regardless of which one is used, the installation of this device is crucial for optimum system performance.

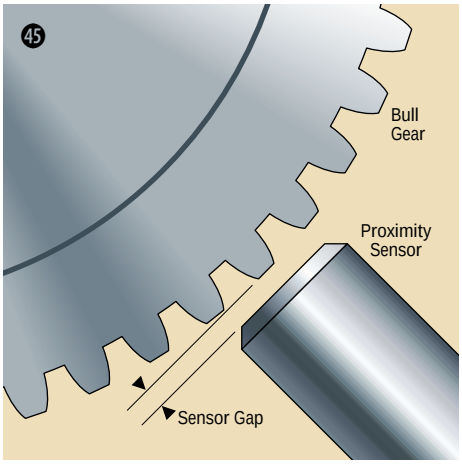
The video system uses a short-duration, xenon strobe light to illuminate the camera's viewing area. This short-duration strobe flash causes the web material to appear stationary while the camera captures an image. The signal input device provides a timing signal so that the operator can control the point at which the strobe fires (*Figure* 43). The timing signal is directly related to the print cylinder circumference, which, in effect, divides the print repeat into sections as illustrated in *Figure* 44. The timing signal provides the ability to advance or retard the point on the web, in the machine direction, where the strobe will flash. When used in conjunction with the camera's crossweb-positioning capability, any area on the printed repeat



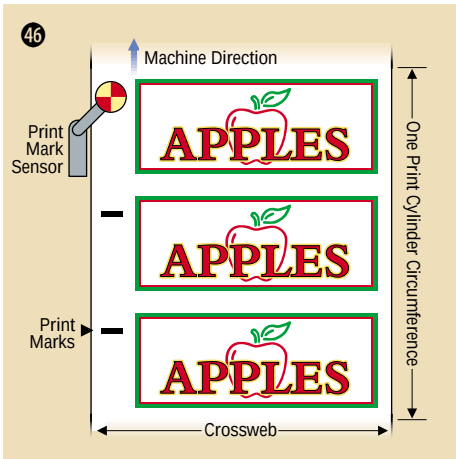


43 The signal input device provides a timing signal so that the operator can control the point at which the strobe fires directly related to the print cylinder circumference.

44 Each mark in the timing signal represents a standard number of strobe pulses. Thus, the opertor porgrams the strobe to pulse at a rate that will allow it to view the appropriate portion of the web.



45 The proximity sensor determines the number of teeth on a bull gear, and doing so, measures the rate of web travel.



46 A proximity sensor will detect the beginning of the repeat and then develop strobe timing pulses via software. This type of sensor is most commonly used in non-printing applications such as inspection rewinders.

length can be viewed.

As an example, in *Figure* 44 each mark in the machine direction represents 10 timing pulses. In order to view the center area of the web, the camera-positioner would be moved crossweb to the center of the web and the timing pulse would be set to fire the strobe at pulse 75, since there are a total of 150 pulses per repeat length.

Proximity Sensor. The proximity sensor is an inductive device that detects the presence or absence of ferrous metal. It is most commonly used in video inspection systems to detect and count the teeth on a gear that is relative to the print cylinder. The proximity sensor would be installed to sense the teeth of the bull gear (*Figure* 45). It is critical for proper operation of the video system that the distance between the proximity sensor and the gear teeth being sensed (sensor gap) is adjusted correctly. Incorrect setting will cause the system to lose synchronization.

Since the pitch of the bull- and print-cylinder gears are known, this determines that every four teeth detected by the proximity sensor results in one inch of web travel. The only setup information the video system requires to synchronize properly is how many teeth are on the print cylinder gear for the current job. This value must be changed each time a different size print cylinder is used.

Optical Encoder. An optical encoder utilizes an internal transmitted-light sensor and a transparent disk with non-transparent marks equally spaced on the disk to generate a timing signal. This signal is directly relative to the shaft of the encoder (i.e., each complete rotation of the encoder shaft generates an exact number of timing pulses).

This arrangement requires that the encoder be geared to the press so that, for each complete revolution of the encoder shaft, the print cylinder also makes exactly one revolution. Because of this exact 1:1 ratio requirement, the encoder has limited applications. On a variable-repeat press, it would require the operator to change the encoder or gear ratio for every job change. The optical encoder is most commonly used on fixed repeat presses.

Print Mark Sensor. A print mark sensor can be used to synchronize the video system by optically detecting a printed mark on the web surface. The printed mark must be of significantly opposing contrast to the background color. The printed mark must only occur once per printed pattern and no other printing can occur between the marks (*Figure* 46). In this mode the video system will detect the beginning of the repeat and then develop strobe timing pulses via software. This type of sensor is most commonly used in non-printing applications such as inspection rewinders.

CONCLUSION

Video inspection systems are capable of viewing high press speeds without jitter and distortion. They are also capable of high magnification and can detect printing defects normally seen only with the aid of a magnifying glass on a stationary web. They are particularly helpful in detecting registration errors, doctor blade streaks, dot gain and UPC code verification.

As these systems have evolved, they have become capable of automatically monitoring preset tolerances and warning the operator when the press exceeds these tolerances, i.e., registration, color variance, repeat variations, etc. By changing illumination they also have the capability of viewing clear varnishes and lacquers without using additives.

The biggest drawback to date has been the cost of such units. They have obviously appeared on the latest high-tech presses, but it seems that it will be some time before they are available as retrofits for older presses.

Substrate Treatment and Processing

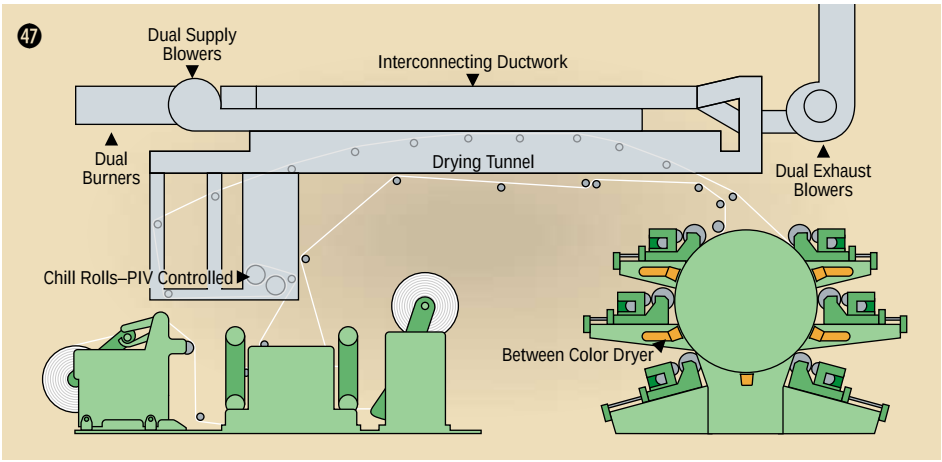
One of the key functions of the flexographic printing process is the proper treatment and handling of the substrate material. One of the primary considerations is, of course, the drying of the ink on the substrate after the print stations. Further considerations include additional treatment in order to receive the ink, cleaning of the substrate and control of static electricity carried by the substrate. Finally, lamination and varnishing will be briefly discussed.

DRYERS

Some flexographic presses have integrated drying systems. A typical arrangement for a central impression (CI) press is shown in *Figure* 47. There are individual dryers after each print station except the last one. These dryers are known as either between-color or interstation dryers. The dryer after the last print station is called the main tunnel or overhead dryer.

Interstation dryers remove a sufficient amount of the volatile solvents from the ink so that the next print station may apply another color without altering the previous one. On a four-color stack press there are typically three interstation dryers. A color CI press usually has five. On either a stack press or CI press, there is one main tunnel dryer. The latter removes the volatile solvents from the last printing station and completes the heat setting of all the inks applied. The main tunnel dryer also removes the final traces of volatile solvents from products where retained solvents could present problems, such as blocking.

The interstation and main tunnel dryers have various air flow schemes, depending on the vintage of a press. For example, a press



47 A typical dryer system on a central impression (CI) press. There are individual dryers after each print station except the last one.

might have one supply fan, one burner and one exhaust fan for the main tunnel dryer, and a parallel system for the interstation dryers, with each one sharing one supply fan and one exhaust fan (*Figure* 48). This system gives the press operator the ability to independently control air temperatures in either the interstation dryers or the main tunnel.

Other examples of airflow schemes are:

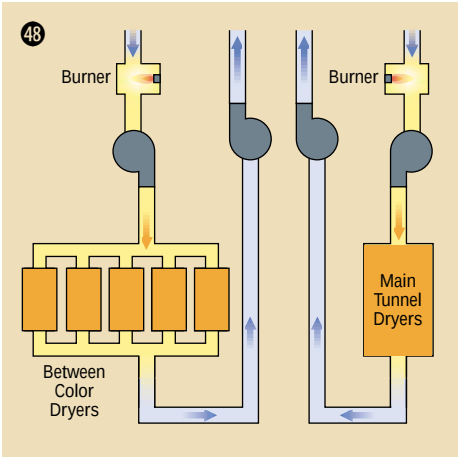
- one supply fan and one burner ducted to both the interstation dryers and main tunnel dryer, then exhausted through a common exhaust fan;
- independent supply fans and burners, but exhausted with a common exhaust fan; and
- independent supply fans with one common burner with exhaust through an independent or common exhaust fan.

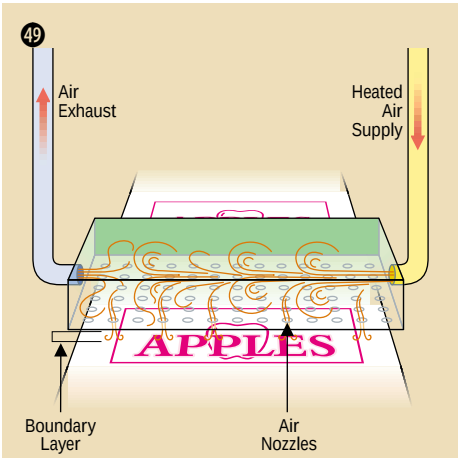
As with any rule, there may be exceptions. Some may exist where the interstation dryer exhaust is also the main tunnel supply or vice versa, as in a cascading airflow system.

Again, flexographic press dryers use hot air to remove the volatile portion of the ink. This air is ducted and directed to the substrate where the substrate, ink solids and ink solvents are raised to a temperature that causes volatilization. The important considerations for any dryer are:

Air Temperature. The higher the temperature, the quicker drying can occur, but high temperatures can have drawbacks, such as possible substrate damage. High temperatures can also dry the top surface of the ink, forming a crust that must be broken to vaporize ink trapped under the surface against the substrate. This defect can show up as pock marks or "fisheyes."

Air Velocity and Volume. The greater the velocity and volume of heated air directed to the substrate, the quicker the volatile ink components can be vaporized. The ink must reach the ink-vapor temperature for volatilization to occur. The moving air helps carry the volatile components away, speeding additional evaporation. Velocity and volume relate directly to fan horsepower.





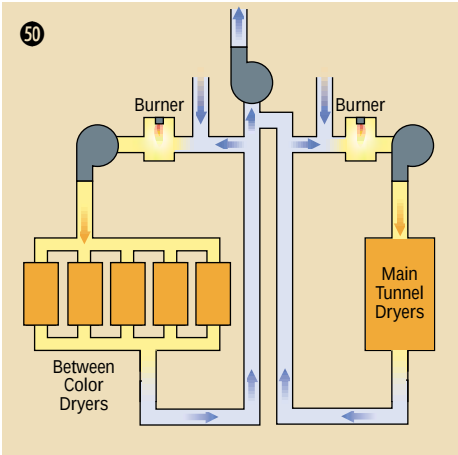
48 A typical dryer air-flow scheme.

49 How a dryer works: The heated air is pushed onto the substrate through a series of air nozzles, narrow slots running perpendicular to the substrate travel, across the width of the substrate. After vaporizing the volatile component of the ink, the air is exhausted.

Time. Sufficient time with a proper combination of air velocity, air volume and air temperature, allows the substrate and ink to get hot enough to vaporize the volatile component of the ink. The length of the air dryer versus the linear speed of the substrate determines the length of time.

How Dryers Work

Normally, the supply fan takes air, from either the roof or inside the plant, past a gas-fired burner and directs this air to the substrate (*Figure* 49). The heated air is pushed onto the substrate through a series of air



50 A recirculation airflow scheme that recycles air containing volatilized solvents.

nozzles, narrow slots running perpendicular to the substrate travel, across the width of the substrate. After vaporizing the volatile component of the ink, the exhaust fan pulls the air from the dryer and sends it to either the atmosphere or a pollution-control device. When the air is exhausted, ambient air is pulled into the dryer at the web entrance and exit. In all cases, the exhaust volume is greater than the supply volume. Therefore, the dryer is kept under a slight negative pressure, which prevents volatile air from escaping into the plant.

NFPA Guidelines

The exhaust airflow volume from the press dryer is designed according to National Fire Prevention Association (NFPA) guidelines which dictate that the ventilation or exhaust rate must be designed and maintained to prevent the vapor concentration in the dryer from exceeding 25% of the lower explosive limit. The NFPA says that an estimated rate of ventilation or exhaust cannot be less than 10,000 cubic feet (measured at 70°F) per gallon of solvent evaporated in the dryer. This rate makes for a 25% lower explosive limit. This limit is based on ink/solids/solvent concentrations, types of solvents, press speed, substrate width and the number of printing units. All these factors must be considered to determine the maximum solvent conditions or the most solvent the dryer will have to evaporate.

Now that pollution-control equipment is mandatory, flexographic press dryer airflow schemes have been revised to reduce the volume of air processed by this equipment and released to the environment. The EPA's capture requirements on total emissions must be met, limiting the amount of air that can be treated and exhausted.

Most press manufacturers offer a recirculation airflow scheme that recycles air containing volatilized solvents (*Figure* 50). The recirculation principle utilizes a supply fan sized to provide the necessary volume and pressure of hot air to the dryer and to exhaust the majority of the air containing the vaporized solvents. A smaller exhaust fan removes the filtered air, products of combustion and any leakage into the dryer. In all cases, this exhaust must meet the guidelines of NFPA for lower explosive limits. When dealing with dryer exhaust rates, consult your press or dryer manufacturer and the proper authority in pollution control.

COOLING ROLLS

When subjected to heat, polymeric films can soften, lose strength and stretch. Although heat is required to complete some of the coating and printing operations, temperatures must be carefully controlled, and this usually necessitates the use of cooling rolls.

Cooling rolls can be devised by using other rolls as substitutes, such as uncovered fountain rolls, plate cylinders or impression cylinders, in positions following the dryers, between the last dryer and rewind, or where a temperature reduction is necessary.

Heat Transfer

Regardless of the composition of the majority of substrates, the heat transfer through

them to the surface of the cooling roll is primarily by conduction. The heat transfer from the surface of the cooling roll, through the wall of the cooling roll, to the cooling medium, is also by conduction.

With the ever-increasing cost of energy, cooling-roll heat transfer efficiency will become an ever-increasing cost problem. Cooling-roll efficiency is equal to the roll's output of energy divided by the energy input. Energy input is the heat transferred from the substrate to the cooling-roll shell; energy output is the heat transferred from the shell to the coolant and finally carried away.

The basic heat transfer expression, without any refinements is:

$$H = U \times A \times \Delta T_L$$

Where

H = The total heat removed from the substrate in British Thermal Units (BTU) per hour.

U = Overall conductance or rate of heat transfer of the system (BTU/hr/ft^2/°F)

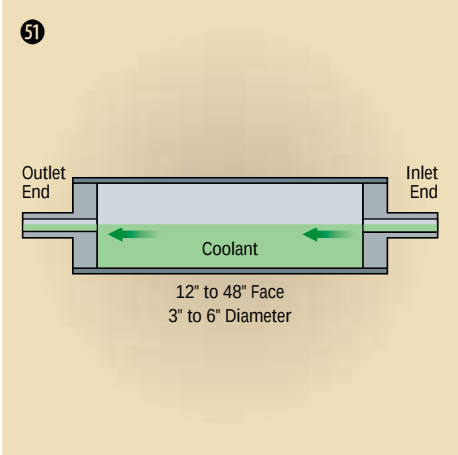
A = The area of the web in contact with the cooling roll surface

ΔT_L = Log_e mean effective temperature difference between substrate and coolant (°F)

These heat calculations can be very complex because of the many factors that affect the heat flow:

- press speed and dryer temperature;
- mass and conductance of the web material;
- conductance of the cooling drum material;
- type and temperature of the coolant;
- level of smooth versus turbulent coolant flow in the cooling drum; and
- corrosion scale on the inner wall of the drum.

If an open coolant system is used, with the source being the local water supply, inlet water temperature variation in the summer and winter must be considered, along with the total pressure range available and the flows required.



51 A typical single-body cooling unit for small presses, where coolant flows in one end, fills the roll about half way and flows out the opposite end.

Understanding the expression can also help bring about a practical balance of factors for an application. How many substrates can be run? At what speeds? At what weights and widths? For instance, where a single roll diameter may be too large and impractical, then two or more smaller rolls may be more suitable and add flexibility to an operation. For a sophisticated cooling roll application, the only foolproof approach is to fabricate an experimental model and then use the experimental value obtained to confirm theoretical value calculated.

Cooling Roll Design

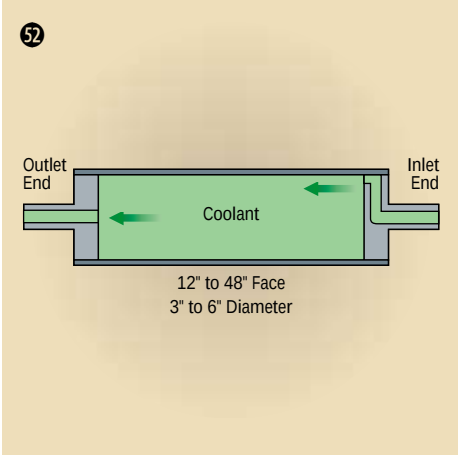
If the press is small (36" or less), runs at speeds of only 300 to 400 feet per minute, and substrate temperature reduction needed is minimal, a simple single-body cooling roll may do the job. (*Figure* 51). The coolant flows in one end, fills the roll about half full, and flows out the opposite end. The substrate must possess some strength since it will have to withstand some roll imbalance.

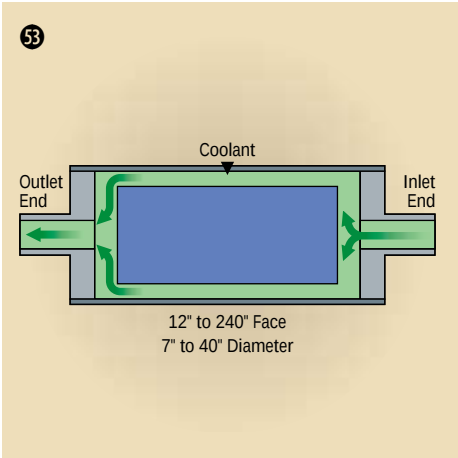
If more substrate cooling is required and imbalance must be minimized, the self-venting roll (*Figure* 52) may do the job. In this

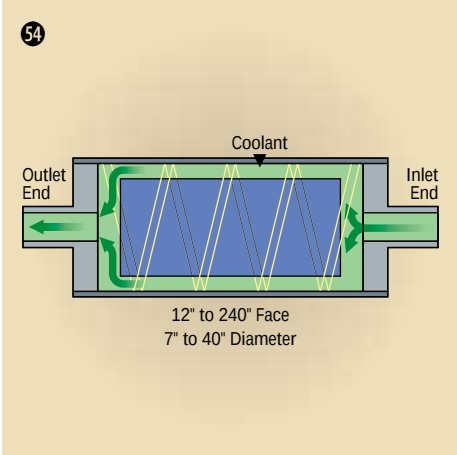
52 For substrates that require more cooling, a self-ventilating cooling roll automatically exhausts the air as the roll rotates comes in contact with the coolant.

53 In a double-bodied cooling roll, coolant is forced to flow in an annular space. The increased flow and velocity control promote greater heat transfer from the substrate.

54 A spiral-wound double-body cooling roll provides a coolant passage that allows accurate control of the flow rate and velocity of the coolant.







design, most of the air bank is automatically exhausted as the roll rotates and most of the roll body is in contact with the coolant.

A further improvement in substrate cooling and roll efficiency is the double-bodied roll (*Figure* 53). The coolant is forced to flow in the annular or ringed space. Consequently, more flow and velocity control can be designed into the roll, resulting in more heat transfer from the substrate. Generally the flow rate will remain in the laminar flow range and heat transfer will be limited by that condition.

A refinement of the double-bodied cooling-roll design is the addition of a spiral wound coolant chamber (*Figure* 54). The ideas and designs that have come out of this refinement effort over the past few years are many and varied. Some of these designs are patented, which may attest to their importance in this phase of the roll business. Only the spiral-wound version is shown and discussed. The outside diameter of the inner body is spirally wound with an appropriate material. When this inner body assembly is placed into position within the outer body, a distinct coolant passage is formed in the annular space. This design gives accurate control of the rate of flow and the velocity of the coolant.

$$\mathbf{Q} = \mathbf{A} \times \mathbf{V}$$

Where :

Q = rate of flow or discharge (ft^3/sec)

A = passage area (ft^2)

V = coolant velocity (ft/sec)

If a single passage area is required, the pitch or angle of the spiral is equal to the passage width plus the width of one spiral. If, for example, four passages are required to handle the rate of flow, the pitch is figured as mentioned and the lead would be four times the pitch. With this control available, the designer can increase the coolant velocity and change laminar flow to turbulent flow. Turbulent flow is desirable since it increases heat transfer most by reducing the coolant film and agitating, with eddy currents, the coolant itself. In this cooling roll, using

water and water-base coolants with a range of velocities from 11 to 15 feet per second will generally result in turbulent flow.

Where an application requires a minimum temperature gradient across the face of the roll, the spirals can be mounted with a decreasing helix angle. Continually decreasing the flow area increases the coolant velocity as its temperature is increasing and brings about this desirable effect. As these rolls become more efficient due to improved design and better flow characteristics, it is important to stay within the pressure capabilities of the system. Remember that the friction head varies in close relation to the square of the velocity. This type of roll is usually used in a closed system along with a treated coolant and an automatic chiller as part of the package.

A hydrostatic or pressure test is necessary on all of these rolls. The speed of the substrate and roll will determine whether a static or dynamic balance is required. On the more critical cooling-roll applications, dynamic balancing is performed with the roll full of coolant.

The flexographic process is growing because it can be adapted to handle a wide variety of packaging substrates. The heating, drying and cooling equipment components make up a very important segment in this process. The cooling roll is also being adapted so it too can handle a wider variety of substrates.

STATIC ELECTRICITY

Whenever nonconductive materials touch or rub against one another, a charge of static electricity may be generated. This electrostatic charge attracts dust particles, causes materials to cling to each other and can cause mild to violent electric shocks.

What is static electricity and how do we get rid of it, or at least control it? When the phenomenon is understood and controlled, the principles can be harnessed to provide advantages for the printer, such as substrate cleaning, film surface treatment and dust control.

Causes of Static

Static electricity is generated by unbalancing the molecular construction of relatively nonconductive materials such as plastics and paper. All matter is composed of single elementary atoms, or groups of atoms called molecules. An atom consists of a nucleus surrounded by one, or many, orbiting electrons, which have a negative charge. The nucleus consists of positively charged particles (protons) and neutral particles (neutrons). Atoms are most stable when they are electrically neutral and carry no charge. An atom in this state requires the number of orbiting electrons and protons to be equal.

In certain complex molecules, the forces between the protons and outer electrons are very weak and electrons may be easily removed. The loss of any electrons causes such molecules to become positively charged, because the number of protons exceeds the number of electrons. Conversely, nuclei of certain atoms exert very strong forces on their electrons and on others in close proximity. As a result, these nuclei pick up additional electrons and become charged negatively because the number of electrons now exceeds the number of protons. This exchange of electrons may simply be caused by contact with a dissimilar material.

The ability of a material to surrender its electrons or absorb excess electrons is purely a function of the conductivity of the material. For example, in a pure conductor, such as copper, the molecules offer little resistance to the flow of electrons and any charge imbalance within the material is soon dissipated. However, in the semiconductor range of materials, such as some bond papers, the ability of the atoms to surrender their electrons is relatively high and can be accomplished by friction, heat or pressure. With

purely nonconductive materials, such as plastics, it is extremely easy to disrupt the molecular construction, causing the material to charge with the slightest friction, heat or pressure and, because the material is nonconductive, the charge remains static.

Static electricity has as its basis an imbalance of electrons in a material. Instead of the material being electrically neutral in its normal state, it has either a positive or negative charge. In other words, the atoms or molecules on its surface have either gained or lost electrons. The number of electrons that have been added or removed from a material's surface determines the magnitude of the static charge.

To achieve electrical neutrality, a charged material exerts a force on other adjacent materials. This force is known as an electrostatic field. As is the case with magnets, similarly charged materials repel each other, whereas oppositely charged materials attract each other.

Controlling Static

Three basic methods for controlling static electricity are:

- antistatic conductive coatings, additives or sprays;
- grounding of the charged material; and
- cyclic ionization of the air surrounding the charged material.

Anti-static Coatings. If the surface conductivity of the processed material can be raised, then preventing static electricity becomes relatively easy. For example, adding surface conductivity to plastics will move them up into the higher conductivity range and prevent the build-up of static electricity that is caused by friction. This is normally accomplished by the use of additives such as moisture and antistatic sprays. The average antistatic spray is made from a soap-based material that has been diluted in a solvent, such as mild alcohol. A fire retardant is added to combat flammability of the solvent, then pressurized gases are added to form an aerosol can of antistatic spray. As this spray leaves the nozzle of the aerosol can, the propulsion gases, fire retardant and solvents evaporate a short time after contact with the nonconductive material, leaving a conductive coating on the surface of the material. As long as this coating is not disturbed, it will be difficult to generate static electricity in this material.

Grounding. The simplest and oldest method of removing or neutralizing static electricity is by a combination of induced ionization and grounding. These nonpowered (or passive) systems use conductive bristles placed in close proximity to the charged material, inducing an electrostatic field between the bristle tips and the material. The electrostatic field ionizes the air, which in turn neutralizes the static charge on the material.

Such passive devices are relatively inexpensive. However, if the static charge is not sufficiently high, or the bristle tips not sufficiently conductive, the electrostatic field between the bristle tips and the material may not form, in which case ionization of the air cannot occur and the static charge will not be neutralized.

Tinsel is the most common tool for this application. However, tinsel is often misused and, therefore, not successful. For a passive induction device to be effective, the following conditions must be met:

- the tinsel must have a metal core to be conductive;
- the tinsel must be well-grounded electrically;
- the tinsel must be within 0.25" (6 mm) of the material to be neutralized; and
- there must be "free air space" under the material to be neutralized.

In this fashion the tinsel can reduce static electricity on both sides of the static-laden material.

It must be recognized that any passive induction device, such as tinsel, will never reduce or neutralize static electricity to the zero potential level. This limitation is due to the fact that a threshold or beginning voltage differential is needed to "start" the process.

Operator Grounding. It is also possible to disturb the molecular construction of the human body. As strange as this sounds, if an operator is isolated by standing on a wooden floor or wearing crepe rubber-soled shoes, he or she will soon pick up a static charge, which will create a voltage difference above ground (zero) voltage. It is possible for an operator to gain a charge of several hundred volts each time he or she handles a piece of charged plastic. As the operator handles many different pieces, he or she may become charged to a sufficient voltage to cause a flashover. The operator may receive a mild to severe shock, or damage a static-sensitive device.

This build up of static potential can be prevented by having the operator stand on a grounded conductive mat or by the use of commercially available personnel grounding equipment. Personnel grounding equipment is important if operators are sitting while working. Sitting is the best means of isolating an operator from grounded conductivity; making them extremely vulnerable to static discharge.

Machine Grounding. In addition to personnel grounding equipment, grounding all plant machinery and related equipment is most important. Besides the safety factor, a well-grounded machine will help drain off extremely high charges of static electricity from partial conductors. Remember, grounding is only an aid to reducing problems with static electricity; it is not a solution.

Powered Static Eliminators. Static eliminators are ionizing units that produce both positive and negative ions. The unbalanced material attracts the ions so that neutralization occurs.

Most powered static neutralizers ionize the air by placing a high, alternating voltage (4,000–8,000 volts) on sharp points, in close proximity to a grounded shield or casing. As the high-voltage, alternating potential pulses through the 60-cycle-per-second operation, the air passing between the sharp points and the grounded casing is ionized, generating both positive and negative ions. Since the United States operates on a 60 cycles per second voltage, the polarity of the ionization changes every 1/120 of a second.

Cyclic air ionization is the most widely used method of static control. It involves removal of electrons from air molecules, creating positively charged cations and, conversely, adding electrons to form negatively charged molecules called anions. If the material being neutralized is positively charged, it will immediately attract negative anions from the static neutralizer, absorbing their free electrons, while repelling the positive ions. Conversely, if the material being neutralized is negatively charged, it will attract the positive ions and give up the spare electrons, while repelling the negative ions. When the material becomes neutralized, there is no longer an electrostatic attraction and the material will cease to absorb ions.

An outside source of AC power is used to operate an ionizing unit. Such systems are very efficient and can be operated at moderate cost with a long life expectancy.

Radioactive Isotopes. Nuclear-powered equipment may also be used to generate ionized air for static neutralization. These devices, powered by Polonium 210 isotopes, which have a half-life of only 138 days, continually lose their strength and must be replaced annually. They are more expensive and less effective than electrically powered devices. These nuclear devices cannot be purchased and are leased by users. One-year lease costs are usually more than the purchase price of comparable electrically powered devices.

CONCLUSION

In order to solve problems related to static electricity, certain basic steps must be taken. The logical approach is to identify the problem; determine the solution; and then select the proper equipment to solve the problem.

To identify the problem, some sort of measuring equipment must be used. For example, an electrostatic locator will measure the amount of static electricity that is present and identify the polarity as either positive or negative. Measuring and locating static electricity will remove the mystery often related to this phenomenon.

Once the problem is identified, the solution should be considered next. Can the static electricity be controlled by grounding, induction, ionization or a combination thereof? In making this decision, keep in mind the facts mentioned relative to conductivity. With pure conductors or partial conductors (such as the human body or some paper), grounding should be considered. However, if working with insulators, such as plastics, ionization must be added.

Choosing Equipment

The most effective neutralizing equipment is electrically powered. If powered devices are located where employees may come in contact with them, they should be mechanically shockproofed to prevent contact with the "hot" ionizing points.

For explosion-prone environments, explosion-proof induction-type neutralizing equipment should be chosen. Also, a number of specialized pieces of equipment are available to the electronic industry to provide static-free work areas.

By following the above steps, the risks of building up dangerously high charges of static electricity can be greatly reduced. It is important to understand that static electricity cannot be entirely eliminated. In fact, the term "static eliminator" is definitely misleading. For example, a charged piece of material can be neutralized by utilizing a static eliminator. However, it does not eliminate static electricity because, if friction is applied to the material after being neutralized, static electricity will again be generated.

Substrate Cleaning

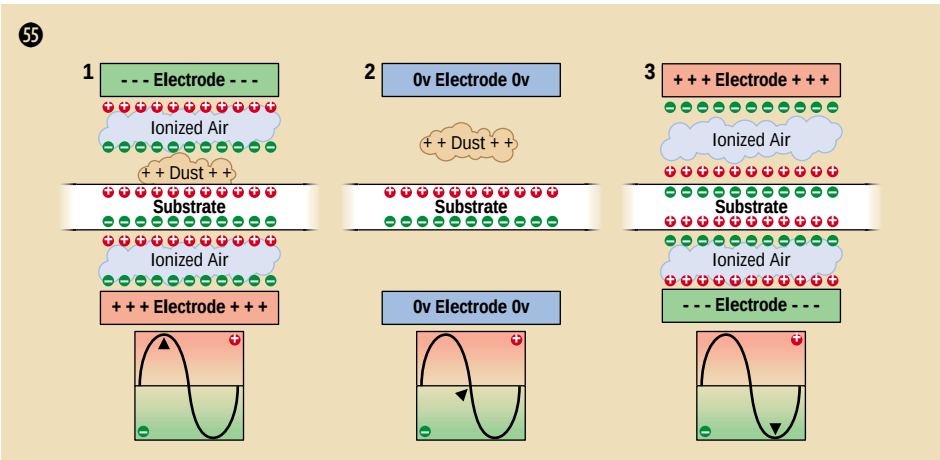
Dust is by far the biggest enemy of quality printing, especially in polymer film, paper or corrugated processing operations, and therefore must be addressed by press builders and converters alike.

No dust removal system is absolutely perfect. However, if the problem is addressed at its source, i.e., immediately where dust and electrostatic charges are produced, it can be controlled, yielding higher production and quality. The most effective system for removing dust from a substrate prior to printing uses the electrostatic repulsion principle as explained in the preceding section.

The most advanced ionic cleaning systems involve a corona field formed between two oppositely charged electrodes in a quartz enclosure. The substrate to be cleaned is passed through this corona field, which is generated using an alternating high voltage (15,000 volts) at high frequency (5,000–7,000 cycles/sec).

At peak voltage a corona field is built up between the two electrodes (+/–) and everything within the corona field (air, substrate, dust) becomes conductive. When this happens, electrons begin to flow between the two electrodes. As the substrate is passed between the electrodes, the surface of the substrate is charged positively on the side facing the negative electrode and is charged negatively on the side facing the positive electrode. Any dust particles on the surface of the substrate will also be charged in a similar fashion *Figure* 55.

As the polarity of the electrodes change, the corona field breaks down. The air between the surface of the substrate and the adjacent electrode functions as insulation. Powerful electrostatic fields are formed, which are charged positive above the sheet to be cleaned and negative on the underside. The dust particles now show an opposite polar charge, are repelled by the substrate, float into the positive field and are sucked away by a fan.



55 In electrostatic cleaning, as the substrate is passed between the electrodes, the surface of the substrate as well as the dust particles are charged (positively on the side facing the negative electrode, negatively on the side facing the positive electrode.) This causes dust particles having an opposite charge to be repelled and sucked away by a fan.

After reversing the polarity of the electrodes, the corona field forms again as soon as maximum current is reached. With the repeated polarity change and subsequent breakdown of the corona field, the cleaning process takes place again. Each change of polarity, which occurs upwards of 10,000 times per second, results in a cleaning action.

FILM TREATING

A number of the flexible packaging materials, particularly polyethylene and polypropylene, need to be treated prior to subsequent printing or coating operations in order to make them more wettable, that is, more receptive to accepting printing inks, coating and adhesives. Corona discharge treating of the substrate is one means of making the surface more polar, hence more wettable.

Corona Discharge

Corona discharge is a unique means of applying a concentrated electrical discharge to the surface of a moving web. It is accomplished by passing a moving web over a special dielectric-covered treating roll and applying a source of high voltage, high frequency power to an electrode properly spaced over the surface of the traveling web. The resultant voltage gradient breaks down the air into a gaseous conductor, and the corona and ozone that are generated make the substrate surface more polar, and more wettable.

Typical Film Treating Applications

Film treating stations are specially designed and engineered enclosures that house the treating electrode and roll assemblies. They have access doors for web threading and routine servicing, inspection windows to observe corona discharge and hoods, and extraction ports for ozone removal. Each station is tailored to the particular application and sized to match line speed and web width. Stations can be specified to treat one or both sides of the web. Station enclosures are normally of a steel frame and panel construction. Ferrous parts are primed and finish-coated with corrosion-resistant paint. Access doors have Plexiglas inspection windows. The doors are electrically interlocked to prevent corona discharge from operating when opened. Ozone exhaust openings are normally located and cut to size at the installation site, but this can also be done during fabrication of the unit.

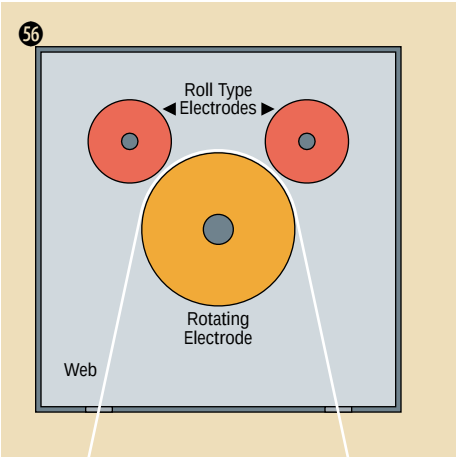
Electrodes are wired to a porcelain high-voltage insulator. Stations have pneumatically actuated electrode assemblies, interlocked to prevent treating operation when the electrode assembly is retracted. Treating rolls are equipped with adjustable electronic zero-speed control switches to prevent treating operation unless the roll is turning.

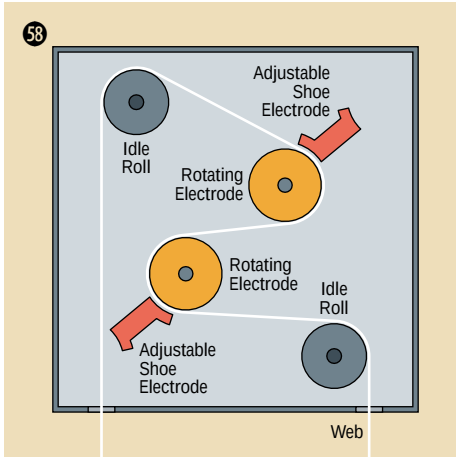
Foil and Conductive Substrates. Foil and conductive substrate-treating stations may be single-sided or double-sided stations, with hard chromium-plated ground rolls and dielectric-covered rotating electrode rolls. They will treat web widths up to 100" at line speeds up to 1,000 fpm (*Figure* 56).

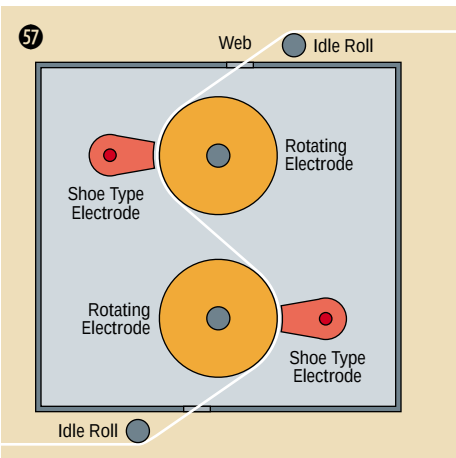
Split-Box Film Treating Station. These stations have drop through automatic web thread-up and single- or double-sided stations for treating variable-width substrates. They are usually available with 4" diameter rolls and will treat web widths up to 98" at speeds up to 250 fpm. (*Figure* 57).

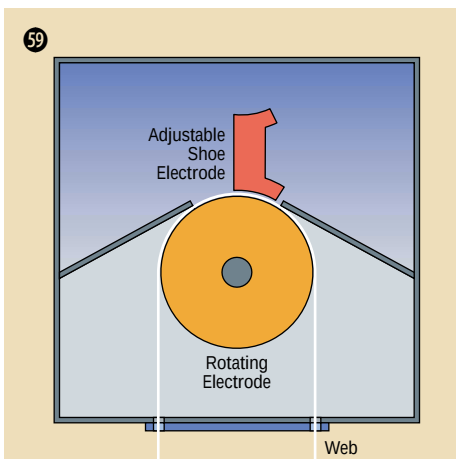
Adjustable Shoe Electrode Station. These stations are also single- and double-sided. They treat variable widths up to 144" at line speeds up to 1,500 fpm. They are usually available with 6" to 24" diameter rolls (*Figure* 58).

Pressurized Film-Treating Station. Specially engineered, the pressurized film-treating station has single- and double-sided stations for operation in hazardous atmospheres. It can be obtained with a pressurized treating station and high voltage transformer enclosure and with a pressurized remote-control station (*Figure* 59).









56 A foil and conductive substrate-treating station may be single- or double-sided, and is capable of handling webs widths up to 100" at line speeds up to 1,000 fpm.

57 A split box film-treating station treats variable width substrates.

58 Adjustable-shoe electrode stations may be single- or double-sided stations capable of handling widths up to 144".

59 Pressurized film-treating stations are specially engineered for hazardous atmospheres.

POWDER SPRAY SYSTEMS

Powder spray systems are used to evenly distribute micron-sized particles onto the surface of the moving web. The particle material may be starch, to promote ink drying or to prevent ink offset and blocking in the rewound roll; or in a laminating process, it may be a heat-set powder adhesive. The system uses the principles of electrostatic attraction and repulsion to control the distribution of the particles.

Electrostatic Powder Spray

The electrostatic system feeds the micron-sized dry powder particles from a hopper to the surface of a micro-etched chromium plated roll. The rotating speed of the roll controls the feed rate of the particles. The particles adhere to the surface of the roll until they enter an electrostatic field created by a high voltage discharge tube, at which point they become ionized. The web, passing in close proximity, is charged with the opposite polarity to the powder particles, thereby attracting them. The electrostatic dispersal of the particles tends to space them very evenly over the surface of the web, which eliminates pyramiding and with the electrostatic bond, prevents particle drifting.

Dust Control

Within the electrostatic spray unit there are twin air curtains to envelop the spray and prevent excess floating powder. Downstream of the coating station is an extraction hood to collect any particles that

may become airborne. These particles are drawn to vacuum plenums on each side of the hood and transported to a collection filter bag. The dusting ability of the electrostatic sprayer is not affected and the system helps to assure a cleaner press and cleaner plant air.

IN-LINE LAMINATING

Film laminating has had a growth curve parallel to flexography in flexible packaging and has usually been performed by converters who were already flexographic printers. Competition forced converters who did not have the capital or market volume for separate out-of-line techniques to adapt existing presses to include a lamination section.

The first development in this modification was to add a thermal combine (heat and pressure) unit to the exit end of the press and combine two Saran-coated cellophane webs. As more types of film entered the flexible packaging field, and as increased production speeds became necessary, solvent-based adhesives were used for film laminations, both in-line and off-line. For in-line operations, the adhesives were applied by the last printing station of the press, then dried in the drying tunnel before being combined with the second web.

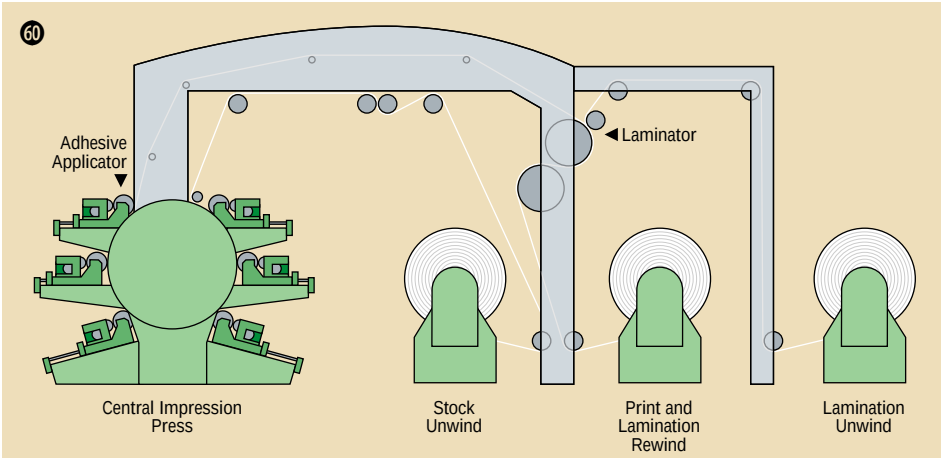
Modified Press for Laminating

Figure 60 shows a six-color flexo press modified for in-line laminations. This arrangement has the disadvantage of slow speed operation. In order to eliminate ink blistering, it is necessary to slow the press to speeds that allow all the ink to dry before applying the adhesive in the last printing station.

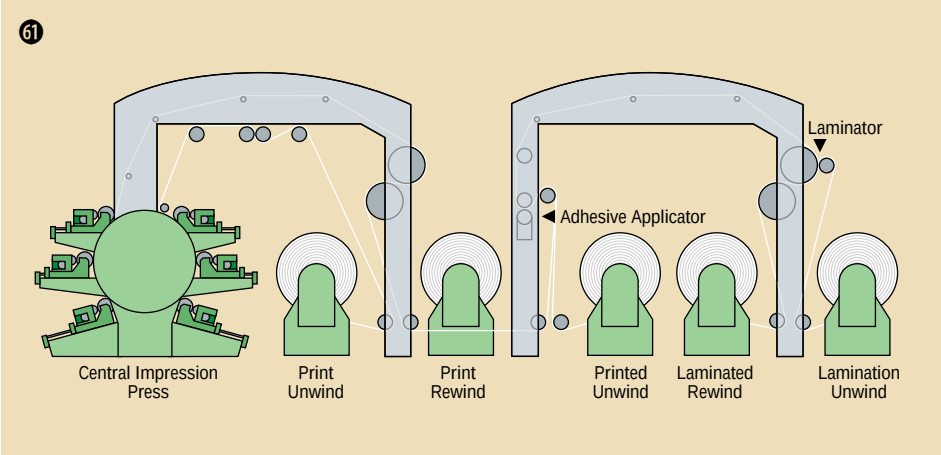
Should the converter wish to modify an existing press so that in-line laminations can be performed, there are a number of steps that must be taken. They will be addressed in the following four sections.

Space. Approximately 12" of space at the rewind end of the press is necessary to provide for installing the second unwind stand. The unwind can be any suitable type, but it is preferable for it to be the same as the existing unwind. This match-up permits running roll-for-roll at both unwinds and minimizing mid roll splices in the laminated material.

Structure. An overhead structure with idler rolls is required to transport the web from the second unwind to the laminating nip. Since the web passes above the rewind, the structure must be high enough so as not to interfere with the personnel servicing the rewind or with the rotation of the rewind if it is the turret type. The idlers should be spaced not more than 4' apart and preferably grooved to prevent air from getting between the web and idler rolls.



60 This six-color central inpression press has been modified for laminating after printing.



61 This In-line laminating setup incorporates a separate and self-contained laminating machine in-line with the flexo press.

Lamination Nip. If the press has two chill rolls, the first may be made into the laminating nip by adding a rubber impression roll. If the press has only one chill roll, another roll is needed to form the laminating nip. This roll should be about 14" in diameter and bored for heating. It should be driven at the same speed as the chill roll, preferably with a variable speed drive. Heating of the roll can be by hot oil or hot water, as most film laminations are performed at temperatures less than 175° F. Hot water is desirable in that it is cleaner than oil. Also, switching from hot water to cold water provides another chill roll when not laminating.

A rubber-covered nip roll is required to supply the laminating pressure. This roll should be a minimum of 6" in diameter and covered with 80–85 durometer rubber, 1" thick. The roll should be hydraulically or air operated to apply variable laminating pressures up to a maximum of 100 lb/in^2, and should be located so that the web has at least a 90° wrap on the steel roll after laminating.

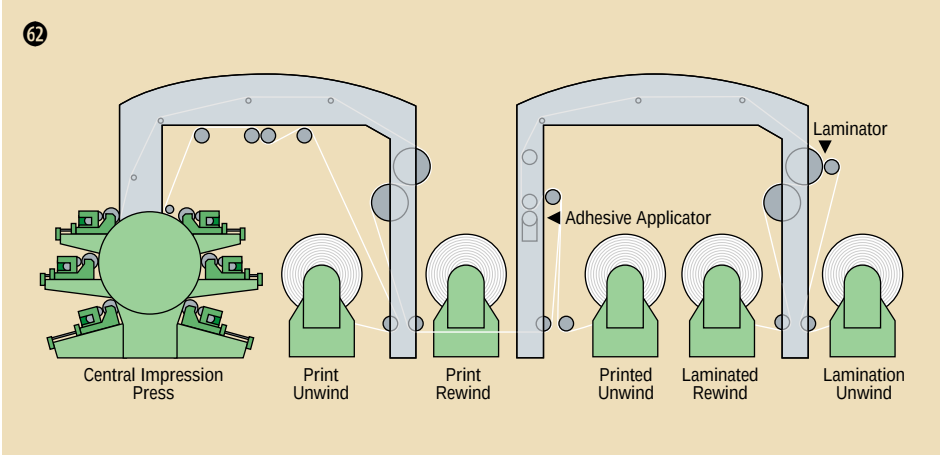
Adhesive Application. Immediately following the adhesive application station, which is the last press color station, a 2" diameter chrome plated steel roll is needed. The purpose of this roll is to smooth the adhesive to improve laminating clarity. The roll should be adjustable to the web and driven in reverse rotation to web direction. A small air motor is adequate for this function.

If the adhesive is to be applied by a flexo print unit, the rubber transfer roll on the plate cylinder must be solvent-resistant and have good release properties.

To apply the adhesive by gravure in the last color station, a gravure roll, rubber impression roll (plate-cylinder position), doctor blade and change gears for the color station are needed. The web must pass up between the gravure roll (anilox roll position) and the impression roll (plate-cylinder position). Consequently, change gears are required to change the direction of rotation of these two rolls. The doctor blade attachment should have adjustments for angle and pressure of wiping, and an air or hydraulic motor for oscillation. The attachment is mounted in the area normally occupied by the flexo rubber fountain roll. The ink pan must be modified in order to supply adhesive to the gravure roll. To cut down on the expense of rubber impression rolls, rubber sleeves can be placed on existing plate cylinders.

Separate Laminator Section

The next generation of in-line laminating incorporated a separate and self-contained laminating machine in-line with the flexo press (*Figure* 61). It is independent of the press except that it, and the press, use the



62 A flexo press with a separate laminator allows the converter to use both machines in tandem or independently, thus offering a wide variety of applications.

same rewind, and the electric drives of the two machines are connected and employ necessary web tension controls. The laminator consists of a gravure-type adhesive application station, with a smoothing roll, drying tunnel of sufficient length to dry the web at printing speed, laminating nip, chill roll(s) and unwind equipment for the primary and secondary webs. With this type of setup for in-line laminations, several precautions must be taken:

- The web travel between the two machines and to the rewind should be as short as possible to prevent loss of web control.
- The electrical and mechanical drive systems that synchronize the laminator to the press must be of the highest quality with adequate web tension controls to maintain precise control of the web throughout the operation.
- The adhesive application station must be tied into the press functions so that when the press stops, the nip opens and the applicator roll continues to rotate. Automatic or manual controls can be incorporated for engaging the adhesive application station.
- The above functions must also be incorporated into the laminating machine drying tunnel controls. When the press stops, the drying temperatures must be reduced to prevent damage to the web in the tunnel.
- The laminating station must also automatically open at press stop to prevent damage to the rubber impression roll, as well as the web. Independent control for closing the nip at press start-up is acceptable.

For the converter who has a large volume of laminating with printing, the machine arrangement shown in *Figure* 62 could be used. It shows the press and laminator completely separated except for electrical and mechanical controls, which can be operated individually or in tandem. This arrangement allows the converter to laminate in-line with printing, print without laminating, laminate without printing, or use both machines at the same time but independent of each other.

Solid Adhesive Laminating

With the advent of 100% solid adhesives for film laminations, the interest in in-line laminating has greatly increased. Using the 100% solids (solventless) adhesives eliminates drying requirements and consequently reduces the overall length of the machine. Also, greater printing and laminating speeds can be obtained since the problem of insufficient

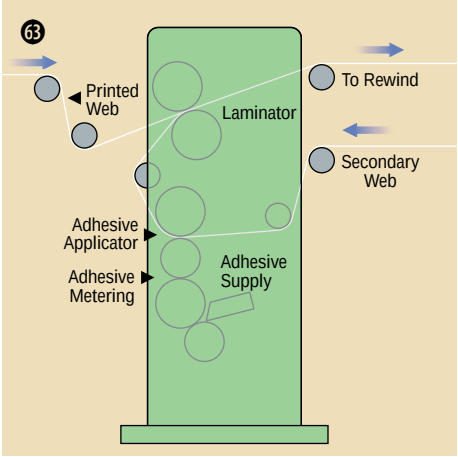
drying, or trapped solvents, is eliminated.

Figure 63 shows the adhesive application and laminating unit of a solid adhesive laminator, and it is readily seen that this unit lends itself to in-line operations. However, turning bars must be installed between the press and laminator if it is desired to have the printing sandwiched between the two webs. This laminator can be arranged as discussed in *Figures* 61, 62 *and* 63. Due to the nature of solid adhesives, they require special application methods that eliminate the use of the last station on the flexo press.

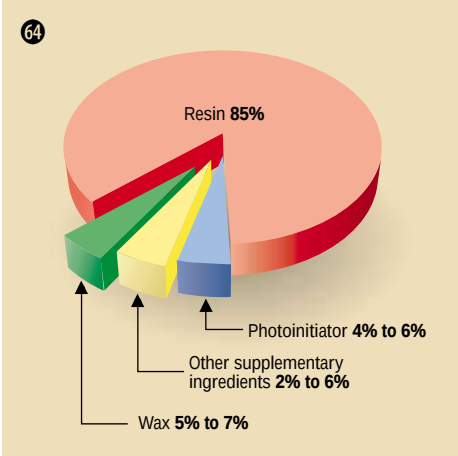
The same economic forces that are pushing the expansion of laminating in-line with flexo printing are also leading to the development of various in-line coating processes such as:

- overall heat seal coating;
- thermal-stripe heat seal coating; and
- co-adhesive latex, both overall and registered heat seal coating.

In general, the same production limitations and precautions outlined for laminating should be followed when considering in-line coating with a flexo press.



63 An adhesive and laminating unit of a solid adhesive laminator. This type of setup can be easily placed in-line with a flexo press.



64 A typical makeup of a UV varnish.

UV/EB VARNISHING

Varnishes that can be cured with ultraviolet light have gained tremendous popularity. The flexographic process is well suited for applying such varnishes over the entire printed surface, or selectively where needed. The most important aspect of applying a UV coating is to ensure that inks laid down previously (in-line) are completely dry before the UV varnish is applied over them.

Without going into specific details of their chemical nature, UV varnishes are composed of 100% solids (no volatile components), all of which have to be cured. A typical composition is illustrated in *Figure* 64.

- 85% resin (mixture of viscous and highly viscous resins);
- 4%–6% photoinitiators;
- 5%–7% wax;
- 2%–6% other supplementary ingredients.

The selection of resins determines the flexibility of a varnish coating. Some resins form a flexible surface but remain rather sticky. Others form a relatively hard, brittle surface that cracks during scoring or bending of the substrate. It is therefore important to perform tests on different substrates with different coating film thickness before large production runs are undertaken.

Curing

UV curing units (polymerization units) are designed to cure printing inks, varnishes, and plastic coatings. Intensive UV radiation

causes polymerization and curing in a very short period.

UV/EB curing makes use of ultraviolet (UV) light or electron beams (EB), respectively, to polymerize a combination of monomers and oligomers. The UV/EB material may be formulated into an ink, coating, adhesive or other product. The process is also known as radiation curing because UV and EB are radiant energy sources. The energy sources for UV and visible light curing are typically medium pressure mercury lamps, pulsed xenon lamps or lasers. The coatings cured by these light sources are usually clear or translucent, though thin opaque coatings are also possible. Electron beam accelerators are used to generate the electron stream capable of curing thicker, pigmented coatings. Unlike photons of light, which tend to be absorbed mainly at the surface of materials, electrons have the ability to penetrate through matter.

For UV curing, UV radiation (light) must be generated. With a mercury lamp, the light is generated by heating mercury droplets in a sealed quartz tube to a gaseous ionized state. When excited to an ionized gas form, mercury naturally emits radiation in the ultraviolet frequency. Either an electrical current or microwave radiation can be used to vaporize the mercury. Polished reflectors are used to direct the light at the web. For better, deeper or faster curing of some colors or of some specialty formulations, other materials may be added to the mercury in the lamp to alter the spectral "signature" or profile of the emitted light.

The quartz tube and reflector are contained in a chamber called an irradiator. In most cases, the chamber will also contain some means to block energy from the web when it is stationary. Blocking when the web is stopped is required because of the high operating temperature of the lamp, and because a large amount of infrared (IR) energy is also emitted from the UV lamp and directed at the web by the reflector. Various designs are used to block the energy, including shutters and rotating reflectors. Some lamp designs can be instantly turned off and back on, making shutters unnecessary.

Safety

Ultraviolet radiation burns the skin and can cause temporary blindness. For this reason, the curing chambers, or irradiators, must be tightly constructed to avoid light escaping in any direction other than toward the web. Additionally, light shields are often used to prevent the press operator from looking into the irradiator, and to prevent exposure to light reflected by the web.

UV Lamp Cooling. The high temperatures in the irradiator require that some form of heat management be incorporated into the design. The most common methods used to cool the irradiator and its components are to blow or pull air through the housing. Some designs use water cooling. Both air and water cooling are effective means to control the internal and external temperature of the irradiator. Neither address the issue of web temperature, which is another heat management issue of importance to the printer/converter. Because of the large amount of infrared energy associated with UV systems, web temperatures may be elevated beyond acceptable levels in some applications. Elevated temperatures are most common in film applications, but can also be an issue with paper products, especially if multiple UV lamps are used.

There are three possible strategies to control web temperature. The first is to remove the heat from the web. The second is to avoid heating the product. The third is to do both. Removing heat from the web usually requires some form of heat sink, or chill drum. Chill drums transfer heat, through contact, from the web to a roller or series of rollers. The rollers are cooled with air or water to maintain their capacity

to transfer heat. The chill drum(s) may be located at the point of exposure to UV and IR energy, or downstream from that point. The temperature that the web can tolerate, and the temperature rise created by the UV system, determine the location of the chilling mechanism.

There are a number of ways to reduce or limit the amount of heat put into the web. Simply running the lamp system at a low power level will significantly reduce web temperature. Increasing press speed will also reduce web temperature since it will decrease the exposure time of the web to the IR energy. Beyond these steps, which often may not be possible in a production environment, the UV system may be designed to limit the amount of IR energy reaching the web. For example, the diameter of the lamp determines the amount of IR radiation that is emitted and the shape of the reflector defines the concentration of the IR radiation on the web. Each factor therefore, will affect the degree of temperature rise of the web.

Air Filters. Another method to restrict the amount of IR energy reaching the web is to use filters that affect some portions, or wavelengths, of energy and not others. These filters are made from dichroic coatings or materials. A dichroic coating on the reflector either absorbs or transmits IR radiation while reflecting UV radiation toward the web. Filters placed between the bulb and the web transmit UV radiation and reflect IR. Water may be used as the filtering material, but more typically, a dichroic material is used. These filters normally reduce the peak temperature of the web to an acceptable level. However, the cumulative effect of multiple lamp exposures may still result in unacceptable temperature increases. Combining dichroic filters with methods to remove residual heat from the web is required in these situations.

Corrugated Postprint Presses

Corrugated single-faced board or combined sheets have been used in the packaging industry for over a hundred years. In 1871, an American, Albert L. Jones, received a patent for improved corrugated packing paper. From the outset, the material was recognized for its strength and cushioning characteristics, but certainly not for its ability to receive a printed image. None of the printing equipment in existence could efficiently print on this spongy packaging substrate.

BEGINNINGS

Crude machinery was used to produce corrugated board and for decades the world identified brown boxes or shipping containers as replacements for wooden crates. After World War II, some machinery manufacturers, as well as some board converters, started to build printing units to complement in-line corrugated converting operations.

Letterpress printing came into existence around the turn of the century and is still utilized today for certain display work. The oil-based inks used in letterpress, however, take many hours to dry and special measures are needed to prevent smearing, sticking or offsetting. This method of printing has always been, and still is, a bottleneck in corrugated converting plants. The corrugated industry was truly waiting for the arrival of flexography, a means to mark or rotary-stamp corrugated boxes.

EVOLUTION AND GROWTH

In those early days, no one anticipated that graphics on corrugated board would evolve much beyond the most basic techniques. The first flexographic in-line machines, built in the mid-to-late 1950s, printed one color, almost without exception black. Compared to other industries (tag and label, cups, etc.) corrugated flexo received little recognition well into the 1970s.

Printing on combined corrugated board continued to receive little recognition and seemed to have little potential for producing high quality, multicolor graphics. When process printing was mentioned, it produced blank stares, or a rebuffing laugh, at best. Today, the sheet-fed freestanding flexo press for corrugated has developed into a high-tech “marvel,” producing results that rival lithographic label and preprint quality.

MARKETS FOR FLEXO PRINTING

The predominant market in the corrugated industry has always been, and remains today, the so-called “brown box” market. The majority of linerboard produced on paper making machines worldwide is brown paper, meaning virgin and recycled kraft paper. A figure of 90% to 93% may be used to quantify this segment of the total linerboard production.

The remaining 7% to 10% is bleached, clay-coated, often called "mottled white" paper, or white top sheets. It is this small segment that is of primary interest to the high-quality flexographic preprinter or postprinter. This is not

to say that brown liners are not conducive to so-called "value-added printing." In fact, the contrary is true. Brown boxes almost always contain some printing, and in fact, even multicolor halftone screens are found on brown boxes. In some cases this is achieved by tinting the board with a white coating on the corrugator, or by printing a white background with titanium dioxide-based white flexo ink. It is safe to say that a very large quantity of brown boxes, or shipping containers, are produced with value-added graphics and point-of-purchase messages.

The crossover from flexographic printing on brown kraft liners to white-top or coated liners, as well as bleached liners, is by no means the frontier for high graphics or value-added printing. It is therefore difficult to establish statistics that clearly differentiate between a high-graphics operation and a "brown box" operation. One can also not classify value-added or plain brown box printing by the type of printing equipment used. Value-added graphics are categorized primarily according to their quality and have therefore no significant connection as to what substrate they are printed on or with which type of machine they are printed.

PREPRINTING VS. POSTPRINTING

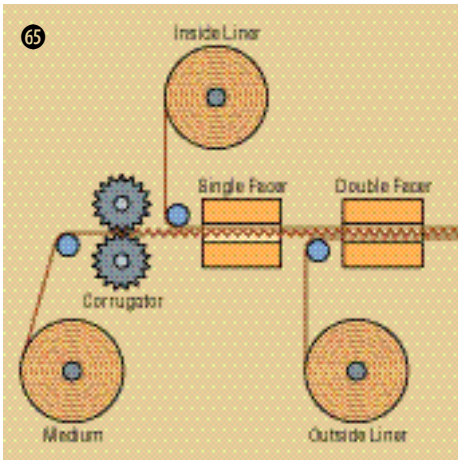
The terms preprinting and postprinting are used to describe when the printing is performed in the corrugating process. A corrugator, in its basic version, produces single-faced board, consisting of the medium (the corrugated paper) onto which a liner is glued. This first liner is called the single-face liner, which is never, or very seldom, printed. On this same corrugator, another liner is glued on the opposite side, on the tips of the fluted or corrugated medium. This liner is called the double-face liner (*Figure* 65) and may be printed on wide-web flexo presses before it is applied by the corrugator. We call this process preprinting, i.e., the printing has taken place before the combining process.

In the preprinting converting process, the web of double-faced board is cut into sheets in register with the printing on the double-face liner and stacks of preprinted sheets are produced for subsequent converting into containers, boxes or die cuts. In some cases, the printing and die-cutting units are incorporated into the corrugating line.

It is noteworthy to mention that preprinting in the corrugated industry has been in existence for less time than postprinting. Flexographic preprinting, first introduced in the United States on a large commercial basis 20 years ago by a company in Wisconsin, has grown to tremendous output capacity. Preprint methods other than flexo, such as offset and rotogravure, are also utilized. The preprinting onto linerboard process lends itself to more refined graphics; however, relatively large press runs are needed to make it cost-effective. The cost of preprinting short run promotional graphics is prohibitive

Today, there are approximately 45 to 50 preprint presses for linerboard operating in North America.

Postprinting, as the term defines it, is performed on combined double-face corrugated sheets after the corrugating process. The postprint process lends itself readily to the



65 In corrugated preprinting on wide-web flexography, the double-face liner may be printed before it is applied by the corrugator.

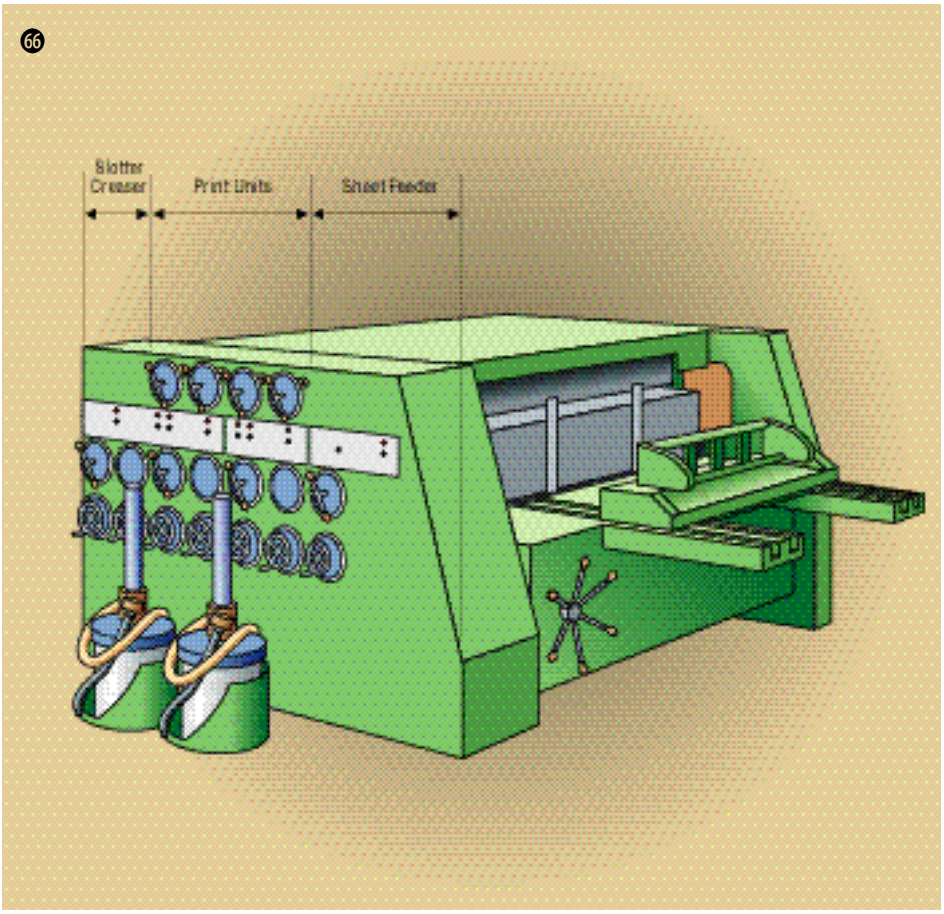
"just in time" manufacturing methods being adopted by today's industries.

Economics of Postprinting

Postprinting is by far the most common method for printing on corrugated. A conservative estimate is that there are over 10,000 flexographic printing units of one kind or another in use in integrated and independent corrugated converting plants.

The economic advantages of flexography on corrugated depend largely on what level of flexographic printing is performed. For example, profit margins in brown box plants can only be achieved if the printing process is performed at the highest possible production speeds, e.g., 600–800 linear feet/minute or 10,000 boxes/hour. Printing, which is performed in-line, should never slow down the converting process. On the other hand, when manufacturing high-quality display work or halftone-process screen work, the profit margin depends on how much cheaper the printing operation can be performed compared to labeling or laminating, while maintaining acceptable quality.

Generally speaking, the medium and linerboard raw materials constitute the biggest cost share in any corrugated plant. By the time the flexo printer receives combined sheets on the printing press, the sheets represent more than 80% of the value compared to the final selling price. When clay-coated or bleached liners are used, the basic material cost (raw material) is, of course, even higher.



66 A typical corrugated postprint press today can handle printing boxes from finished sizes of 7.5" x 13.5" up to 104" x 210".

Flexographic postprinting, because of its inherent simplicity and high-speed production capabilities, remains the preferred method for producing graphics of any level at a reasonable profit.

RANGE OF PRODUCTS

From the beginning, corrugated shipping containers, which replaced wooden crates, in sizes from 4" x 4" up to triple-wall containers (which may be used today to pack the body of a car) required marking or stamping for identification purposes. Such markings included a minimum of information such as: "Do Not Drop," "This Side Up," or an umbrella graphic warning against exposure to the sun. The printed markings also sometimes listed the contents in large bold text, and only rarely were illustrations of the packed merchandise shown on the outside of the box or container. Today, there are very few markets, from food production to computers and appliances, that do not utilize the power of graphics on corrugated shipping containers and point-of-purchase displays.

The brown box or container is, by a large margin, the most common type of corrugated container. Sheet sizes needed to produce such boxes and containers may range from 7.5" x 13.5" up to 104" x 210". Flexo printing equipment for the entire size range exists today (*Figure* 66).

Press Construction

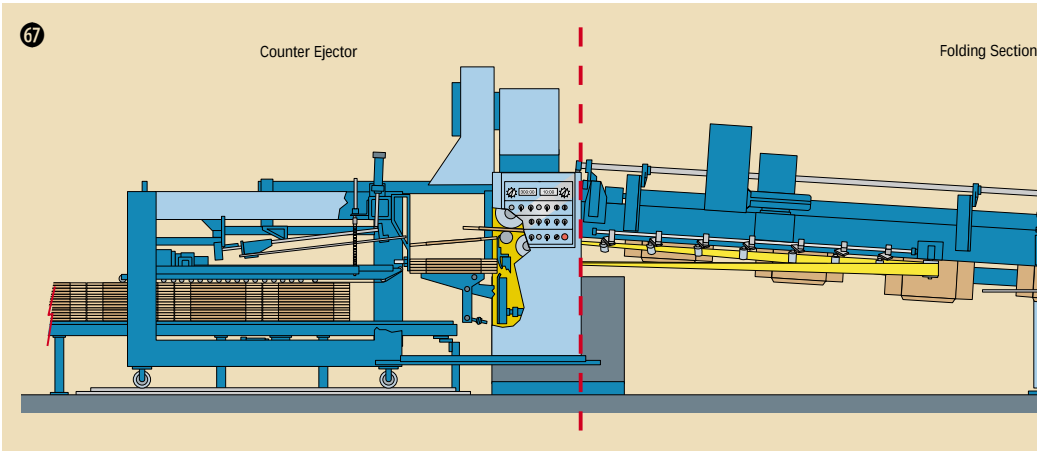
In the corrugated industry, many components of the flexo printing process remained crude until parallel industries started to introduce new plate materials such as photopolymers, cushioning materials, modernized inking systems, and mechanically engraved anilox rolls (which today are increasingly being replaced by laser-engraved rolls).

The most appreciated characteristic of flexo printing on corrugated is its simplicity. The thick, soft, flexible plates, which adjust easily to a relatively uneven substrate, together with the fast-drying inks, allow in-line printing to be combined with a multitude of other converting processes in a single operational step.

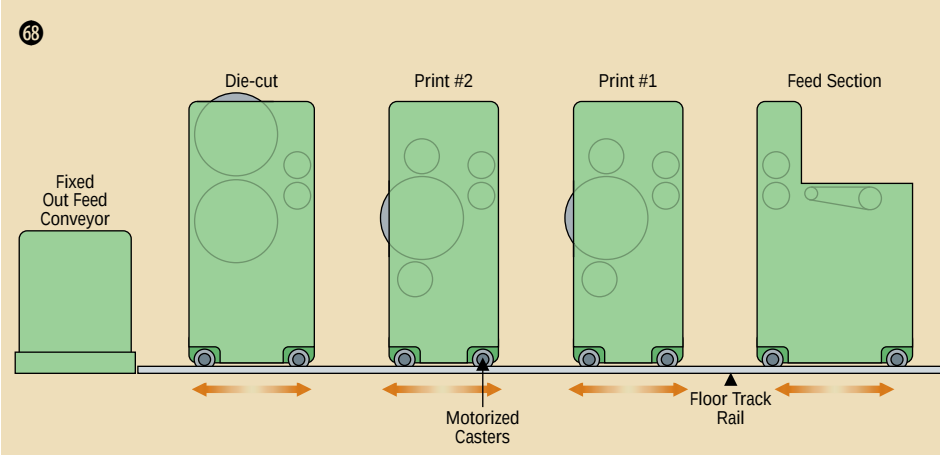
Flexographic printing units, whether on flexo folder-gluer machines, or in-line with rotary die cutters or with platen-type die cutters, allow converters to produce boxes, containers, regular slotted cartons, and sometimes multi-out rotary or platen die-cuts, as an integrated manufacturing step(*Figure* 67). Repeat orders of medium-to-long runs lend themselves especially well to such in-line production. Today's flexo folder-gluer or rotary die cutter is generally equipped with up to four printing units, which can offer more intricate graphics and also accommodate two-color work. In the case of two-color work, while two units are printing, two others can be prepared for very quick job changeovers, especially on small runs.

The close coupled printing units of the printer/rotary die cutter and flexo folder-gluer machines have so-called roll-away units on tracks (*Figure* 68) to permit access to various printing elements for setup or wash-up.

The advantages of producing regular slotted cartons on a flexo folder-gluer, at ever-increasing production speeds, are well known and appreciated in the corrugated converting industry. The disadvantages of in-line flexo printing at most types of converting operations are: dust, frequent printing plate washing, limitations in print coverage, and limited placement of graphics to avoid



67 In-line flexo folder-gluer components.



68 Close coupled printing units of the printer/rotary die-cutter and flexo folder-gluer machine have roll-away press units, which allow access to the various printing elements for setup and wash-up.

smearing or rubbing by folding or die-cutting components. For example, a jam-up on a rotary or platen die-cutting line with in-line printing may cause production stops requiring printing plate washing and causing subsequent start-up waste.

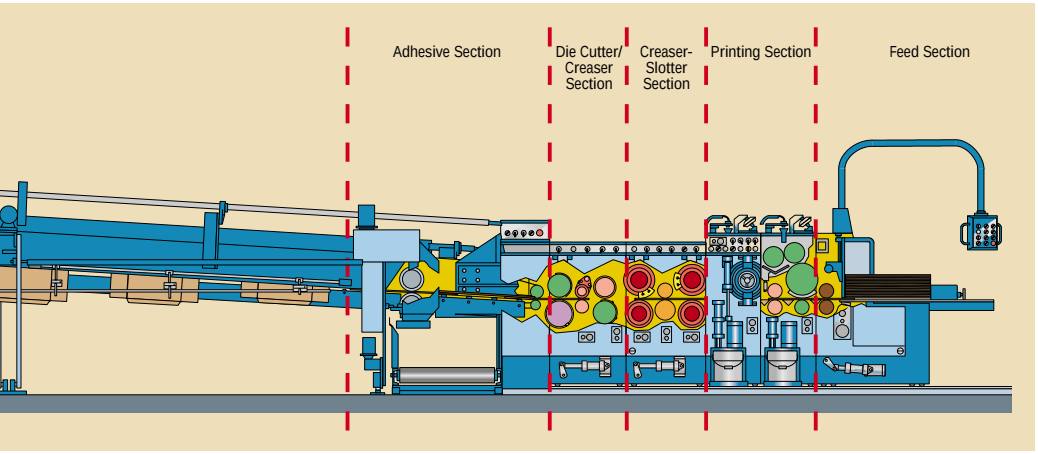
SHEET FEEDERS

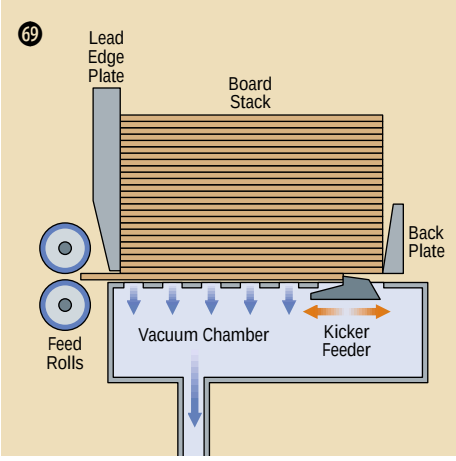
On corrugated sheet-fed presses, the first element of importance is the feeding unit for the sheets, which must ensure very good register accuracy of each introduced sheet. Registration tolerances have been in the area of ±0.0625" for many years and have steadily decreased for tighter tolerances. Today, some manufacturers talk about tolerances of ±0.010", however, the reality is more in the area of ±0.020" during production.

The following are short descriptions of different feeding principles, all of which can be found on machines of different models.

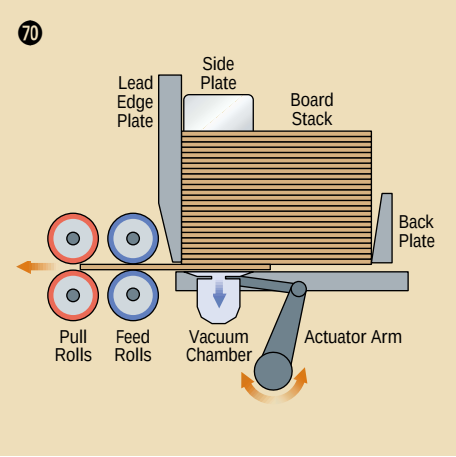
Kicker Feeder

The kicker feeder is the oldest of all feeder designs and works best with narrow sheets in the throughput direction of a machine. It is still found on so-called “mini-flexo” setups because it is capable of introducing sheets at speeds of 30,000 per hour. A stack of sheets is placed on the vacuum bed and located against a lead-edge stop plate (*Figure* 69).





69 Trail-edge kicker units are still found on so-called "mini-flexo" setups because they are capable of introducing sheets at speeds of 30,000 per hour and work best with narrow sheets in the throughput direction of the machine.



70 During production,the suction-plate feeder allows corrugated sheets to be accurately registered against their lead-edge by using powerful vacuums to help prevent slippage between the suction plate and sheet.

The vacuum draws the bottom sheet flat against the feeder bed and the trail edge of the sheet locates against the kicker fingers. The kicker fingers, timed to the press rotation, then push the bottom sheet into the feed roll nip. Feeding accuracy depends on manual adjustments, board warp, consistency of the pre-trimmed sheets and whether or not the feeder is equipped with a suction-assist. Kicker feeders can only feed sheets with their corrugation oriented in the machine direction. If the direction of the corrugations is across the machine, feeding against the soft edge may result in very inaccurate register or frequent jamming. E-flute is generally the lowest flute profile that can be fed with such feeders. F- and N-flute are too fine for this type of feeder. It is safe to say that kicker feeders are not found on high graphics machines.

Lead-edge Feeders

The most significant advantage of suction-plate feeders is that the corrugated sheets are accurately registered against their lead-edge. Therefore, trimming variations from the corrugator have less influence on feeding accuracy. Vacuum distribution may be achieved through rotary or piston-type valves. On suction plate feeders (*Figure* 70), powerful vacuum pumps – which can maintain a vacuum of 18" to 22" Hg under production conditions – are needed, otherwise, slippage between the suction plate and the sheet will occur.

Vacuum timing at start and release is important. Most suction plate lead-edge feeders are timed as follows:

- The stroke of the plate must correspond to the distance from the in-feed gate to the center of the feed rolls, at a minimum.
- Suction must begin during a standstill cycle (hopefully prolonged), when the plate is in its most backward position.
- The suction plate must release the sheet when the sheet has arrived at the center of the in-feed roll nip.
- The speed of the suction plate and the surface speed of the in-feed rolls must be 1:1 to eliminate the vacuum at the time when the sheet has to be released. Venting to the atmosphere or injection of compressed air are two methods commonly utilized.

Belt Type. Belt type lead-edge feeding by friction goes back several decades and is found on folder-gluer machines, both in the folding carton and the corrugated industries (*Figure* 71). Continuously running belts pull one blank after another, from underneath a stack of blanks or sheets, in an "untimed" manner.

Obviously, to apply a similar technique on a printing machine, the process needs to be

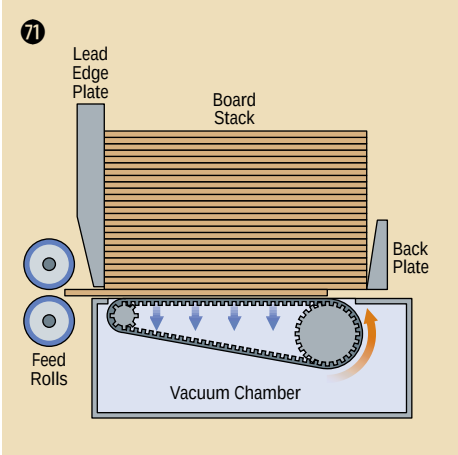
timed. A vacuum fan is utilized to ensure a slippage-free transport of each sheet. In its simplest form, such a feeder has continuously running belts over a suction box or chamber which has lifters that, in a timed fashion, lower the stack of sheets onto the belts, allowing the lowermost blank to be introduced into the feed roller nip. The vacuum is continuous and needs only to be interrupted when feeding needs to be stopped.

Reciprocating Belt Feeder. Another type of lead-edge belt feeder has reciprocating belts with forward and backward motion. With this design, the belts are lifted through cam rollers to meet the lowermost sheet of a stack lying on top of stationary slats. The feeding cycle consists of four steps:

- The stationary belts are lifted above the slats.
- The belts move forward in lifted position to introduce the sheet into the feed rollers.
- The belts are lowered away from the sheet at the end of the forward stroke.
- Backward movement of the belts in lowered (non-contact) position below the slats completes the cycle.

Roller-type Feed Wheels. This category of lead-edge feeder is also based on a high volume vacuum, which transports the sheet on continuously rotating feed wheels that are covered with a high friction material. Timing is controlled through a vertically-arranged lifting grid (slats) that has a low friction surface. The up-and-down cycling, generally done through a cam arrangement, determines when a sheet starts its travel forward and when it is to be taken over by the feed rolls in pace with the machine.

With feed-wheel or feed roller-type lead-edge feeders, many variables in design exist. Generally speaking, such feeders are very reliable and good feed accuracy is obtained. Such feeders can feed stock with excessive warp to the point that a jam-up somewhere in the printing units may occur, which is potentially a bigger evil compared to a jam-up in the feeder. Flat sheets are, on all types of feeders, the best insurance for trouble-free operation of a machine.



71 In a belt-type feeder, the lowermost blank is pulled from a stack of blanks or sheets, and pushed through the feed rolls to the folder-gluer.

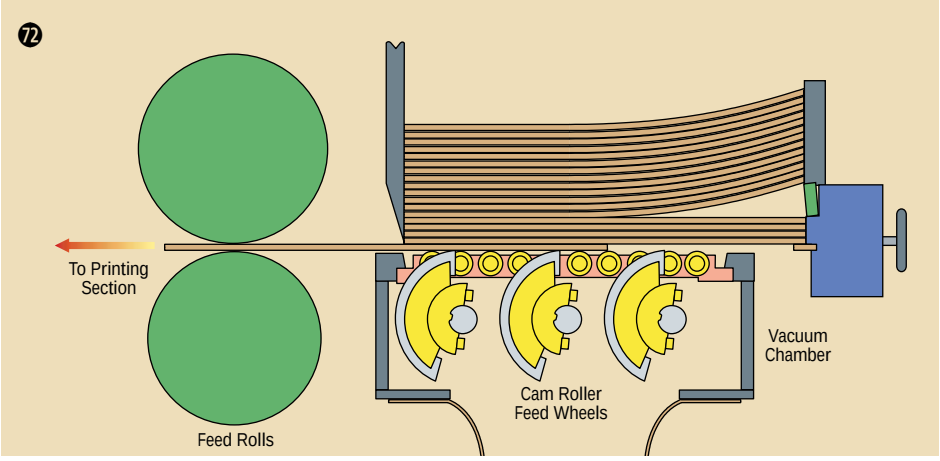
Cam Roller Feeder. With this type of feeder, small quantities of blanks are placed in the feed table hopper by the operator or an automatic pre-feeding device. The leading edge of the sheet locates against vertical fingers that are set above the feed table to allow only one sheet to pass at a time (*Figure* 72). A set of cam-shaped feed wheels contacts the bottom blank in the pile and pulls it into the nip of the feed rolls. The feed rolls grip the blank and delivers it to the printing section.

PRINT STATION

Having examined the different substrate-feeding methods, it is now time to look at the next step in the process: the print station. There is more to printing than simply applying ink. Proper mounting, gear and roll position and technique are all important factors.

Top Printing vs. Bottom Printing

Flexo printing on corrugated evolved in a round-about fashion. It was developed or integrated into various existing manufacturing processes and has only existed as a self-



72 With a cam roller feeder, a set of cam-shaped feed wheels contacts the bottom blank in the pile and pulls it into the nip of the feed rolls.

contained off-line process since the late '70s. For this reason, top-and-bottom printing units were developed to adapt the printing units to whatever converting operation already existed. Top and bottom printing are each applicable in different circumstances. For example:

- On a folder-gluer with an "up-folding" principle, the printing needs to be on the bottom of the sheet.
- On a so-called "down-folder", the printing is performed on the top of the sheet.
- On a rotary die cutter with the rotary cutting die on the top shaft, printing needs to be on the bottom because the creasing lines to form a box or container must be on the inside of the box.
- Conversely, if the cutting die is on the bottom shaft, the printing must be on top. The same principles apply for platen-type die cutters.

The quality of flexo printing on corrugated sheets, whether performed from the top or from the bottom, is not truly an issue. Rather, the key question is: Which approach is better aligned with the overall scope of the total corrugated manufacturing and converting process? One way to address this question is to begin with the corrugator. Consider the following:

- The corrugator, without exception, delivers the combined sheet with the print liner on the bottom.
- The majority of corrugators have automatic down-stackers or up-stackers that deliver piles of combined sheets with the print liner on the bottom.
- The majority of pre-loaders deliver the sheets into the feeders of converting and printing machines from the top of piles in batch form or in a shingle stream. Others deliver sheets from the bottom in a shingle stream, without turning them over.
- Most rotary or platen die cutters cut from the top and therefore need the printing on the bottom.
- Stitching machines and tape applicators insert staples or apply box-joining tape from the top.

In all of the above cases, printing must take place on the bottom of the sheet. While all the above scenarios can be overcome, it would certainly be at the cost of additional equipment, such as pile turning devices.

On a top printer, the printing is done above the board line (where board dust and debris cannot fall onto the printing plates) and away from floor-level dirt (*Figure* 73) One major advantage of top printing is that the printed image can readily be seen without removing a sheet from the in-line process.

Plate Mounting

Generally speaking, photopolymer plates have made tremendous progress in corrugated printing and are used almost exclusively today, especially in the value-added graphic arts field.

On sheet-fed corrugated flexo presses, plates are very seldom glued directly onto the print cylinder. However, this practice does still exist for mounting so-called "slugs," i.e., when only a box certificate or a bar code is needed. For such applications magnetic cylinders are generally preferred, where the printing plates are pre-mounted on 0.010" sheet steel.

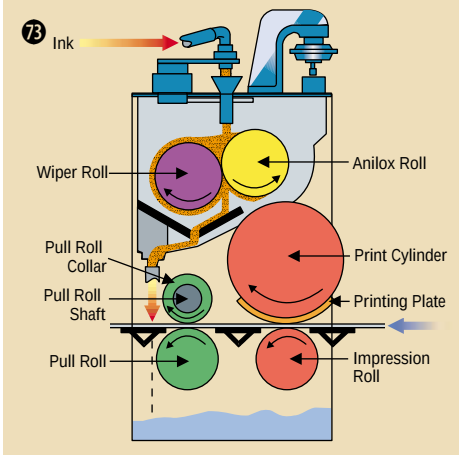
Plate mounting methods in corrugated vary. However, the most widely used method uses polyester, vinyl or other plastic material, 0.030" thick, onto which the plates are glued. This plastic mounting or carrier sheet is provided with a lead-edge hook, which locates into a slot on the press cylinder (*Figure* ❼❹). Slots are provided in the tail end of the mounting carrier sheet, where elastic straps are used to tighten it around the printing cylinder.

Several other mounting methods exist, such as full wrap-around systems with a take-up device, as well as steel-backed plates for mounting onto magnetic cylinders.

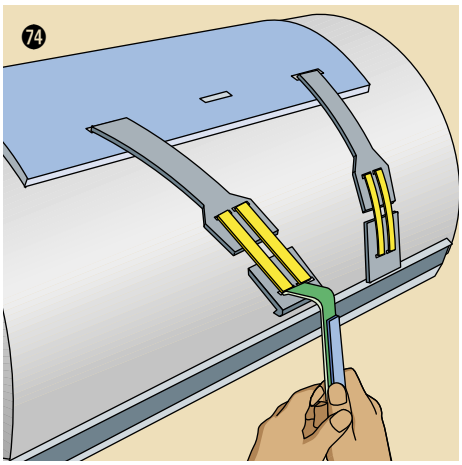
In a typical high-production box plant, plate slugs are mounted on print carrier sheets. The slugs are designed according to customer specifications and ordered from an outside supplier. The designs are often simply company logos, but can be made for almost any graphic design, including halftone screens. Text can also be engraved on the slugs.

The slugs are made of photopolymer or rubber compounds that easily conform to the round shape of the print cylinder. When the slugs have been manufactured and delivered, they are mounted onto a carrier sheet. A number of different slugs can be attached to a single carrier sheet. All slugs required for printing a single color are mounted on one carrier sheet and arranged to register with the panels of the final printed boxes (*Figure* ❼❺).

A centerline mark is placed on the print carrier sheets and on the print cylinder. Centerline marks are used as a tool for mounting the print carrier sheets in the correct location on the print cylinder. When the machine is running, the centerline of the sheet should be aligned with the centerline of the print cylinder. Pin registering systems may also be installed on the press and the carrier sheet to facilitate correct plate-mounting and registration on a press.



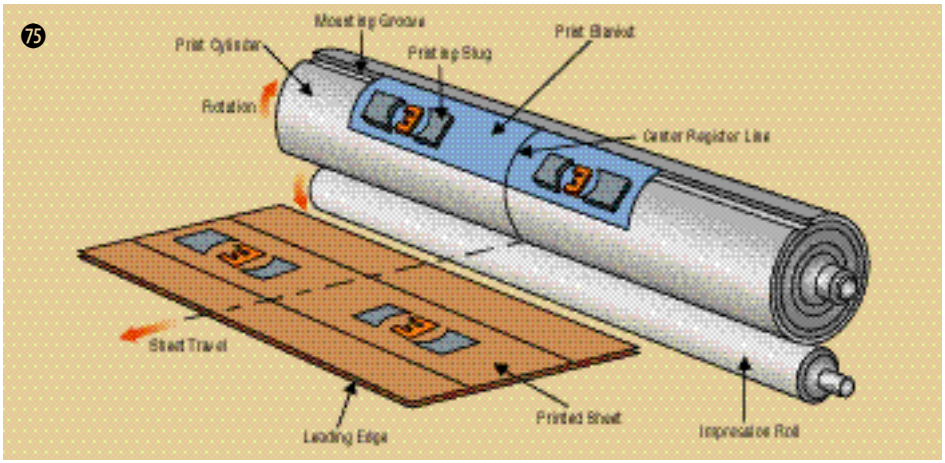
❼❸ With its print components positioned above the board line, a top printer allows visual inspection of a job without having to remove a sheet from the line.



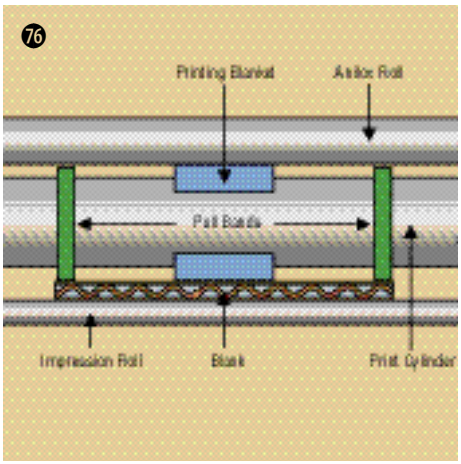
❼❹ A popular method of platemounting for corrugated involves use of a plastic mounting or carrier sheet with a lead-edge hook that locates into a slot on the press cylinder, corresponding with the slots on the tail end of the mounting sheet. The elastic straps are then tightened around the printing cylinder.

Pull Bands

In addition to the print carrier sheets, pull bands are also placed around the print cylin-



75 In this mounting scheme, plate slugs have been mounted about a center register line, which is used to aid in locating the corner sheet on the print cylinder.



76 Pull bands, placed outside the width of the print blanket, will grip the outside edges of the sheets as they pass through the print station, holding the sheets in position during the printing process and advancing them to the next station.

der (*Figure* 76). The pull bands are placed outside the width of the print blanket, where they will grip the outside edges of the sheets as they pass through the print station. On large, full-cover images, the pull bands may be incorporated with the printing plates on the same carrier sheet. Using pull bands will:

- eliminate skewing for square boxes;
- eliminate shallow slots for better-closing boxes; and
- eliminate floating in the print station for better print register.

Pull bands are used when small sheets (less than 22") are run through the machine. The pull bands help to hold the small sheets in position during the printing process and advance them to the next station. They are also used when there is not enough printing plate in contact with the sheet to hold the sheet square as it moves into the next nip point. Pull bands are necessary when only one end of the sheet is being printed.

Any time that a print cylinder does not have a print blanket mounted on it, pull bands that wrap all the way around the cylinder should be used. Use of wrap-around bands eliminates the setup time of trying to register small bands to a small box.

Counter-impression Roll

The counter-impression roll is a smooth steel cylinder located directly opposite the print cylinder, forming the impression nip. The impression roll imparts a light pressure on the back face of the blank as it passes over the printing plate. The light pressure exerted ensures a positive contact of the liner with the printing plate, necessary for transfer of ink. The nip with the printing plate also assists in pulling the blank through the press.

Permanent-mesh Coupling

The position of the impression roll with respect to the print cylinder is important to the efficient operation of the machine and the print quality on the blank. The gap between the print cylinder and the impression roll should allow contact between the blank and the printing plate without crush-

ing the blank. The range of nip adjustment necessary to accommodate various calipers of combined board, i.e., 0.040" to 0.300" (1 mm to 7.6 mm), is achieved by the use of a permanent-mesh drive coupling mounted between the driven gear and the counter impression roll drive (*Figure* ⓐ). This coupling allows the gears in the drive system to remain in a constant mesh position while allowing the impression roll to be moved. These permanent-mesh couplings are also used on other shafts such as the anilox roll, pull rolls and slotter shafts, where a large range of nip adjustment is required.

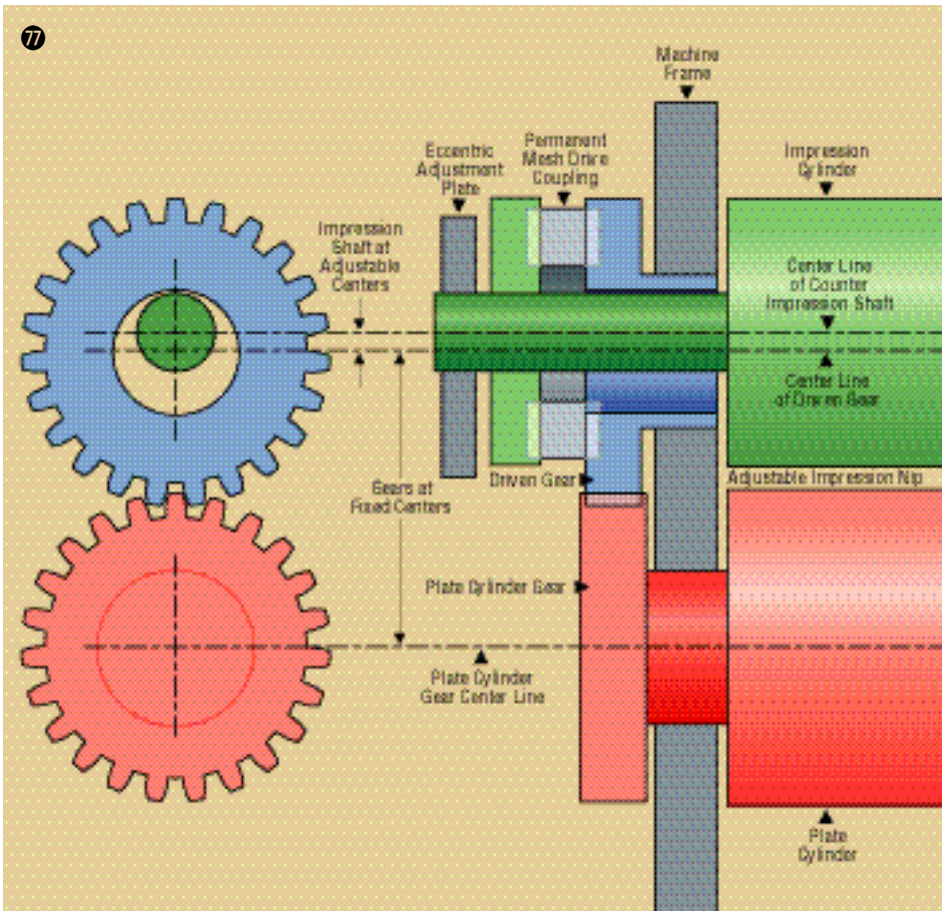
Inks

In flexographic postprinting, water-reducible inks are used almost exclusively. The biggest challenge in corrugated postprint for ink suppliers is to overcome the wide range of substrate variables. Therefore, wide volumetric differences of anilox rolls are used to try to conform the box or display to consumer specifications. In corrugated postprinting, ink consumption may vary from run to run: from as little as 2.5 BCM/in^2 (billion cubic microns per square inch) on a high-holdout liner to 10 BCM/in^2 on a high-recycle content kraft linerboard.

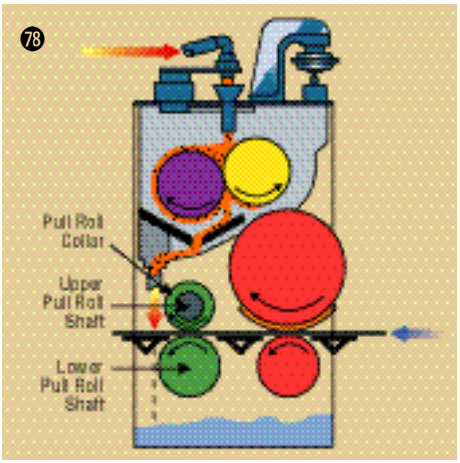
It is still a trend today to supply the corrugated industry with fast-drying inks (one of the attributes of flexo inks) even though dryers are installed on many presses.

Anilox Rolls

There are no limitations as to what type of anilox roll may be used for corrugated printing. Because of economics, mechanically



ⓐ Permanent mesh-drive coupling between the driven gear and the counter impression roll drive allows the gears in the drive system to remain in a constant mesh position, ensuring proper contact between the printing plate and blank.



78 Pull rolls control the blanks and, on the last print station, crush the fluted edges where the two ends of the box are glued together.

engraved rolls are the most commonly used; however, use of laser-engraved ceramic rolls is increasing.

Since process printing on corrugated is finding more and more applications (even on old machines), improvements in print quality are needed. The first improvement necessary is to obtain better ink metering through the use of finer (laser-engraved) anilox rolls. In many cases, retrofits of reverse-angle doctor blades or even chambered doctor-blade systems can improve print quality. The long life span of laser-engraved ceramic-coated rolls with blade-doctoring systems seems to offset the additional purchase cost for laser-engraved versus mechanically engraved rolls.

Because of the very wide spectrum of graphics printed onto even more variable substrates, almost any shape of anilox cell, widely varied volumetric capacities and probably any available screen-angle (engraving angle) can be found on different corrugated flexo presses.

SHEET TRANSPORT SYSTEMS

In order to print correctly, each sheet transported through a flexo press must travel at the exact same speed as the circumferential speed of the print cylinder. Since the inception of flexo printing, sheet conveyance has been assured through pull rollers, also called pull collars, from the feeder through the printing units and other converting elements.

Pull-roller

On a flexo folder-gluer, two steel pull-roll shafts are located in each printing station (*Figure* 78). The purpose of the pull rolls is to control the blanks and, on the last print station, to crush the fluted edges where the two ends of the box are glued together. Thus, when the blank is folded into a box, the overlapping parts will not be thicker than the walls. This procedure allows the boxes to stack flatter when folded. If the fluted edges are not crushed properly, the finished boxes will bow in the middle and will not stack evenly.

The upper roll has two laterally adjustable collars on the shaft, one for each end of the blank. The pull collars on the printing station are serrated, whereas the collars on the last station are designed to crush the flutes on the edge of the board so that the board edge will not spring back into shape.

The nip formed by the collar and lower pull roll is used to grip and pull the blanks through the printing station. The nip, or gap, between the pull collar and the bottom pull roll is adjustable. The gap must be set according to the caliper of the blanks being used. If the gap is too wide, the blanks will not be held securely during the printing process and registration will not be held. If the gap is too narrow, the blanks will be crushed, resulting in reduced box strength.

The distance between pull roller nips dictates what minimum size sheet can be processed in the throughput direction of the machine. On a machine with pull roller nips 18" apart, the minimum sheet throughput dimension needs to be 18.375", so that it remains in control between nips at all times.

Any time a print cylinder does not have a print blanket mounted on it, pull bands that

wrap all the way around the cylinder should be used (See *Figure* 76). Wrap-around pull bands eliminate the setup time of trying to register small bands to a small box. When positioning pull bands on the print cylinder, they should be set on the edges of the sheet to provide an equal pull across the sheet.

Pull-roller pressure must be adjusted to hold each sheet firmly in order to avoid slippage or skewing. Diameters of pull collars must be extremely accurate and should be checked frequently for wear or ink and fiber buildup. Even with all parameters in good working shape, pull roller machines generally yield register tolerances of ±0.0312" between two printing units.

Since most pull-roller machines are generally linked from gear to gear, cumulative register variations over several printing units may be severe. However, several thousands of this type of machine are successfully used throughout the world to satisfy printing criteria in the corrugated field.

Vacuum and Belts

Several pull-vacuum belt transport systems for sheet transport through flexo units (and other elements) can be found today on corrugated sheet-fed printing presses. One such system, used on a top printer, has a long, endless timed belt with vacuum holes. The belt reaches from the feeder, starting after the infeed pull rolls, through two, or up to four, printing units (*Figure* 79). This sheet transport belt actually travels over the counter-impression roll, holding the sheets while they are being printed. The belt is of uniform thickness to assure even ink transfer onto the board it transports. The belt is kept in correct timing and at the correct speed by timing belts vulcanized to its underside.

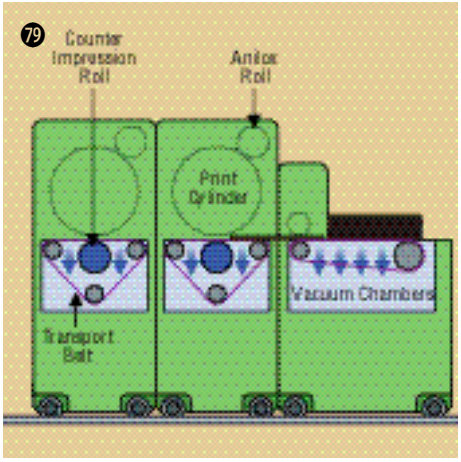
This system assures improved register compared to a pull roller machine. However, the belt is prone to becoming dirty and clogged if ink spills into the inking units. Ink spillage is one of the disadvantages of top printing, since the sheets and transport system are below the inking units.

Another vacuum-belt transport design incorporates vacuum belt sections between printing units, with several belts side by side reaching from the exit of a printing nip to the entrance of the following one. In certain cases, such belts are movable across the width of a machine, according to sheet size. The more common design has multiple permanently positioned belts spaced across the machine width, with a vacuum strong enough to hold any size sheet.

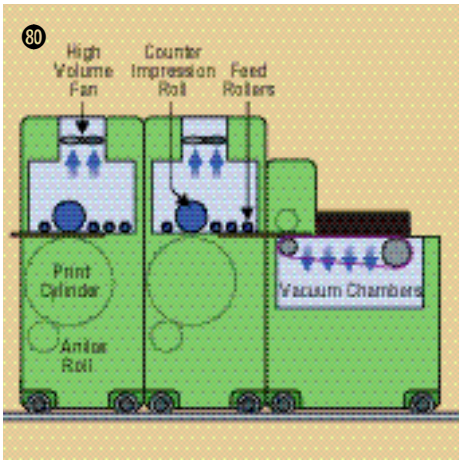
One design incorporates speed adjustments, by servo drives, of any transport belt section between printing units to correct for possible register inaccuracies. Vacuum belt transports are a significant improvement over pull roller sheet transports.

Rollers and Vacuum

The latest design for sheet conveyance through a printing press incorporates closely spaced precision rollers (*Figure* 80). Large vacuum fans pull the sheets against these rollers with a force equal to about 2" of water column. The transport rollers have a circumferential speed corresponding to the print cylinder's surface speed. Such an arrangement assures an extremely high-precision sheet transport without skipping or



79 A vacuum-belt transport system assures improved register compared to a pull roller machine. The timed belt reaches from the feeder through the printing units. This sheet transport belt actually travels over the counter-impression roll, holding the sheets while they are being printed.



80 Closely spaced precision rollers with circumferernetial speeds corresponding to the print cylinder's surface speed assure extremely high-precision sheet transport without skipping or skewing.

skewing. On some of the latest presses a vacuum is even created around the counter impression cylinder, assuring that the sheets are pulled perfectly flat. This method assures so-called "kiss" contact between the printing plates and the corrugated sheets. This type of vacuum transfer is generally driven by a line shaft through as many printing units as are necessary.

The many advantages of such a sheet transport system are: register accuracy of ±0.008" through six-color stations can be achieved reliably; full-coverage printing, side to side and front to back, without any trim, is easily achieved; no setup time is needed; and no contact on or near any printing is ever made, in contrast to pull-roller machines.

PRINTER-SLOTTER

The printer-slotter was probably the first machine to be equipped with in-line flexo units, replacing the letterpress printing units from which flexo-printing units have evolved.

The printer-slotter, as a self-contained entity, still exists today. However, it is mostly used to produce very large boxes in small quantities. Most of these machines are fed manually and have either a kicker bar or chain feeder. Almost without exception, a very simple lay-boy belt stacker is used to collect the finished printed-and-slotted blanks. In a few cases the printer-slotter is equipped with more automation and may fall into the category of "jumbo" flexo-folder-gluer. Such machines can handle blank sizes up to 104" x 210" for the production of furniture boxes and other bulk boxes or containers. In most cases, one or two flexo units, in their simplest form, with roll-to-roll metering, are in-line with such machines. While the printing may not be very sophisticated, the need for graphics with text or symbols can be achieved as an in-line operation.

PRINTER DIE CUTTERS

There are two categories of printer die cutters: the printer with rotary die cutting, and the printer with platen-type die cutting. In North America, the printer/rotary die cutters outnumber printer/platen die cutters by a ratio of about 10 to 1. In Europe, this trend is exactly the opposite. Rotary die cutters, known for their simplicity and high speed, are today available in various degrees of sophistication with up to six flexo printing units in-line. Any ink metering system, from roll-to-roll to combination systems of roll-to-roll plus chambered or reverse-angle doctor blades, are offered by a growing number of manufacturers. Print register accuracy of ±0.020" through all colors and process printing up to 85 and 100 dpi are achievable. In its more conventional form, the printer/rotary die cutter (soft anvil die cutting) is considered a "workhorse" in brown box plants, where 15% to 18% of production consists of die-cut blanks.

FLEXO FOLDER-GLUER

An entire book on the flexo folder-gluer has been written by Joel J. Shulman and was first published in 1986. It took Shulman six years to gather technical input on flexo folder-gluer operations alone, without getting into in-depth printing techniques on corrugated

board. This time line is mentioned just to emphasize how vast the application of flexography in the corrugated field is. In the sector of flexo folder-gluers, it is fair to estimate an annual worldwide growth of flexo printing units at between 500 and 600 print stations.

Bottom-printing units are predominant although top-printers have certain other advantages and, again, any kind of ink-metering system is offered. Since this book deals primarily with flexography and its principles, the comments on converting principles other than flexo will be brief.

An Overview

Once the double-face board is constructed from roll stock on the corrugator, the following events occur in the sheeting section in preparation for the flexo folding and gluing operations:

- Scores are embedded onto the board to produce creases.
- Full-width board is slit into narrower widths.
- Edges of the board are trimmed.
- Boards are cut to the desired length to produce a cut-to-size blank.
- Blanks are stacked and stored ready for printing.

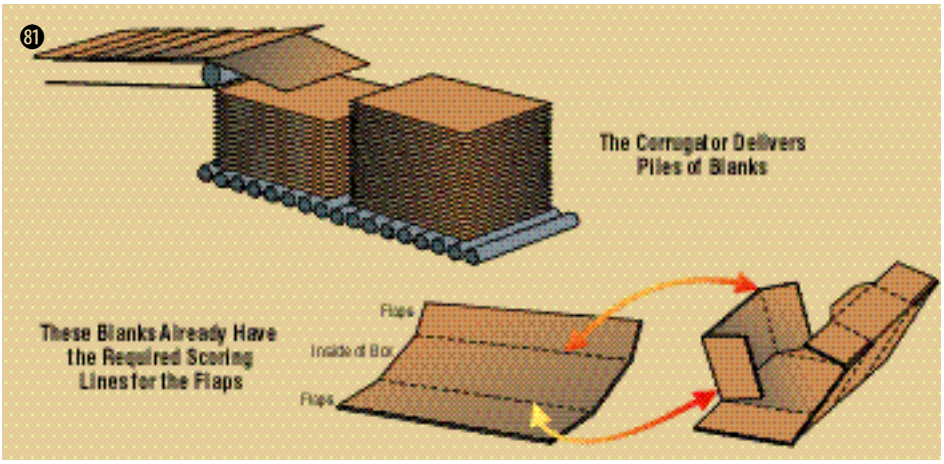
We now have a corrugated board, cut to size, with creases running down its length where the flaps of the box are to be folded (*Figure* 81). This corrugated board is referred to as a blank and is ready to be converted into a box at the flexo folder-gluer.

The flexo folder-gluer produces completely finished boxes from sheets directly off the corrugator (*Figure* 82). Standard operations performed by the flexo folder-gluer include:

- feeding;
- printing in two colors;
- creasing and slotting;
- die cutting;
- inside or outside lap glueing;
- folding; and
- squaring, stacking and delivery of corrugated boxes in uniform, accurately counted piles that are now ready for shipping.

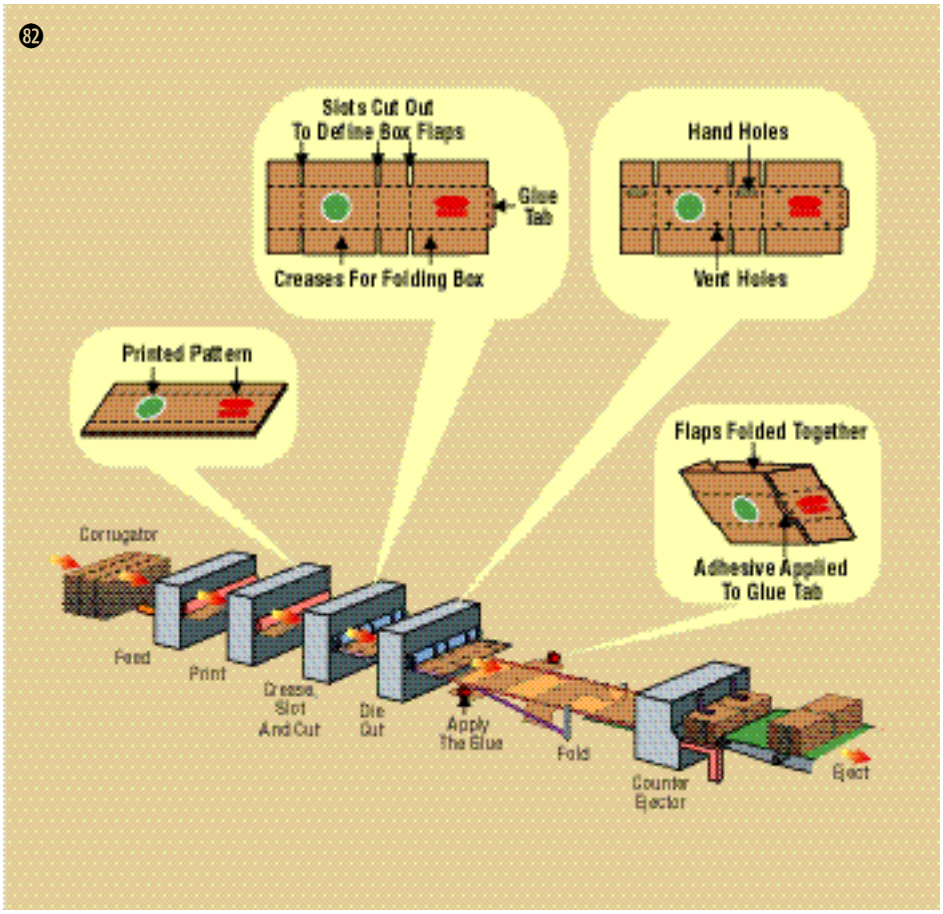
The cut-to-size blanks are delivered to the "work in progress" area in large stacks. They are stored here until needed by the flexo folder-gluer. The function of the flexo folder-gluer is to convert the scored, corrugated blanks into finished, ready-to-use boxes.

The converting line has two major sections, the flexo section and the folding section. The flexo section of the machine is where the corrugated blanks are actually printed. The blanks first have a printed pat-



81 Preformed corrugated blanks are ready to be converted into a box at the flexo folder-gluer.

82 A look at how the flexo folder-gluer turns blanks into printed, finished boxes.



tern applied to the top sheet. This pattern is usually the manufacturer's logo and name, along with the product description, instructions and other basic information.

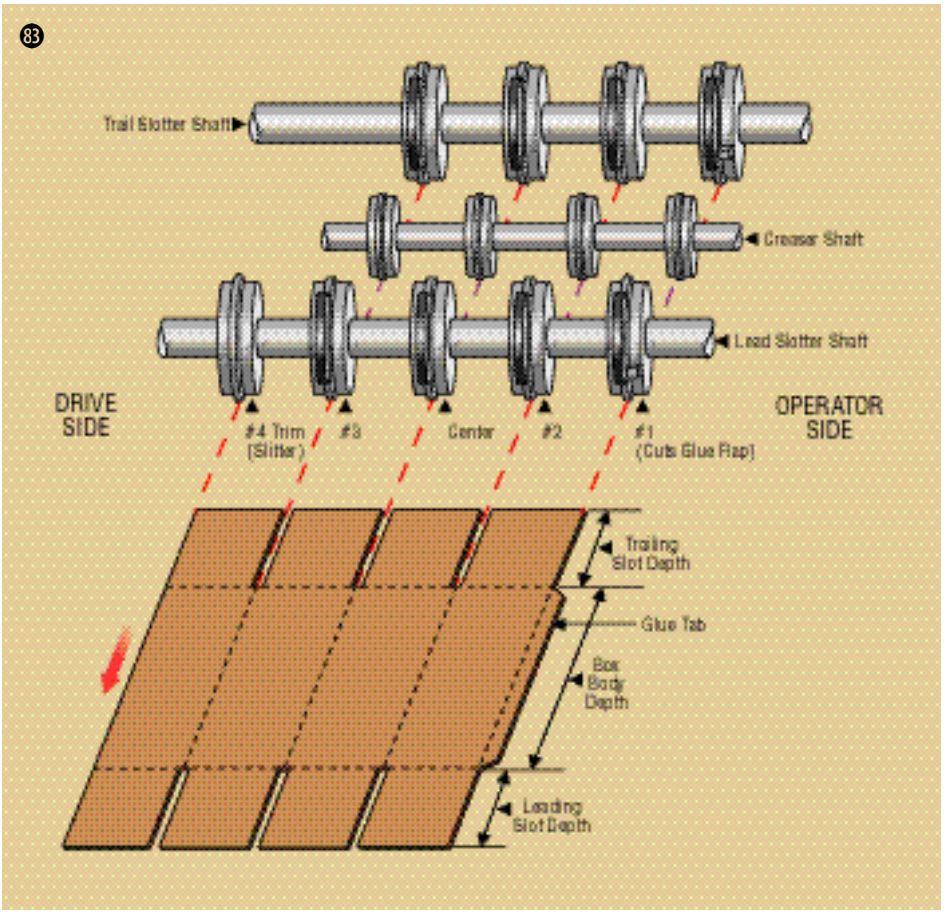
The first printing station prints graphics in a single color onto the top surface of the blank. The print station uses a rotary flexographic printing process to print the blanks. An anilox roll and wiper roll meter ink that is transferred to the printing plate. To make the print impression, the impression cylinder presses each sheet against an inked printing plate mounted on a print cylinder. A pair of pull rolls then advances the sheets on to the second printing station. The next and subsequent printing stations are identical to the first. When the subsequent color graphics are placed onto the top surface of the blank, the pull rolls of the last printing station feed the printed blank to the slotter-creaser section.

In the creasing and slotting section of the machine, the printed blanks are creased and cut to form boxes (*Figure* 83). Creases are impressed into the blank where the box is to be folded, and slots are cut out to define the box flaps. Glue tabs are also cut out to provide a way of joining the two ends of the cutout box pattern.

The creaser/slotter section consists of:

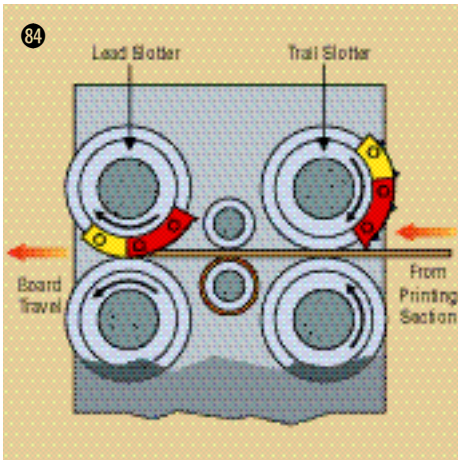
- Creasers (upper and lower shafts);
- slotters (lead and trailing); and
- scrap recovery system.

The purpose of the creaser heads is to impress a line in the sheet between the trailing slots and the lead slots. The creaser section



83 Creasing and slotting shfts shape the blanks prior to folding.

84 A cross-section of the creasing/slotting process.



consists of an upper and lower steel shaft. The upper shaft has four rubber-covered female anvil heads mounted onto it. The lower shaft houses the male profile-creasing heads.

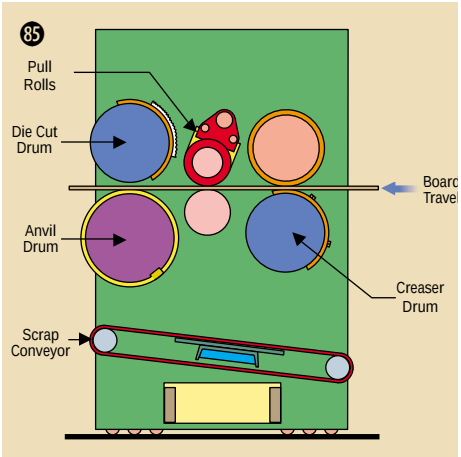
Creasing is done, from the bottom up, on the inside of the blank. The male profile head scores a crease on the blank as it passes between the nip of the two shafts. Each pair of creaser heads is carefully aligned so that the crease, or fold line, it produces runs exactly in the middle of the lead and trailing slots cut in the blank. These creases form impressions in the sheet to form the end and side panels when the blank is folded into a box at the folding section (*Figure* 84).

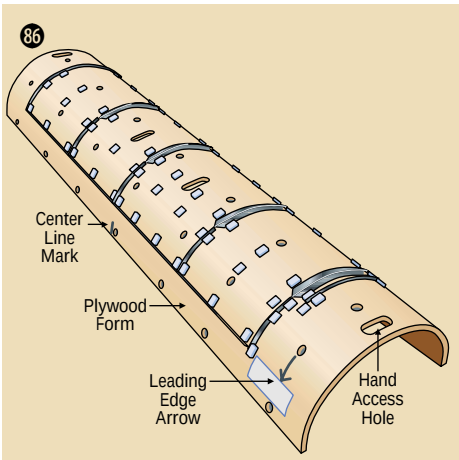
The operator must manually set the gaps between the upper and lower creaser heads according to the caliper of the board being run. If the nip pressure is too great, cracks will occur along the score. If the shafts are too far apart, a weak or non-existent crease will occur. A weak crease results in improper carton folding and possible rolled creases. The lead slot knives also advance the blanks

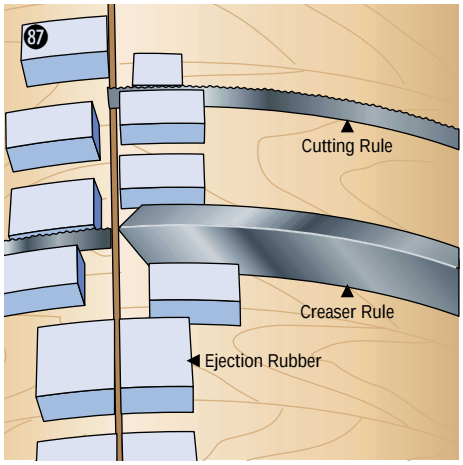
85 The creaser/die cutter makes it possible to score on both sides of the sheet or to produce offset scores and slit scores. It also allows the flexo folder-gluer to run unscored blanks off the corrugator.

86 A creaser die-cut tool.

87 A rotary die-cut shell.







into the next section of the machine.

The flexo section may also have a creaser/die-cutter unit. If required by the customer's specifications, additional cuts or all of the cuts needed (such as hand holes, vent holes, extra flaps or other types of holes on the box) may be made in the creaser/die-cutter section. The creaser is used to place creases on the blank for folding extra flaps on specialty boxes and displays.

The creaser/die-cutter section is made up of the creaser drum and anvil drum, a set of pull rolls and the die-cut drum and anvil drum (*Figures* 85, 86 *and* 87). The creaser/die cutter makes it possible to score on both sides of the sheet or to produce offset scores and slit scores. It also allows the flexo folder-gluer to run unscored blanks off the corrugator.

An angled scrap conveyor removes the cutting waste from beneath the station. On some machines the creaser/die-cutter station is equipped with the powered side roll out so that it can be removed from the flexo folder-gluer when not in use.

At the folding section (*Figure* 88), adhesive is applied to the glue tab or to the bottom of the fourth panel, depending on requirements. The blanks are then pulled through the folding section by a set of vacuum belts. Here, they first encounter tapered folding bars that start the first 90° fold of the outer blank flaps. The final folding occurs in the spiral folding belts.

The formed boxes are transferred from the folding section to the counter/ejector, where the boxes are counted and placed into bundles (*Figure* 89). As the boxes enter the counter/ejector from the folding section, they drop onto an elevator. As the bundle height increases, the elevator drops to keep the top of the bundle a fixed distance from the in-feed conveyor. When the bundle reaches a pre-set count, a set of trombone fingers extend down and out, on top of the last box in the bundle. To complete the folding of the box, the belts help in joining the glue tab to the opposite side of the sheet to form the actual box. Compression is applied to the overlap panel of the folded box so that the glue tab and fourth panel are bonded togeth-

er to form the knocked down boxes.

The discharge compression-conveyor section applies pressure to the top of the bundle to help the glue applied to the tab form a good bond. From the compression section, the bundles are conveyed away from the flexo folder-gluer.

PLATEN DIE CUTTING

Today, printer-platen die cutters are generally built on the principle of spaced-apart stationary printing units (*Figure* 90). After the printing units are finished, a belt-conveyor or vacuum-conveyor transports the printed sheets into a platen-type die cutter.

The number of printing units most commonly used today is three or four. However, it is possible to go up to five or six colors. The question of how many units are needed is not a technical one, but rather a viewpoint of practicality.

A platen-type die-cutting printing operation is governed in speed by the platen die cutter. The die-cutting/stripping process may be intricate and slow, and any jam-ups cause the entire line to stop, creating downtime, lengthy washing of printing plates and waste at each restart. On the other hand, platen die cutting is the most accurate die-cutting process and a virtually unlimited number of die cuts can be placed on a sheet. Also, smearing or offsetting with a platen die-cutting operation is virtually non-existent, allowing very high quality printed and varnished sheets can easily be cut, creased, stripped of waste, and delivered in piles or bundles.

STACKING

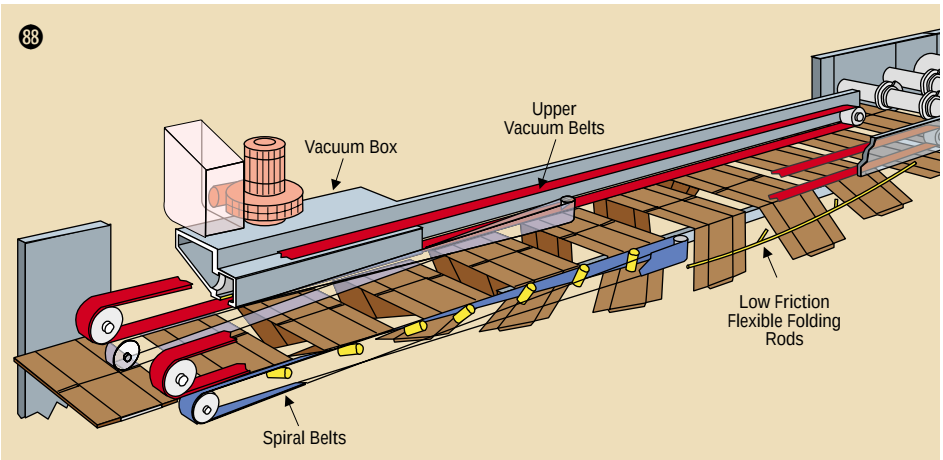
Off-line printing presses, rotary die cutters, platen die cutters and flexo folder-gluers need a means to form piles of finished product or printed sheets. Many press suppliers use lay-boy stackers, manufactured for many different applications.

Up-stackers

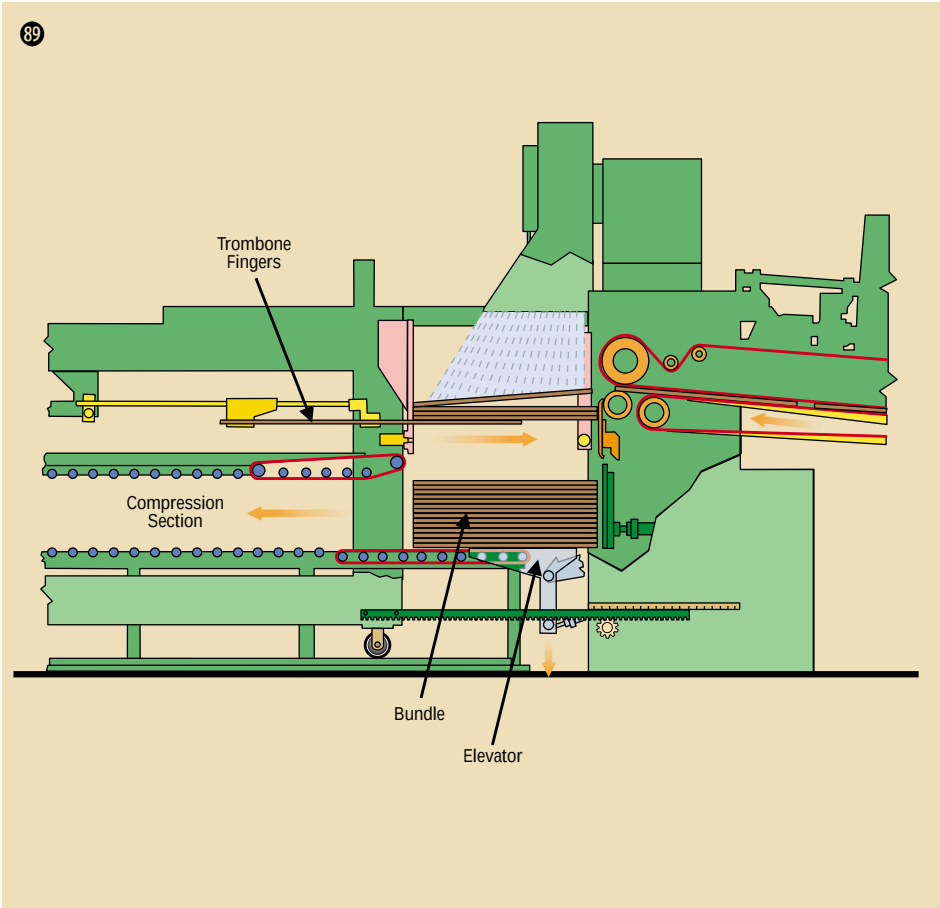
On low board-line machines, either top or bottom printers, an up-stacker is usually utilized. Such stackers, of simple or rugged construction, consist of belt conveyors with the exit end raised progressively to form a pile from the bottom up to a pre-selected height. Two-way jogging of the sheets is offered by most manufacturers and are equipped with a simple non-stop device. Generally an operator is needed to control the operation.

Down-stackers

On high board-line machines (80" and higher), a down-stacker is generally utilized.



88 In this folding section, material moves right to left, past low friction rods, which make the first fold, and spiral belts, which make the last fold.



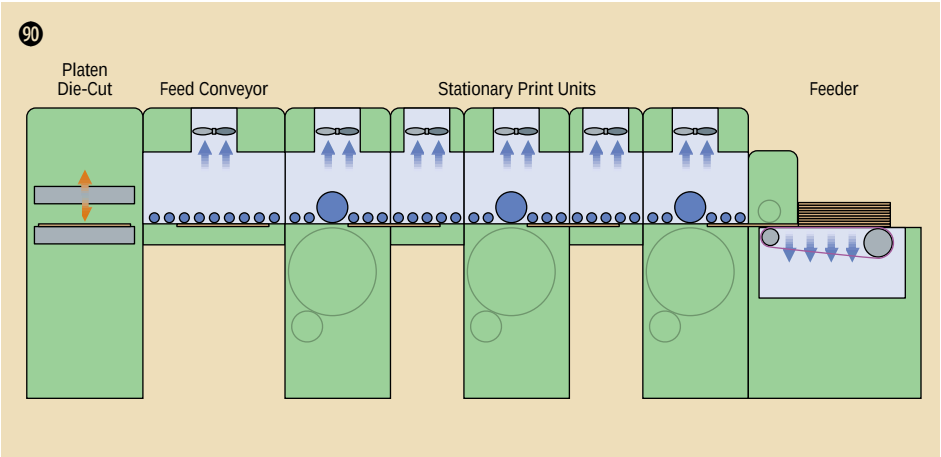
89 At the counter/ejector, boxes are counted, bundled and finally, compressed so that the glue tab and fourth panel bond.

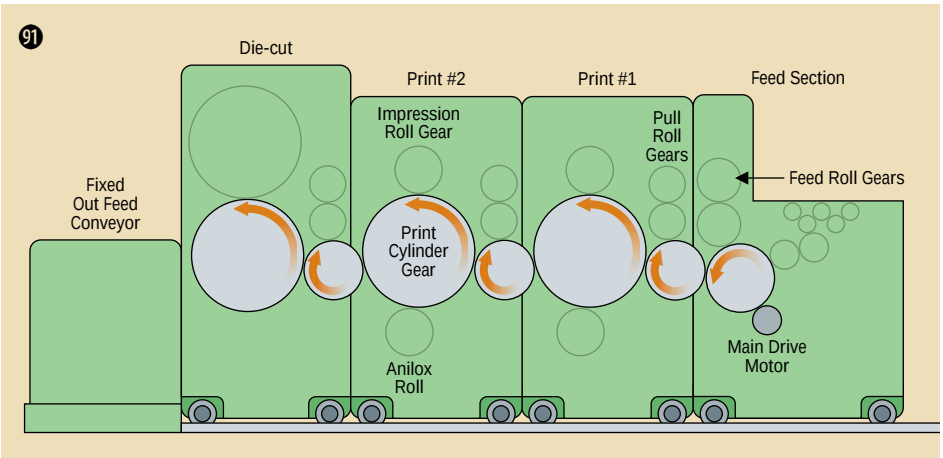
ven gears throughout the gear train in the press (sheet feeder, feed rolls, pull rolls, counter-impression rolls, print cylinders and anilox rolls) are in constant mesh position. Impression adjustments do not alter the gear positions. Compensation for these adjustments is allowed by using the permanent mesh drive coupling.

Registration

The print cylinder can be rotated independent from the main drive gear, through a motor-driven planetary gear or other arrangement, to place printed colors into the desired position on the sheet. This positioning is generally called the register adjustment. The quality of a machine is judged on its ability to hold register.

machines (the flexo folder-gluer) it was a natural to transmit the drive from element to element by a gear train (*Figure* 91). Generally, the feeder is the motor-driven unit from which all subsequent elements receive their drive-through meshing gears. The simplest design is to have the print cylinder gear equipped with a drive gear of a pitch diameter equal to the printing diameter measured over the printing plates. When printing units are closely linked, this gear may mesh with the drive gear of another printing unit directly, or more often through an intermediate gear. The pull-roller shafts that transport the sheets through the machine must then have a gear ratio that will produce a surface speed equal to the printing circumference of the printing cylinder. When the press is closed, all the dri-





90 After printing, a feed conveyor transports the sheets to the platen die cutter.

91 A gear-driven press, is powered by a main drive motor, from which all subsequent units receive their power.

The printed sheets are conveyed into down-stackers either by belt ramps or with a vacuum conveyor at the sheet-traveling level. A suspended pile-carrying platform cycles downward until a certain pile height is reached. A so-called "non-stop device," either a roller rack or a belt-type interceptor, is then introduced to catch the continuously arriving sheets for the next load.

In a typical operation the boxes enter the counter/ejector section, where they are counted, stacked and placed into bundles. As the bundle height increases, the elevator drops to keep the top of the bundle a fixed distance from the in-feed conveyor. When the bundle reaches the pre-set count, a set of trombone fingers extends down and out, on top of the last box in the bundle. The trombone fingers catch the first few boxes of the next bundle while the elevator drops and discharges the finished bundle into the discharge compression conveyor section. Once the first boxes are stabilized, a set of auxiliary fingers extends to allow the trombone fingers to retract and return to their ready position above the bundle that is accumulating on the auxiliary fingers. The elevator then rises to support the accumulating bundle and the auxiliary fingers retract, leaving the bundle on the elevator. To gain pile height, down-stackers may be installed into a floor pit.

THE GEAR-DRIVEN PRESS

Since flexo in the sheet-fed post-printing sector evolved first on in-line, close coupled

On a typical close-coupled, gear-driven press, once the printing plate is mounted, the machine is closed and started up. Print registration control can be achieved using the motor-driven running register and the manual lateral print register wheel on the operator side of the print station. The motor-driven planet gear register is adjusted to change the placement of the printing design with respect to the leading edge of the carton. The register control switch moves the cylinder in either the forward or reverse direction with respect to the main drive gear. The actual registration position relative to the main gear is displayed on an indication dial located on the print section.

The print cylinder can be moved laterally, across machine direction, in relationship to the sheet during the setup of the machine by using the hand wheel located on the operating side of the print station. The hand wheel moves the cylinder laterally, either left or right, ±1", without interfering with the printing plates.

As long as the machine is properly timed and zeroed between each setup, the print register will normally be very close to correct, even before the first blank is run through the machine. Fine-print register control is achieved by the operator running a test board through the machine before an order run is started. The operator runs a sheet through the machine, examines the results on the printed box, and then adjusts the register until the test box meets customer specification. On some of the more modern presses, the operator can use the print controls on the print station or on the counter/ejector station to adjust the print register in forward and reverse, or from side to side.

Gear-driven machines are, by a large margin, predominant in the corrugated industry. It is easy to understand why gear play must be controlled to the greatest extent to ensure register accuracy. Many methods are used to ensure that a minimum of play exists, while still allowing effective lubrication of the gear train and ensuring that gears are not becoming loose on the shafts they are driving. Nevertheless, machines with 100% gear-driven elements are subject to increasing register variations as the machine ages.

Typically, on a gear-driven flexo folder-gluer with four-color stations, in-line register tolerances of ±0.040" (1 mm) from first to last color are to be expected. Such inaccuracies come into play mainly when machine speeds need to be varied during production and therefore, the total accumulated play between gears enters into account. During acceleration cycles, this play is toward one side and during slowdown it is toward the other side. On older machines, the last printing cylinder of the machine may need to be rotated back and forth up to a quarter of an inch due to accumulative gear play. Failure to properly close and lock the individual machine sections will result in excessive backlash and poor print register.

LINE SHAFT-DRIVEN PRESS

A line shaft-driven press already has a certain advantage over straight gear-driven machines in that gear play from print unit to print unit is not cumulative. A rigid line shaft in this case drives each printing cylinder through right-angle gearboxes in a worm-gear arrangement (*Figure* 92). If one discounts some slight torsion forces on the line shaft, it becomes apparent that only one gear play enters into account per printing unit rather than a cumulative effect involving several in a gear train. This setup means, at least in theory, that the gear play of only one printing unit determines print register tolerance.

TRENDS IN PRESS DESIGN

As recently as 20 years ago, manufacturers did not build a sheet-fed flexo press for corrugated as a separate entity. Instead, flexo

printing units were always put in-line with slotting, folding and glueing operations (flexo folder-gluer), flexo rotary die cutting or flexo platen die cutting. The close-coupled printing units of the printer-rotary die cutter and flexo folder-gluer machines have so-called roll-away units on tracks to gain access to the various printing elements for maintenance or repair. This setup was disadvantageous, especially when printing on coated stock, as there is lack of space available for installing effective drying equipment to guarantee dry-trapping of colors.

With the advent of vacuum-transport for the sheets instead of roller nips, several press manufacturers have already successfully addressed this space problem. In some cases, special drying elements are placed between or after printing units, allowing complete exposure of the sheets to a drying source or simply to the ambient air.

Servo-drive Presses

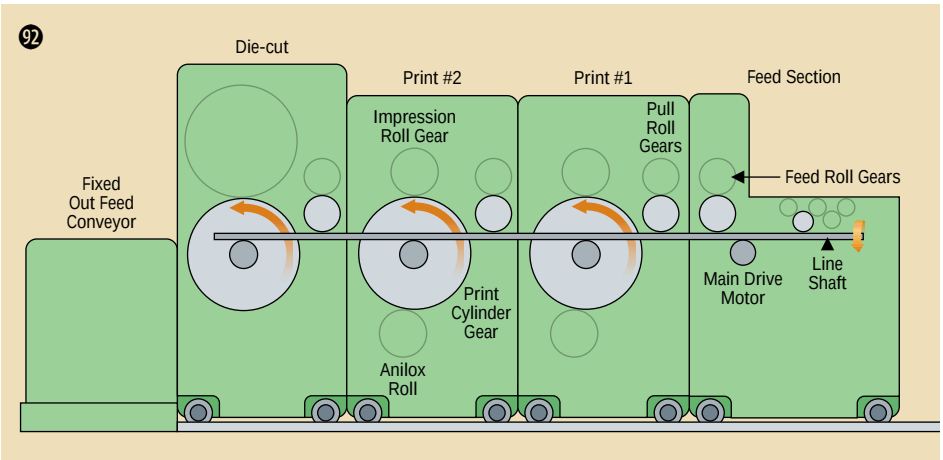
The newest approach in drive technology on printing machines is the so-called servo drive, whereby each printing unit has a separate drive motor, or motors. The motors are controlled electronically to rotate at a synchronized speed with each other. With this technology, the angular position of the print cylinders can be controlled with incredible accuracy. The scale of measure is truly in the region of one-thousandths of an inch.

Some manufacturers go as far as driving every shaft on each printing unit with a separate motor, while others use one motor per printing unit. In the latter case, the auxiliary functions such as driving the anilox or rubber roll are still a chain of gears.

Servo-drive technology has truly opened new horizons in the flexibility of sheet-fed printing presses. One manufacturer's printing press has the following drive arrangement:

- one motor to drive the feeder;
- one motor to drive a roller/vacuum sheet transport system through all printing units; and
- one motor to drive each printing unit (up to eight printing units may be placed in-line).

On servo-drive machines, register adjustment is achieved through angular displacement of the print-cylinder drive motor in reference to a mechanical fixed point or to the motor position on another printing unit. Real time position of each and every motor is fed into microprocessors through high quality encoders fixed directly on the motor shafts. Servo-drive printing press technology is in a very advanced development and implementation state, even though many applications



92 In a line-shaft driven press, a rigid line shaft drives each print cylinder, thus eliminating accumulative gear play.

still remain to be explored.

Closed-loop register and quality controls have already been introduced to the industry, including features such as utilization of variable caliper printing plates, and automatic printing length adjustment, all of which can be controlled through computers controlling the servo drives.

The technology of servo drives, responder drives or electric line shafts, was introduced, for even very large in-line machines, about 1980. Even some of the early machines equipped this way had over 50 independent motors controlled by computer.

Free-standing Off-line Presses

As outlined in the introductory comments about evolution and growth, flexo printing in the corrugated industry was first seen as a necessary "add-on," if not "evil," to equip converting processes with graphics capabilities for tasks such as identification or handling instructions. This simple start evolved rather quickly into a demand for more refined messages on the outside of boxes and a demand for more colors.

In the late 1970s, the quality of printed images produced on a sheet-fed flexo corrugated press was being pushed to its limits, always as an in-line operation. The technology did not begin to change until flexo post-print quality was required to compete with other processes that were perceived as much higher quality. The time had come for multi-color free-standing flexo presses where no mechanical influence, such as folding rods, die-cutting anvils, under-stackers and other machine components would negatively influence printed images. The need for inter-station drying and isolation of the printing process from dust producing converting processes led to the self-contained free-standing sheet-fed flexo press.

Today, multi-color, high quality post-printing on corrugated is becoming a self-contained manufacturing step, similar to offset printing, where the printing process is separated away from other converting operations. This trend is true to the point where flexo printing operations are often enclosed in a clean, dust-free environment to reach the highest quality and production standards. With this change in mind, a majority of press manufacturers are no longer building machines to match other equipment in terms of size. However, the aforementioned arguments for conforming to the corrugated manufacturing process, as a whole, are still respected. Bottom-printing is becoming, more and more, a standard in off-line, sheet-fed postprinting.

Flexibility of Off-line Presses. The increasing demand for value-added graphics and more "defect-free' printing has stimulated press manufacturers to produce "pure" printing presses, isolated if possible, from other manufacturing operations. The idea appears to be the same as in preprinting, where central impression or stack presses are put in an isolated, protected environment to keep the operation clean from dust, noise and other hazards. A sheet-fed off-line flexo press installed in this manner is indeed very flexible. Printing quality and operational speed no longer depend on other manufacturing steps.

Practice has shown that a flexo press can run roughly twice as fast as a platen die cutter. Therefore, the true capacity of the flexo press can be exploited since it is, when installed off-line, no longer a slave to a possibly slower converting operation. Dust from other operations does not have to be dealt with. Many of today's installations benefit from air conditioning and noise abatement, making the press operator's environment a more friendly one. Off-line flexographic presses are the most ideal for achieving high quality on short or long runs.

A disadvantage of the off-line press may be that the finished printed sheets need to be transported through additional conveyors or other means of transportation to the finishing machines, such as rotary or platen die cutters.

Thinner Printing Plates

Since flexo corrugated presses are a derivative of letterpress presses, printing plates of 0.25" thickness, mounted on a 0.030" backing for a press undercut of 0.280", are still found in the majority of corrugated converting plants today. Such plates may be produced from natural molded rubber (a dying art), synthetic molded rubber, liquid or sheet photocurable polymer, or laser-engraved rubber. Even on brand-new machines, cylinders are sized to receive plates as mentioned above simply because converters have accumulated hundreds, if not thousands, of printing plates for ongoing repeat business.

Thinner printing plates provide the advantages of lower print relief and higher print image definition – necessary if high-resolution halftone images are to be printed. Fortunately, an increasing number of printers have decided to part with the past and work with an overall plate thickness starting at about 0.125" (3 mm), up to about 0.1875" (5 mm). Although the thickness of the plate material itself may measure only 0.067" (1.7 mm), the thinnest is used on corrugated today, because corrugated is such a variable substrate, a “cushioning foam” backing material is used to bring the plate to the overall caliper necessary to meet the undercut built into the press.

Some compromises are always necessary to conform to the printing diameter of the press and the cylinder undercut. For example, if an overall plate caliper of 0.185" (4.65 mm) is chosen, a 0.125" (3.15 mm) plate must be under-packed, or permanently mounted, with 0.060" foam backing material. Any combination of plate thickness plus foam (cushioning material) can generally be used as long as the overall caliper corresponds to the printing diameter of a press. A 1:2 ratio of cushioning material to plate is preferred.

Quick-change Anilox Roll Systems

An anilox roll is capable of giving only one amount of ink: the content of its engraved, or laser-burned cells. Any deviation from this simple law means variation in ink laydown or ink density.

Mixing of large solids with screens or fine type on the same printing unit is not recommended in flexography. In corrugated postprinting, for years, printers were compelled to compromise because the anilox roll was, for all practical purposes, a fixed part of the printing press. To change a roll or rolls would take a team of mechanics from several hours to an entire weekend. Today, most printers understand that the characteristics of a particular anilox roll limit its application to a narrow band of substrates as well as selected graphics. Several anilox rolls may be needed per printing station to enable the printer to use the right tool for the job at hand.

With the increasing demand for more and more intricate graphics, such as process work with plate screens up to 150 lpi, it has become necessary to build printing presses with quick-change anilox roll systems. The tremendously varied substrates utilized in corrugated demand ink lay downs from as little as 2 BCM/in^2 (e.g., with process print on heavily clay coated paper) to as much as 14 BCM/in^2 for very absorbent recycled liner. These very large differences between rolls explain why press manufacturers for the corrugated postprinting field are compelled to build machines with “quick-change” systems for anilox rolls.

Internal Change, Semiautomatic. Today, machines with 100% automated anilox roll-changing systems are available. The semi-automated system will be discussed first.

The idea of accelerating and simplifying the mounting and dismounting of anilox rolls is not a new one, simply because of the excessive time needed to change anilox rolls even on one or two printing units. Some manufacturers provide “roll-out ramps” to facilitate this process. Even with the ramp, changing a roll can take one to two hours.

On some top printing machines, roll-change designs involve an overhead hoist equipped with pillow-block bearing housings. The housing can be opened up to lift out an anilox roll and replace it with another. The fastest system of this kind can complete a roll change in about 30 to 45 minutes.

On certain bottom-printing machines, a permanent anilox roll elevator can take an anilox roll down from its working position and bring another one up by manually opening clamshell-type bearing housings. Five to seven minutes are needed with such an approach. Chambered doctor-blade systems are a prerequisite with this design in order not to have to remove rubber rolls or ink fountains, which would obstruct the lifting or lowering path of the anilox roll.

Internal Change, Automatic. A number of press manufacturers have designed, or have announced plans to design, systems that would change anilox rolls fully automatically. One manufacturer is already providing a top-printing press with a fully automatic system. This particular machine is a servo-driven machine where the anilox roll is driven directly with a separate servo motor. The spare anilox roll is stored above the inking system with its own drive motor already attached. A rack-and-pinion arrangement brings the roll to its working position in less than a minute. The entire exchange is executed by the machine operator using push buttons. This design provides quick exchange between two rolls in any printing unit. It is a much larger job to bring any of the rolls outside the machine for maintenance and repair.

Another design on a bottom-printer allows push-button exchange of two rolls in about two minutes. On this machine, the rolls are exchanged with a vertical elevator. The anilox rolls have no journals, but have a female cone arrangement on each end. The drive journals are part of the machine structure and can be moved laterally to clamp the roll in a horizontal position. Again, changing of anilox rolls using pushbuttons is a machine operator's task, without involving any plant mechanics or engineers. With this design, up to three rolls can be exchanged. One anilox roll is in printing position and two are in a storage cradle ready to be exchanged with the roll in printing position.

A third approach is to have several anilox rolls on a horizontal turret system. This design is, as of this writing, still on the drawing board. The design resembles a triplex slitter/scoring system on older corrugators.

Changing Anilox Rolls Between Printing Units. In order to provide a printing press that is even more flexible regarding ink lay-down, one manufacturer has gone a step further. Not only can anilox rolls be exchanged within one printing unit, but also from one unit to another. This change is achieved with a roll storage cradle below each inking unit. The cradle can be transported by a cart or trolley to move the anilox rolls from one printing station to another if and when needed. This approach makes economic sense, as possibly fewer anilox rolls may need to be purchased for the daily mix of work done by a printer.

DRYERS

The popularity of drying by air impingement is mostly due to safety concerns, as this approach is free of fire hazards. It is probably the oldest method used to dry ink and the technology is well known in many other segments of flexography, as well as rotogravure. In sheet-fed flexo on corrugated, especially on machines with spaced-apart printing units, warm air dryers are today capable of fully drying large surface printed or varnished sheets at machine speeds exceeding 10,000 sheets per hour.

Infrared Dryers. Within the invisible light spectrum, infrared radiation produces heat that, depending on wavelength, penetrates the substrate to varying degrees. Short-wave

infrared, together with an air blanket, has proven to be an effective drying source for inks and varnishes. This technique appears to be well utilized, especially on closed linked machines where little room exists to install other means of drying.

Infrared is a very effective heat source, but with long enough radiation exposure to the printed board, could cause a fire hazard. Therefore, when infrared is used as the heat source for drying, it is generally arranged to preheat moving air, which is then extracted after it has saturated itself with moisture.

Sheet Cleaners

Compared to other printing industries, corrugated plants have a multitude of problems with dust, beginning at the corrugator. Dust and slivers are in the stacks of corrugated sheets and are the No. 1 cause of downtime and quality problems in postprinting or corrugated.

With printers producing finer and finer graphics with thinner and thinner ink films, dust-generated hickeys are a nightmare for press operators. In the past the problem was also present, since print quality standards were low, a heavy ink film was used to cover up the dust. Dust is by far the biggest external obstacle to quality printing, especially in a corrugated operation, and press builders and converters alike must address it aggressively. Today, quality printers are more and more conscious of dust. Increasingly sophisticated sheet-cleaning devices are being installed on printing presses and have become more common on corrugators.

Stationary Brushes. Stationary brushes, in combination with a vacuum mouth or funnel, are the simplest method for cleaning sheets or a web from one or both sides. Such systems are effective only to clean coarse matter, though, and do not do a good job with finer dust. In some cases, the friction of the bristles on the board causes static electricity, making the dust adhere even more. Use of static eliminators does help, but does not eliminate this problem totally.

Stationary brush-type cleaners are generally used in confined areas near the feed rolls and are always installed with a dust-suction device. Unfortunately, since such equipment is sometimes installed in very tight spaces, cleaning the brushes becomes difficult, and the system becomes less and less effective.

Rotary Brushes. Dust suction systems for sheet cleaning with rotary brushes is another arrangement found on corrugated printing presses. Very similar to stationary brushes, the sheets are brushed by the rotary brushes, which rotate in the opposite direction of the sheet travel. Again, on certain substrates static electricity is created, making the dust adhere to the surface of the sheets instead of loosening it for removal by suction. The brushes also saturate themselves with dust and if not removed frequently, become ineffective. As with all systems involving suction, it is necessary to evacuate the dust into filter bags or cyclones. Cyclones, although cumbersome and large, are the preferred means. Filter bags, if not cleaned frequently, reduce the vacuum flow severely.

Static Elimination Cleaners. Corrugated sheets, besides being dusty, are often charged with static electricity, which makes dust removal by vacuum and contacting stationary or rotary brushes even more difficult. Static elimination devices are therefore implemented to counteract the problem.

Stationary-brush sheet cleaners and rotary-brush sheet cleaners, as described earlier, are available with a more advanced design that utilizes static-neutralizing devices. Just as in every other converting and printing operation, static electricity is created in the corrugated field through friction, induction, rapid changes in temperature, and rupture of the molecular structure created by slitting or sheeting. All of these actions create an imbalance of electrons.

The most advanced ionic cleaning systems

involve a corona field formed between two electrodes in a quartz enclosure. The sheets to be cleaned pass through this corona field, which is generated through high voltage and high frequency (5,000 to 7,000 cycles/sec and at 15,000 volts). None of the dust removal systems are absolutely perfect. However, if the problem is addressed at its source, i.e., at the point where dust and electrostatic charges are produced, it can be controlled.

For more information on ionic substrate cleaning, see the previous section.

Updating and Upgrading for Continued Development

As mentioned previously, upgrading existing printing presses is in many cases as simple as installing finer anilox rolls and either reverse-angle doctor blades or a chambered doctor-blade system. Nevertheless, one has to be aware that anilox rolls are only a tool (albeit an expensive tool) and that there is no universal anilox roll that can successfully print more than a relatively narrow band of graphics with a given volumetric capacity.

It is, of course, necessary that the machine be in good mechanical condition, especially with regard to register accuracy. Some manufacturers offer vacuum transfers for board conveyance as retrofits to improve on-press register. The addition of a good lead-edge feeder on an older press can also lead to improved graphics.

Many on-press inspection devices, from fiber optics to video cameras, are utilized in the industry. Viscosity/pH control devices are also finding more application in the corrugated flexo printing field.

In a few years printing presses will have "closed loop" controls whereby register corrections, ink density and even color hue, will be constantly monitored and corrected without the press operator's intervention.

JOB PREPARATION AND PLANNING

With the increasing number of off-line flexo printing presses and the push to reach higher and higher quality with very fine screen process images, it has become increasingly important for corrugated flexographic printers to better prepare and organize all aspects of the converting process. For instance, when four to five colors are printed and UV varnish has been applied over dark colors, creases may crack (also called checking) on the folder-gluer, the very last operation performed before the boxes are shipped. One can easily imagine the seriousness this problem presents considering the waste of materials, man-hours and press time.

It is highly recommended that with each new project, the printer/converter conduct certain lab tests such as rub tests, creasing and bending tests, and moisture content measures of substrates. Collaboration with trade shops and art designers must be established by the printer/converter to have a good exchange of ideas and practices that can be applied (or not) to a printing/converting job.

Today, many corrugated boxes are used where folding carton boxes were once used exclusively. Such cartons are generally called "folding-carton-style" corrugated boxes. The placement and disposition of graphics on these boxes is done with the same scale of measure as with folding cartons. Graphics must appear parallel to creases and, if possible, not run over box scores. Basically, graphic designs and dispositions that leave no room for manufacturing tolerances during printing, die cutting and folding/gluing create unnecessary waste.

As a general guideline, a converter must know the manufacturing tolerances possible on his printer, die cutter and folder/gluer, and design the job for his equipment; not the other way of trying to adapt the converting machine to a job, which is an expensive and incorrect process. As machinery becomes

more accurate and allows for finer and finer register tolerances, the many prepress operations, such as plate mounting, cutting die tolerances (especially on rotary dies) and waste stripping tools must be manufactured with tolerances even finer than those allowed on the end product for which they are built.

Machinery manufacturers offer many options on equipment to allow for correcting errors. These are just a few examples:

- printing plate skewing devices correct inaccurate printing plate mounting or mounting of the lead-edge hook on a bias;
- anilox roll adjustments put the roll out of parallel to adjust for printing plate caliper variations; and
- feeders with skewable front gates adjust for printing performed on a bias.

Such features can sometimes help operators to "save the job." Unfortunately, if machine operators neglect to return such systems to their zero position after a badly mounted job has been run, a job that is mounted correctly by a quality supplier will not perform correctly without sometimes lengthy adjustments.

Equipment Maintenance

In corrugated converting operations, whether starting with rolls of linerboard or in a sheet plant, maintenance involves many different machines and many different converting operations. Machinery maintenance is generally handled by a crew of specialized mechanics and electricians. In some smaller operations, machine operators and press crews are deeply involved in maintaining their respective pieces of equipment. Both options work quite well when the people involved are very familiar with the process or processes performed on a piece of equipment. An increasing number of equipment suppliers offer maintenance and process-oriented seminars to help converters maintain and improve their machinery and operations.

Training for Continued Improvement

Flexo postprinting, the most-common printing method for corrugated, high-end graphics or just plain everyday printing, has been experiencing a period of renewed excitement. Different universities have started to show great interest in teaching flexography, right down to on-press training. Continued emphasis on education is crucial for meeting the increasing demand for high-quality flexo products.

Press Mechanics

The increase in printing speeds and quality standards in the flexographic printing industry today makes it necessary to consider the importance of accurately balancing the various rolls and cylinders used in the press. To better understand the problems involved with an unbalanced cylinder, we must consider that balancing is a process whereby the distribution of mass in a roll is altered to eliminate vibration at the supporting bearings. A roll can be manufactured to very close dimensional tolerances and can be properly designed structurally so that it is a rigid integral unit in a static state. Sometimes, however, in spite of all the care and precautions taken, the press in which the roll functions does not perform satisfactorily due to excessive vibration. In the case of plate cylinders, the addition of the plate mass itself may cause imbalance vibrations. These vibrations often limit the printing speeds the press is mechanically capable of producing.

BALANCING FLEXO ROLLS

Consider the following problems that are a direct result of vibrations produced by unbalanced cylinders:

- excessive printing plate wear;
- excessive bearing wear;
- excessive roll wear;
- reduction of the overall mechanical efficiency of the printing unit, such as uneven impressions;
- associated resonant vibration of other parts of the press or its supporting structure;
- possible failure of structural components of the press; and
- excessive noise created as a side effect, which often reduces efficiency of the pressmen.

The cause of imbalance in rolls, although usually obvious, is frequently overlooked. Imbalance is caused by the lack of homogeneity in a material, whether it is cast, rolled, forged, extruded or otherwise produced. In the case of tubular or cylindrical products, an uneven wall section can cause imbalance. Evidence such as blow holes, slag occlusions and variations in the crystalline and chemical structure of a material are indications that the raw materials used to produce the rolls are not homogenous. Variation in the distribution of mass due to manufacturing tolerances, which must be allowed on all machine surfaces, is a major contributing factor.

Any manufacturing tolerances that permit eccentricity or lack of squareness of machine surfaces with respect to the rotational axis are sources of imbalance. Non-symmetrical distortion of a roll while running at its operating speed can also produce excessive vibration. This distortion is generally the result of poor design, such as too small a diameter in relation to face length, or of variations in wall thickness of the material used to manufacture the roll.

The need for balancing a flexographic press roll is evident when we consider that the center of mass of a roll will not necessarily coincide with the rotational axis as determined by its supporting bearings. A roll that is not restrained by bearings will naturally rotate about its center of mass.

However, when the same roll is restrained by bearings, it is forced to rotate about an axis other than its center of mass due to the run-out of the bearings. Consequently, centrifugal forces are introduced, which cause vibrations. To state it very simply, balancing is merely an operation that eliminates vibration by redistributing the mass of the cylinder so as to cause its center of rotation to lie on the same axis as that determined by the supporting bearings.

Although there is varying terminology used with respect to balancing, we are concerned primarily with two types: static imbalance and dynamic imbalance.

Static Imbalance

In static imbalance, only gravity or weight force is involved, and balancing can be accomplished without rotation. This type of balancing is generally not satisfactory for flexo rolls due to the rotational speeds at which they operate and the ratio between their diameter and axial length.

Dynamic Imbalance

Rotating parts ordinarily have both static and dynamic imbalance. This combined static and dynamic imbalance is corrected by weights placed in two different planes perpendicular to the axis of rotation (*Figure* ❾❸). The weight compensates not only for the static imbalance at rest but also for the dynamic imbalance caused by centrifugal force when the roll is rotating.

This two-plane balancing, which corrects both static and dynamic unbalance, is generally referred to by engineers as dynamic balancing. Due to the physical and rotational characteristics of flexo rolls they should in every case be in dynamic balance when high press speeds are used.

Forces on Bearings

The centrifugal force exerted on the restraining bearings of an unbalanced roll is proportional to both the weight of the roll and the distance that its mass center is displaced from the rotational axis.

The general formula for centrifugal force is:

$$\textbf{FORCE} = \omega^2 \times \textbf{R} \times (\textbf{W/g})$$

$$\text{or } \textbf{FORCE} = \omega^2 \times \textbf{DYNAMIC UNBALANCE}$$

Where:

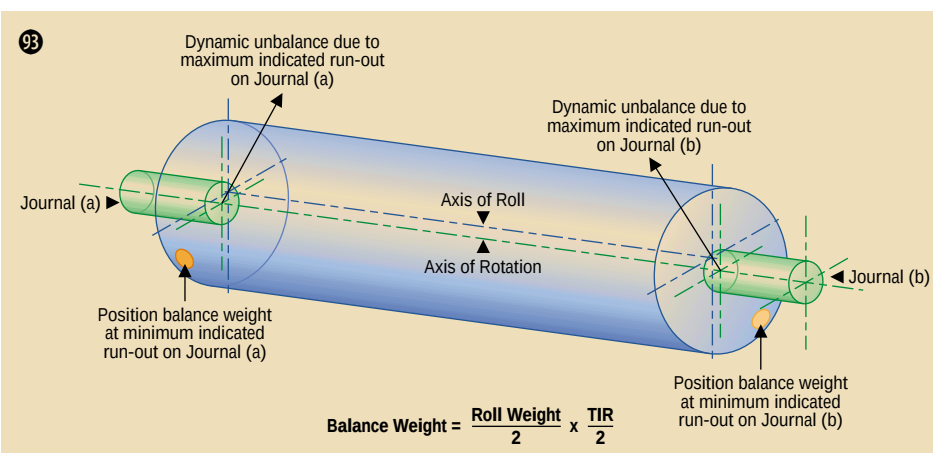
W = roll weight

g = gravitational constant

R = radius of rotation

ω = angular speed of rotation

We must therefore measure imbalance as the product of weight and displacement, expressed in terms of ounce-inches. An imbalance of two ounce-inches is produced



❾❸ The process of dynamic balancing: Placing weights in two different planes perpendicular to the axis of rotation compensates not only for the static imbalance at rest but also for the dynamic imbalance caused by centrifugal force when the roll is rotating.

by a two-ounce weight displaced 1" from the rotation axis. For example, a roll weighing 125 lbs. (2,000 oz.) with its center of mass 0.001" from its rotational center as determined by its bearings, is 2 (2,000 x 0.001) ounce-inches out of balance.

The magnitude of the centrifugal force produced by a two-ounce unbalanced condition is a function of the speed of rotation or in other words, the revolutions per minute of the roll. This force, which produces vibrations, increases as the square of the rotational speed. For example, consider again the roll that has an unbalanced condition of two ounce-inches. When this roll is operated at 500 rpm, it will produce a centrifugal force of approximately 0.9 lbs. However, when we increase the speed to 1000 rpm, we create a centrifugal force of 3.6 lbs., or 4 times the force at 500 rpm.

The example illustrates that there is a much greater need for accuracy of balance at higher speeds than at lower speeds. The degree of balance required in a roll can only be determined after consideration is given to the operating speed in revolutions per minute and the conditions under which the roll will be used. Some of the factors that must be considered are:

- the structural rigidity of the roll itself;
- the diameter in relation to the distance between bearings; and
- the overall rigidity of the supporting structure of the bearings.

Although all factors must be considered, the following is recommended:

- All rolls, regardless of press speed, should be in static balance.
- Rolls operated at 300–500 rpm should be in dynamic balance within 10 ounce-inches.

ROLL SPEED VS. PRESS SPEED

	ROLL DIAMETER (INCHES)								
	2	4	6	8	10	12	14	16	18
	ROLL CIRCUMFERENCE (INCHES)								
	6.283	12.566	18.850	25.133	31.416	37.699	43.982	50.265	56.549
PRESS SPEED (FT/MIN)	ROLL SPEED (Revolutions Per Minute)								
100	191	95	64	48	38	32	27	24	21
200	382	191	127	95	76	64	55	48	42
300	573	286	191	143	115	95	82	72	64
400	764	382	255	191	153	127	109	95	85
500	955	477	318	239	191	159	136	119	106
600	1146	573	382	286	229	191	164	143	127
700	1337	668	446	334	267	223	191	167	149
800	NA	764	509	382	306	255	218	191	170
900	NA	859	573	430	344	286	246	215	191
1000	NA	955	637	477	382	318	273	239	212
1100	NA	1050	700	525	420	350	300	263	233
1200	NA	1146	764	573	458	382	327	286	255
1300	NA	1241	828	621	497	414	355	310	276
1400	NA	1337	891	668	535	446	382	334	297

Table 7

- Rolls operated at 500–1,000 rpm should be in dynamic balance within 5 ounce-inches.
- Rolls operated at over 1,000 rpm should be in dynamic balance within 2 ounce-inches.

Table 7 converts press speed in feet per minute into roll speed in revolutions per minute for various roll diameters and/or circumferences. *Figure* 94 indicates centrifugal force as a function of roll speed for various units of imbalance in the base roll.

Allowable Total Indicated Runout (TIR)

Table 8 gives allowable total indicated runout (TIR), also called eccentricity, of bearing journals for various rotational speeds.

DEFLECTION OF ROLLS

All rolls deflect, even under their own weight. In addition to the weight of the roll there are other factors, such as web tension, impression loading and out-of-balance forces that cause the roll to deflect. The following discussion is limited to a uniformly loaded roll running at low speed, so that conditions approximate a uniformly loaded beam freely supported at the ends.

The general formula for the deflection at the center of a simply supported roll with a uniformly distributed load is:

$$\text{Maximum deflection} = \frac{5 \times W \times L^3}{384 \times E \times I}$$

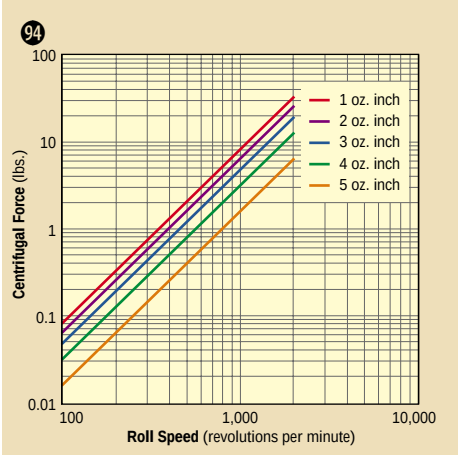
Where:

W= the total load on the rolls in lbs.

L = the length of the roll in inches.

I = the moment of inertia of the roll-body cross-section, a function of the fourth power of the shaft diameter (D^4) in inches.

E = the modulus of elasticity of the roll material in pounds per square inch.



94 Centrifugal force as a function of roll speed for various units of imbalance in the base roll.

ALLOWABLE TIR FOR VARIOUS SHAFT SPEEDS

SHAFT SPEED RPM	ALLOWABLE TIR INCHES	MICRONS
100	0.02000	508.0
200	0.00500	127.0
300	0.00222	56.4
400	0.00125	31.8
500	0.00080	20.3
600	0.00056	14.1
700	0.00041	10.4
800	0.00031	7.9
900	0.00025	6.3
1000	0.00020	5.1
1100	0.00017	4.2
1200	0.00014	3.5
1300	0.00012	3.0
1400	0.00010	2.6

Table 8

Note:

- The amount of deflection varies directly with the load; i.e., doubling the load doubles the deflection.
- Deflection varies directly with the cube of the length; i.e., doubling the face length while maintaining the same total load increases the deflection *eight* times.
- Deflection varies inversely with the moment of inertia of the cross-section.
- The moment of inertia of the cross-sec-

MODULUS OF ELASTICITY OF DIFFERENT ROLL MATERIALS

MATERIAL	MODULUS MILLION LB/SQ. IN.
Steel	30
Cast Iron	15
Copper	14
Brass	14
18/8 Stainless Steel	14
Aluminum alloys	10.0–10.3
Air-Seasoned Fir	1.5*
Air-Seasoned Poplar	1.5*

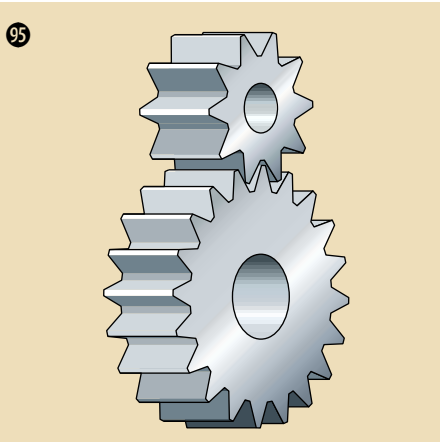
**Varies considerably.*

Table 9

tion varies as a function of the fourth power of the diameter.

- Deflection varies inversely with the modulus of elasticity.

Since a roll is composed of shafts, heads and a body, the cross-section of the roll is not uniform. For practical purposes, the cross-section may be considered to be that of the main roll body, and the face length as the distance between the support bearings. In order to calculate the approximate deflection of a given roll, one must first determine I, the moment of inertia of the roll-body cross-section.



95 Spur gears have straight teeth, which are machined parallel to the rotating axis of the gear, at right angles to the face of the gear.

For a solid roll :

$$I = 0.049 \times (\text{Roll Diameter})^4$$

For a hollow roll:

$$I = 0.049\,(OD^4 - ID^4)$$

Where:

OD = the outside diameter of the roll

ID = the inside diameter of the hollow roll

Table 9 lists the modulus of elasticity for different roll materials. For example, if a roll made of steel tube were to be replaced with a similar one made of cast iron, then the deflection would be doubled because the modulus of elasticity of cast iron is only half that of steel. Similarly, the same roll made of aluminum would have three times the deflection.

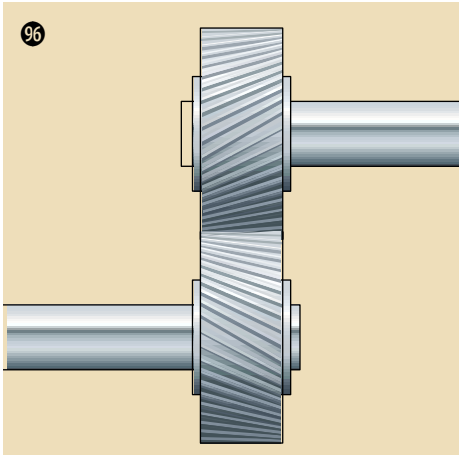
To design a roll of cast iron having the same deflection as a hollow steel roll it would be necessary to double the moment of inertia for the roll body, since the modulus of elasticity is only half that of steel. This design could call for a solid cast iron roll of approximately the same diameter, weighing more than twice the hollow steel roll.

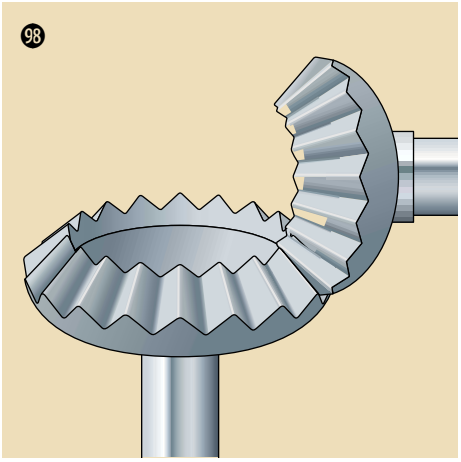
The message here is: Changing rolls within a press, or from press to press is not recommended. Although the rolls may look the same, they may have very different deflection characteristics.

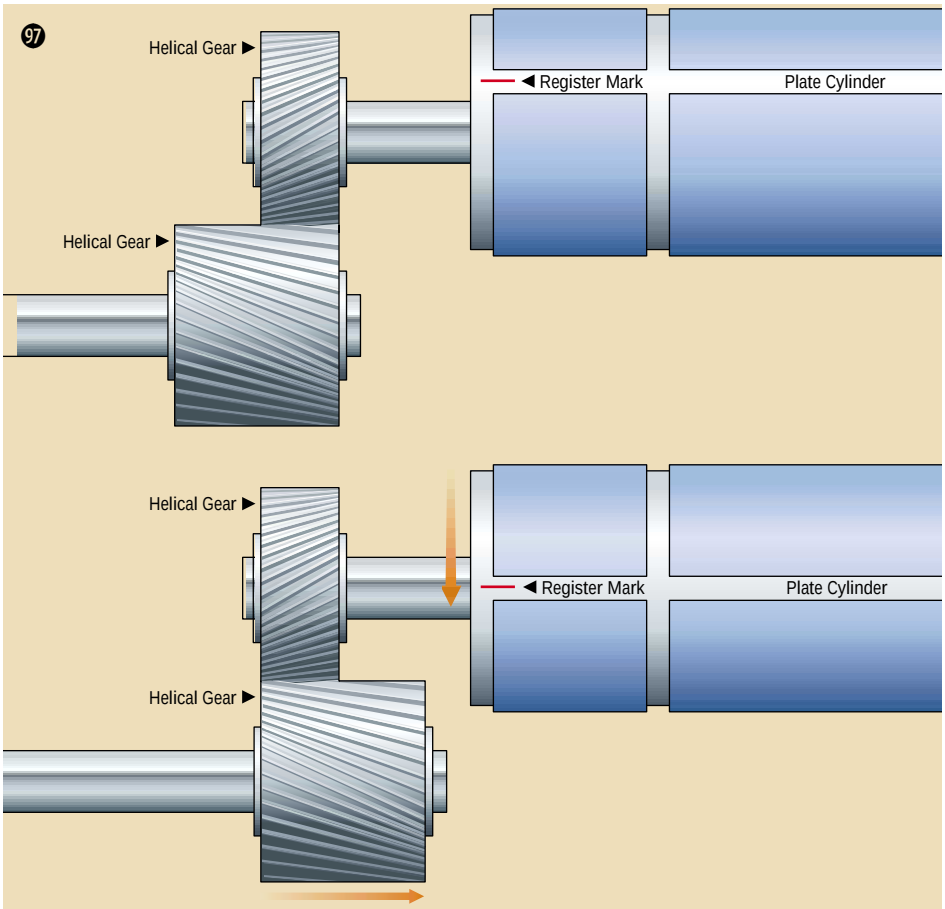
GEAR DRIVES

There are many different types of transmission gearing, but the most common found on flexographic presses are the spur, helical, bevel and worm gears.

Spur Gears. A spur gear has straight teeth, which are machined parallel to the rotating axis of the gear, at right angles to the face of the gear (*Figure* 95). It is the most common type of gear because it is the least expensive. Spur gears are used to transmit power between parallel shafts. They are generally used to transmit power from the plate cylinder to the anilox roller.







96 Helical gears have teeth machined in the form of a helix, at an angle to the gear body. This allows multiple teeth to be engaged simultaneously, providing higher torque loading

97 Helical gear register control between color stations is achieved by lateral movement of the plate cylinder gear relative to the impression cylinder gear.

98 Bevel gears are used to transmit power between two shafts that are at right angles to each other.

Helical Gears. The helical gear (*Figure* 96) has its teeth machined in the form of a helix, at an angle to the gear body. The angled teeth permit the helical gears to have multiple teeth engaged at the same time, allowing higher torque loading. Because of this difference, helical gears can have finer teeth (more teeth per inch or centimeter) than spur gears used to transmit the same torque.

Helical gears are used to transmit power between two parallel shafts. Helical gears are the most common type of gearing used to

drive flexo plate cylinders. They can have smaller teeth than spur gears, require less running clearance and therefore have less backlash. The angled teeth allow for plate cylinder color registration without using additional gears, such as in a differential gearbox. The fewer gears there are in the drive chain, the fewer the gear meshing points and, as each mesh point must contain a degree of backlash, the smaller the total amount of backlash. The result of using helical gears is improved multicolor registration tolerance.

Register phase-shifting between color stations is achieved by lateral movement of the plate cylinder gear relative to the impression cylinder gear (*Figure* 97) The amount of register correction is a function of the helix slope angle and the degree of sideways movement of the gear. This phase shift is limited to approximately two gear pitches in either direction on each print station.

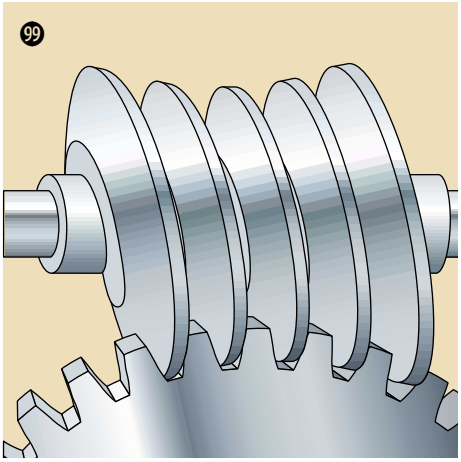
Bevel Gears. Bevel gears are used in conjunction with spur gears as a register control device on the indirect (swing gear) impression-drum drive system. They are incorporated into a differential gearbox, which can change the register of one plate cylinder in relation to the other cylinders. A differential register correction system has an important advantage over the system used on direct drive flexo presses in that it has the ability to rotate the plate cylinder 360° relative to any other cylinder. The helical gear-color registration system used on direct drive presses has a limited correction distance.

Bevel gears are used to transmit power between two shafts that are at right angles to each other (*Figure* 98). Many right-angle gearboxes use two bevel gears, and more sophisticated gearboxes use four bevel gears. Bevel gears are almost never used to directly transmit power to the plate or anilox rollers, because the shafts of these rollers are parallel to the impression-roller shafts.

Worm Gears. Worm-gear sets are used as speed reducers and as right-angle gearboxes. A special type of worm-gear system called the sliding-worm gearbox is used as a registration device on some types of printing presses. Worm gears are never used to propel the plate cylinder on flexo presses, but they are used in other locations on the press such as for print deck impression control.

Right-angle, speed-reducing gearboxes use worm gears, which consist of a worm shaft and a worm gear (*Figure* 99). The worm shaft is a cylindrical gear with a special screw profile machined to mesh with the round worm gear. The worm gear is a special type of round gear with teeth that are concave to match the profile of the teeth on the worm shaft. More than one tooth may be meshed together in a worm-gear assembly and the number of meshed teeth is determined by the number of helical threads on the worm. The multiple meshing of teeth provides maximum torque transmission, as compared to spur and bevel gears.

Gear Materials. Gears are made from many different materials. The bull gear, which is mounted on the impression drum, is usually made from cast iron with surface-hardened teeth. The anilox and fountain roller gears are usually made from steel or hardened cast iron, although some presses use synthetic gears for these purposes. The plate-cylinder gears can



99 The multiple meshing of teeth in a worm gear provides maximum torque transmission, as compared to spur and bevel gears.

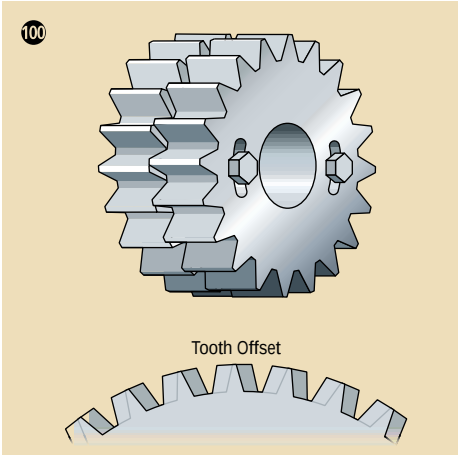
be made from annealed steel or synthetic composite materials.

The press manufacturer specifies all gears, except those for the plate cylinder. The flexographer can select the type of gear material for his plate cylinders. The plate-cylinder gear must be softer than its drive gear, so that it will wear out first. It is easier to replace a plate-cylinder gear than a bull gear or other internal machine gears. Many flexographic printers prefer synthetic composite or plastic plate cylinder gears because they help reduce drive gear vibration and shock waves.

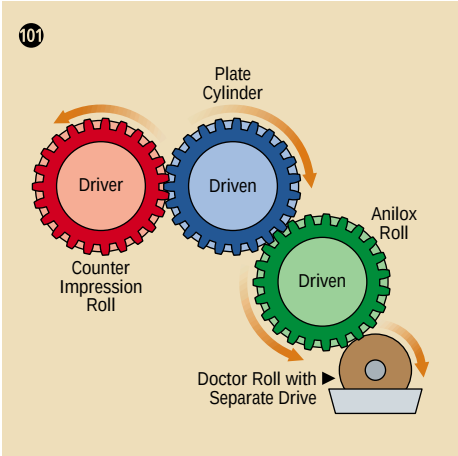
Gear Backlash. There must be a small amount of space between meshing-gear teeth to allow them to mesh correctly with sufficient lubrication and to become engaged and disengaged easily. However, gear wear will increase this space, and the amount of backlash in any set of gears gradually increases.

Excessive backlash is a condition in which there are larger-than-normal spaces between successive gear teeth, normally caused by incomplete meshing or tooth wear. Backlash is detrimental to high quality printing and can occur on all types of gears. Backlash allows the position of the driven cylinder to change in reference to the drive cylinder, which in turn causes misregister. The number of gears in the drive chain multiplies this register error. Excessive backlash makes it impossible for the operator to maintain accurate multicolor register and therefore it is essential to replace one or both gears in a set that has developed excessive backlash. Vibrations associated with backlash also increase plate bounce and other print quality problems.

There are two types of gears that allow maintenance personnel to remove all excessive backlash without having to remove or replace the gear set; these gears are collectively known as anti-backlash gears. An anti-backlash gear consists of two narrow width gears whose angular position can be changed so that there is less space between each tooth. The screws on the side are loosened, and one thin gear is shifted or offset, as indicated in *Figure* 100, to remove excess backlash. Another type of anti-backlash gear is the sliding-worm type, which also allows for the removal of backlash without removal of the gears.



100 An anti-backlash spur gear is actually two gears. By changing the position of one relative to the other, tooth spacing can be altered, thus removing excess backlash.



101 On a gear-driven press, constant speed between all rollers is ensured since a main roller delivers power to all the rolls.

Gear Train. The impression cylinder (drum or roller), the plate cylinder and the anilox roll all must rotate with exactly the same surface speed as the web speed in the flexographic printing process. If any of them is turning at a slightly different rate, there will be severe printing problems as well as excessive plate wear. On a gear-driven press, matching the speed of these three rollers with the web is accomplished through the use of a gear-train power transmission system (*Figure* 101). Typically, the power is

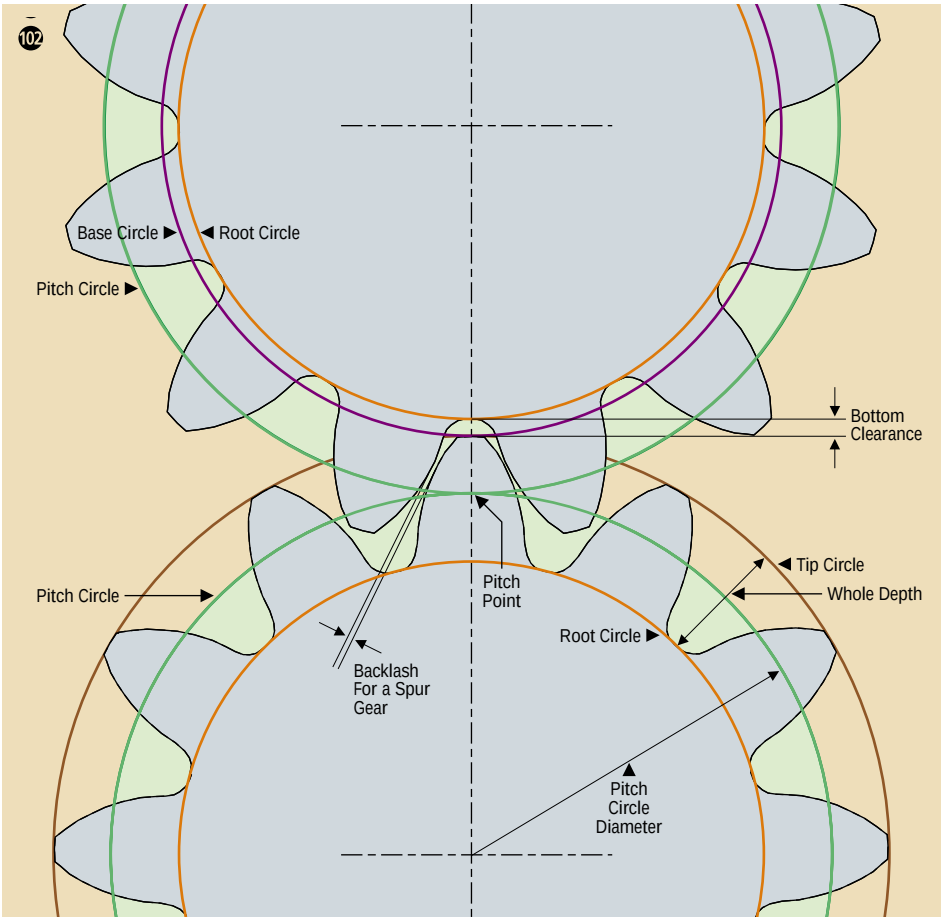
delivered from the main motor to the impression rollers or drum by a single drive system. A separate gear-train transmission on each printing deck then delivers the power from the impression roller to the printing and anilox rollers; the pitch of the gears on all three rotating parts is the same. A separate drive motor generally drives the inking or fountain roller.

The diameters of all impression, printing and inking rollers must match the pitch diameter of the gear that propels them. Pitch diameter is the diameter at which the gears operate, not the internal or external diameter of the teeth. The pitch diameter of a gear is represented by the shaded portion of the bottom gear in *Figure* 102.

It is extremely important that the gears always operate on their pitch diameter, because if they do not they can create a speed mismatch and/or vibrations that will cause print quality problems and excessive plate wear. It requires correct printing-plate mounting and a skillful press operator to set all of the gears on the moveable anilox and plate rollers so that they turn on their exact pitch diameters. If one gear is set past the pitch diameter, it will cause that roller to rotate at a slower speed than desired. Conversely, if one gear is meshed before the pitch diameter position, the roller that it drives will rotate faster than desired.

Repeat-length Increment

On a direct gear driven press, it is not possible to have a different gear pitch on the



102 The diameter at which the gears operate (the shaded portion on the bottom gear) is the pitch diameter of the gear.

impression drum or rollers than is used to drive the plate and anilox rollers. Therefore, the printing repeat-length of a flexo press can only be changed in increments that are equal to the pitch of the gearing driving the plate cylinder.

Gear Measurement. Gear pitch is the distance measured from the same point on each tooth of adjacent teeth on a gear, and is measured along the pitch diameter of the gear. Incremental increases in printing repeats on gear-driven presses is restricted to the distance between the teeth, or gear pitch.

The three methods for specifying gears are:

- **Circumferential Pitch.** The circumferential pitch (CP) of a gear is obtained by dividing the pitch-circle circumference of the gear by the number of teeth on the gear.

$$\text{CP} = \frac{\pi \times \text{PITCH CIRCLE DIAMETER}}{\text{NUMBER OF TEETH}}$$

- **Diametral Pitch.** The diametral pitch (DP) of a gear is obtained by dividing the number of teeth on the gear by the pitch-circle diameter of the gear in inches (in).

$$\text{DP} = \frac{\text{NUMBER OF TEETH}}{\text{PITCH CIRCLE DIAMETER (IN)}}$$

- **Module Pitch.** The module pitch of a gear is obtained by dividing the pitch circle diameter of the gear in millimeters (mm) by the number of teeth on the gear.

$$\text{MODULE PITCH} = \frac{\text{PITCH CIRCLE DIAMETER (MM)}}{\text{NUMBER OF TEETH}}$$

The most common gear used on a flexo press is a 0.25" CP. This gear has spaces of 0.25" between adjacent teeth, measured along the circumference of the pitch diameter of the gear. The next most common pitch for flexo gearing has increments between the teeth of 0.125". The most common diametral pitch gear is 10. This means there are 10 teeth for each 1" of diameter and increments of 0.314" (10/in DP) between adjacent teeth, as measured along the circumference of the gear-pitch diameter.

From the above formulae, given the specification of the gear (Module, DP or CP) and the number of teeth on the gear, it is a simple calculation to find the rolling diameter of the associated cylinder or roll. Tables are given for reference in the *Appendix*.

Pitch and Bare Cylinder Diameters. When a gear is mounted on the shaft of a plate cylinder (*Figure* 105), the printing diameter of the combined plate, mounting system and bare cylinder must match the pitch diameter of the gear. Therefore, the printing diameter is the diameter of the bare plate cylinder plus twice the thickness of the mounting system and plate. For example:

A customer requires an image on a 16" printed repeat;

- This repeat length would require a 64-tooth gear with 0.25" CP;
- The pitch diameter of the gear would be 5.093";
- The press uses 0.107" plates mounted with 0.020" foam tape for a total thickness of 0.127";
- The bare plate cylinder diameter would be 5.093"−(2 × 0.127")=4.839";
- Include 0.002" for plate squeeze (this will increase the diameter), for a final diameter of 4.839” + (2 × 0.002") = 4.843".

Plate-squeeze Allowance. In order to transfer ink from one cylinder to another in the flexo process there must be some squeeze between the plate and the anilox or impression roll. If the mounted plates and the plate cylinder were exactly the same size as the pitch diameter of the gear there would be zero printing pressure (plate squeeze) when the gears were correctly set to turn on their pitch diameters. The operator would not obtain good printing across and around the cylinder and would need to increase the printing and inking pressure by moving the

103 When a gear is mounted on the shaft of a plate cylinder, the printing diameter of the combined plate, mounting system and bare cylinder must match the pitch diameter of the gear. Notice the horizontl lines extending across the printing plate align with the pitch diameter.

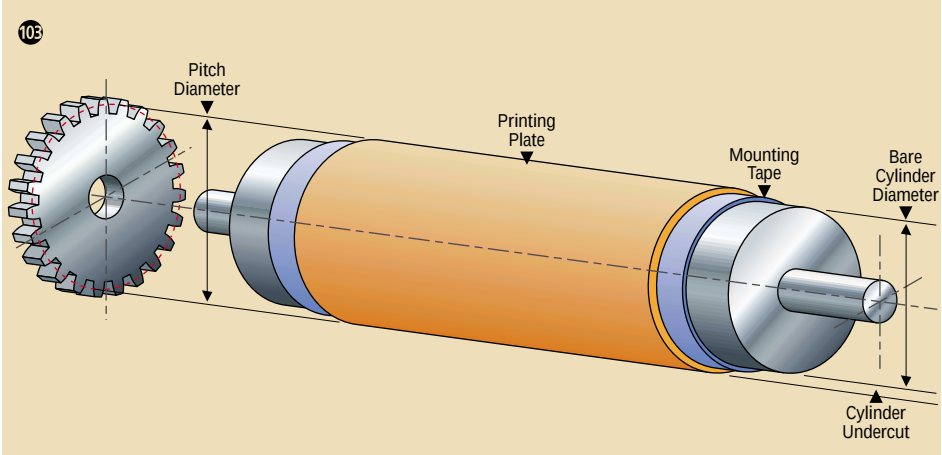


plate cylinder closer to the impression drum and anilox roller. This move would force the plate-cylinder gear to over-mesh with the other gears (running under the pitch diameter), causing vibrations and typically "gear striped" printing.

To overcome this problem, flexographic printers allow for plate squeeze, by either increasing the diameter of their plate cylinders, or by increasing the overall plate mounting height. The typical plate-squeeze allowance is approximately 2% of the overall plate height, including the mounting tape.

Gear Mounting

The gears that drive the plate cylinder and the anilox roller are mounted on their respective shafts. The gear driving the anilox roller is mounted permanently, on a one-way (Sprag) clutch to allow for continuous rotation of the anilox when the print cylinder is stationary. The gear on the plate cylinder shaft can be mounted permanently or temporarily.

Gears are precise parts of the flexographic printing system, and if they become damaged or worn they will affect print quality and register. Many presses are equipped with removable plate cylinders and when several sets of cylinders have the same diameter, to save money on gear sets, some flexographic printers mount the gear temporarily on the plate cylinder shaft and then remove it when the job is finished. However, temporary mounting of plate cylinder gears creates faster tooth wear (because the gears are used more frequently) and increases the possibility of damaging the gears during the transfer from shaft to shaft.

It is common to see temporarily mounted gears with excessive wear cause backlash and poor register, and succumb to broken teeth, nicks and other damage marks. Any faults in the plate cylinder gear are transmitted to a second gear on the opposite side of the plate cylinder, which delivers power to the anilox roller. For these reasons, it is recommended that the gear that drives the plate cylinder be permanently mounted.

A minority of flexographic printers mount the gear permanently on the plate cylinder shaft; that gear is used only when the plate cylinder is printing a job. This method reduces the wear and potential damage to the gears. While it may be more expensive to purchase a gear for each plate cylinder, it saves money in the long run by reducing makeready time, color register and generally improving the print quality.

Gears and In-line Processing

The vast majority of flexographic presses with diametral pitch (DP) gearing use 10/in

DP in favor of a metric gear scale module, even though the press may have been made or used in countries that use the metric system. The reason for this choice is that the U.S. standard of 10/in DP has been universally accepted in the paper bag industry. Paper bags and related products that employ continuous web in-line processing are made almost exclusively with diametral-pitch flexo presses. With the in-line process, when the printed web is processed in a continuous motion, the pitch of the gears on a flexo press must match the gear pitch of the secondary machine. If the secondary machine has an intermittent web flow, the gearing on the two machines does not have to match. Almost all intermittently fed secondary machines use a photoelectric detection system to register the printed web with the secondary finishing.

Because of the difference between the circular pitch of the respective gears it is impossible for a flexo press with circumferential pitch gears to match the printed image length of another flexo press with diametral pitch gears, and vice versa. In addition, diametral pitch gears and circumferential pitch gears are not interchangeable.

Dual-gear Systems

One of the most difficult decisions to make when purchasing a flexo press is the selection of the gear pitch, or the repeat increments, of the press. Most flexo presses can only be purchased with one gear system, for example 0.25" CP, 10/in DP or 5 mm module. A few common impression flexo presses are built with dual gearing; that is, they can print in either of two gear pitch (increment) systems, such as 0.25" and 10/in DP, or 5 mm module and 4/cm pitch. The impression cylinder must have a diameter that equals the pitch diameter of the gears used to turn them. If a dual pitch of 0.25" and 10/in DP was desired on a direct-drive press, the impression cylinder might have a 60.001" diameter and a 188.5" circumference. The bull gear used to turn the impression cylinder would have 754 teeth .025" CP. The cylinder would have a second bull gear 600 tooth 10/in DP with a 188.52" circumference, attached to the first one. Both of these gears would have approximately the same pitch diameter as that of the impression cylinder (CP gear = 60.001" diameter; DP gear = 60.008" diameter). With dual-gear systems, the choice of impression cylinder diameter must always be a compromise between the combination of CP and DP gear diameters.

Central-Impression Press Drives

For CI presses there are essentially two types of gear drives, the direct drive and the quadrant drive, sometimes called a swing gear.

Direct Drive. In the direct drive, a large bull gear is usually mounted on the outside of the frame, with a pitch diameter equal to the diameter of the central impression cylinder. Typically the bull gear is a helical gear. The plate cylinder gear, also a helical gear, is fastened to a female spline and the assembly is attached to a circumferential register mechanism. A male spline fixed to the plate cylinder journal will fit inside the female spline. With this arrangement, the plate-cylinder gear can slide back and forth on the male spline to effect the circumferential register without affecting the plate cylinder's side register. The opposite end of the plate cylinder is fastened to the side register mechanism.

A direct-geared press maintains good print register from one color to the next. This registration accuracy is possible because there are fewer gears in the gear train and any inaccuracies machined into the gear train will repeat themselves on the same tooth of each color station.

Direct-geared presses also have several disadvantages. Since the central-impression cylinder diameter is usually locked into the pitch diameter of the bull gear, any damage to the surface of the cylinder once meant

serious modifications to the gear system. Today, there are ways to repair the drum surface quite satisfactorily.

The plate cylinder's impression setting is made to accommodate the web thickness and any plate variation. Once the ultimate impression setting has been achieved, the amount of backlash between the plate cylinder and the bull gear is a factor that must be accepted. There are times when this excess backlash can cause bounce problems.

Because of the amount of hardware involved in driving the plate cylinder, on some press designs the job changeover time could be slightly longer on a direct-geared press. To overcome these productivity problems, spare plate-cylinder gears are recommended. Mounting them on the cylinder in a pre-makeready area eliminates setup times.

Quadrant-geared Press. On a quadrant- or swing-geared press, the bull gear does not come directly in mesh with the plate cylinder gear. The bull gear is still a helical gear but, in this case, a pinion gear mounted on a cross-drive shaft (usually inside the frame) drives a compound spur gear on the outside of the frame. A spur-type swing gear then meshes with the compound gear after the impression of the plate cylinder has been made.

Circumferential register is achieved by lateral adjustment of the cross-drive shaft. The pinion helical gear will be forced to rotate on the bull helical gear, while the compound spur gear will simply slide back and forth on the swing gear. The plate cylinder gear is clamped directly to the plate cylinder journal. Very few of this type of CI press are being manufactured today.

There are a couple of advantages to this type of press. The backlash between the plate cylinder and the swing gear can be minimized. The impression cylinder diameter is not locked in as tightly to the bull gear pitch diameter in the event of drum damage. The positioning of the gears eliminates the need for modifying the gear train for each setup. Also, the elimination of the circumferential register mechanism associated with a direct-geared press streamlines plate cylinder installation. These advantages can result in shorter setup time on a quadrant-geared press.

The quadrant-geared press has some notable disadvantages as well. The register between the groups of print stations on either side of the press cannot be maintained as closely as on a direct-geared press due to the location of the pivot point of the swing gear assembly. But register between the individual print stations within the group can be maintained with greater register accuracy.

Line-shaft Drives

A line-shaft driven press has a distinct advantage over straight gear train-driven machines in that gear backlash from print unit to print unit is not cumulative. A rigid line shaft drives each printing cylinder through a worm or bevel type right angle gearbox. If one discounts some slight torsion forces on the line shaft, it becomes apparent that only one gear backlash per printing unit enters into account. In theory this means that the gear backlash of only one printing unit determines the overall print register tolerances.

Digital-servo Drive

The newest approach in drive technology on printing machines is the servo drive, whereby each printing unit has a separate drive motor, or motors, that are controlled electronically to rotate at a synchronized speed with each other. With this technology, the angular position of the print cylinders can be controlled with incredible accuracy. The scale of register accuracy obtained with these digitally controlled systems is in the region of thousandths of an inch.

Some manufacturers go as far as driving every shaft on each printing unit with a separate motor, while others have one motor per printing unit.

Servo-drive technology has truly opened new horizons in the flexibility of flexographic printing presses. For example, digitally controlled automatic print registration is common and, theoretically, repeat lengths are infinitely variable.

BEARINGS

Webster's defines a bearing as an object, surface or point that supports, or a machine part in which (as a journal or pin) turns another part. From an engineering standpoint, a bearing is a device that accepts motion, combats friction and wear, and supports the load.

Bearings are of two design groups: plain (sleeve type) and rolling-element (anti-friction), with many variations in each group.

A plain or sleeve bearing accepts motion directly on the stationary support. Friction occurs between the two bearing surfaces or within a lubricating film between surfaces. The rolling element bearing is one in which motion and load are accepted by rolling elements located between a moving element and a stationary support element. Rolling element bearings generally offer a wide range of features and performance characteristics.

Plain-sleeve Bearings

A plain bearing is a simple device for providing support and radial positioning, while permitting rotation of a shaft. It is the oldest bearing device known to man. A plain bearing provides simplicity, low cost and short distance from shaft centerline to bearing base. It is usually limited to heavy radial loads and slow-to-moderate speeds. When properly installed and with correct lubrication, excellent bearing life will result.

Plain bearings are generally made of a bronze alloy, and selection of a proper alloy for a given purpose is very important. In the selection of the bearing alloy, it is necessary that the service conditions and operating factors, such as speeds, loads, operating temperatures, lubrication and the presence of foreign materials, first be analyzed. Only then should the bearing alloy be selected, so that its outstanding properties will be to the greatest advantage.

A plain-sleeve bearing is inherently quiet in operation because it has no moving parts. With proper selection, installation and lubrication, it does not fail suddenly. Wear is gradual, and replacement of worn bearings can be scheduled when equipment is normally idle. Sleeve bearings, like all other bearings, must be properly selected and used with control of shaft tolerances, housings, mounting or installation procedures and lubrication.

Bearing alloy selection is generally a compromise of the following essential characteristics:

- conformability;
- wear resistance;
- coefficient of friction;
- load carrying capacity;
- resistance to pounding; and
- fatigue resistance.

Plain-sleeve bearings find limited use on modern flexographic presses. They are commonly used as plate cylinder bearings, although the recent trend has been toward anti-friction needle bearings. Some central impression presses use plain bearings to support the impression cylinder. Plain bearings are commonly used in the bore of idler gears and gear trains where limited space restricts the use of anti-friction bearings.

The sleeve bearing, when used for plate cylinders or central impression cylinders, must be fitted with precision accuracy. As with all bearings, the outside diameter must be concentric with the inside diameter, otherwise, cylinder run-out will occur. Very careful bearing and shaft alignment is an absolute necessity. Running clearance must be proper for trouble-free operation.

Running clearance in sleeve bearings is

the amount of space between the shaft and the inside dimension of the bearing. This space accommodates the lubricant, permits the formation of the protected oil film preventing metal-to-metal contact when in operation, and allows for expansion due to temperature rise. The running clearance for most cylinder applications is 0.001" to 0.002" (25 μ to 50 μ).

Assuming a proper bearing selection has been made, the installation and lubrication of the bearing are the most critical factors in its serviceability. Adequate lubrication, preferably on an automatic program basis, must be provided. Operating environment, and to a great degree, common sense and consideration of the way a bearing functions will influence the service life of precision sleeve bearings.

Rolling Bearing

A rolling-element bearing consists of four basic parts:

- inner ring (inner race);
- outer ring (outer race);
- rollers or balls; and
- retainer or separator.

Three of these parts, the inner ring, the outer ring, and the rollers or balls, support the bearing load. The fourth part, the bearing retainer, serves to position the rolling elements.

Rolling element bearings can be grouped into five standard forms, each having a number of variations. These forms are:

- ball bearing;
- tapered-roller bearing;
- straight-roller bearing;
- ball-thrust bearing; and
- needle-roller bearing.

All of the components and roller element bearings are made of hardened steel. Selection of material and control of material quality are critical in the manufacture of roller-element bearings. The theoretical stress obtained in a rolling contact may exceed 400,000 lb/in^2. Bearing steel must be the finest available through current metallurgical technology. It must possess high strength, toughness, wear resistance and dimensional stability, and be free from internal defects.

A modern flexographic press uses many rolling element bearings. Bearings of all five standard forms are used. Some press manufacturers mount their central impression cylinder on precision-selected taper roller bearings that have a total indicated run-out of less than 0.00017". A tapered-roller bearing is ideally suited to carry all types of loading: radial, thrust and any combination of both. The rollers and races of a tapered-roller bearing are built on the principle of a cone. All lines coincident with the working surfaces of rollers and races meet at a common point on the bearing axis. Thus, the tapered roller bearing handles all loads: radial, thrust and any combination of both.

Most idler rollers rotate on roller bearings. Depending on use and location, the bearings may be of open-type construction or sealed and permanently lubricated. Roller bearings, for some applications, may be mounted in housings or pillow blocks.

The idler rolls located in the press dryer usually require a special type of roller bearing, since, because of their location, they will be subject to temperatures above their heat-stabilized range. Standard bearings are usually heat-stabilized within a range of 275° F to 325° F to minimize growth of the bearing over a period of time. If bearings are to operate above this range, then bearings that have been heat-stabilized at a higher temperature should be used. Heat stabilization will prevent bearing expansion and possible loosening of the bearing on the shaft.

All motors are fitted with roller element bearings. These motor bearings generally have special characteristics, since they are

subject to continuous high operating speeds and elevated temperatures. Most motor bearings have the capacity to absorb moderate-to-heavy thrust loads. It is important that the manufacturer's recommendations for servicing this equipment are followed, and no attempt to substitute, in case of bearing failure, should be permitted. Replacement parts should always be identical or equivalent.

Needle Bearings

Plate-cylinder journals are commonly supported by needle bearings. A needle bearing is a full-complement roller bearing that has rollers with a small diameter-to-length ratio, and uses controlled circumferential clearance rollers. In this application, it is necessary that the plate cylinder journals be hardened, bearing-quality material, since the journals become the bearing inner race. In most cases, the hardened bearing journals are a permanent and integral part of the plate cylinders.

Needle bearings have three distinct advantages:

- They have high capacity ratings – greater than those of a single row ball or roller bearings of comparable outside diameter.
- They permit use of a larger shaft in a given application.
- They provide anti-friction characteristics in a small cross-section.

Bearing Care and Use

All bearings, plain or roller element, must be treated and handled as precision components, which they are. Bearings are produced with care and must be handled with care. The operational life of a bearing is governed by many external factors and influences, which include bearing installation, maintenance and lubrication. Ball and roller bearings are especially susceptible to damage during installation. Proper bearing installation is the most critical factor in a successful bearing application. Bearings must be kept clean; dirt means damage.

Press Maintenance

This chapter, as well as other chapters of this book, covers the subject of tolerances and defines the extremely close accuracy required in all phases of the flexographic process in order to produce top-quality printing at optimum press speeds.

REALITIES OF WEAR ON PERFORMANCE

The tolerance requirements spelled out for the flexographic press and its various components relate to a new press as it is delivered by the press builder to the converter's plant. A flexographic press is a machine with many moving parts and even the finest mechanical assemblies and materials are subject to continual wear. Continual and uninterrupted counter-measures are necessary, not only to maintain the original accuracies but also to forestall major press breakdowns, which are almost always due to lack of day-to-day care.

The most effective countermeasures consist of a program of organized and preventive maintenance, an example of which is defined and outlined in the following paragraphs. First, consider not only the advantages but also the absolute necessity of a well-organized and conscientiously followed maintenance program.

BREAKDOWN MAINTENANCE

Many companies still depend upon a system of breakdown maintenance to keep their equipment running. The press is run day-in and day-out with the bare minimum of routine maintenance until an actual breakdown occurs. The reasoning behind that is, with the cooperation of the press supplier, emergency repairs that now become necessary can be made with little loss of production.

The reasons generally advanced for this type of maintenance, or lack of it, are that personnel are not available to carry out a thorough preventative maintenance program, or that it is the cheapest way to keep a press running, or both. However, even a cursory analysis will show the more obvious fallacies of this reasoning.

Since press breakdowns hardly ever occur while the press is standing idle or at some other convenient time, every minor or major breakdown results in unscheduled press downtime. The cost for press time alone may run as high as $400 or more per hour, which does not include the actual cost of production losses, as well as the intangibles, such as the loss of customer good will due to late deliveries, the need to reschedule subsequent runs and all the additional irritations that are always part of a press breakdown. It becomes quite apparent, even at this point, that the scale measuring the cost of preventing breakdowns rather than curing them is quickly being tipped in favor of prevention.

There is a further effect of this breakdown maintenance system that is not as readily apparent, nor as simple to evaluate cost-wise. Over the years, however, its corrosive effect will be many times more costly than even a series of breakdowns. All mechanical parts are subject to wear, no matter how small they may be, over any given period of time. Normal wear is tremendously accelerated by improper or haphazardly performed maintenance.

This wear may not be noticeable from day to day or even from month to month. Nevertheless, under these conditions the original tolerances of many press components are gradually but consistently being degraded with a simultaneous and proportional loss of press efficiency and print quality. These effects may not become fully apparent until a long-range comparison of production quality control charts reveals the sobering fact that on any particular print job, the quality has veered away from the desired standard until the standards cannot be met unless the press is operated at reduced speeds or by other less profitable operating means.

Since breakdown maintenance consists of a series of emergency and stopgap measures that must be handled when they occur, and not during convenient off hours, it becomes apparent that this method is entirely inadequate to keep a press consistently running at optimum speeds. Also, from a cost perspective, this approach is not in proportion to the temporary results it achieves.

PREVENTIVE MAINTENANCE

An organized maintenance program is well planned, supervised, and conscientiously and consistently carried out. This type of program will provide not only for complete day-to-day routine maintenance, but will anticipate and eliminate a majority of the causes of press breakdowns through periodic inspection and necessary correction of all press components. Only by organizing all facets of maintenance and incorporating them into production scheduling is it possible to achieve the ultimate goal of every printing plant: to keep the press running at its highest efficiency, at an accurately predictable hourly cost, without unscheduled stoppages due to breakdowns.

Management Responsibility

Organizing press maintenance is a management responsibility. Organized preventive maintenance represents a basic opportunity for increasing plant efficiency by keeping equipment running at optimum production speeds with minimum unscheduled stoppages. It must, therefore, be rightfully classified as a major factor in cost control. Just as management considers cost control one of its primary functions in all phases of the business, it must also consider press maintenance as highly desirable and necessary, and must exercise good management techniques to implement preventive maintenance programs.

In order for preventive maintenance to work, management must support its maintenance program with an adequate budget for personnel and material. Materials should not only include day-to-day requirements, such as lubricants and other items of routine maintenance, but also a spare-parts inventory. Reasonable amounts of those press parts that are expected to wear in the normal course of operation, and those that experience has shown may be subject to sudden failure, must be carried in inventory. The cost of such an inventory of spare parts will be made up quickly if even one item is available at pressside immediately when it is needed.

Management must delegate and define maintenance responsibilities, clearly and unquestionably. A sufficiently large plant may warrant the employment of a full-time maintenance engineer who will be entrusted with planning a detailed maintenance program, delegating specific duties under the program to available personnel, and hiring additional personnel if necessary. The maintenance engineer must also keep a constant watch to ensure that the maintenance program, as defined and initiated, is being carried out. The engineer must implement and change the program as the machinery and product mix changes with plant growth.

In a smaller plant, the production or plant manager may be assigned the responsibility of planning and executing the maintenance

program. However, whether the plant is large or small, the important fact is that management must recognize the need for planned preventive maintenance and initiate an appropriate maintenance program with direct line responsibility given to the proper individuals to carry out the program effectively.

Communicating Maintenance Needs

Equally important to the establishment of an effective preventive maintenance program, is a proper means of communication between management, maintenance personnel and the press operators. Press operators are the most important people in any maintenance program, as they alone have day-to-day contact with the machinery and are the first to detect any abnormal press conditions. The press operators must have a person with whom they can communicate simply and directly as to any condition that they feel may hinder press performance. They must also have the assurance that the reporting of these conditions will bring about prompt and decisive action.

A printing press is in its best condition the day it is installed on the press manufacturer's floor and tested. From that day on, all further operation of the press tends to deteriorate the equipment. Therefore, to keep the equipment running as specified by the manufacturer, it is necessary to install the machinery correctly and maintain it properly.

AREAS OF PROPER MAINTENANCE

If proper press maintenance were easy, there would be little need for discussion of the topic. Unfortunately, maintenance is not a simple task. There are quite a few practices that should be carried out on a regular basis, and in the correct fashion.

Installation

A good maintenance program begins with installation of the machinery. Poor installation of the press in a converter's plant can seldom be overcome by even the finest maintenance program. The press should be installed on a solid, level foundation of sufficient strength to carry the weight of the press and accessory equipment, as specified by the press manufacturer.

The press must be installed and assembled perfectly level. Modern high-speed roll printing equipment should only be installed under the supervision of a factory-trained technician. Smaller press equipment should at least be checked out by the press builder's technician before it is placed in operation.

Utilities

Flexographic printing presses require some or all of the following utilities at pressside: electric power, gas, cooled or refrigerated water, an air supply and exhaust ducts, and compressed-air lines. The lines and sources of power and other services must have sufficient capacity as specified by the press manufacturer. Electrical and gas equipment must comply with local safety ordinances and the underwriter's requirements.

Most press suppliers will furnish a detailed floor plan of their equipment showing where the sources of supply must be located. It is best to have these items taken care of in advance of the actual press installation in order to reduce installation time. A pre-installation survey and program will ensure that the installation is "clean" and not a series of uncoordinated supply sources, which may impede the efficiency of the press during operation.

Lubrication

Lubrication is an essential element of maintenance if maximum performance and life is to be realized from any bearing. In a correctly operating bearing, a thin film of lubricant separates the rotating member from the stationary member. This film should

be of sufficient thickness to prevent contact of the metal surfaces. Contact of the metal surfaces will result in overheating, wear, scoring and possible seizure. Providing the wear-preventive film is a primary function of the lubricant. Lubricants also provide:

- protection from corrosion;
- dissipation of heat;
- exclusion of contaminates; and
- the flushing away of wear products.

Lubricants are generally recommended by the bearing manufacturer. These recommendations should be strictly followed for peak performance and maximum bearing life. Lubricants are classified as:

- greases;
- oils;
- sythentic lubricants; or
- dry lubricants.

Greases. Grease is a combination of petroleum oil and a suitable thickener. Thickeners can range from 3% to 30% of the composition, or more. Grease is critical to bearing performance. It must be properly selected to fit the application requirements; it must be utilized in a properly developed maintenance program to accomplish the expected performance of any particular mechanical system.

Oils. This fluid lubricant is generally more versatile than grease and suitable for severe applications involving extreme speeds and elevated temperatures.

Synthetic Lubricants. Synthetic lubricants usually permit a broader operating temperature range and provide good lubrication at high or low temperatures, beyond the limits of petroleum lubricants. Most commercial applications of synthetic lubricants are associated with extreme temperature conditions. Synthetic lubricants are extremely expensive, with costs ranging from double to over 100 times that of petroleum lubricants.

Dry Lubricants. Dry lubricants have been used for many years in either powder or colloidal suspension form. Dry lubricants are commonly used in applications involving high temperatures and extremely slow speeds.

Lubrication: An Overview

The three major factors that determine suitability of a lubricant for a particular application are the rotational speed of the bearing, the load it must support and the temperature at which it operates. In most instances, a standard petroleum lubricant will suffice. However, under conditions in which any of the three three factors are extreme in their requirements, petroleum with special additives or a synthetic are available.

PM Lubrication. Preventive maintenance programs are considered by some as “oiling campaigns.” It is true that proper lubrication of rotating components is an absolute necessity for proper maintenance, but it is not the only function of a preventive maintenance program. However, no discussion of preventive maintenance would be complete without discussing the lubrication procedures for most presses.

Generally required are three basic types of lubricants: oil, grease and gear grease. Press manufacturers furnish a lubricating chart with their equipment, specifying the type and grade of lubricants to be used. It is important that no deviation be made from these specifications, since the suppliers of lubricants have done much in the way of specialization in recent years. Every reliable press builder works closely with one or more oil companies to determine the most efficient lubricants for individual press components.

To ensure systematic lubrication, either a separate lubrication chart or one that is included in the general maintenance checklist should be used. A simple method to ensure correct lubrication is to color code the various lubrication points in accordance with the type of lubricant that is to be used. For instance, color code red for oil, blue for grease, etc.

Anti-friction or Rolling Bearings. In general, ball or roller bearings must be greased, never oiled, since oil will not cling to the balls or rollers and give adequate lubrication. However, some ball bearings on guide rolls are specifically designed to run with a fine silicone-type oil lubricant. In this case, the bearing retainer seals will have been removed to allow the oil access to the bearing. It is especially important that this type of bearing be oiled with the proper lubricant on a regular basis to ensure that it is not contaminated with dirt or grease, which will impair its efficiency and life.

Other bearings should be greased at least once a week. Special attention should be paid to any bearings in the vicinity of the ink fountains, not only to ensure that they are properly lubricated and full of grease, but also to ensure that they have not become contaminated with spilled ink, dust or dirt. Keeping a supply of spare bearings for anilox and rubber fountain roll shafts is a good practice.

Sleeve Bushings. Bushings require daily care and should always be oiled with the grade of oil specified. They should not be greased, since grease is not free-flowing enough to properly distribute itself in the bushings or sliding bearing. Bushings should be oiled at the beginning of each work shift and again after approximately four hours of running time. If the bushings are automatically lubricated by pre-regulated oiling, care should be taken to ensure that the master oiling system is functioning and that it has a sufficient supply of oil to operate during the pressrun.

It is a good practice to keep at least one set of spare plate-cylinder bushings or bearings on hand. These bushings should be replaced as soon as they show any sign of excessive wear or play.

One-shot Oilers. Many presses have been equipped with one-shot oiling systems. These systems will lubricate all, or a major part, of the bushings and sliding bearings on the press by manual or automatic operation of one or more of the oil pumps on the press. A one-shot oiling system greatly simplifies proper periodic lubrication, but it is not an automatic guarantee that all lubricating points attached to this system will actually be oiled. In other words, all lubricating points incorporated in the one-shot oiling system should be periodically inspected to be sure that they are actually receiving oil and that the system has not become clogged or inoperative in some sections.

Because of the problems inherent in one-shot oiling systems and the fact that they tend to over-oil some areas of the press, there has been a trend back to the manual oiling system. Here again, it is necessary that a proper periodic maintenance program be set up so that each point on the press that must be oiled is carefully inspected and oiled at periodic intervals.

Open Gears. Open gears are usually lubricated with gear grease applied either from a brush or paddle and should be greased at least once every four weeks. Special attention should be paid to the gears on or in the vicinity of the printing stations. These gears have a tendency to collect ink between the teeth, which may not only cause premature wear or breakage, but will, in the interim, prevent them from running on their true pitch line.

Closed Gear Boxes. Beveled or spiral gears should be properly enclosed in gear boxes, as the centrifugal forces on these gears are such that they will quickly rid themselves of even heavy gear lubricants. All gearboxes need only be kept filled to the prescribed level with the specified oil or grease to ensure continuous lubrication. Oil level on these gear boxes should be checked on a daily basis and generally should be drained completely every three to four months and refilled with fresh oil or grease.

Brakes and Clutches

In addition to normal oiling and greasing maintenance, inspection of other compo-

nents on the press is required. On presses equipped with manual or automatic flying-splice unwinds, prescribed maintenance must be taken on the unwind brakes, whether they be of the simple hand-adjustable friction type or a more sophisticated electric, pneumatic or electric-particle brake type. The press manufacturer should supply manuals for the unwind brakes that are furnished with the equipment.

In the case of manual or felt friction disc-type clutches or brakes, it is necessary to check with the press manufacturer for the proper procedures to employ.

Hydraulic Cylinders and Lines

Most flexographic presses are equipped with a hydraulic system that controls plate cylinder throw-off, variable-speed fountain drives, nip-roll pressure controls and other equally important operating systems. Hydraulic units are comparatively maintenance free. However, it is important that the manufacturer's instructions be followed closely on the initial start-up. The oil tank must be filled with a proper grade of clean hydraulic oil, and the system must be properly "bled" and checked before starting.

If a loss of hydraulic pressure occurs, it is usually due to leakage in one of the hydraulic oil fittings, the location of which can be readily spotted. Continual visual inspection of the hydraulic lines is necessary. Should leakage develop, new fittings and/or seals should be installed immediately.

Anilox and Fountain Rolls

Inspection of engraved anilox ink transfer rolls, as well as the rubber-covered fountain rolls, can best be delegated to press-operating personnel, since it can be combined with the wash-up of these rollers during press makeready. Press personnel should be instructed to promptly report every nick, pitting or peeling of chrome on the anilox roll. It is possible to repair minor damage at a comparatively small cost if caught at an early stage, since these defects on the anilox roll can cause damage to the rubber fountain roll and the printing plates. Small imperfections in the anilox roll will cause spots to be worn on the rubber roll, appreciably shortening its life. Similarly, slight nicks or other damages to the rubber-covered fountain roll, if detected promptly, can often be repaired by regrinding the roll at considerably less expense than required if the roll is used until complete recovering becomes necessary.

It is important that the rubber-covered fountain roll be separated from the engraved anilox transfer roll whenever the press is shut down between shifts or for any other prolonged stoppages. If these rolls are left squeezed together when not rotating for an extended period of time, a "flat" will invariably develop on the rubber fountain roll surface. This distortion can only be removed by regrinding, or in severe cases, by recovering the roll. Special attention must also be paid to a thorough and deep cleaning of the anilox roll at the end of each work day. Adequate cleaning ensures that ink or solvent residue does not remain in the cells, where it could attack the chrome plating or cause cell plugging.

Electric Systems

Electric motors require periodic lubrication in accordance with each manufacturer's instructions, except for those motors that are equipped with lifetime or sealed bearings. Besides the main drive motor and numerous auxiliary motors, the electrical installation on modern high-speed presses includes relays, switches, eddy-current clutches, commutator rings and either solid-state drive control systems or rotating field AC-to-DC converters.

At the time of press purchase, the press manufacturer should work with the electric motor suppliers and drive-component suppliers to prepare a proper preventive main-

tenance list of spare equipment to be supplied with the press. Drive-system manufacturers should supply a preventive maintenance checklist for their equipment and a listing of the nearest regional office for technical service should such assistance be necessary. Most modern drive systems have been designed so that replacement parts may be easily plugged into the circuit, as it is recognized that the cost of an electrical engineer's time to define problem areas and correct them in the field is expensive.

Dryer

The drying system on most flexographic printing presses consists of heat-supply units with electric motor-driven fans for supply and exhaust air. The drying system should meet local safety codes, and the press manufacturer should supply a clearly defined schematic for the system. It is especially important that periodic checks be made of the drives between the electric motors and the fans, as well as the motors and components in the gas-fired system.

It is also advisable to make sure everything is properly lubricated. Here again, the press manufacturer should supply a list of components that should be checked routinely to ensure that the press will not be down for excessive time due to component failure. Also, the names and locations of the nearest service representatives for component parts of the drying system should be included with the press maintenance material.

If the dryers are equipped with air filter banks, they should be inspected often to ensure that the drying system will operate properly and that the solvent-laden fumes are carried out of the pressroom.

Auxiliary Equipment

There are many types of auxiliary equipment supplied both on and separate from a printing press. This equipment includes web guides, web scanners, ink pumps, viscosity controls, impression counters, slitting attachments, web treatment and other items. The press manufacturer should supply basic catalogs that will advise the proper maintenance procedure for each press component. Proper spare-parts lists should be prepared on each of these major components, since they are just as subject to wear and failure as the printing press itself, and their failure can interrupt the complete system.

Spare Parts Inventory

The spare parts inventory should receive careful attention by the converter and the press manufacturer. If a systematic approach is taken prior to the press installation, it is possible to have on hand at the time of start-up a group of spare parts that can generally cover 95% of all possible breakdown situations. The investment in these parts will normally be such a small fraction of the total cost of the press, its attendant equipment and installation, that it should be an integral part of the initial press purchase. Having the equipment initially on hand, as well as a good control system to replace those items that are used, will, over the years, pay for these parts many times over.

PRESSMANSHIP AND EQUIPMENT CARE

In any preventive maintenance program, the responsibilities of the press operating personnel are of paramount importance. The people who live with the equipment are the first line of defense. Many tasks that come under the heading of maintenance can be best carried out on a day-to-day basis by press-operating personnel. First and foremost is keeping and maintaining a clean press.

Timely Clean-up

It is not easy to keep a flexographic press spotless, especially if there is not time set aside each week for a thorough press clean-

ing. It is, however, easier to wipe away spilled ink when it is fresh than when it becomes hardened or accumulated to the point where removal is a major job. It is easier to empty drip pans when they are half full than wait until they are overflowing or filled to the top when they cannot possibly be removed without spilling. It is easier to wipe small amounts of excess oil off a press than to wait until an entire press frame as well as the floor around the press, becomes covered with an oil film. Any available time when the press is not running, or during wash-up, can be profitably used to take care of such minor cleaning jobs. Cleaning such routine items will remain minor as long as it is done on a routine basis.

Not only must the printing press be kept clean, but the area around the press also must be kept neat and orderly for an efficient operation. Floors should be kept clean and proper containers supplied to hold such items as rags and waste paper. No unnecessary ink pails or loose tools should be scattered about the press area. An orderly work area not only enables personnel to be more efficient and craftsman-like, but also eliminates many of the hazards that might otherwise endanger the safety of the operating personnel.

The press operator should not create unnecessary maintenance problems by operating the equipment improperly, such as by standing on cross-adjustment shafts and other items that are not normally designed to carry an operator's weight. The maintenance department should provide proper platforms, ladders and/or steps to allow proper access to the press. These access areas create a neater area and a safer workplace.

Handling Care

Careful handling of parts that are continually mounted into or removed from the press during normal operating procedures is a necessity. Plate cylinders, ink pans and covers are precision items and require and deserve care. Plate cylinders that are manufactured with very close tolerances and that are quite expensive can perform properly only if their original tolerances are maintained. Rough handling of these items can reduce their effectiveness. Pans or covers that become dented should be repaired immediately, since they will be harder to clean up and may not fit neatly with the color stations, reducing their effectiveness and requiring longer setup times.

The Press Operator's Opportunity

At the end of any operating shift or during makeready, be sure that all fountain rolls are backed off and properly cleaned. When placing the press back into adjustment, make sure that all the components are functioning and that force is not required to make the press settings. The parts of the adjustment system are designed and precision-made to close tolerances and should operate freely and smoothly. If they do not operate in this fashion, then a careful inspection of the color stations must be made to determine what is causing the problem so that it may be properly repaired.

The press operator is the first person to see signs of the press performance deteriorating. The operator's judgment alone will often lead to preventive maintenance beyond the scheduled maintenance on sections or parts of the press that are just beginning to fail. Press operators who are "tuned in" to the press not only keep the press operating at higher efficiency, but make the pressroom a more pleasant place to work and a safer operation.

Appendix A – Diametric Pitches

DIAMETRIC PITCH 8

NO. OF TEETH IN GEAR	PRINTING/PITCH DIAMETER (IN)	REPEAT (IN)	NO. OF TEETH IN GEAR	PRINTING/PITCH DIAMETER (IN)	REPEAT (IN)
20	2.500	7.854	61	7.625	23.955
21	2.625	8.247	62	7.750	24.347
22	2.750	8.639	63	7.875	24.740
23	2.875	9.032	64	8.000	25.133
24	3.000	9.425	65	8.125	25.525
25	3.125	9.817	66	8.250	25.918
26	3.250	10.210	67	8.375	26.311
27	3.375	10.603	68	8.500	26.704
28	3.500	10.996	69	8.625	27.096
29	3.625	11.388	70	8.750	27.489
30	3.750	11.781	71	8.875	27.882
31	3.875	12.174	72	9.000	28.274
32	4.000	12.566	73	9.125	28.667
33	4.125	12.959	74	9.250	29.060
34	4.250	13.352	75	9.375	29.452
35	4.375	13.744	76	9.500	29.845
36	4.500	14.137	77	9.625	30.238
37	4.625	14.530	78	9.750	30.631
38	4.750	14.923	79	9.875	31.023
39	4.875	15.315	80	10.000	31.416
40	5.000	15.708	81	10.125	31.809
41	5.125	16.101	82	10.250	32.201
42	5.250	16.493	83	10.375	32.594
43	5.375	16.886	84	10.500	32.987
44	5.500	17.279	85	10.625	33.379
45	5.625	17.671	86	10.750	33.772
46	5.750	18.064	87	10.875	34.165
47	5.875	18.457	88	11.000	34.558
48	6.000	18.850	89	11.125	34.950
49	6.125	19.242	90	11.250	35.343
50	6.250	19.635	91	11.375	35.736
51	6.375	20.028	92	11.500	36.128
52	6.500	20.420	93	11.625	36.521
53	6.625	20.813	94	11.750	36.914
54	6.750	21.206	95	11.875	37.306
55	6.875	21.598	96	12.000	37.699
56	7.000	21.991	97	12.125	38.092
57	7.125	22.384	98	12.250	38.485
58	7.250	22.777	99	12.375	38.877
59	7.375	23.169	100	12.500	39.270
60	7.500	23.562			

DIAMETRIC PITCH 10

NO. OF TEETH IN GEAR	PRINTING/PITCH DIAMETER (IN)	REPEAT (IN)	NO. OF TEETH IN GEAR	PRINTING/PITCH DIAMETER (IN)	REPEAT (IN)
20	2.000	6.283	61	6.100	19.164
21	2.100	6.597	62	6.200	19.478
22	2.200	6.912	63	6.300	19.792
23	2.300	7.226	64	6.400	20.106
24	2.400	7.540	65	6.500	20.420
25	2.500	7.854	66	6.600	20.735
26	2.600	8.168	67	6.700	21.049
27	2.700	8.482	68	6.800	21.363
28	2.800	8.796	69	6.900	21.677
29	2.900	9.111	70	7.000	21.991
30	3.000	9.425	71	7.100	22.305
31	3.100	9.739	72	7.200	22.619
32	3.200	10.053	73	7.300	22.934
33	3.300	10.367	74	7.400	23.248
34	3.400	10.681	75	7.500	23.562
35	3.500	10.996	76	7.600	23.876
36	3.600	11.310	77	7.700	24.190
37	3.700	11.624	78	7.800	24.504
38	3.800	11.938	79	7.900	24.819
39	3.900	12.252	80	8.000	25.133
40	4.000	12.566	81	8.100	25.447
41	4.100	12.881	82	8.200	25.761
42	4.200	13.195	83	8.300	26.075
43	4.300	13.509	84	8.400	26.389
44	4.400	13.823	85	8.500	26.704
45	4.500	14.137	86	8.600	27.018
46	4.600	14.451	87	8.700	27.332
47	4.700	14.765	88	8.800	27.646
48	4.800	15.080	89	8.900	27.960
49	4.900	15.394	90	9.000	28.274
50	5.000	15.708	91	9.100	28.588
51	5.100	16.022	92	9.200	28.903
52	5.200	16.336	93	9.300	29.217
53	5.300	16.650	94	9.400	29.531
54	5.400	16.965	95	9.500	29.845
55	5.500	17.279	96	9.600	30.159
56	5.600	17.593	97	9.700	30.473
57	5.700	17.907	98	9.800	30.788
58	5.800	18.221	99	9.900	31.102
59	5.900	18.535	100	10.000	31.416
60	6.000	18.850			

DIAMETRIC PITCH 12

NO. OF TEETH IN GEAR	PRINTING/PITCH DIAMETER (IN)	REPEAT (IN)	NO. OF TEETH IN GEAR	PRINTING/PITCH DIAMETER (IN)	REPEAT (IN)
20	1.667	5.236	61	5.083	15.970
21	1.750	5.498	62	5.167	16.232
22	1.833	5.760	63	5.250	16.493
23	1.917	6.021	64	5.333	16.755
24	2.000	6.283	65	5.417	17.017
25	2.083	6.545	66	5.500	17.279
26	2.167	6.807	67	5.583	17.541
27	2.250	7.069	68	5.667	17.802
28	2.333	7.330	69	5.750	18.064
29	2.417	7.592	70	5.833	18.326
30	2.500	7.854	71	5.917	18.588
31	2.583	8.116	72	6.000	18.850
32	2.667	8.378	73	6.083	19.111
33	2.750	8.639	74	6.167	19.373
34	2.833	8.901	75	6.250	19.635
35	2.917	9.163	76	6.333	19.897
36	3.000	9.425	77	6.417	20.159
37	3.083	9.687	78	6.500	20.420
38	3.167	9.948	79	6.583	20.682
39	3.250	10.210	80	6.667	20.944
40	3.333	10.472	81	6.750	21.206
41	3.417	10.734	82	6.833	21.468
42	3.500	10.996	83	6.917	21.729
43	3.583	11.257	84	7.000	21.991
44	3.667	11.519	85	7.083	22.253
45	3.750	11.781	86	7.167	22.515
46	3.833	12.043	87	7.250	22.777
47	3.917	12.305	88	7.333	23.038
48	4.000	12.566	89	7.417	23.300
49	4.083	12.828	90	7.500	23.562
50	4.167	13.090	91	7.583	23.824
51	4.250	13.352	92	7.667	24.086
52	4.333	13.614	93	7.750	24.347
53	4.417	13.875	94	7.833	24.609
54	4.500	14.137	95	7.917	24.871
55	4.583	14.399	96	8.000	25.133
56	4.667	14.661	97	8.083	25.395
57	4.750	14.923	98	8.167	25.656
58	4.833	15.184	99	8.250	25.918
59	4.917	15.446	100	8.333	26.180
60	5.000	15.708			

DIAMETRIC PITCH 20

NO. OF TEETH IN GEAR	PRINTING/PITCH DIAMETER (IN)	REPEAT (IN)	NO. OF TEETH IN GEAR	PRINTING/PITCH DIAMETER (IN)	REPEAT (IN)
40	2.000	6.283	122	6.100	19.164
42	2.100	6.597	124	6.200	19.478
44	2.200	6.912	126	6.300	19.792
46	2.300	7.226	128	6.400	20.106
48	2.400	7.540	130	6.500	20.420
50	2.500	7.854	132	6.600	20.735
52	2.600	8.168	134	6.700	21.049
54	2.700	8.482	136	6.800	21.363
56	2.800	8.796	138	6.900	21.677
58	2.900	9.111	140	7.000	21.991
60	3.000	9.425	142	7.100	22.305
62	3.100	9.739	144	7.200	22.619
64	3.200	10.053	146	7.300	22.934
66	3.300	10.367	148	7.400	23.248
68	3.400	10.681	150	7.500	23.562
70	3.500	10.996	152	7.600	23.876
72	3.600	11.310	154	7.700	24.190
74	3.700	11.624	156	7.800	24.504
76	3.800	11.938	158	7.900	24.819
78	3.900	12.252	160	8.000	25.133
80	4.000	12.566	162	8.100	25.447
82	4.100	12.881	164	8.200	25.761
84	4.200	13.195	166	8.300	26.075
86	4.300	13.509	168	8.400	26.389
88	4.400	13.823	170	8.500	26.704
90	4.500	14.137	172	8.600	27.018
92	4.600	14.451	174	8.700	27.332
94	4.700	14.765	176	8.800	27.646
96	4.800	15.080	178	8.900	27.960
98	4.900	15.394	180	9.000	28.274
100	5.000	15.708	182	9.100	28.588
102	5.100	16.022	184	9.200	28.903
104	5.200	16.336	186	9.300	29.217
106	5.300	16.650	188	9.400	29.531
108	5.400	16.965	190	9.500	29.845
110	5.500	17.279	192	9.600	30.159
112	5.600	17.593	194	9.700	30.473
114	5.700	17.907	196	9.800	30.788
116	5.800	18.221	198	9.900	31.102
118	5.900	18.535	200	10.000	31.416
120	6.000	18.850			

Appendix B – Circular Pitches

CIRCULAR PITCH 0.125"					
NO. OF TEETH IN GEAR	PRINTING/PITCH DIAMETER (IN)	REPEAT (IN)	NO. OF TEETH IN GEAR	PRINTING/PITCH DIAMETER (IN)	REPEAT (IN)
40	1.592	5.000	81	3.223	10.125
41	1.631	5.125	82	3.263	10.250
42	1.671	5.250	83	3.302	10.375
43	1.711	5.375	84	3.342	10.500
44	1.751	5.500	85	3.382	10.625
45	1.790	5.625	86	3.422	10.750
46	1.830	5.750	87	3.462	10.875
47	1.870	5.875	88	3.501	11.000
48	1.910	6.000	89	3.541	11.125
49	1.950	6.125	90	3.581	11.250
50	1.989	6.250	91	3.621	11.375
51	2.029	6.375	92	3.661	11.500
52	2.069	6.500	93	3.700	11.625
53	2.109	6.625	94	3.740	11.750
54	2.149	6.750	95	3.780	11.875
55	2.188	6.875	96	3.820	12.000
56	2.228	7.000	97	3.860	12.125
57	2.268	7.125	98	3.899	12.250
58	2.308	7.250	99	3.939	12.375
59	2.348	7.375	100	3.979	12.500
60	2.387	7.500	101	4.019	12.625
61	2.427	7.625	102	4.058	12.750
62	2.467	7.750	103	4.098	12.875
63	2.507	7.875	104	4.138	13.000
64	2.546	8.000	105	4.178	13.125
65	2.586	8.125	106	4.218	13.250
66	2.626	8.250	107	4.257	13.375
67	2.666	8.375	108	4.297	13.500
68	2.706	8.500	109	4.337	13.625
69	2.745	8.625	110	4.377	13.750
70	2.785	8.750	111	4.417	13.875
71	2.825	8.875	112	4.456	14.000
72	2.865	9.000	113	4.496	14.125
73	2.905	9.125	114	4.536	14.250
74	2.944	9.250	115	4.576	14.375
75	2.984	9.375	116	4.615	14.500
76	3.024	9.500	117	4.655	14.625
77	3.064	9.625	118	4.695	14.750
78	3.104	9.750	119	4.735	14.875
79	3.143	9.875	120	4.775	15.000
80	3.183	10.000			

CIRCULAR PITCH 0.25"

NO. OF TEETH IN GEAR	PRINTING/PITCH DIAMETER (IN)	REPEAT (IN)	NO. OF TEETH IN GEAR	PRINTING/PITCH DIAMETER (IN)	REPEAT (IN)
20	1.592	5.000	61	4.854	15.250
21	1.671	5.250	62	4.934	15.500
22	1.751	5.500	63	5.013	15.750
23	1.830	5.750	64	5.093	16.000
24	1.910	6.000	65	5.173	16.250
25	1.989	6.250	66	5.252	16.500
26	2.069	6.500	67	5.332	16.750
27	2.149	6.750	68	5.411	17.000
28	2.228	7.000	69	5.491	17.250
29	2.308	7.250	70	5.570	17.500
30	2.387	7.500	71	5.650	17.750
31	2.467	7.750	72	5.730	18.000
32	2.546	8.000	73	5.809	18.250
33	2.626	8.250	74	5.889	18.500
34	2.706	8.500	75	5.968	18.750
35	2.785	8.750	76	6.048	19.000
36	2.865	9.000	77	6.127	19.250
37	2.944	9.250	78	6.207	19.500
38	3.024	9.500	79	6.287	19.750
39	3.104	9.750	80	6.366	20.000
40	3.183	10.000	81	6.446	20.250
41	3.263	10.250	82	6.525	20.500
42	3.342	10.500	83	6.605	20.750
43	3.422	10.750	84	6.685	21.000
44	3.501	11.000	85	6.764	21.250
45	3.581	11.250	86	6.844	21.500
46	3.661	11.500	87	6.923	21.750
47	3.740	11.750	88	7.003	22.000
48	3.820	12.000	89	7.082	22.250
49	3.899	12.250	90	7.162	22.500
50	3.979	12.500	91	7.242	22.750
51	4.058	12.750	92	7.321	23.000
52	4.138	13.000	93	7.401	23.250
53	4.218	13.250	94	7.480	23.500
54	4.297	13.500	95	7.560	23.750
55	4.377	13.750	96	7.639	24.000
56	4.456	14.000	97	7.719	24.250
57	4.536	14.250	98	7.799	24.500
58	4.615	14.500	99	7.878	24.750
59	4.695	14.750	100	7.958	25.000
60	4.775	15.000			

CIRCULAR PITCH 0.5"

NO. OF TEETH IN GEAR	PRINTING/PITCH DIAMETER (IN)	REPEAT (IN)	NO. OF TEETH IN GEAR	PRINTING/PITCH DIAMETER (IN)	REPEAT (IN)
20	3.183	10.000	61	9.708	30.500
21	3.342	10.500	62	9.868	31.000
22	3.501	11.000	63	10.027	31.500
23	3.661	11.500	64	10.186	32.000
24	3.820	12.000	65	10.345	32.500
25	3.979	12.500	66	10.504	33.000
26	4.138	13.000	67	10.663	33.500
27	4.297	13.500	68	10.823	34.000
28	4.456	14.000	69	10.982	34.500
29	4.615	14.500	70	11.141	35.000
30	4.775	15.000	71	11.300	35.500
31	4.934	15.500	72	11.459	36.000
32	5.093	16.000	73	11.618	36.500
33	5.252	16.500	74	11.777	37.000
34	5.411	17.000	75	11.937	37.500
35	5.570	17.500	76	12.096	38.000
36	5.730	18.000	77	12.255	38.500
37	5.889	18.500	78	12.414	39.000
38	6.048	19.000	79	12.573	39.500
39	6.207	19.500	80	12.732	40.000
40	6.366	20.000	81	12.892	40.500
41	6.525	20.500	82	13.051	41.000
42	6.685	21.000	83	13.210	41.500
43	6.844	21.500	84	13.369	42.000
44	7.003	22.000	85	13.528	42.500
45	7.162	22.500	86	13.687	43.000
46	7.321	23.000	87	13.846	43.500
47	7.480	23.500	88	14.006	44.000
48	7.639	24.000	89	14.165	44.500
49	7.799	24.500	90	14.324	45.000
50	7.958	25.000	91	14.483	45.500
51	8.117	25.500	92	14.642	46.000
52	8.276	26.000	93	14.801	46.500
53	8.435	26.500	94	14.961	47.000
54	8.594	27.000	95	15.120	47.500
55	8.754	27.500	96	15.279	48.000
56	8.913	28.000	97	15.438	48.500
57	9.072	28.500	98	15.597	49.000
58	9.231	29.000	99	15.756	49.500
59	9.390	29.500	100	15.915	50.000
60	9.549	30.000			

Appendix C – Module Pitches

MODULE PITCH 1

NO. OF TEETH IN GEAR	PRINTING/PITCH DIAMETER (IN)	REPEAT (IN)	NO. OF TEETH IN GEAR	PRINTING/PITCH DIAMETER (IN)	REPEAT (IN)
40	40.0	125.7	81	81.0	254.5
41	41.0	128.8	82	82.0	257.6
42	42.0	131.9	83	83.0	260.8
43	43.0	135.1	84	84.0	263.9
44	44.0	138.2	85	85.0	267.0
45	45.0	141.4	86	86.0	270.2
46	46.0	144.5	87	87.0	273.3
47	47.0	147.7	88	88.0	276.5
48	48.0	150.8	89	89.0	279.6
49	49.0	153.9	90	90.0	282.7
50	50.0	157.1	91	91.0	285.9
51	51.0	160.2	92	92.0	289.0
52	52.0	163.4	93	93.0	292.2
53	53.0	166.5	94	94.0	295.3
54	54.0	169.6	95	95.0	298.5
55	55.0	172.8	96	96.0	301.6
56	56.0	175.9	97	97.0	304.7
57	57.0	179.1	98	98.0	307.9
58	58.0	182.2	99	99.0	311.0
59	59.0	185.4	100	100.0	314.2
60	60.0	188.5	101	101.0	317.3
61	61.0	191.6	102	102.0	320.4
62	62.0	194.8	103	103.0	323.6
63	63.0	197.9	104	104.0	326.7
64	64.0	201.1	105	105.0	329.9
65	65.0	204.2	106	106.0	333.0
66	66.0	207.3	107	107.0	336.2
67	67.0	210.5	108	108.0	339.3
68	68.0	213.6	109	109.0	342.4
69	69.0	216.8	110	110.0	345.6
70	70.0	219.9	111	111.0	348.7
71	71.0	223.1	112	112.0	351.9
72	72.0	226.2	113	113.0	355.0
73	73.0	229.3	114	114.0	358.1
74	74.0	232.5	115	115.0	361.3
75	75.0	235.6	116	116.0	364.4
76	76.0	238.8	117	117.0	367.6
77	77.0	241.9	118	118.0	370.7
78	78.0	245.0	119	119.0	373.8
79	79.0	248.2	120	120.0	377.0
80	80.0	251.3			

MODULE PITCH 2

NO. OF TEETH IN GEAR	PRINTING/PITCH DIAMETER (IN)	REPEAT (IN)	NO. OF TEETH IN GEAR	PRINTING/PITCH DIAMETER (IN)	REPEAT (IN)
20	40.0	125.7	61	122.0	383.3
21	42.0	131.9	62	124.0	389.6
22	44.0	138.2	63	126.0	395.8
23	46.0	144.5	64	128.0	402.1
24	48.0	150.8	65	130.0	408.4
25	50.0	157.1	66	132.0	414.7
26	52.0	163.4	67	134.0	421.0
27	54.0	169.6	68	136.0	427.3
28	56.0	175.9	69	138.0	433.5
29	58.0	182.2	70	140.0	439.8
30	60.0	188.5	71	142.0	446.1
31	62.0	194.8	72	144.0	452.4
32	64.0	201.1	73	146.0	458.7
33	66.0	207.3	74	148.0	465.0
34	68.0	213.6	75	150.0	471.2
35	70.0	219.9	76	152.0	477.5
36	72.0	226.2	77	154.0	483.8
37	74.0	232.5	78	156.0	490.1
38	76.0	238.8	79	158.0	496.4
39	78.0	245.0	80	160.0	502.7
40	80.0	251.3	81	162.0	508.9
41	82.0	257.6	82	164.0	515.2
42	84.0	263.9	83	166.0	521.5
43	86.0	270.2	84	168.0	527.8
44	88.0	276.5	85	170.0	534.1
45	90.0	282.7	86	172.0	540.4
46	92.0	289.0	87	174.0	546.6
47	94.0	295.3	88	176.0	552.9
48	96.0	301.6	89	178.0	559.2
49	98.0	307.9	90	180.0	565.5
50	100.0	314.2	91	182.0	571.8
51	102.0	320.4	92	184.0	578.1
52	104.0	326.7	93	186.0	584.3
53	106.0	333.0	94	188.0	590.6
54	108.0	339.3	95	190.0	596.9
55	110.0	345.6	96	192.0	603.2
56	112.0	351.9	97	194.0	609.5
57	114.0	358.1	98	196.0	615.8
58	116.0	364.4	99	198.0	622.0
59	118.0	370.7	100	200.0	628.3
60	120.0	377.0			

MODULE PITCH 3

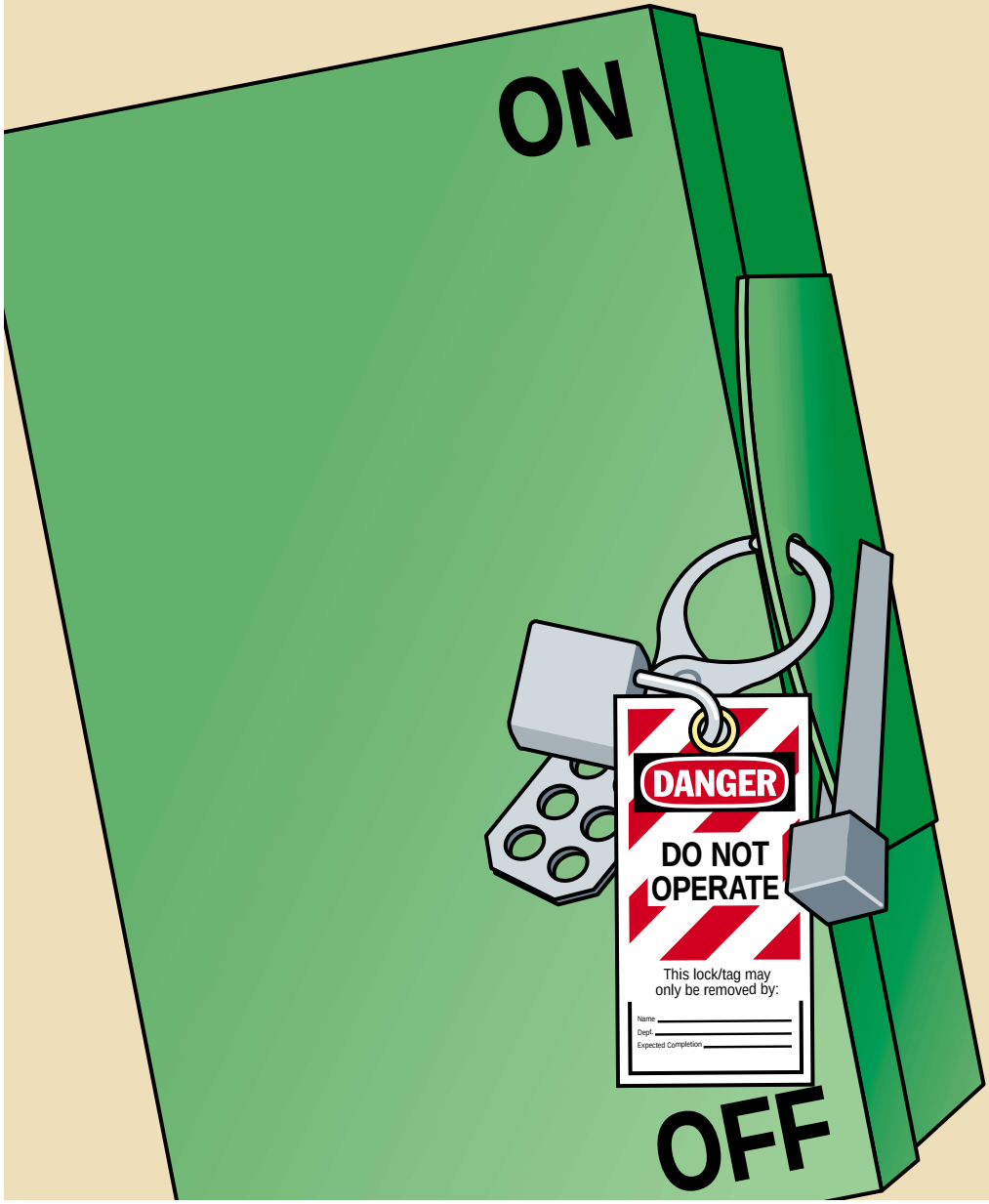
NO. OF TEETH IN GEAR	PRINTING/PITCH DIAMETER (IN)	REPEAT (IN)	NO. OF TEETH IN GEAR	PRINTING/PITCH DIAMETER (IN)	REPEAT (IN)
20	20.0	62.8	61	61.0	191.6
21	21.0	66.0	62	62.0	194.8
22	22.0	69.1	63	63.0	197.9
23	23.0	72.3	64	64.0	201.1
24	24.0	75.4	65	65.0	204.2
25	25.0	78.5	66	66.0	207.3
26	26.0	81.7	67	67.0	210.5
27	27.0	84.8	68	68.0	213.6
28	28.0	88.0	69	69.0	216.8
29	29.0	91.1	70	70.0	219.9
30	30.0	94.2	71	71.0	223.1
31	31.0	97.4	72	72.0	226.2
32	32.0	100.5	73	73.0	229.3
33	33.0	103.7	74	74.0	232.5
34	34.0	106.8	75	75.0	235.6
35	35.0	110.0	76	76.0	238.8
36	36.0	113.1	77	77.0	241.9
37	37.0	116.2	78	78.0	245.0
38	38.0	119.4	79	79.0	248.2
39	39.0	122.5	80	80.0	251.3
40	40.0	125.7	81	81.0	254.5
41	41.0	128.8	82	82.0	257.6
42	42.0	131.9	83	83.0	260.8
43	43.0	135.1	84	84.0	263.9
44	44.0	138.2	85	85.0	267.0
45	45.0	141.4	86	86.0	270.2
46	46.0	144.5	87	87.0	273.3
47	47.0	147.7	88	88.0	276.5
48	48.0	150.8	89	89.0	279.6
49	49.0	153.9	90	90.0	282.7
50	50.0	157.1	91	91.0	285.9
51	51.0	160.2	92	92.0	289.0
52	52.0	163.4	93	93.0	292.2
53	53.0	166.5	94	94.0	295.3
54	54.0	169.6	95	95.0	298.5
55	55.0	172.8	96	96.0	301.6
56	56.0	175.9	97	97.0	304.7
57	57.0	179.1	98	98.0	307.9
58	58.0	182.2	99	99.0	311.0
59	59.0	185.4	100	100.0	314.2
60	60.0	188.5			

MODULE PITCH 4

NO. OF TEETH IN GEAR	PRINTING/PITCH DIAMETER (IN)	REPEAT (IN)	NO. OF TEETH IN GEAR	PRINTING/PITCH DIAMETER (IN)	REPEAT (IN)
20	40.0	125.7	61	122.0	383.3
21	42.0	131.9	62	124.0	389.6
22	44.0	138.2	63	126.0	395.8
23	46.0	144.5	64	128.0	402.1
24	48.0	150.8	65	130.0	408.4
25	50.0	157.1	66	132.0	414.7
26	52.0	163.4	67	134.0	421.0
27	54.0	169.6	68	136.0	427.3
28	56.0	175.9	69	138.0	433.5
29	58.0	182.2	70	140.0	439.8
30	60.0	188.5	71	142.0	446.1
31	62.0	194.8	72	144.0	452.4
32	64.0	201.1	73	146.0	458.7
33	66.0	207.3	74	148.0	465.0
34	68.0	213.6	75	150.0	471.2
35	70.0	219.9	76	152.0	477.5
36	72.0	226.2	77	154.0	483.8
37	74.0	232.5	78	156.0	490.1
38	76.0	238.8	79	158.0	496.4
39	78.0	245.0	80	160.0	502.7
40	80.0	251.3	81	162.0	508.9
41	82.0	257.6	82	164.0	515.2
42	84.0	263.9	83	166.0	521.5
43	86.0	270.2	84	168.0	527.8
44	88.0	276.5	85	170.0	534.1
45	90.0	282.7	86	172.0	540.4
46	92.0	289.0	87	174.0	546.6
47	94.0	295.3	88	176.0	552.9
48	96.0	301.6	89	178.0	559.2
49	98.0	307.9	90	180.0	565.5
50	100.0	314.2	91	182.0	571.8
51	102.0	320.4	92	184.0	578.1
52	104.0	326.7	93	186.0	584.3
53	106.0	333.0	94	188.0	590.6
54	108.0	339.3	95	190.0	596.9
55	110.0	345.6	96	192.0	603.2
56	112.0	351.9	97	194.0	609.5
57	114.0	358.1	98	196.0	615.8
58	116.0	364.4	99	198.0	622.0
59	118.0	370.7	100	200.0	628.3
60	120.0	377.0			

CHAPTER 2

Pressroom Practices



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Introduction

In any flexographic printing plant, big or small, whether it is corrugated, tag and label, or wide-web packaging, the printing press is the key element in the graphic reproduction process. The pressroom is where all the planning and elements of the flexographic process come together to ensure that the customer's requirements are met, and success is achieved for the customer as well as the printer.

Success in the pressroom can only be achieved when pressroom personnel understand basic flexographic principles and practices and apply them to every customer request.

Because of the scope of the flexographic printing industry, it is not practical to explain all the procedures used in every printing and converting plant in the industry. This volume will discuss generic procedures for pressroom personnel involved in narrow-web, wide-web and corrugated flexographic printing, as well as common principles that can be used in every segment of the flexo process.

Personal and Pressroom Safety

Personal and pressroom safety issues are critical concerns for every flexographic printing company and for each individual. Printing presses have numerous pinch points that will cause serious injury. Every person involved in a printing department must be concerned with personal safety and the well-being of the environment. As is true with any discussion of safety, the intent is not to interfere with the work environment or the company procedures that have been tailored to meet specific work requirements. The guidelines that have been set up by the management and supervisory personnel to maintain a safe workplace must be followed to prevent injury to individuals.

PROPER DRESS

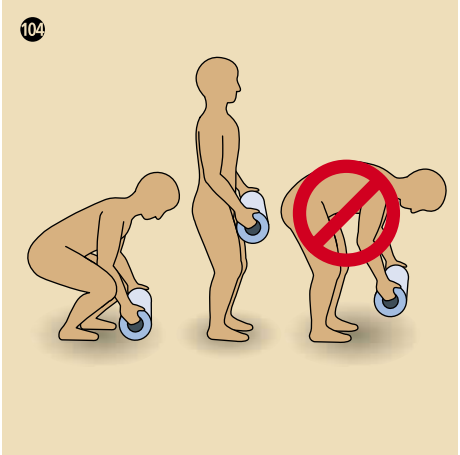
Proper dress is vitally important at the work site. Personal safety begins with the following basic rules:

- Clothing must be relatively tight-fitting. Short sleeves and regular work pants are appropriate. Loose clothing could catch on moving parts.
- Steel-toed shoes help prevent foot injury. For extra safety protection, clamp-on steel boots can be worn. Steel clamps afford better protection than steel-toed shoes alone.
- Jewelry such as rings, watches, chains or long earrings should never be worn around machinery since they can easily get caught in moving parts.
- Long hair must be tied back or contained in a hair net so it doesn't become entangled in moving parts.
- Eye protection must be worn during cleanup to prevent ink or wash-up solvent from being splashed into the eyes. Personal eye glasses must meet the standards for safety glasses. Many regular glasses do not.
- Ear plugs or protectors should be worn to minimize noise exposure.
- Tight-fitting protective gloves should be worn during ink wash-ups to prevent skin contact.

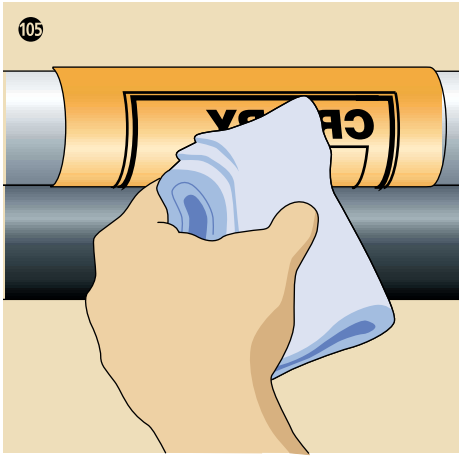
COMMON SENSE

Common sense is an important part of overall safety. This concept is difficult to explain or teach, yet comes very much into play when working around the press. Some examples of common sense include:

- Keeping hands away from moving parts.
- Familiarization of all pinch points between various rolls. A pinch point is referred to as a nip and is created by the direction that each roll turns. Use extra caution when working near these areas since rags, clothing and fingers can easily be drawn between these rolls and into the nips;
- Using proper lifting techniques (back straight and knees bent) as shown in *Figure* 104.
- Folding rags neatly during wash-ups to prevent corners from getting caught in



104 Proper lifting technique allows the weight to be absorbed by the legs – not the back and knees.



105 Rag corners should be tucked in to prevent them from becoming caught in the machinery.

machinery parts (*Figure* 105).

- Noting an excessive solvent smell, which may indicate faulty or insufficient ventilation.
- Asking questions about equipment or procedures when points are not clearly understood. It is easier to answer a question than it is to fix a mistake.
- Not smoking on the job. Smoking is an extreme fire hazard and will not be tolerated on the work floor and, in many cases, on company premises.
- Insuring flammable materials are not close by when operating an electrical hand tool. Flammable gases or liquids are easily ignitable.
- Insuring careful handling of metal-to-metal tasks. A small spark may start a fire or cause an explosion.
- Grounding all presses properly.

When using solvents around the press, UL-approved containers should be used and grounded to the press. Alligator-type clips should be clamped to the container and to an unpainted metal part of the press.

SAFETY SIGNAGE

A press can be very dangerous if handled improperly. Operators and service personnel must obey all caution signs and safety instructions. If not, severe injuries and possibly death, could result.

There are rules to be followed and signs to be aware of on the shop floor. The most important rule on the floor is: Do not run any of the press sections with their safety guards removed.

There are many signs used in the industry that represent different dangers. The Occupational Safety and Health Administration (OSHA) regulates signs that are applied to equipment to warn of any physical dangers. Signs and colors are used on machines to point out possible dangers. These labels are used to give personnel a continual mental reminder that a danger is present. Although these labels differ from industry to industry, they all have four general headings:

Caution signs. Yellow, black and white signs indicate a possible danger area or condition that could cause personal injury (*Figure* 106).

Danger signs. Red, black and white signs indicate a possible "condition" that could cause personal injury or damage to the equipment (*Figure* 107).

Warning signs. Orange, black and white signs indicate a possible danger area or condition that could cause personal injury, such as a nip area (*Figure* 108).

Note signs. Green and white signs indicate parts or situations needing special attention and/or an explanation (*Figure* 109).

EMERGENCY EQUIPMENT

Personal safety goes hand in hand with a good knowledge of the printing press and department. A safety-first approach to the press and surrounding area is essential at all times.

Personnel working in the pressroom must know the location of safety and emergency equipment in the pressroom such as emergency stops, lockout switches, personal emergency equipment and fire extinguishers.

Emergency Stops. Emergency stop buttons will bring the press to a quick, though not an immediate stop (*Figure* 110). Emergency life lines are cords that can be pulled to bring the press to a quick stop.

These safety features are located in various convenient places on the press to be easily reached by operators. Emergency stops should only be used in emergency situations when the press must be stopped quickly.

Lockout Switch. A lockout switch prevents the machine from being turned on (*Figure* 111). It cuts the power to all of the switches on the press, thus eliminating an unwanted starting of the machine. A lockout switch is used when the press is being cleaned or is down for simple maintenance. Examples of simple maintenance include such things as making simple adjustments or fixing paper jams. The device shown in *Figure* 111 locks the power off when the button is pushed in. It remains off until the operator resets the switch by pulling it back out.

OSHA requires that equipment be locked-out during repair or service and under cer-

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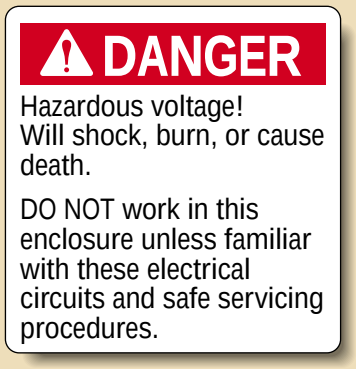

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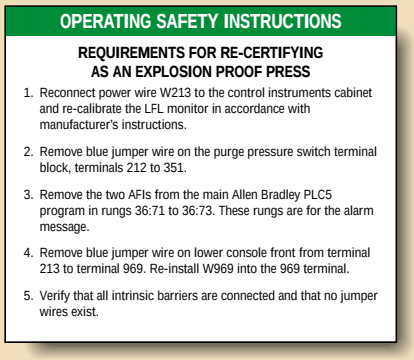


106 Caution signs, yellow, black and white in color, indicate a possible danger area or condition that could cause personal injury.

107 A red, black and white sign indicates a possible dangerous condition that could cause personal injury or damage to the equipment.

108 An orange, black and white warning sign indicates a possible danger area, such as a nip area, or condition that could cause personal injury.

109 A typcial notice sign, green and white in color, indicates parts or situations needing special attention and/or an explanation.

110 The emergency stop button brings machinery to a quick but not immediate stop during emergency situations.

111 Lockout switches prevent machinery from being turned on, especially during cleanup or maintenance.

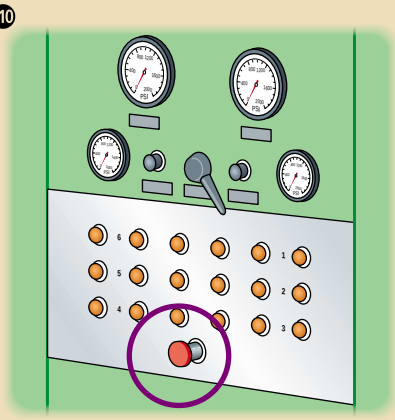
112 The machine is under "tag-out," which means it is down for repair or service and should not be turned on.

113 A typical tag that could be attached to a lockout device, identifies the lockout status of the equipment.

114 Eye-wash stations should be easily accessible in the press area during emergencies.

115 Fire extinguisher classifications indicate the type of fire extinguisher needed to put out a fire.

110



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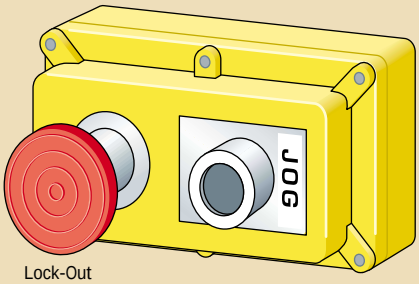
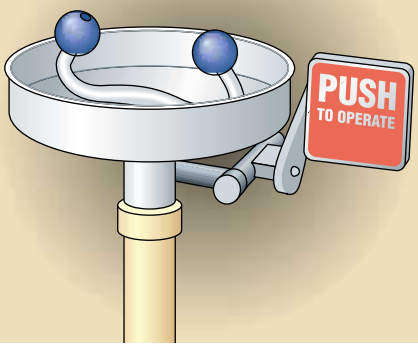


Lock-Out Switch

114



112

115

Letter Symbol	Types of Fires	Picture Symbol
A	For wood, paper, cloth, trash, and other ordinary materials.	
B	For gasoline, grease, oil, paint, and other flammable liquids.	
C	For live electrical equipment.	

tain other conditions. Generally in these cases a padlock or other locking device is utilized over the main power switch or plug.

Tag-out. Tag-out is a safety procedure, used in conjunction with the lockout device, to alert everyone that the tagged machine is down for repair or service; and that under no circumstance should the power be turned back on (*Figure* 112). A lock/tag is attached to the lockout device (*Figure* 113).

This tagging procedure brings attention to the reason that the machine or tool has been locked-out. If a lock/tag is hanging on a machine, instructions must be carefully followed. *Figure* 113 illustrates one of the many phrases used on lock/tags to identify the lockout status of the equipment. Other phrasing examples of lock/tags are:

- Do Not Start.
- Do Not Close.
- Do Not Open.

Personal Emergency Equipment. In every press area, there should be one or more eye-wash stations (*Figure* 114). Personnel must know their locations and how to use them in an emergency.

There should also be one or more first aid kits within a plant. Kit location and injury treatment policies must be known by all employees, as well as the locations of any other safety items, such as emergency showers, spill containment kits and fire blankets.

At least one individual on every shift should have emergency medical training and be designated to handle emergency situations. Some companies employ full-time nurses. Press operators should identify these people to insure clear responses during emergency situations.

Fire Extinguishers. Fire extinguishers are vital safety equipment in any printing plant. As with any emergency equipment, all people in the pressroom should know extinguisher location and use.

Fire extinguishers vary and may be effective on some types of fires but not others. Extinguishers are labeled to indicate the type of fire they will be effective to control (*Figure* 115).

Many printing plants have installed carbon dioxide (CO_2) fire systems onto each press. Entire pressrooms can be protected with a Halon gas fire safety system, which can put out a fire in two to four seconds by depleting the room of oxygen. This system requires that all doors and windows be closed to contain the gas. To further aid containment, all outgoing exhausts are stopped on the press when the system goes off. Halon leaves no residue to contaminate ink or damage press equipment.

FLAMMABLE MATERIALS

Many inks and solvents are flammable materials and must be handled with care to avoid ignition and fire. There are three possible causes for pressroom fires: heat from friction, static electricity and sparks.

Heat from Friction. Rubbing parts can start a fire if the temperature of the ink is raised to its flash point. The flash point of a material is the lowest temperature at which the substance can be ignited under standard test conditions. Friction can occur in an ink station while the press is running. Extinguish this type of fire with the press running slowly to keep heat from building up and overheating the next higher print station.

Static Electricity. Sparks from static electricity can create a fire. Static is especially noticeable during the winter months when the humidity indoors is low. All flammable solvent containers must be grounded when filling or dispensing to protect against static sparks. (*Figure* 116).

Also, it is important for the press to be grounded to eliminate a buildup of static electricity between the web and the press rollers.

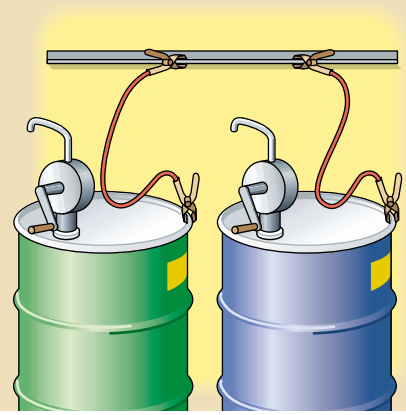
Spark or Flame. Solvent liquid and vapor can be ignited by spark or flame. Hand tools should be properly grounded and operated in an area where there are no signs of flam-

116 All flammable solvent containers must be grounded when filling or dispensing to protect against static sparks.

117 The hazardous material label is a diamond-shaped label that is divided into four color-coded categories. The categories are rated by number from zero to four, indicating the degree of hazard.

mable or gaseous materials. Metal striking metal can also be a source of sparking. Individuals must use extreme caution when working with a spark or flame potential on the pressroom floor.

116



HAZARDOUS MATERIALS

OSHA regulations require that hazardous materials such as solvents, inks and cleanup solutions be marked with a Hazardous Materials Identification System label.

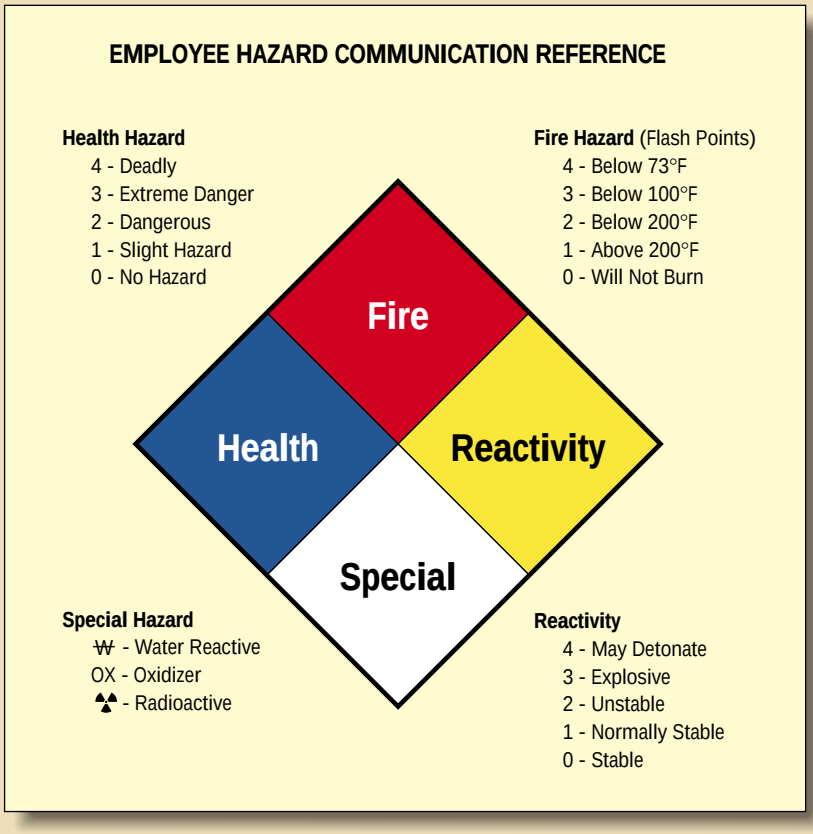
The hazardous material label is a diamond-shaped label that is divided into four color-coded categories (*Figure* 117). The categories are rated by number from zero to four, indicating the degree of hazard. These degrees are:

Health Hazard (blue). Indicates the health hazard of using a material on a scale of zero to four, four being fatal.

Flammability (red). Indicates the material's flash point on a scale of zero to four, four being below 73° F.

Reactivity (yellow). Indicates detonation sen-

117



sitivity of a material on a scale of zero to four, four being extreme.

Special (white). Indicates whether the material is a chemical base that might react violently with air and water. It also includes recommended personal protection equipment.

Disposal of Hazardous Materials

Flexographic printers, like those in other industries, are facing stricter regulations concerning personal safety and the environment. While this subject is covered in another volume, the intent here is to point out some basic regulatory concerns in the pressroom.

Hazardous substances and materials include:

- ink;
- solvent;
- wash-up solutions; and
- solvent-laden disposable rags.

Several basic rules concerning the disposal of hazardous substances and materials are:

- No liquid waste, ink or solvent may be poured into sinks, toilets or drains.
- No liquid waste, ink or solvent may be disposed of in a regular garbage can or on the ground outside the plant.
- Solvent-laden disposable rags must be placed in special containers and sent out for burning by an approved waste incinerator.
- Solvent-laden shop rags should be placed in designated containers to be washed by an industrial cleaning company.

Right-to-Know Law

Companies that use hazardous materials in the workplace must comply with the Emergency Planning and Community Right to Know Act. This federal law requires that every company have a written program that lists all the hazardous materials used; and that forms called Material Safety Data Sheets (MSDS) are on-hand and available for employee inspection.

118 Soiled rags should only be placed in designated containers with tight closing lids.

MSDS forms are detailed information sheets provided by the product's vendor. They describe the hazards of the material. MSDS forms also provide treatment instructions in case of exposure or ingestion. (*See Volume 3, Chapter 1*, for further details and examples of MSDS sheets.)

TOOL SAFETY

Many tasks in the press area involve the use of hand tools or power tools. The following guidelines are intended to prevent injury or damage to the equipment when such tools are being used:

- Use the proper tool for the job.
- Put away tools immediately after they are used;
- Use explosion-proof tools in ink rooms or press areas when flammable liquids are being used or stored;
- Never use electric extension cords in explosion proof areas where solvent or solvent based ink is stored.
- Never use bare razor blades. Razor blades should always be used in blade holders. Old blades should be placed in a waste container designated for razor blades only.

Doctor Blades

Many flexographic printing presses are equipped with metal doctor blades. This thin metal strip is sharp when new, and can become razor sharp after being used. Extreme care must be taken when cleaning or installing new blades in the blade holders. Wearing steel or fiber mesh gloves will prevent cuts. Plastic gloves are a poor alternative.

Doctor blades should be properly disposed of after removal. Since they are extremely sharp, blades should never be put in any container that a coworker may reach into unknowingly.

Extreme caution must be used during press wash-ups. Usually wash-ups are done with cloth or paper rags that are easily cut by the doctor blade material.

Use of Rags

Rag use and the storage of soiled rags raise both personal safety and environmental concerns. From a safety stand-point, rags should be folded neatly when used for cleaning. Folding the rags helps prevent loose ends from being entangled when wiping a rotating anilox roll.

Soiled rags should only be placed in designated containers with tight closing lids (*Figure* 117).

Color-coded rags are sometimes used to distinguish ink clean-ups from general shop use. These rags should always be kept separate from each other. General-purpose rags often contain metal filings which may damage rolls or plates if used carelessly.

Die-Cutting Safety

Care must be used when handling and installing dies onto the press. Wearing gloves will help prevent cuts to hands or nicks to the die. Extreme care must also be taken when the press is running and the dies are rotating. Personnel must keep hands and loose clothing clear of the rotating die. Stop the press completely before clearing any items that are caught or stuck in the die nip.

Narrow-Web Procedures

Setting up a narrow-web press is different from machine to machine. This variation is due to the wide variety of presses used in the market today. For this reason, this section will focus on the basics of set up that are common to most narrow-web printers.

The first step to setting up any job on the press is to read the job jacket (*Figure* 119). A job jacket is a folder or envelope that stores valuable information about the job to be run. In many cases a prepress proof, art or a sample from a previous pressrun will be in the job jacket. The operator must visualize the final product and how it will be used by the customer by reviewing the information on the job jacket and sample. Afterwards, the operator can develop a set-up plan.

PRESS SETUP

In the next section, we'll discuss the procedures for setting up the press:

Select the Print Stations

Generally, art is designed to print the lightest color first and darkest color last when the job is to print on the face of the substrate. In order to hide the areas where two colors overlap for registration (trap), the darkest color must print on top of the lightest. The operator must keep this technique in mind, and also consider the following items, when determining which print stations to use:

Existing Colors in the Press. It is important to think ahead and plan a strategy for all the jobs being printed, not just the present one. In some cases, existing colors from a previous job will meet the requirements for the next job. If planned from job to job, color strategies will alleviate unneeded wash-ups and reduce changeover time.

Anilox Roll Requirements. If the operator can set up a job to take advantage of existing anilox rolls, less time will be spent on changeovers.

Drying Capacity Between Ink Stations. With large solid ink coverages, it may be necessary to leave an open print station between colors. This additional web travel length allows extra drying time for the ink to dry thoroughly.

Prepare the Dies

The first step of set-up is to locate all tooling required for the job. This process begins by locating the necessary dies. Care must be taken to avoid nicking the sharp cutting edge of the die. To avoid blade damage do not wear rings when handling dies.

Operators should wipe the shaft and bearers clean and check the blades for built-up adhesive, ink and dust before the die is put into the press.

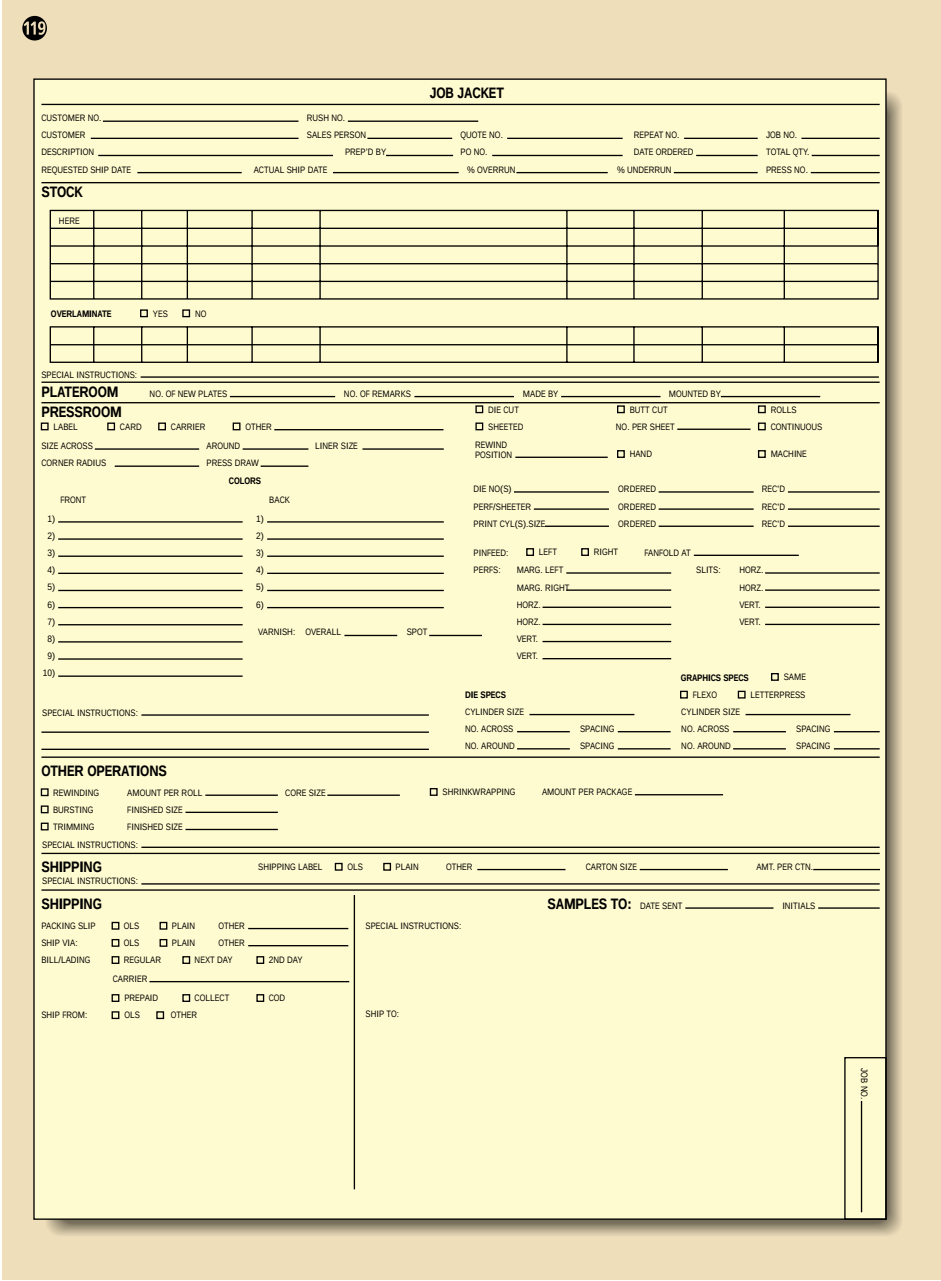
All foreign material must be removed prior to use. Extreme care must be used when cleaning the blades on a die. A clean rag and solvent may be used.

A wooden or plastic paint stick may also be used to scrape away any debris. A metal object should never be used to clean a die.

Inspect the Mounted Plates

Mounted-plate cylinders should be brought to the press area and readied for placement in the assigned print stations. Plates should be checked against the design on the prepress

119 A job jacket is a folder or envelope that stores valuable information about the job to be run.



JOB JACKET

CUSTOMER NO. ____ RUSH NO. ____
CUSTOMER ____ SALES PERSON ____ QUOTE NO. ____ REPEAT NO. ____ JOB NO. ____
DESCRIPTION ____ PREP'D BY ____ PO NO. ____ DATE ORDERED ____ TOTAL QTY. ____
REQUESTED SHIP DATE ____ ACTUAL SHIP DATE ____ % OVERRUN ____ % UNDERRUN ____ PRESS NO. ____

STOCK

HERE									

OVERLAMINATE ☐ YES ☐ NO

SPECIAL INSTRUCTIONS: ____

PLATEROOM NO. OF NEW PLATES ____ NO. OF REMARKS ____ MADE BY ____ MOUNTED BY ____

PRESSROOM
☐ LABEL ☐ CARD ☐ CARRIER ☐ OTHER ____
SIZE ACROSS ____ AROUND ____ LINER SIZE ____
CORNER RADIUS ____ PRESS DRAW ____

COLORS
FRONT: 1) ____ 2) ____ 3) ____ 4) ____ 5) ____ 6) ____ 7) ____ 8) ____ 9) ____ 10) ____
BACK: 1) ____ 2) ____ 3) ____ 4) ____ 5) ____ 6) ____
VARNISH: OVERALL ____ SPOT ____

☐ DIE CUT ☐ BUTT CUT ☐ ROLLS
☐ SHEETED NO. PER SHEET ____ ☐ CONTINUOUS
REWIND POSITION ____ ☐ HAND ☐ MACHINE

DIE NO(S) ____ ORDERED ____ REC'D ____
PERF/SHEETER ____ ORDERED ____ REC'D ____
PRINT CYL(S).SIZE ____ ORDERED ____ REC'D ____

PINFEED: ☐ LEFT ☐ RIGHT FANFOLD AT ____
PERFS: MARG. LEFT ____ MARG. RIGHT ____ HORZ. ____ HORZ. ____ VERT. ____ VERT. ____
SLITS: HORZ. ____ HORZ. ____ VERT. ____ VERT. ____

SPECIAL INSTRUCTIONS: ____

DIE SPECS
CYLINDER SIZE ____
NO. ACROSS ____ SPACING ____
NO. AROUND ____ SPACING ____

GRAPHICS SPECS ☐ SAME
☐ FLEXO ☐ LETTERPRESS
CYLINDER SIZE ____
NO. ACROSS ____ SPACING ____
NO. AROUND ____ SPACING ____

OTHER OPERATIONS
☐ REWINDING AMOUNT PER ROLL ____ CORE SIZE ____ ☐ SHRINKWRAPPING AMOUNT PER PACKAGE ____
☐ BURSTING FINISHED SIZE ____
☐ TRIMMING FINISHED SIZE ____
SPECIAL INSTRUCTIONS: ____

SHIPPING SHIPPING LABEL ☐ OLS ☐ PLAIN OTHER ____ CARTON SIZE ____ AMT. PER CTN. ____
SPECIAL INSTRUCTIONS: ____

SHIPPING
PACKING SLIP ☐ OLS ☐ PLAIN OTHER ____
SHIP VIA: ☐ OLS ☐ PLAIN OTHER ____
BILL/LADING ☐ REGULAR ☐ NEXT DAY ☐ 2ND DAY
CARRIER ____
☐ PREPAID ☐ COLLECT ☐ COD
SHIP FROM: ☐ OLS ☐ OTHER

SAMPLES TO: DATE SENT ____ INITIALS ____
SPECIAL INSTRUCTIONS:
SHIP TO:

ON BACK

proof or the previously printed sample, as well as to the information on the job jacket. Plates must also be inspected for damage, ink buildup left from previous runs, and any other defects. The plate edges should be checked to make sure there is no lifting from the sticky-back. Repairs or remounts of the plate should be done before placement in the press.

Change Anilox Rolls

The operator may need to change anilox rolls for the job if the rolls are not present in the press or in the correct ink station. The appropriate anilox needed to deliver the required color density must be determined by either reading the job jacket or job history sheet, or viewing the prepress proof or a

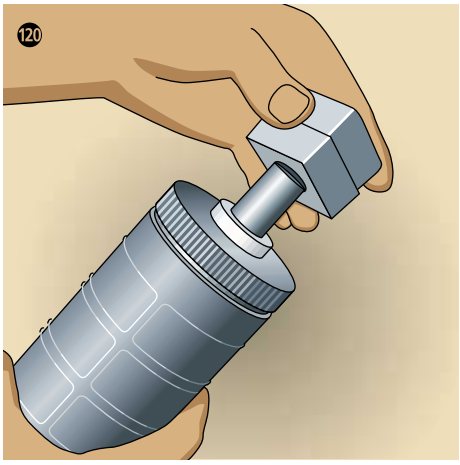
printed sample if the job has been run before.

When handling an anilox roll, operators must remember that the engraving on the surface is very fragile and can be easily damaged. Although a ceramic coated anilox roll surface is very hard, it is also brittle, and can be chipped if the roll comes into contact with anything made of metal. Roll covers protect the surface from damage during handling.

Die Installation and Setup

The following procedure details a typical die installation and setup:

1. Apply spacers on the journals of the gear side of the die. Spacers are usually nylon, brass or fiber washers.
2. Slip on a bearing block on the gear side of the die. A bearing block has an inner diameter that matches the diameter of the journal (*Figure* 120).
3. Slide the die journal with the bearing block into the slot on the gear side of the press. Care must be taken not to let the die strike the anvil roll. Place the die gently against the anvil roll.
4. Check to see that the die is pushed firmly against the gear side of the press.
5. Check the alignment of the gears and bearers on the die with the gears and bearers on the anvil roll. If the gears and bearers are not aligned, add or subtract spacers until alignment is reached.
6. Slide spacers and the bearing block on the operator's side die journal. Once again, add or subtract spacers until the die slides smoothly into the press with no side to side play. Adjustable bearing blocks can be used to eliminate the need for spacers. The procedure might vary depending on the press manufacturer and the type of press used.
7. Install appropriate pressure assemblies, using one of the downward-pressure methods detailed in *Table 1*.
8. Install felt bearer wipers. The wipers should be positioned to ride on the nip and should be in contact with the bearers on each roll in the die station. The wipers keep the bearers clean and free of dust, which may change die settings during the press run. Oil is placed on the wipers to lubricate the bearers of the die station assembly.
9. Run several feet of web through the die station. Strip away the waste matrix from the web and attach it to the waste rewind or bring it through to the vacuum system. This method will vary depending on the initial setup.
10. Examine the liner to see if the die is cutting with the correct pressure. If the liner does not appear to be damaged, the die is cutting with the correct pressure. If the liner is damaged or if the label is not releasing properly, the die needs to be adjusted for the proper cut depth.



120 Die installation begins by applying a spacer, then fitting on a bearing block.

To assist in stripping the matrix, it is often necessary to underscore the material to provide extra support to the matrix ladder. Underscoring the edges of the stock places a slight "U" shape on the back side of stock – making the matrix ladder much stronger than a flat ladder. Many times an 0.125" to a 0.025" extra substrate must be allowed on the edge of the web to allow room for underscoring. This may seem like wasted material,

METHODS OF EXERTING DOWNWARD FORCE

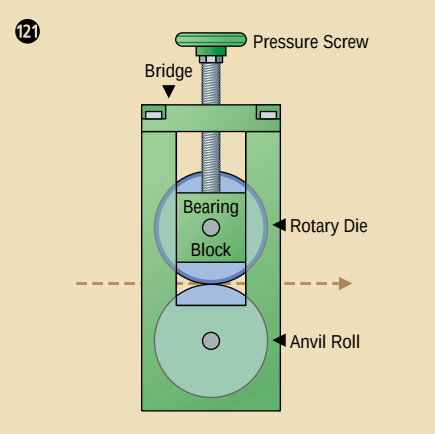
There are three methods of exerting downward force to hold the die bearers firmly against the anvil roll. Each method uses a bridge that is held on top of the press frame at each side by pins or bolts. Threaded rods run through the bridge and apply pressure to the die when screwed down.

Method 1: The screws apply pressure directly to the die bearing blocks. The pressure, in turn, presses downward on the shafts of the die to hold the die against the anvil roll (*Figure* 121).

Method 2: An assist roll is added to the assembly. An assist roll has some form of bearing on each end. Some are removable and some are in a fixed position (*Figure* 122). The assist roll assembly is placed in the same slots as the die blocks, and its bearers ride on top of the die bearers. The bridge is fixed in position and the pressure screws are screwed down to apply pressure on the assist roll shafts. The pressure exerted tends to be displaced through the bearings on the assist roll. This displacement puts pressure directly on the die bearers.

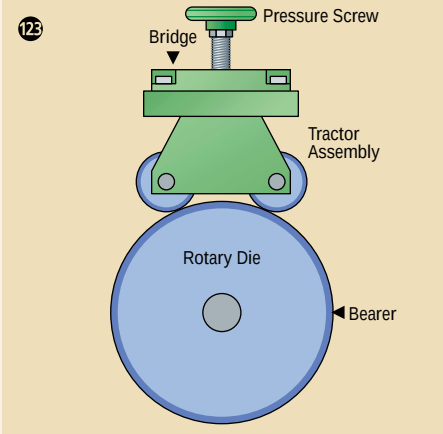
Method 3: This method utilizes a tractor-style hold down and is similar to the assist roll method. The main difference, however, is that the pressure is brought directly over the bearer on the die, not through the bearings (*Figure* 123). Hydraulic die pressure gauge assemblies are available to use in place of the pressure bridge. This system allows operators to observe the force applied to the rotary die, calibrated in pounds of force. The assembly also enables the operator to make adjustments more consistently, as well as maintain the minimum die pressure throughout the press run (*Figure* 124).

121



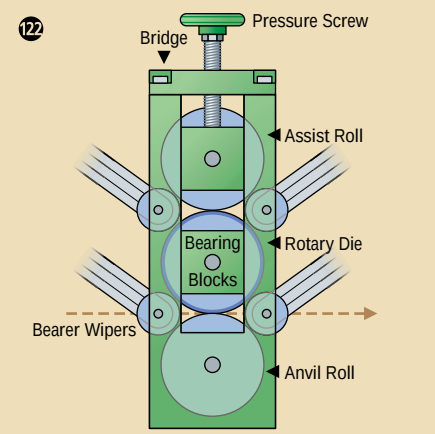
Pressure screw applies pressure to the die bearing blocks.

123



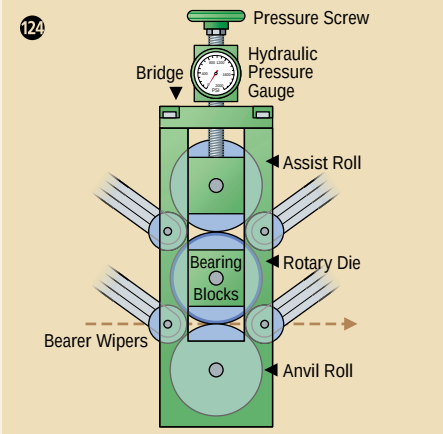
Tractor method of applying pressure.

122



Assist roll used to apply pressure.

124



Hydraulic-pressure gauge and felt wipers.

Table 1

but the benefits of more effective stripping will offset the extra stock substantially.

If a problem occurs with predispensing labels, and more die pressure cannot be used, strip the matrix directly from the die using no assist roll. By stripping directly from the die, the adhesive on the pressure sensitive material will not flow back to cause this problem.

Use Setup Stock

When setting up the press, substitute a cheaper, lower-grade stock, called set-up stock, for the more expensive stock that may be specified on the job jacket. This substitution prevents the wasting of valuable material when setting up the printing stations. The set-up stock should be wide enough to cover the print area and be of similar gauge to the actual job. The substrate is one of the more costly portions of a job, making it important to minimize stock waste when possible.

Set Edge Guides

The edge guide keeps one edge of the web in the same position at all times to provide side to side register during production. The sensor that monitors the position of the web must be positioned at the edge of the substrate.

Set Auxiliary Stations

At this point in the setup process, the auxiliary stations should be set up. Auxiliary station functions may include slitting and laminating.

Dry Registration

In order to eliminate waste when setting up a press, it is advisable to dry-register the print stations. Dry registration of the print stations simply means the process of setting up the plate cylinders in the print stations as close as possible to the required position for color-to-color registration, and setting the ink and impression settings before inking the plates. The following procedure is a general dry-register technique used by some printers. There are many other methods to accomplish this task.

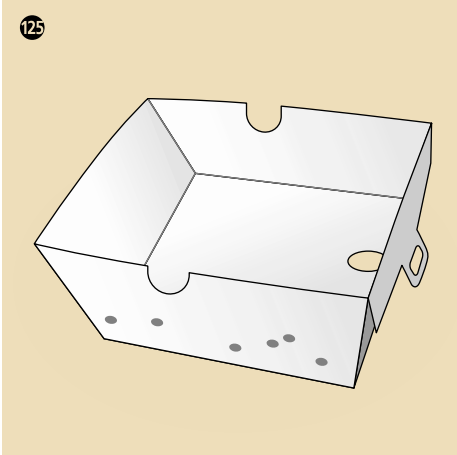
First, use check gauges to establish parallelism between the anilox to plate cylinder and plate cylinder to impression cylinder. This gauging also establishes a starting point for ink and impression settings. Check gauges are wheels that temporarily slide onto the plate-cylinder shaft in place of the plate cylinder. The outer diameter of the wheel is the same as the plate-cylinder repeat length. One check-gauge wheel is placed on each side of the plate-cylinder shaft. Adjust the press settings so that the wheels barely touch the anilox roll and the web on the impression cylinder. This adjustment is done by using a thin piece of paper, such as a piece of release liner, as a feeler gauge. The piece of paper used as the feeler gauge must be thinner than the stock being run. Keep adjusting the settings until some pressure on the piece of paper is felt from both the web and the anilox roll. This setting ensures that the plate roll is parallel to the anilox and impression cylinder, and also establishes a start point for ink and impression settings. After all adjustments are made, remove the two check gauges from the shaft and prepare to install the plate cylinders.

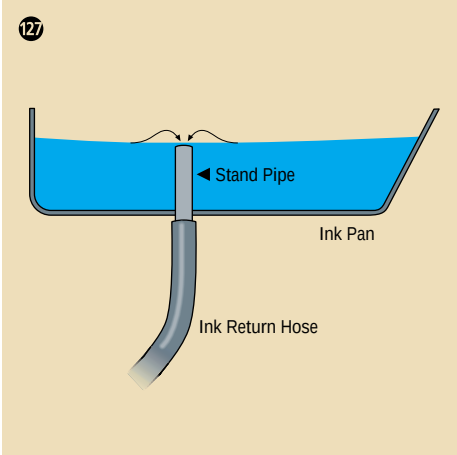
Second, install the plate cylinder for each color in the correct station in approximately the same location. If this step is done correctly, the location of the printed images will be very close to alignment from color to color. This step minimizes the number of register adjustments needed during setup, and reduces the amount of wasted stock. Each print cylinder or gear should be marked in the same location. This marked tooth or spot on the cylinder is used when mounting the plates to line up the center marks of each plate to the accompanying cylinder. Therefore, the images on the plates should be in close registration from cylinder to cylinder in relationship to that mark. When loading the cylinders in the press, this mark can be used to install

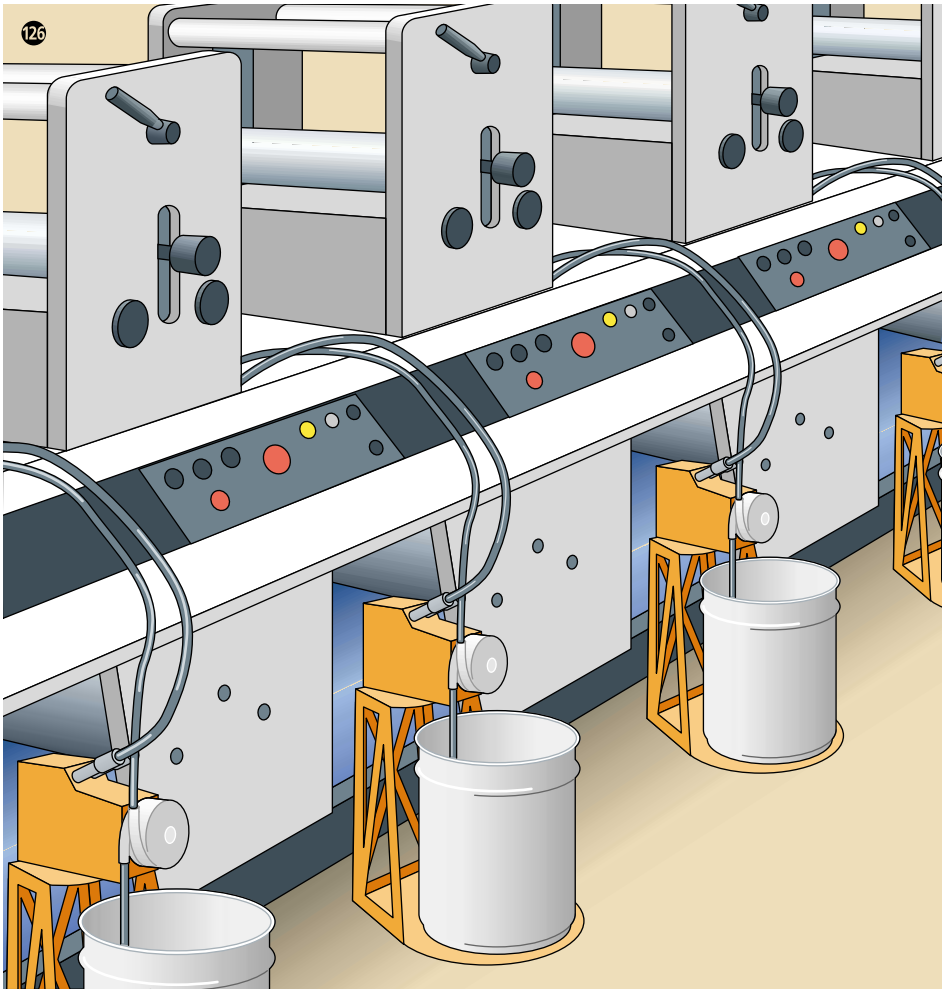
125 A paper fountain pan liner reduces cleanup time short runs.

126 Ink pumps lift the ink from the buckets to the pans in a steady manner, thus ensuring color consistency.

127 When using an ink pump, a stand pipe will ensure constant ink levels in the ink pan.







the cylinders very closely (within a gear tooth) to each other in each station. This alignment is accomplished by drawing a mark on the web. The mark on the web is aligned with the mark on the cylinder or gear in the first station. The web is then jogged forward to the next station, where the next cylinder is aligned to the mark. Even with 360° registration control, this method can reduce the amount of wasted substrate and setup time.

Set Ink Distribution Unit

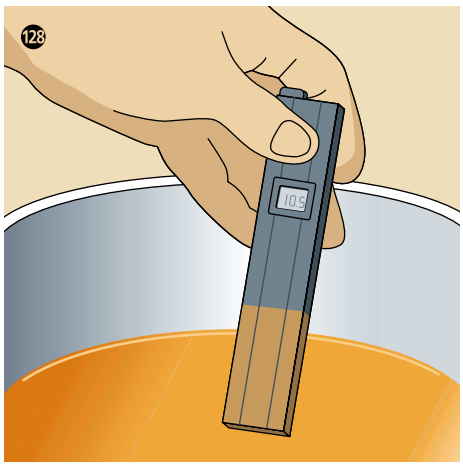
The ink distribution unit must be set up before the press run can begin. The following procedure details a typical ink distribution setup:

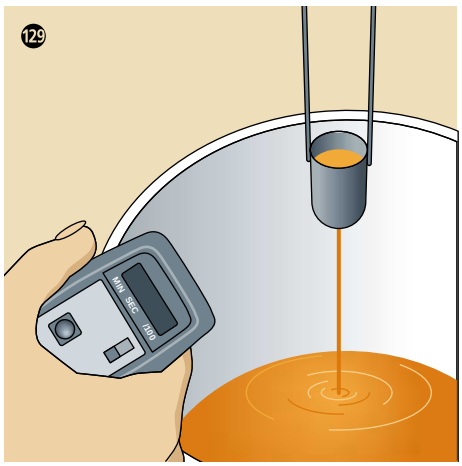
1. Clean all fountain pans and ink wipes.
2. Install wiper assemblies and pans into the press following the manufacturer's specifications.
3. Install paper or plastic fountain pans or liners if the press can accommodate their use (*Figure* 125). Using the paper or plastic liners saves on changeover time during short run work.
4. Install ink pumps if the job requires a fairly long press run. Ink pumps ensure color consistency throughout the press run (*Figure* 126). Pumps come in different styles, but all perform the same function of getting the ink from the ink bucket to the pan.
5. Place ink into the fountain. This procedure varies depending on whether an ink pump is being used, or if the ink will be poured directly into the fountain. When an ink pump is being used, place a stand pipe in the drain hole of the fountain (*Figure* 127). The stand pipe keeps the ink at a constant level in the fountain pan. Then place the ink into the pumping unit and the supply hose into the pan. Start the pump to begin circulating the ink through the ink distribution unit.
6. Check the ink's pH and viscosity if using water-based ink, or viscosity if using solvent-based ink. This step should be done to ensure that the ink is at its running parameters (*Figures* 128 129).

For short runs when the ink is placed directly into the fountain, the ink must be mixed in its container for a time. After mixing, pour a sample of the ink into a disposable paper cup. Check pH and viscosity in the cup to ensure it is within its running parameters. If not, the ink needs to be adjusted and rechecked to specifications before the pressrun begins.

Set the Fountain Roll and/or Doctor Blade

Once the ink is in the fountain and is within its recommended running pH and viscos-



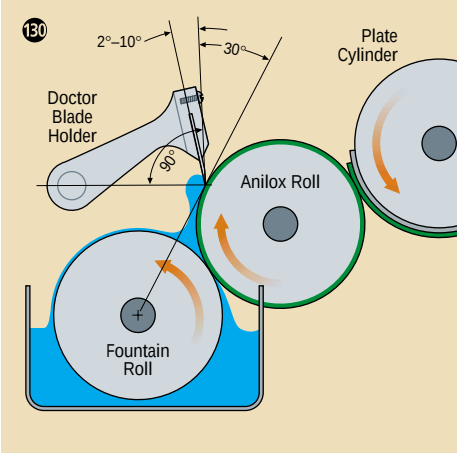


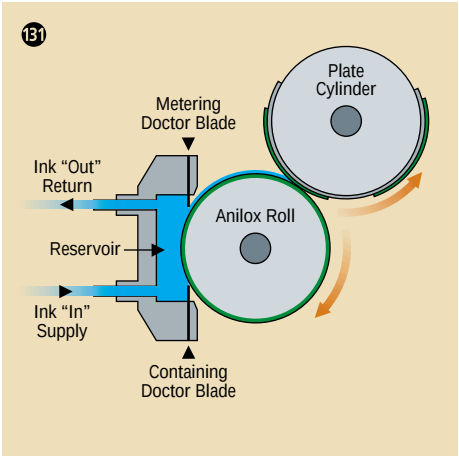
128 Testing the pH of a water-based ink ensures that the ink is at proper running condition.

129 Another method of ensuring that the ink is at running parameters is to test the viscosity using a Zahn cup.

130 Maintaining proper blade angle is important to effective metering.

131 A chambered doctor-blade eliminates the need for a fountain roll.





ity parameters, the anilox roll may be inked.

When using a two-roll system, the fountain roll is adjusted to squeeze against the anilox roll. Once the press is started, the rubber roll is adjusted to evenly squeeze the ink off the anilox using the minimum amount of pressure. This pressure setting is checked by backing the fountain roll off until the operator can see the nip flood with ink. Then the operator squeezes back in with both sides of the rubber roll, making sure they are even, until the flooding on the surface goes away. By doing this several times, the ink wipe is set. On many narrow-web presses, a doctor blade is used in conjunction with the rubber fountain roll. In this case, the doctor blade must be set to meter the anilox roll (*Figure* 130).

When setting a station with a doctor blade, the fountain roll pressure should be set a little loose. This setting allows for extra ink to go through to the doctor blade where it will be metered off. The doctor blade assembly is set into its holder and then slowly tightened down until it touches the anilox. As the blade is tightened to the anilox, the operator will notice that the ink will meter from the center of the anilox roll outward to the ends. When the ink is metered off of the ends of the anilox roll, the wipe is set. Similar to the procedure for setting fountain-roll pressure, the doctor blade should be backed out and brought back in to the anilox several times in order to set the wipe with the minimum amount of pressure. Over tightening the doctor blade can cause the blade to fold under the pressure, causing the ink to dry due to the friction and heat buildup behind the blade. If ink drying occurs, the dried ink pigments can cause damage to the anilox roll.

Once the ink is metered correctly, the ink fountain covers should be placed on the fountains. The covers reduce the amount of amine or solvent evaporating out of the ink and help keep the ink more stable during the pressrun.

If the press is equipped with a chambered doctor-blade assembly, install the assembly before the pump is turned on. The ink wipe should be set in the same manner as a single blade, and there is no rubber roll to set (*Figure* 131).

Set Impression, Inking and Registration

The following procedure details a typical impression, inking and registration setup:

1. With the press running at a slow speed, start with the last color to be printed and achieve the correct impression and ink settings. First, turn down the impression slightly so the plate comes into contact with the web.
2. Turn in the anilox-to-plate adjustment to begin inking the plate. While looking at the print on the web, make adjust-

ments to the impression and ink settings until there is a clear print with no images missing.

3. Similar to the setting of the rubber roll or doctor blade, back in and out on the settings to achieve both ink and impression settings with the minimum amount of pressure.
4. Set the remaining ink and impression settings, working backward to each print station in order from last to first.
5. After all the settings are complete for each print station, adjust for color-to-color registration. Start with the first station (front of the press) and set register for each station in order.
6. Once all the colors for the job are in register with each other, check print-to-die registration. Register the die cutter and slitter to the printed image. In all flexo press settings, it is important to use the minimum amount of pressure to do the job.

Check Colors to Standard

Once the press is set up and all settings are complete, the printing must be checked for accuracy against a color standard approved by the customer in the design stage of the job. A color standard may be a previously printed sample, a Pantone®[10] sample, an ink drawdown or a spectrophotometer reading.

All visual color-matching should take place in a viewing booth designed for this purpose. This type of booth provides a standardized light source with a neutral gray background to check color, eliminating the color variations during the color-matching process caused by lighting conditions.

A sample of the print should be compared to the color standard to ensure that the printed job meets the customer requirements. The operator should check to make sure the color is printing at the correct density (lightness and darkness) either visually or with the use of a densitometer. If the color is not printing at the correct density, the anilox may be changed to achieve a density match with the standard. This change is especially useful when working with ultraviolet inks. For slight density changes that are needed when working with conventional inks, the ink viscosity may be changed by adding solvent, or the ink may be extended to reach the color standard.

The ink hue should also be checked visually in a light booth or with the aid of a spectrophotometer. If changes in hue are needed, the operator should add the correct ink bases to reach the color standard. All of the information from the color-matching process should be documented so the job can be reprinted without additional downtime.

Approval Form

Many companies use a checklist approval form that is filled out after the job has been set up and approved (*Figure* 132). This form helps ensure that all the details for printing the job have been covered and that the job matches the specifications on the job jacket.

PRESSRUN PROCEDURES

Next, we'll discuss the areas that must be monitored during pressrun:

Ink Viscosity and pH

Maintaining viscosity, or pH and viscosity in the case of water-based inks, is essential for producing consistent print throughout the production run. If an ink is color-matched at a 25-second viscosity, a higher viscosity will make the color print darker. A higher viscosity occurs because the solvent or amines evaporate out of the ink during the pressrun, causing the customer's product to become inconsistent as the run progresses. In order to maintain the same density of print throughout the press run, viscosity (solvent-

[10] Pantone, PMS and the Pantone Matching System are trademarks of Pantone, Inc.

132 A checklist approval form ensures that all areas of setup have been carried out properly.

132

PRESS APPROVAL START-UP SHEET

CUSTOMER _____ JOB NO. _____ ITEM NO. _____
DATE _____ PRESS NO. _____
STOCK _____ INV. NO. _____ SIZE _____

MULTIWEB OR COUPON
- ☐ CONSTRUCTION TYPE _____ ☐ GLUE _____
- ☐ BASE STOCK _____ ☐ TOP STOCK _____
- ☐ PROPER RELEASE (NOT TOO TIGHT/NOT TOO EASY)

SIZE
- ☐ JACKET ☐ DIE NO. _____
- ☐ MOCK-UP ☐ LINER SIZE _____

DIE CUTS
- ☐ HAND APPLIED ☐ MACHINE APPLIED ☐ CARD CURL
- ☐ REGISTRATION ☐ DIE CUT ☐ BUTT CUT ☐ SHEETED
- ☐ PERFED ☐ SCORED ☐ SLITS ☐ MARGINAL PUNCHES
- ☐ CUTTING CLEAN ☐ LINER TEST ☐ HOLES ☐ TEAR TAB
- ☐ SINGLES LAY FLAT ☐ JOG EVEN SIZE

FANFOLD
- ☐ FOLDING STRAIGHT ☐ PERF TEARS CORRECTLY (NOT TOO HARD/NOT TOO EASY)
- ☐ CUTTING CLEAN ☐ HINGE FOLDING CORRECTLY ☐ PINFEED HOLE ALIGNMENT
- ☐ POSITION OF FOLD ☐ SPLICES REQUIRED ☐ NO SPLICES ☐ SIZE OF FOLD _____

MISC.
- ☐ MACHINE COUNT: _____ ☐ SCRATCH OFF
- ☐ % OVERRUN _____ ☐ UPC SCAN

COPY
- ☐ REGISTRATION REWIND _____ ☐ COLOR SEPARATIONS
- ☐ READ ☐ POSITION ☐ IMPRESSION ☐ QUALITY
- QUALITY LEVEL ☐ 1 ☐ 2 ☐ 3

INK — LIST PMS COLORS
- ☐ FACE COPY—WATER BASED 1) 2) 3) 4) 5) 6) 7)
- ☐ FACE COPY—SOLvENT BASED 1) 2) 3) 4) 5) 6) 7)
- ☐ BACK COPY—WATER BASED 1) 2) 3) 4) 5) 6) 7)
- ☐ BACK COPY—SOLVENT BASED 1) 2) 3) 4) 5) 6) 7)
- ☐ WRITE ON _____ ☐ VARNISH _____
- ☐ PRIMER ☐ UV CURING ☐ TAPE TEST ☐ RUB TEST

NEXT OPERATION
- ☐ REWINDER ☐ FANFOLDING ☐ TRIMMER ☐ TIPPING
- ☐ SHRINKWRAPPING ☐ PADDING ☐ OTHER _____
- ☐ SHIPPING FROM PRESS

BOXES
- ☐ STANDARD ☐ SPECIAL SIZE _____

LABELING
- ☐ STANDARD ☐ SPECIAL

COMMENTS: _____

I HAVE MADE ALL THE APPLICABLE CHECKS AND APPROVE THIS ORDER FOR START-UP.

_____ OPERATOR _____ SUPERVISOR

based inks), or pH and viscosity (water-based inks), must be maintained.

When doctor blades or chamber blade systems are used, high viscosity inks will cause ink starvation by not reloading the anilox cells. The print will not be consistent and the color variations in the product will not be acceptable to the customer. If the ink is running at a lower viscosity than the viscosity of the color match, the color will get lighter. If the viscosity gets too close to the minimum running viscosity for that ink, printing defects may occur.

Controlling Ink Viscosity and pH. Viscosity checks should be completed every 10 to 15 minutes when using solvent-based inks. When using water-based inks, pH and viscosity should be checked every 30 minutes. It is important to check pH first, followed by viscosity, when using water-based inks because the viscosity is affected by the pH level. Solvent inks require more frequent

checks of viscosity since the solvent evaporates quickly and is more unstable than the water in water-based inks.

To control an ink's viscosity, small amounts of a reducer should be added. The viscosity level should never get so high that it takes more than a pint of reducer to return the viscosity to the correct level. Careful control of ink viscosity (pH and viscosity for water inks) results in consistent color and uniform ink flow throughout the production run.

To control solvent-based ink viscosity, solvent reducer is added during the pressrun. The make-up solvent should have a slightly higher percentage of the fast solvent than the solvent in the ink system. For example, if the ink system is 10% normal propyl acetate and 90% normal propyl alcohol, the acetate is the fast solvent and will tend to evaporate faster than the alcohol, which is the slow solvent in the blend. The make-up solvent should be a slightly higher concentration of acetate to keep the ink stable, as well as maintain the viscosity during longer runs.

To control viscosity in water-based ink systems, water and amine are used. A stabilizing varnish may also be used. Stabilizing varnish is water and amine that have been premixed to the correct percentages for the ink system being used. An addition of stabilizing varnish should lower the ink viscosity while maintaining the pH of the ink. Water alone will reduce the viscosity, but it may also reduce pH, which causes other print problems.

Many presses that are used for long runs are equipped with automatic viscosity controllers. Viscosity controllers dispense a predetermined amount of solvent into the ink system to keep the ink stable throughout the pressrun. It is important, however, to check the viscosity manually when using these controllers to ensure that they are working properly.

Water-based inks should be run in a specific pH range to keep them working efficiently. The pH range for a given ink varies by manufacturer and the requirements of the job. Generally, water-based inks are in the pH range of 8.0 to 9.3. When the pH of a water-based ink falls too low, the ink will begin to body and thicken, eventually causing rewetting problems and dirty printing. If the pH is too high, the viscosity of the ink will be too low, causing drying or blocking problems. Color variations and print defects caused by pH levels can be eliminated by maintaining pH within its recommended range.

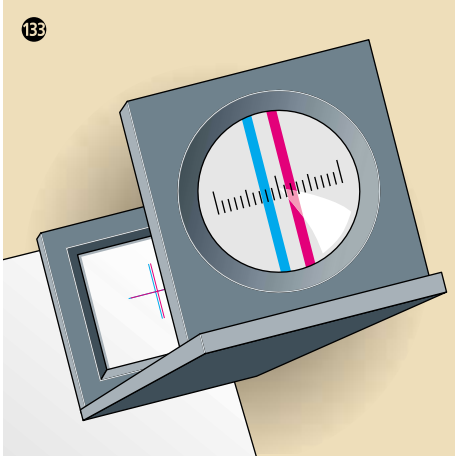
A pH meter is the instrument used to read pH levels. These instruments should be calibrated to a buffer solution with a known pH on a regular basis. Similar to viscosity controllers, many presses have automatic pH controllers that check pH and add predetermined amounts of stabilizer or amine to maintain the proper pH level in the ink. Operators should double-check these devices by reading the pH manually to guarantee they are working properly during the run.

Adding Ink to the Fountain

During longer runs, the press operator may find more ink is needed. This requires specific attention to detail. The text below details a typical ink addition procedure:

1. Double-check the ink to be added for correct color. Do not assume that an ink container is marked correctly.
2. Adjust viscosity (and pH for water-based inks), of the ink to be added. Solvent-based ink to be added to the fountain should be thinned to a viscosity that is two to four seconds higher than the ink in the fountain. Viscosity of water-based inks should be five to 10 seconds higher than the ink in the fountain. Agitation of the ink will cause a viscosity drop of three to five seconds.
3. Add only enough ink to bring the level back to the optimum level.

The optimum level should be determined before the production run. It is based on the



133 A magnifier, or loupe, should be used to aid in visual print checks.

amount of ink coverage for a given color, which depends on the ink coverage for the job being printed. The big print areas that use more ink will require the ink pans to be filled more often than those that use little ink. Add fresh ink each hour to a low coverage area rather than filling up the fountain and adding only solvent or stabilizer for the whole shift. Fresh ink helps maintain the correct balance between colorant, resin and solvent (water and amine for water-based inks).

Ink loses printability and flow characteristics if only solvent (water and amine for water-based inks) is added over a period of time. This loss is due to the depletion of the colorant and the resin in the ink. For the ink to work properly, and to avoid printability problems, press operators must know the following about the inks they are using:

- upper and lower working viscosity limits;
- solvents and additives to be used;
- range of pH for water inks; and
- maximum pigment load the ink can handle.

By maintaining the proper percentages of ink components, the color will be more consistent and fewer print problems will occur.

Inspection and Quality Checks

During a pressrun, the operator should make ongoing inspections of the press and the job being printed. The following items are typical pressrun checks:

- Listen to the press for any unusual noises that may indicate a mechanical problem.
- Double-check the ink level in the fountain or pumping unit. When using a pump, check the ink flow to the pan.
- Ensure that the low roll indicator is on. Prepare for roll changes and splices.
- Monitor print quality during the pressrun with the use of a strobe light, video monitor or the naked eye.

During the pressrun, print registration may change. This change in registration could be due to any of the following:

- incorrect web tension between in-feed and out-feed ends of the press;
- rewind roll tension is too high;
- web splices offsetting the web;
- rolls of stock varying from roll to roll;
- baggy edges on the rolls of stock moving the web to one side; and
- web thickness and adhesive coating vary on rolls.

Inspecting a print sample is the most accurate check of print quality. Operators should not rely on checking print quality on the moving web alone. Samples of the printed product must be checked visually with the aid of a magnifier for poor registration, poor ink lay, color drifts, color match and ink adhesion or cure (*Figure* 133).

During the inspection the operator should be looking for variations in:

- the cleanliness and sharpness of the print;
- ink or impression misses;
- ink picking;
- flaws due to plate lift, lint or other causes; and
- print quality.

Printed samples should be checked against

the color standard on an ongoing basis to ensure consistency throughout the run. If a densitometer or spectrophotometer is being used when the job is set up, and during the initial color match, it should be used during the pressrun. Samples from each printed roll should be evaluated.

Color-drift checks are performed by laying consecutive samples in a row on a white background (*Figure* 134).

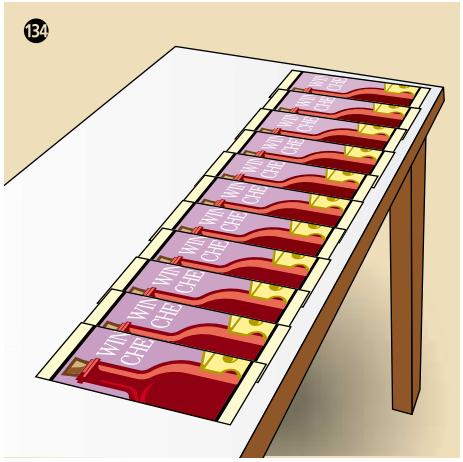
Ink-adhesion tests are performed by putting cellophane tape firmly onto the printed image and pulling upward from the image slowly for half of the length of the tape. The remaining tape is pulled quickly off the other half. The tape is then examined to see if it is free of ink (*Figure* 135).

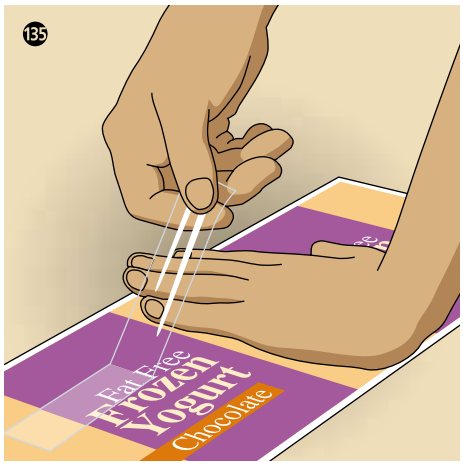
Rewind tension must be monitored regularly. Too much or too little tension will cause the roll to telescope or collapse. Variances in the tension may also cause registration or blocking problems. Blocking occurs when the ink or varnish sticks to the back of the liner.

Die-cutting and stripping quality must be checked throughout the pressrun to ensure consistency from label to label and roll to roll. One cause of die-cutting changes during a run is heating of the die and the anvil roll. As a result, the running pressure between these two rolls increases. The operator must make periodic adjustments to offset that change.

Quality Awareness

The flexographic printing process requires consistent and careful monitoring during the pressrun. There are no assurances that a job printing well presently will be doing so in five or 10 minutes. Proper pressrun procedures are the mainstream of top quality finished products. Press operators must learn and perform all pressrun procedures well. Quality checks should be performed regularly and the results should be documented. These results should be kept for a period no less than the life of the product produced. Quality is the result of conscious effort by the operator.





134 Check for color-drift of the printed piece by laying consecutive samples in a row on a white background.

135 Testing for ink-adhesion requires putting a strip of cellophane tape firmly onto the printed image and pulling upward from the image slowly for half of the length of the tape. Then pull the remaining tape quickly off the other half. The tape is examined; it should be free of ink.

Shipping Preparation

Shipping specifications are typically on the job jacket for each printing order. The product labels should be checked closely. Personnel must ensure that the customer is provided the proper information for weight, footage, number of impressions or a combination of these items. Some customers may also require densitometer or spectrophotometer readings from the finished rolls.

Preparing for the Next Job

Preparing for an upcoming job is commonly done while the current job is running. Preparation generally requires assembly of the necessary plate rolls, substrates, inks, cores and tooling. The press operator and assistants should perform the following

activities in preparation for the next job:

- review information in the next job jacket;
- plan print station wash-ups;
- note required inks and colors;
- note colors and anilox rolls in current use that may be needed; and
- gather all materials and supplies.

CLEANUP PROCEDURES

Most jobs require some degree of cleanup after a pressrun because inks for the next run are often different. Since the press is profitable only when it is in production, an efficient cleanup program is needed. A correct wash-up procedure minimizes downtime between jobs and maintains the press in good working condition. Cleanup procedures vary by company and brand of equipment.

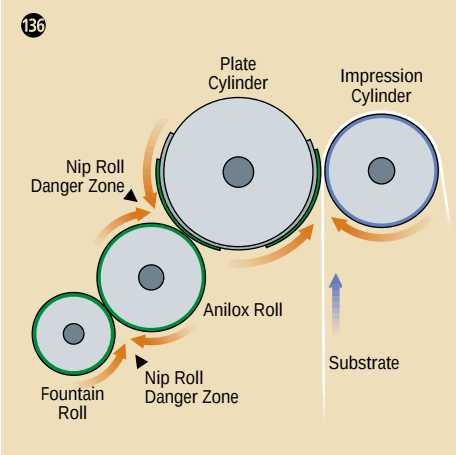
Before beginning the actual cleanup, the operator should double-check the next order to determine if any inks can remain for the next job.

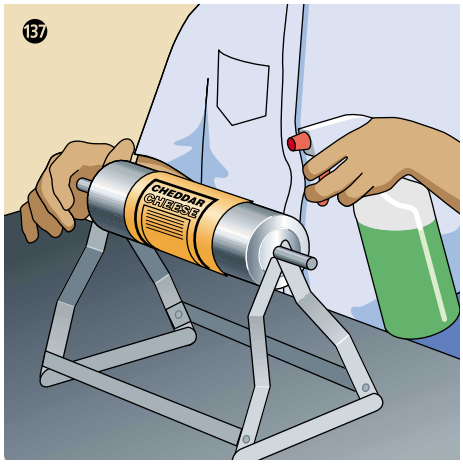
Cleanup Steps

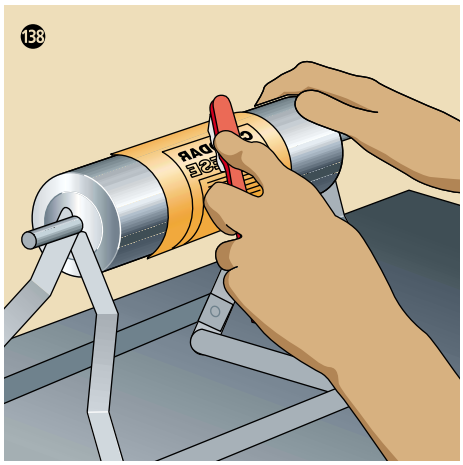
The following details typical cleanup procedures:

1. Turn off all heaters and blowers so the web is not damaged or burnt.
2. Remove all pressure from the dies, nip rolls and fountain roll.
3. Remove the plate cylinder.
4. If using a pump, turn off the pump and disconnect the power supply to stop the flow of ink.
5. Remove the ink supply hose (if using a pump).
6. Remove the stand pipe in the fountain (if using a pump) and drain the ink back into the ink container. Use a scraper or card to push the remaining ink down the drain hole.
7. If not using a pump, place the drain hose from the fountain into the ink container and remove the drain plug to drain the ink. Use a card or scraper to push the remaining ink down the drain and into the container.
8. Plug the drain hole again.
9. Pull back on the doctor blade pressure so it is not resting on the anilox.
10. Run the fountain roll into the anilox and flood the rolls with cleanup solution.
11. Quickly remove the ink pan and doctor blade assembly and place in a cleanup container.
12. Clean the face and sides of the rubber roll and anilox, and any other areas where ink is built up, using a shop rag and cleanup solution. Do not allow the rolls to dry.
13. Wipe each roll with normal propyl alcohol to remove any residue from cleanup soaps that may be used in a water-based ink cleanup.
14. Clean the fountain pan and drain hose, concentrating on areas where ink buildup exists. Use a dry rag to give the pan a final shine.
15. Clean the doctor blade assembly. Use caution when cleaning the assembly. Remove ink collected on all sides of the assembly.
16. If using submersible pumps, place the pump in a bucket of cleanup solution and flush it out. This procedure cleans the pump and the hoses. After flushing with cleanup solution, flush with fresh solvent or water.
17. Repeat the above steps for each printing station.
18. Clean any excess ink or adhesive from all impression cylinders, idlers and nip rolls.

The print station of a two-roll system contains pinch points between various rolls. These pinch points are referred to as inward nips (*Figure* 136). Use extreme care in this area because it is easy to catch a rag or finger in the nip.







136 Pinch points between various rolls are referred to as inward nips. The person cleaning the print station must use extreme care in this area because it is easy to catch a rag or finger in the nip.

137 A cleanup soap should be used to remove water-based inks from the plate.

138 A soft-bristled brush may be used to scrub the plate clean after the solvent or soap is applied to the plate.

Clean the Plates

The plates may be removed from the plate cylinders for cleaning, or they may be cleaned on the cylinders before demounting. When cleaning solvent-based ink off of the plates, the solvent blend for the ink system should be used. Excessive amounts of acetate should be avoided, as it will damage the plates. When cleaning water-based ink off plates, a cleanup soap should be used (*Figure* 137).

A soft-bristled brush may be used to scrub the plate clean after the solvent or soap is applied to the plate (*Figure* 138). The plates should be blotted dry with a rag or absorbent towel. Avoid rubbing the plate as this may damage the plate image.

Remove and Clean the Cutting Die

After the press stations and plates have been cleaned, the die should be removed and stored. Lay the die on a clean rag. A soft fiber brush, wooden paint stick, or other pointed instrument be used to remove any adhesive or ink buildup in the areas between the cavities of the raised engraving.

With the die cavities clean, the die should be inspected for damage and stored back in its shipping box or another protective storage container.

Label Ink Containers

Ink containers used during the run should be marked with the correct ink color and/or number. Any additives, bases or solvents that were added to the ink, and their quantities, should be noted on the containers. Dirty cleaning solution must be removed from the press and poured into a waste disposal container. The waste container should be recycled or disposed of as hazardous waste.

Remove Unprinted Stock

Unprinted stock should be labeled and returned to its assigned storage location.

Clean Tools and Press Area

All pH meters, viscosity cups and other tools used during the pressrun should be

cleaned and prepared for use on the next run. All spills and splashes around the machine should be wiped up not only for the sake of appearance, but for safety as well.

Clean Ultraviolet Curing Units

When using ultraviolet (UV) curing stations for inks or varnishes, the curing unit must be cleaned on a regular basis for it to function properly and create the needed radiation to set the ink or coating.

Use isopropyl alcohol to clean UV lamps and reflectors. Cotton gloves supplied with the lamp should be worn when installing or handling the light source to keep skin oils from coming into contact with the bulb. This is important because oil from the skin will affect the lamp's performance.

Wide-Web Press Procedures

Setting up a wide-web press varies from machine to machine. This variation is due to the wide variety of presses used in the market today. For this reason, this section focuses on the basics of setup that are common to most wide-web printers.

PRESS SETUP

The first step in press setup is to review the job jacket (*Figure* 139), job history sheet and any supporting material such as prepress proofs and previously printed samples of the job. From this information, the press operator and press assistants must visualize how the job must be set up to meet the customer's requirements.

In many cases, a mounter proof is supplied. This should be inspected to ensure that the printing plates are not defective, registration between colors is correct, and makeready is not needed on the print cylinders to compensate for plate height variations.

Select the Print Stations

From the information contained in the job jacket, mounter proof, and prepress proof or sample, the operator must select the appropriate printing station for each print cylinder. A primary consideration when choosing print stations is whether the job is a surface print (design prints on the outside of the substrate) or reverse print (design prints on the inside of the substrate). For example, a potato chip bag is surface printed to keep the ink from coming into contact with the chips; bathroom tissue is reverse printed so that after packaging the ink will be against the tissue to help protect the ink and enhance the gloss of the package.

Surface-printed colors are placed in the press so that the lightest colors are printed first, and the darkest colors last. Reverse print orders are just the opposite. This reversal is to facilitate trapping the lighter colors with the darker colors. All print stations may not be required for a given job. The operator must determine which stations to use based on existing colors in the press, colors needed for upcoming jobs, anilox rolls that are in each printing station, and the drying capacity needed between print stations. Large ink coverages may need to pass through several between-deck dryers to dry the ink properly before the next ink color is printed.

The print cylinders must be inspected for damage to the plates, and to ensure that the design on the plates matches the information on the job jacket and supporting material.

Determine the Substrate Wind

Before cylinders can be shafted and geared for the pressrun, it is essential to determine the required unwind and rewind for the job's end use. A rewind number that corresponds to the position of the copy on the printed roll is assigned to the design (*Figure* 140). This rewind number determines the end of the plate cylinder on which

139 A job jacket is a folder or envelope that stores valuable information about the job to be run.

139

JOB JACKET

CUSTOMER NO. ____ RUSH NO. ____
CUSTOMER ____ SALES PERSON ____ QUOTE NO. ____ REPEAT NO. ____ JOB NO. ____
DESCRIPTION ____ PREP'D BY ____ PO NO. ____ DATE ORDERED ____ TOTAL QTY. ____
REQUESTED SHIP DATE ____ ACTUAL SHIP DATE ____ % OVERRUN ____ % UNDERRUN ____ PRESS NO. ____

STOCK

HERE									

OVERLAMINATE ☐ YES ☐ NO

SPECIAL INSTRUCTIONS: ____

PLATEROOM NO. OF NEW PLATES ____ NO. OF REMARKS ____ MADE BY ____ MOUNTED BY ____

PRESSROOM

☐ LABEL ☐ CARD ☐ CARRIER ☐ OTHER ____
SIZE ACROSS ____ AROUND ____ LINER SIZE ____
CORNER RADIUS ____ PRESS DRAW ____

☐ DIE CUT ☐ BUTT CUT ☐ ROLLS
☐ SHEETED NO. PER SHEET ____ ☐ CONTINUOUS
REWIND POSITION ____ ☐ HAND ☐ MACHINE

COLORS

FRONT
1) ____
2) ____
3) ____
4) ____
5) ____
6) ____
7) ____
8) ____
9) ____
10) ____

BACK
1) ____
2) ____
3) ____
4) ____
5) ____
6) ____

VARNISH: OVERALL ____ SPOT ____

DIE NO(S) ____ ORDERED ____ REC'D ____
PERF/SHEETER ____ ORDERED ____ REC'D ____
PRINT CYL(S).SIZE ____ ORDERED ____ REC'D ____

PINFEED: ☐ LEFT ☐ RIGHT FANFOLD AT ____
PERFS: MARG. LEFT ____ SLITS: HORZ. ____
MARG. RIGHT ____ HORZ. ____
HORZ. ____ VERT. ____
HORZ. ____ VERT. ____
VERT. ____ VERT. ____

SPECIAL INSTRUCTIONS: ____

DIE SPECS
CYLINDER SIZE ____
NO. ACROSS ____ SPACING ____
NO. AROUND ____ SPACING ____

GRAPHICS SPECS ☐ SAME
☐ FLEXO ☐ LETTERPRESS
CYLINDER SIZE ____
NO. ACROSS ____ SPACING ____
NO. AROUND ____ SPACING ____

OTHER OPERATIONS

☐ REWINDING AMOUNT PER ROLL ____ CORE SIZE ____ ☐ SHRINKWRAPPING AMOUNT PER PACKAGE ____
☐ BURSTING FINISHED SIZE ____
☐ TRIMMING FINISHED SIZE ____
SPECIAL INSTRUCTIONS: ____

SHIPPING SHIPPING LABEL ☐ OLS ☐ PLAIN OTHER ____ CARTON SIZE ____ AMT. PER CTN ____
SPECIAL INSTRUCTIONS: ____

SHIPPING

PACKING SLIP ☐ OLS ☐ PLAIN OTHER ____
SHIP VIA: ☐ OLS ☐ PLAIN OTHER ____
BILL/LADING ☐ REGULAR ☐ NEXT DAY ☐ 2ND DAY
CARRIER ____
☐ PREPAID ☐ COLLECT ☐ COD
SHIP FROM: ☐ OLS ☐ OTHER

SAMPLES TO: DATE SENT ____ INITIALS ____
SPECIAL INSTRUCTIONS:

SHIP TO:

JOB NO.

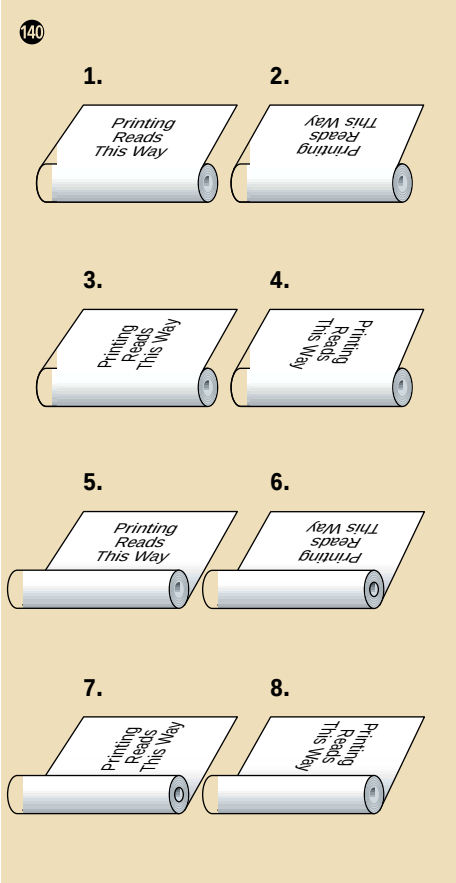
the gears must be placed to provide the customer with the correct wind for end-use applications. In some cases, gears are not interchangeable and the correct gear position is determined when the job is mounted. In this case, the operator needs to check the gear and rewind numbers.

Install Cylinder Hardware

After the gear side of the plate cylinders is determined, the necessary plate-cylinder hardware must be installed in the correct sequence. At this point in the setup sequence, the operator or assistant should place the bearers, gears, bushing and register control mechanisms on the plate cylinders. Some cylinder hardware setup should be performed during the previous pressrun to help reduce downtime.

Change Anilox Rolls

In many cases, anilox rolls must be



140 A rewind number corresponds to the position of the copy on the printed roll. The rewind number is used to determine the unwind and rewind requirements for the job.

changed in the press during the setup of a job to acheive the correct ink density for the design. Changing anilox rolls is often more complicated than changing plate cylinders since more disassembly of the press is required. An anilox that is removed or installed in a print station should be covered to protect against surface damage.

Anilox Roll Selection Guidelines

Anilox roll selection varies with the printing application, substrate, plate material and the ink system being used. The best selection is an anilox roll that will provide the ink transfer needed to meet the customer's color standard while providing consistent inking of the images on the plates. This selection rule is especially true when printing tone or process work.

When selecting laser-engraved anilox rolls, consider the following general guidelines:

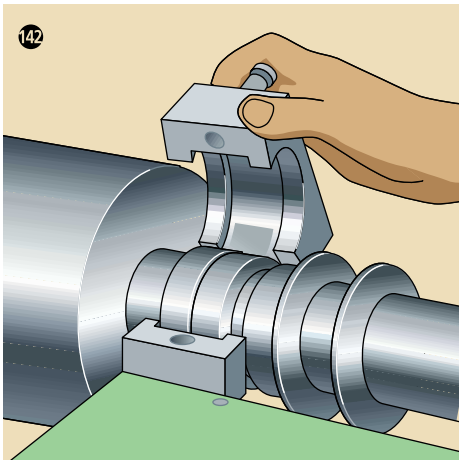
- 60° engravings are generally used for most applications. Although laser engraved anilox rolls can be manufactured with 30°and 45° configurations, 60° rolls have been shown to provide advantages in ink release.
- Line-count selection is determined by the copy to be reproduced on the press. In applying coatings and varnishes, rolls with line counts of between 85 and 200 are commonly used. For printing solids (large ink coverage areas), line counts of between 200 and 400 are usually used. When printing screened areas (tone and process images), the general rule is to use an anilox roll with a minimum of a 4:1 ratio between the line count of the screened area on the plates and the line count of the anilox roll. In other words, to print a 100-line process job, an anilox with a minimum of 400 lines should be selected. In this example, the higher line-count roll can be used to provide finer inking of the plate images as long as the density of the print can meet the color standards for the job. This 4:1 ratio is only a general starting point.
- Cell-volume selection is determined by the job to be produced on the press. A volume range of 1.6 BCM (billion cubic microns) to 4 BCM is generally used for reproducing screen and process work. Rolls with a BCM between 3 and 7 should be selected for printing line work. Volumes used for printing solids are generally in the 5 to 8 BCM range. Higher BCM rolls should be used to apply coatings, adhesives and varnishes.

Load Cylinders into the Print Stations

After the anilox rolls have been selected for the job and are loaded into the press, the print cylinders should be loaded into the

141 Due to the heavy weight of wide-web plate cylinders, most operations use carts for the safe handling of cylinders.

142 When installed and tightened, bearing caps keep the roll stable during the pressrun.



appropriate print stations.

Wide-web plate cylinders are extremely heavy, thus requiring the operator to use carts and/or hoists for the safe handling of cylinders (*Figure* 141). Operators must use caution when loading print cylinders into the press to prevent the plate surfaces from being bumped and damaged. After all the cylinders are loaded into place, bearing caps must be installed and tightened to keep the roll stable during the pressrun (*Figure* 142).

Ink the Print Stations

The next step in the setup procedure is to ink up the print stations. The following procedure details a typical print station inking:

1. Double check the color in the ink container to verify that it is the color to be placed in that print station.
2. Circulate the ink in the ink pump through the supply hose back into the pump to remove air from the system.
3. If an ink pan is being used, align the ink pan and lock down the hold down mechanism. Ensure that the pan will not rub on the ends of any rolls or the surface of the plate cylinder.
4. Connect the return hoses from the ink pan to the ink pump, making sure they are routed around any moving parts. With water-based inks, return hoses must be slightly submerged in the ink of the ink pumping unit to help avoid foaming.
5. Connect the supply hose from the pump to the ink distribution system.
6. Pump the ink into the distribution system.
7. After the ink has been pumping for a time, take the viscosity (pH and viscosity for water-based inks) to ensure that the ink is at its running parameters. If the ink is not at its running parameters, it should be adjusted and rechecked to meet specifications before the pressrun begins.

Set the Fountain Roll and/or Doctor Blade

Once the ink is in the fountain and is within its recommended running pH and viscosity parameters, the anilox roll may be inked.

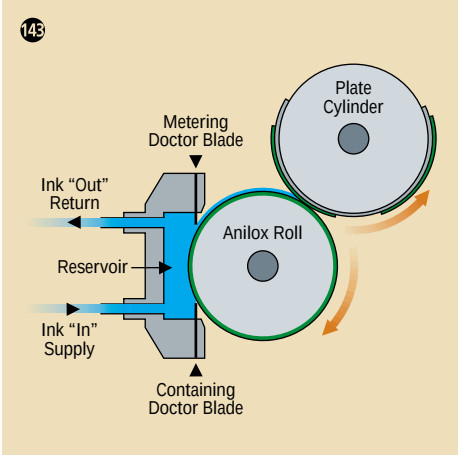
When using a two-roll system, the fountain roll is adjusted to squeeze against the anilox roll. Once the press is started, the rubber roll is adjusted so that it evenly squeezes the ink off the anilox using the minimum amount of pressure. This pressure setting is checked by backing the fountain roll off until the operator can see the nip flood with ink. Then the operator squeezes back in with both sides of the rubber roll, making sure they are even, until the flooding on the surface goes away. By doing this several times, the ink wipe is set.

On some wide-web presses, a doctor blade is used in conjunction with the rubber fountain roll. In this case the doctor blade must be set to meter the anilox roll.

When setting a station with a doctor blade, the fountain roll pressure should be set a little loose. This setting allows for extra ink to go through to the doctor blade where it is metered off. The doctor blade assembly is set into its holder and then slowly tightened down until it touches the anilox. As the blade is tightened to the anilox, the operator will notice that the ink will meter from the center of the anilox roll outward to the ends. When the ink is metered off the ends of the anilox roll, the wipe is set. Similar to the procedure for setting fountain roll pressure, the doctor blade should be backed out and brought back in to the anilox several times in order to set the wipe with the minimum amount of pressure. Overtightening the doctor blade can cause the blade to fold under the pressure, causing the ink to dry due to the friction and heat buildup behind the blade. If ink drying occurs, the dried ink pigments can cause damage to the anilox roll.

Once the ink is metered correctly, cover the fountains with the ink-fountains covers. The covers reduce the amount of amine or solvent that evaporates out of the ink to help keep the ink more stable during the pressrun.

If the press is equipped with a chambered doctor-blade assembly, the assembly is installed before the pump is turned on. The ink wipe should be set in the same manner as a single blade, and there is no rubber roll to set (*Figure* 143).



143 A chambered doctor-blade assembly should be installed before the pump is turned on. The ink wipe should be set in the same manner as a single blade, and there is no rubber roll to set.

Set Impression, Inking, and Registration

The following procedure details a typical impression, inking and registration setup:

1. With the press running at a slow speed, start with the last color to be printed and achieve the correct impression and ink settings. Turn down the impression slightly so the plate comes into contact with the web.
2. Turn in the anilox-to-plate adjustment to begin inking the plate. While looking at the print on the web, make adjustments to the impression and ink settings until there is a clear print with no images missing.
3. Similar to the setting of the rubber roll or doctor blade, back in and out on the settings to achieve ink and impression settings with the minimum amount of pressure.
4. Set the remaining ink and impression settings, working backward to each print station in order from last to first.
5. After all the settings are complete for each print station, adjust for color-to-color registration. Start with the first station (front of the press) and set register for each station in order.
6. Once all the colors for the job are in register with each other, check print-to-die registration. Register the die cutter and slitter to the printed image. In all flexo press settings, it is important to use the minimum amount of pressure to do the job.

Check Colors to Standard

Once the press is set up and all settings are

complete, the printing must be checked for accuracy against a color standard that has been approved by the customer in the design stage of the job. A color standard may be a previously printed sample, a Pantone®[11] sample, an ink drawdown or a spectrophotometer reading.

All visual color matching should take place in a viewing booth designed for this purpose. This type of booth provides a standardized light source with a neutral gray background to check color, eliminating the color variations during the color-matching process caused by lighting conditions.

A sample of the print should be compared to the color standard to ensure that the printed job meets the customer's requirements. The operator should check to make sure the color is printing at the correct density (lightness and darkness) either visually or with the use of a densitometer. If the color is not printing at the correct density, the anilox may be changed to achieve a density match with the standard. This change is especially useful when working with ultraviolet inks. For slight density changes that are needed when working with conventional inks, the ink viscosity may be changed by adding solvent, or the ink may be extended to reach the color standard.

The ink hue should also be checked visually in a light booth or with the aid of a spectrophotometer. If changes in hue are needed, the operator should add the correct ink bases to reach the color standard. All of the information from the color matching process should be documented so the job can be reprinted without additional downtime.

Approval Form

Many companies use a checklist approval form that is filled out after the job has been set up and approved (*Figure* 144). This form helps ensure that all the details for printing the job have been covered and that the job matches the specifications on the job jacket.

The goal in setting up any wide-web flexographic press is to minimize the preparation time to get the job running quickly. This timing requires efficient teamwork between all production personnel. Operators must anticipate the next task to be completed during the setup to reduce downtime. A press will only make money when it is in production. Setup time is expensive.

PRESSRUN PROCEDURES

Once the press is running, there are quite a few other areas that must be checked regularly. Here's what needs to be done next…

Ink Viscosity and pH

Maintaining viscosity, or pH and viscosity in the case of water-based inks, is essential for producing consistent print throughout the production run. If an ink is color-matched at a 25-second viscosity, a higher viscosity will make the color print darker. A higher viscosity occurs because the solvent or amines evaporate out of the ink during the pressrun, causing the customer's product to become inconsistent as the run progresses. In order to maintain the same density of print throughout the pressrun, viscosity (solvent based inks), or pH and viscosity (water-based inks), must be maintained.

When doctor blades or chamber blade systems are used, high viscosity inks will cause ink starvation by not reloading the anilox cells. The print will not be consistent and the color variations in the product will not be acceptable to the customer. If the ink is running at a lower viscosity than the viscosity of the color match, the color will get lighter. If the viscosity gets too close to the minimum running viscosity for that ink, printing defects may occur.

Controlling Ink Viscosity and pH. Viscosity

[11] Pantone, PMS and the Pantone Matching System are trademarks of Pantone, Inc.

144

PRESS APPROVAL START-UP SHEET

CUSTOMER _____ JOB NO. _____ ITEM NO. _____
DATE _____ PRESS NO. _____
STOCK _____ INV. NO. _____ SIZE _____

MULTIWEB OR COUPON
- ☐ CONSTRUCTION TYPE _____ ☐ GLUE _____
- ☐ BASE STOCK _____ ☐ TOP STOCK _____
- ☐ PROPER RELEASE (NOT TOO TIGHT/NOT TOO EASY)

SIZE
- ☐ JACKET ☐ DIE NO. _____
- ☐ MOCK-UP ☐ LINER SIZE _____

DIE CUTS
- ☐ HAND APPLIED ☐ MACHINE APPLIED ☐ CARD CURL
- ☐ REGISTRATION ☐ DIE CUT ☐ BUTT CUT ☐ SHEETED
- ☐ PERFED ☐ SCORED ☐ SLITS ☐ MARGINAL PUNCHES
- ☐ CUTTING CLEAN ☐ LINER TEST ☐ HOLES ☐ TEAR TAB
- ☐ SINGLES LAY FLAT ☐ JOG EVEN SIZE

FANFOLD
- ☐ FOLDING STRAIGHT ☐ PERF TEARS CORRECTLY (NOT TOO HARD/NOT TOO EASY)
- ☐ CUTTING CLEAN ☐ HINGE FOLDING CORRECTLY ☐ PINFEED HOLE ALIGNMENT
- ☐ POSITION OF FOLD ☐ SPLICES REQUIRED ☐ NO SPLICES ☐ SIZE OF FOLD _____

MISC.
- ☐ MACHINE COUNT: _____ ☐ SCRATCH OFF
- ☐ % OVERRUN _____ ☐ UPC SCAN

COPY
- ☐ REGISTRATION REWIND _____ ☐ COLOR SEPARATIONS
- ☐ READ ☐ POSITION ☐ IMPRESSION ☐ QUALITY
- QUALITY LEVEL ☐ 1 ☐ 2 ☐ 3

INK — LIST PMS COLORS
- ☐ FACE COPY—WATER BASED 1) 2) 3) 4) 5) 6) 7)
- ☐ FACE COPY—SOLvENT BASED 1) 2) 3) 4) 5) 6) 7)
- ☐ BACK COPY—WATER BASED 1) 2) 3) 4) 5) 6) 7)
- ☐ BACK COPY—SOLVENT BASED 1) 2) 3) 4) 5) 6) 7)

- ☐ WRITE ON _____ ☐ VARNISH _____
- ☐ PRIMER ☐ UV CURING ☐ TAPE TEST ☐ RUB TEST

NEXT OPERATION
- ☐ REWINDER ☐ FANFOLDING ☐ TRIMMER ☐ TIPPING
- ☐ SHRINKWRAPPING ☐ PADDING ☐ OTHER _____
- ☐ SHIPPING FROM PRESS

BOXES
- ☐ STANDARD ☐ SPECIAL SIZE _____

LABELING
- ☐ STANDARD ☐ SPECIAL

COMMENTS: _____

I HAVE MADE ALL THE APPLICABLE CHECKS AND APPROVE THIS ORDER FOR START-UP.

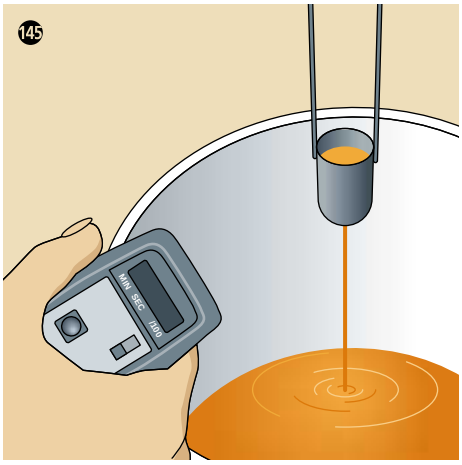
_____ OPERATOR _____ SUPERVISOR

144 A checklist approval form should be filled out after setup has been completed and approved.

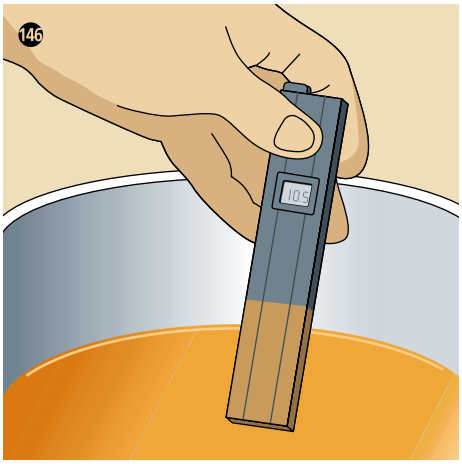
checks should be completed every 10 to 15 minutes when using solvent-based inks. When using water-based inks, pH and viscosity should be checked every 30 minutes. It is important to check pH first, followed by viscosity, when using water-based inks because the viscosity is affected by the pH level. Solvent inks require more frequent checks of viscosity since the solvent evaporates quickly and is more unstable than the water in water-based inks.

To control an ink's viscosity, small amounts of a reducer should be added. The viscosity level should never get so high that it takes more than a pint of reducer to return the viscosity to the correct level. Careful control of ink viscosity (pH and viscosity for water-based inks) results in consistent color and uniform ink flow throughout the job run.

To control solvent-based ink viscosity, solvent reducer is added during the pressrun. The make-up solvent should have a slightly



145 One way of checking viscosity is by timing the ink flow through a Zahn cup.



146 When using water-based inks, it is crucial to maintain a pH in the range of 8.0 to 9.3.

higher percentage of the fast solvent than the solvent in the system. For example, if the ink system is 10% normal propyl acetate and 90% normal propyl alcohol, the acetate is the fast solvent and will tend to evaporate faster than the alcohol, which is the slow solvent in the blend. The make-up solvent should be a slightly higher concentration of acetate to keep the ink stable, as well as maintain the viscosity during longer runs.

To control viscosity in water-based ink systems, water and amine are used. A stabilizing varnish may also be used. Stabilizing varnish is a water and amine combination that has been premixed to the correct percentages for the ink system being used. An addition of stabilizing varnish should lower the ink viscosity while maintaining the pH of the ink. Water alone will reduce the viscosity, but it may also reduce pH, which causes other print problems.

Many wide-web presses used for long runs are equipped with automatic viscosity controllers. Viscosity controllers dispense a predetermined amount of solvent into the ink system to keep the ink stable throughout the pressrun. It is important, however, to check the viscosity manually (*Figure* 145) when using these controllers to ensure that the they are working properly.

Water-based inks should be run in a specific pH range to keep them working efficiently. The pH range varies by ink manufacturer and the requirements for the job. Generally, water-based inks are in the pH range of 8.0 to 9.3. When the pH of a water-based ink falls too low, the ink will begin to body and thicken, eventually causing rewetting problems and dirty printing. If the pH is too high, the viscosity of the ink will be too low, causing drying or blocking problems. Color variations and print defects caused by pH levels can be eliminated by maintaining pH within its recommended range.

A pH meter is the instrument used to read pH levels (*Figure* 146). These instruments should be calibrated to a buffer solution with a known pH on a regular basis. Similar to viscosity controllers, many presses have automatic pH controllers that check pH and add predetermined amounts of stabilizer or amine to maintain the proper pH level in the ink. Operators should double-check these devices by reading the pH manually to guarantee they are working properly during the run.

Adding Ink to the Fountain

During longer runs, the press operator may be required to add ink to the fountain or pump. This requires specific attention to detail. The following procedure details a typical ink addition procedure:

1. Double-check the ink to be added for correct color. Do not assume that an

ink container is marked correctly.

2. Adjust viscosity (and pH for water-based inks), of the ink to be added. Solvent-based ink to be added to the fountain should be thinned to a viscosity that is two to four seconds higher than the ink in the fountain. Viscosity of water-based inks should be five to 10 seconds higher than the ink in the fountain. Agitation of the ink will cause a viscosity drop of three to five seconds.
3. Add only enough ink to bring the level back to the optimum level.

The optimum level should be determined before the production run. It is based on the amount of ink coverage for a given color, which depends on the ink coverage for the job being printed. The big print areas that use more ink will require the ink pans to be filled more often than those that use little ink. Add fresh ink each hour to a low coverage area rather than filling up the fountain and adding only solvent or stabilizer for the whole shift. Fresh ink helps maintain the correct balance between colorant, resin and solvent (water and amine for water-based ink).

Ink loses printability and flow characteristics if only solvent (water and amine for water-based inks) is added over a period of time. This loss is due to the depletion of the colorant and the resin in the ink.

For the ink to work properly, and to avoid printability problems, press operators must know the following about the inks they are using:

- upper and lower working viscosity limits;
- solvents and additives to be used;
- range of pH for water inks; and
- maximum pigment load the ink can handle.

By maintaining the proper percentages of ink components, the color will be more consistent and fewer print problems will occur.

Inspection and Quality Checks

During a pressrun, the operator should make ongoing inspections of the press and the job being printed. The following items are typical pressrun checks:

- Listen to the press for any unusual noises that may indicate a mechanical problem.
- Double-check the ink level in the fountain or pumping unit. When using a pump, check the ink flow to the pan.
- Ensure that the low roll indicator is on. Prepare for roll changes and splices.
- Monitor print quality with a strobe light, video monitor or the naked eye.

During the pressrun, print registration may change and could be caused by the following:

- incorrect web tension between in-feed and out-feed ends of the press;
- rewind roll tension is too high;
- web splices offsetting the web;
- rolls of stock varying from roll to roll;
- baggy edges on the rolls of stock moving the web to one side; and
- web thickness and adhesive coating vary on rolls.

Inspecting a print sample is the most accurate check of print quality. Operators should not rely on checking print quality on the moving web alone. Samples of the printed product must be checked visually with a magnifier for poor registration, poor ink lay, color drifts, color match, and ink adhesion or cure. The operator should be looking for variations in:

- print registration (*Figure* 147);
- the cleanliness and sharpness of the print;
- ink or impression misses;
- ink picking;
- flaws due to plate lift, lint or other causes; and
- print quality.

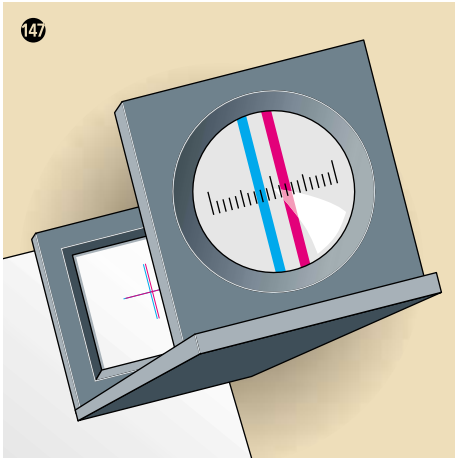
Printed samples should be checked against the color standard on an ongoing

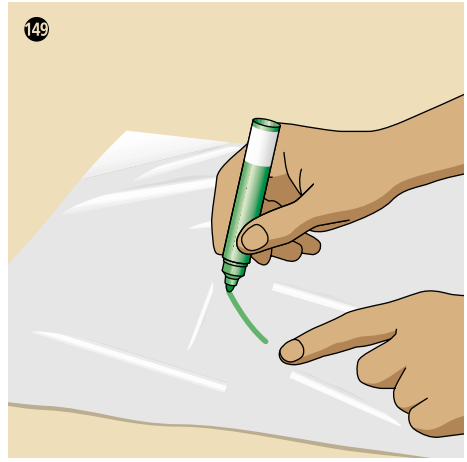
147 A magnifier can be used to check for errors in print registration.

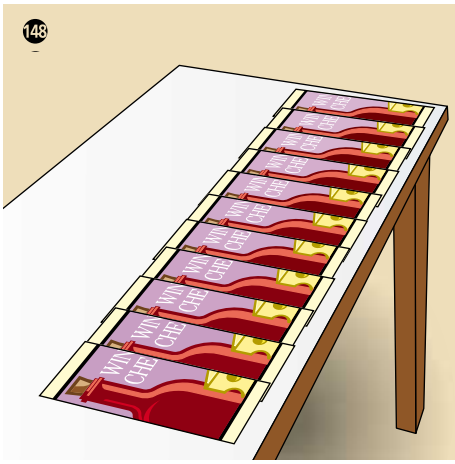
148 A color-drift check is accomplished by placing consecutive samples in a row on a white background.

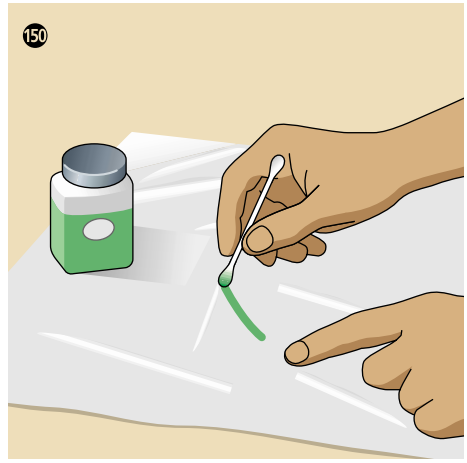
149 Conducting a dyne test with a pen.

150 Conducting a dyne test with liquid.









basis to ensure consistency throughout the run. If a densitometer or spectrophotometer is being used when the job is set up, and during the initial color match, it should be used during the pressrun. Samples from each printed roll should be evaluated.

Color-drift checks are performed by laying consecutive samples in a row on a white background (*Figure* 148).

Ink-adhesion tests are performed by putting cellophane tape firmly onto the printed image and pulling slowly upward from the image for half of the length of the tape. The remaining tape is pulled quickly off the other half. The tape is then examined to see if it is free of ink.

Solvent-based inks typically have a dyne level of about 23. Water-based inks have a dyne level of around 30 or higher depending on the surfactants being used. In order to have good ink transfer and adhesion, the film being printed should have a dyne level approximately 10 levels higher than the ink being used.

Flexographic printing on film generally requires that the film be treated, which changes the surface of the substrate so that the ink can adhere. The amount of treatment on a film is measured in dynes with a special solution using pens or liquids (*Figures* 149 150).

Quality Awareness

The flexographic printing process requires consistent and careful monitoring during the pressrun. There are no assurances that a job printing well presently will be doing so in five

or 10 minutes. Proper pressrun procedures are the mainstream of top quality finished products. Press operators must learn and perform all pressrun procedures well. Quality checks should be performed regularly and the results should be documented. These results should be kept for a period no less than the life of the product produced. Quality is the result of conscious effort by the operator.

Preparing for the Next Job

Preparing for an upcoming job is commonly done while the current job is running. Preparation generally requires assembly of the necessary plate rolls, substrates, inks, cores and tooling. The press operator and assistants should perform the following activities in preparation for the next job:

- review information in the next job jacket;
- plan print station wash-ups;
- note required inks and colors;
- note colors and anilox rolls in current use that may be needed; and
- gather all materials and supplies in advance.

CLEANUP PROCEDURES

Most jobs require some degree of cleanup upon the completion of a run. Inks for the next run are often different, which requires that the press equipment be washed. Since the press is profitable only when it is in production, an efficient cleanup program is needed. A correct wash-up procedure minimizes downtime between jobs and maintains the press in good working condition. Cleanup procedures vary by company and brand of equipment.

Before the actual cleanup, the operator should double-check the next order to determine if any inks can remain for the next job.

Preliminary Cleanup Steps

The following preliminary steps should be taken before starting the cleanup process:

1. Cover the lower decks with scrap material to protect them from ink drips caused by washing an upper deck.
2. Position ladders needed to reach the upper decks.
3. Move ink decks away from the impression cylinder if appropriate.
4. Fill a container with wash-up solution and place it near the print station.
5. Get an empty container to catch wash-up solution coming from the ink pan.

In an effort to conserve ink, the operator should lower the ink pan and squeegee the ink down the ink return hose and into the ink pump before wash-up begins. The return hose should be switched to the wash-up container, at which point the clean up process begins.

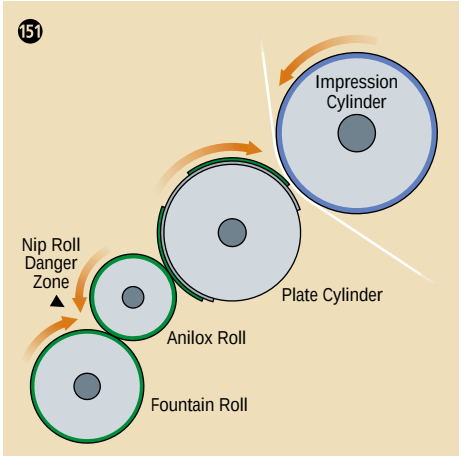
Two-roll Station Cleanup

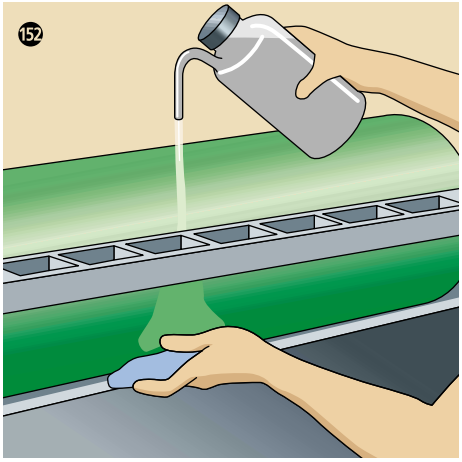
The following procedure details a typical cleanup for a two roll system:

1. Turn off the ink pump and disconnect the power supply to stop the flow of ink.
2. Pump cleaning solution through the entire system. This pumping makes the entire system easier to clean.
3. Remove the ink supply hose from the deck.
4. Stop the rotation of the rubber roll.
5. Release the pressure between the rubber roll and the anilox roll.
6. Move the ink return hose from the ink pump to the wash-up container.
7. Reset pressure between the anilox and rubber roll and restart their rotation.
8. Flood the anilox and rubber roll with wash-up solution as they slowly turn. The solution will remove ink from the surface of the rolls. Thorough cleaning may require several passes over the rolls with fresh solution to remove the ink.
9. Release the pressure between the anilox roll and rubber roll on one end only.
10. Wipe the anilox roll. Begin on the side with the released pressure. Use a folded

151 The area where two rolls meet is known as a nip zone. Care must be taken to avoid catching fingers or rags in nip zones during cleaning.

152 Use extreme care when cleaning the plates.





rag or shop towel soaked with cleaning solution. If water-based ink is being washed up, it is best to keep the fountain roll and anilox roll wet until the ink is washed off, otherwise the dried ink will be difficult to clean later.

11. When the end of the roll is reached, release the pressure on the remaining end. Finish wiping the anilox roll.
12. Clean the rubber roll the same way as the anilox roll.
13. Stop the rotation of the rubber roll and thoroughly clean both ends of the anilox and rubber roll.
14. Go over each roll with propyl alcohol to remove any residue left from the soap used to clean water-based inks.

The print station of a two-roll system contains pinch points between various rolls. These pinch points are referred to as inward nips (*Figure* 151). The person cleaning the print station must use extreme care in this area because it is easy to catch a rag or finger in the nip.

Chamber-bladed Station Cleanup

The following procedure details a typical cleanup for a chamber blade system:

1. Disengage the doctor blade assembly from the anilox.
2. Lock the blade assembly into the cleanup position using the appropriate safety mechanism.
3. Clean the anilox roll by passing a folded clean rag or towel soaked in cleanup solution along the entire face of the roll as it rotates.
4. Turn off the anilox drive motor and wash both ends of the anilox thoroughly.
5. Carefully remove any ink buildup from the sides of the anilox.
6. Make a final pass with a clean damp rag. Follow with a clean dry rag to finish the cleaning process.

Extreme caution is required when cleaning the anilox roll when a doctor blade is being used. The cleanup person must be aware of the location of the blade to avoid accidental bumping while cleaning. Doctor blades are extremely sharp and can cause severe injury.

Cleaning the Plates

When cleaning solvent-based ink off of the plates, the solvent blend for the ink system should be used. Excessive amounts of acetate should be avoided, as it will damage the plates. When cleaning water-based ink off of plates, a cleanup soap should be used (*Figure* 152). A soft-bristled brush may be used to scrub the plate clean after the solvent or soap is applied to the plate. The plates

should be blotted dry with a rag or absorbent towel. Avoid rubbing the plate, as this may damage the plate image.

After the plate is clean, ink on the cylinders and gears should be removed. The operator should make note of any damaged or worn plates and identify any defects so new plates can be ordered for the next run of that job. A bad cylinder or gear should be reported so it can be repaired or replaced.

Doctor-blade Assembly Cleanup

Cleaning the doctor-blade assembly requires direct contact with the doctor blade. Cut-resistant gloves should be worn to minimize the risk of injury. In some cases, the blade assembly is removed from the press for cleanup. The following procedure details a typical cleanup for a doctor blade assembly:

1. Soak a shop rag or towel in cleaning solution and wipe the inside and outside of the assembly. Also wipe both sides of the blade. Light pressure will reduce the chance of the blade cutting through the rag.
2. Check the condition of the doctor blade. Carefully remove blades that show excessive wear or damage. Dispose of blades in a designated container.
3. Continue cleaning the blade assembly with a soaked rag until most of the ink on the assembly is gone. Complete a final pass with a clean damp rag to remove any last traces of ink.

Operators must remember that the anilox roll is already clean. Splatters that land on the roll surface from cleaning the assembly must be removed.

Replacing a Doctor Blade

If a worn or damaged doctor blade must be replaced, the blade assembly may need to be removed from the station. The following procedure details replacing the doctor blade:

1. Loosen and/or remove the hold-down bolts.
2. Remove the doctor blade using slow, steady pressure. Work carefully along the length of the blade holder, pulling short 6" to 9" sections until the blade is totally removed.
3. Clean all ink from the hold-down cavity to ensure that the new blade will sit in the assembly properly.
4. Install a new blade in the hold-down cavity.
5. Tighten the hold-down bolts slightly, working from the center out to each end.
6. Tighten down the hold-down bolts all the way, again working from the center out to the ends to ensure the blade is seated evenly.

In many cases, the blade assembly must be broken down to allow for further cleaning before the new blade is installed. This step removes any pooled ink from inside the holder. It is especially important if the next run has a contrasting ink color that can be contaminated by the old ink color.

When cleaning up water-based inks, the doctor-blade assembly should be thoroughly dried. Moisture trapped within parts of the assembly can result in rust damage. The assembly should be set on end to dry rather than face down to ensure that the moisture can escape.

Cleanup Ink Pans

The next step after washing the doctor-blade system is cleaning the ink pans. The following procedure details a typical ink pan cleanup:

1. Put the pan into position for washing. Scrape any liquid ink into the drain hole.
2. Place a rag at the bottom of the ink pan and saturate it with cleaning solution.
3. Pass the rag over the entire interior of

the ink pan to rewet the dried ink in the pan. Concentrate on areas where ink buildup exists, rewetting the rag as needed.

4. Wipe the ink pan dry using a second rag when all ink buildup is removed. Only a haze should remain.
5. Dampen another clean rag with cleaning solution to remove the remaining pan haze. Immediately use a dry rag to give it a final shine.
6. Use the two rags to clean the outside of the pan and deck cover.
7. Remove the ink return hose. Wipe any remaining ink out of the drain hole.

Label Ink Containers

The containers holding the ink used during the run should be marked with the correct ink color and/or number. Any additives, bases or solvents that were added to the ink, and their quantities, should be noted on the containers.

Dirty cleaning solution must be removed from the press and poured into a waste disposal container where it will be recycled or disposed of as hazardous waste.

Remove Unprinted Stock

Unprinted stock should be labeled and returned to its assigned storage location.

Clean Tools and Press Area

All pH meters, viscosity cups and other tools used during the pressrun should be cleaned and prepared for use on the next run. All spills and splashes around the machine should be wiped up, not only for the sake of appearance, but for safety as well.

Clean the Pumps

If submersible pumps are used, the operator should place the pump in a bucket of cleanup solution and flush out the pump and hoses. After flushing with cleanup solution, the pumps should be flushed with fresh solvent or water. Repeat these steps for each printing station.

Corrugated Press Procedures

The procedures for a corrugated flexographic press setup, run and cleanup vary depending on the press manufacturer, the age of the press and the different methods used by printers. For this reason, this section focuses on the basics of setup that are common to most corrugated printers.

PRESS SETUP

Corrugated press crews typically make several setups each day. Each setup must be made in the most time-efficient manner possible. In order to achieve a high level of efficiency, it is important for the crew to look ahead to future orders. Looking ahead allows crews to coordinate the colors being run from print station to print station and the type of board being run. This coordination creates better efficiency because the press should not need to be broken down as much, and only the stations to be changed need to be washed for the next order. Crews must plan ahead to have the next order's ink, stock and other materials ready before the existing run is finished. Running a corrugated press requires good communication and thorough planning between the crew members.

Supply Assurance Precheck

A supply assurance precheck should be completed prior to press setup. The following items detail a typical precheck. All items should be available and reviewed by the crew before press setup:

Shop orders. Sometimes referred to as job instructions, work orders or job jackets, this order contains all of the instructions needed to produce the finished product to the customer's specifications.

Print card. Sometimes called a print copy, this card is a part of the shop order. It contains specific instructions for the job being printed, and provides information on dimensions, position, color and quantity (*Figure* 153). In most cases, the card also contains a graphic layout of the job.

Printing plates. Plates should be at the press site and checked against the copy to be printed.

Ink. Ink should be at the press site and checked for the proper color and quantity.

Stock. Stock should be at the press site and checked against the work order for size, flute and test. Board test refers to the proper liner, medium weights of stock and flute.

Once the crew has determined that these items are at press side and meet requirements, the press setup may begin. All safety lockout devices must be in the proper position before beginning the setup.

Set the Feed Mechanism

The press setup is initiated by the setup of the feed mechanism. The basic height of the feed table is fixed in relationship to the bottom feed roll, the pull roll collars and the print cylinder with the plates attached.

First, the side-hopper feed guides and

153 A print card layout contains specific instructions for the job being printed, including dimensions, position, color, quantity and in most cases, a graphic layout of the job.

154 Side guides are mounted on a bar across the feed table.

155 A back stop is set by placing a stack of stock within the feed guides and adjusting to the width of the blank.

113

CUSTOMER _____

BOX NO. _____

PLATES RECEIVED _____ ☐ CUST ☐ GPB

_____

PLATES USED ON _____

REPLACES _____

PRINT CARD

PRINT NO. _____

LOCATION _____

PANELS _____

COLORS 1 _____ 2 _____

TRANSPARENCY _____ 3 _____ 4 _____

REMARKS _____

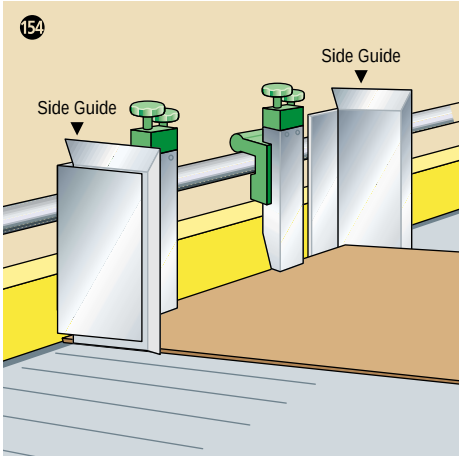
MASTERS FOR DIES LOCATED AT

☐ PE ☐ PRP

☐ RE ☐

JOB#

154



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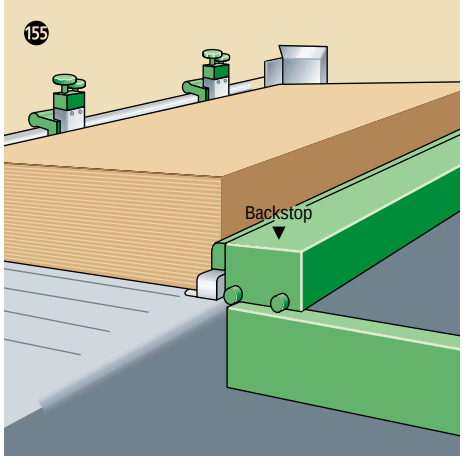
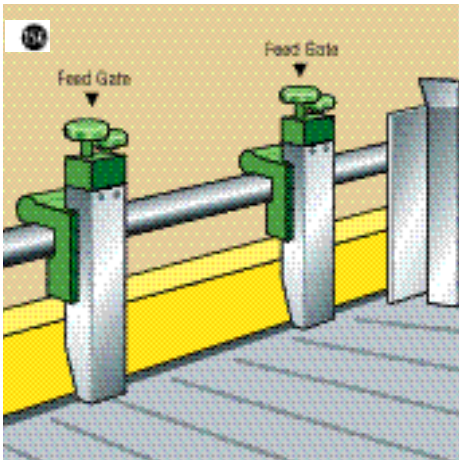
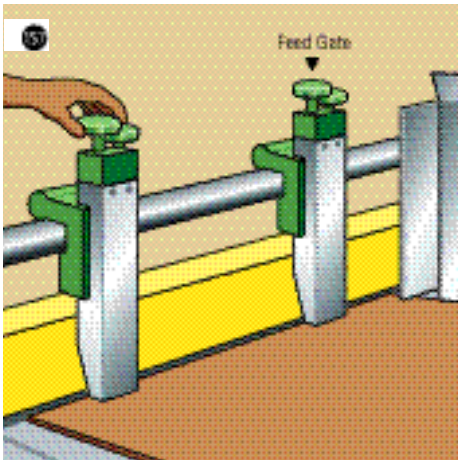
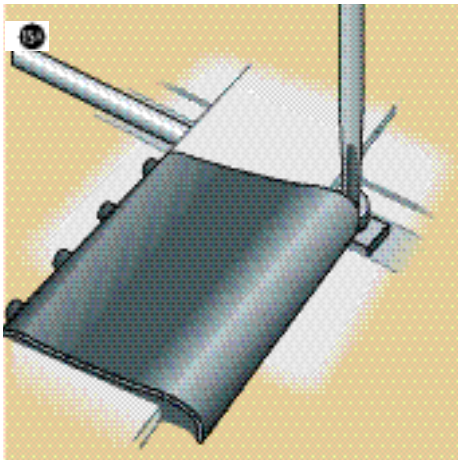


backstops must be set. Many corrugated presses set up over center, meaning that the length of the sheet to be printed is in the center of the press. The feed (side) guides are mounted on a bar across the feed table and have measurement tapes or scales attached. They are adjustable on this bar from the center of the machine to either side and are locked by means of a screw-handle device. Feed guides should be positioned on the







Feed gates should be set so as to allow only one board to pass onto the press at a time.

Feed gates are raised or lowered by rotating the dial at the top.

The feed gates are adjusted by sliding one sheet of board under the gate and allowing an additional space the thickness of one-quarter of the caliper of the board.

guide bar one-half the stock length from center (*Figure*).

The backstops must be properly positioned in conjunction with the feed hopper. Proper setting of the backstops is best attained by placing a stack of the stock to be run within the feed guides and adjusting according to the width of the blank, as seen in *Figure*). This setting will vary depending on the type of feed style being used, such as a kicker feed or a lead-edge feed.

Set the Feed Gates

Feed gates should be set to allow only one flute thickness of stock to pass under it during the feeding operation of the press. If the feeder should allow more than one sheet to pass at a time, the press may jam. It is important to set the feed gates for each job to be run. Similar grades of corrugated board may differ in caliper due to variations in manufacturing.

All corrugated presses have two feed gates (*Figure*). Once each gate has been set for proper caliper, they each should be placed at an equal distance between the feed guides (hopper) and the center of the press.

The feed gates are adjusted by sliding one sheet of board under the gate and allowing an additional space the thickness of one-quarter of the caliper of the board (*Figure*).

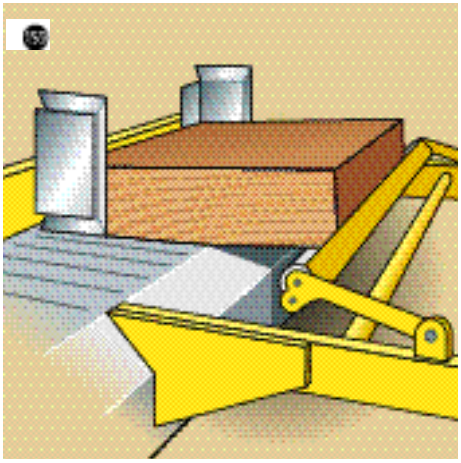
When working with a press that has a computer control system, the setting should be checked with a sheet of board and fine tuned before the run.

Set the Feed Device

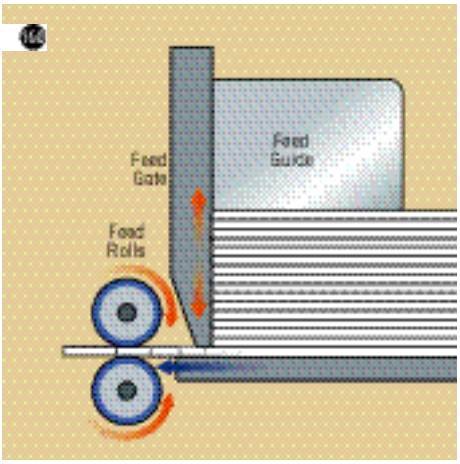
The two most common feed devices used on direct-print presses are the kick feeder and the lead-edge feeder. The kick-style feeder hits the sheet from the rear edge to push the board into the press. The lead-edge feeder carries the sheet into the press from the front edge of the sheet.

To adjust a kick feeder, the operator should set the kicker bar to the width of the board being run (*Figure*)

To adjust a lead-edge feeder, the operator typically only sets the feed gates and feed guides because the feed action is preset for



A lead-edge feeder transports the board to the press by grabbing it from the lead, or front edges.



Feed rolls must be set tight enough to grip the blank so as to prevent slippage as the blank enters the press.

most operating conditions (*Figure*).

The next step in the setup of the feeding device is to set the feed roll. On manually set machines, the feed roll is set with a locking lever adjustment. The feed roll has an up and down adjustment. It must be set tight enough to grip the blank so as to prevent slippage as the blank enters the press (*Figure*). More feed-roll pressure is required on prescored blanks than on non-prescored blanks to prevent score-line slippage of the blank when it is entering the nip of the rolls. Score-line slippage can cause print and slot variation. On many newer presses, the feed-roll setting is done with a computer using motorized methods.

All feed sections have a caliper setting adjustment, which consists of a handle that raises and lowers the rolls. The caliper setting should be set to the caliper of the board being run. Often, the caliper readings on the presses are approximate due to feed-roll wear or play in the gear mechanism. If this is the case, the machine should be recalibrated to eliminate error and board crush.

Check Plates to Print Card

After the press-feed section has been set, and before the plates are mounted in the press, the plates should be checked against the print card to verify that the copy is correct for the job to be run. Once the copy has been verified, the plates should be checked for damage, ink and wax buildup, dirt from previous runs and proper bonding to the carrier sheet.

Select the Print Stations

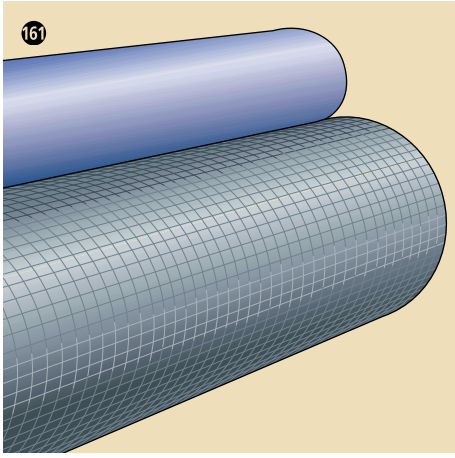
Before the plates are mounted to the printing cylinder, the operator must determine which print station to use for each color. When selecting the print station, consideration should be given to how the graphics must be trapped. The graphics are usually prepared on the plates to have the ink colors printing from lightest to darkest, allowing the darkest ink color to trap the lightest in areas where there is registration between colors. The subsequent colors hide the lighter color beneath it to create good trapping.

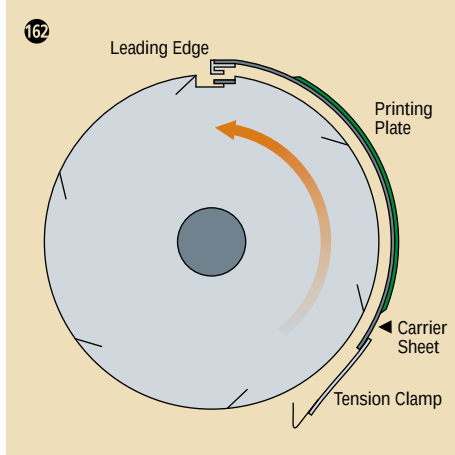
Mounting the Plates to the Print Cylinders

Plates should be mounted on the appropriate plate cylinders after a decision has been made about which station to use for each color based on the trapping requirements of the graphics.

There are various methods used to mount the plates on corrugated presses. The following three methods are typically used:

- In *Figure* , individual plates are mounted onto the plate cylinders using scribe lines that are engraved on the





161 Scribe lines engraved on the cylinder facilitate positioning of the plate during mounting.

162 In this mounting system, a hooked edge on the plate carrier is fitted to a clamp on the cylinder to provide a strong fit. A clamp at the trail end of the carrier sheet provides additional support.

cylinder. Scribe lines on the plate cylinder are also used to position plates that are premounted on a carrier that has a center mark. The center mark on the carrier is positioned to a cylinder's center scribe line and adhered.

- The plate cylinder is magnetized and the plates either have a metal backing or are positioned on a metal carrier. The magnetism of the plate cylinder holds the plates in position without the use of tape or straps.
- The plate cylinder uses a clamping system to hold the mounted plates. The plates are premounted on a carrier that has a hooked lead edge. This edge is attached to a bar and clamp mechanism on the lead edge of the plate cylinder. The trailing edge of the carrier is then attached to the plate cylinder with straps, clamps or tape (*Figure* 162).

Set the Pull Rolls

The purpose of pull rolls is to control the movement of the sheet from one print station to the next without slippage or change in board speed. These rolls control the print-to-board register throughout the press.

The operator can set the pull rolls either manually or with a motorized system. The pull rolls are set in a position to ride on the ends of the sheet and away from any printed copy. Running pull roll collars over the printed image may cause ink smearing on the board.

Set the Ink Distribution System

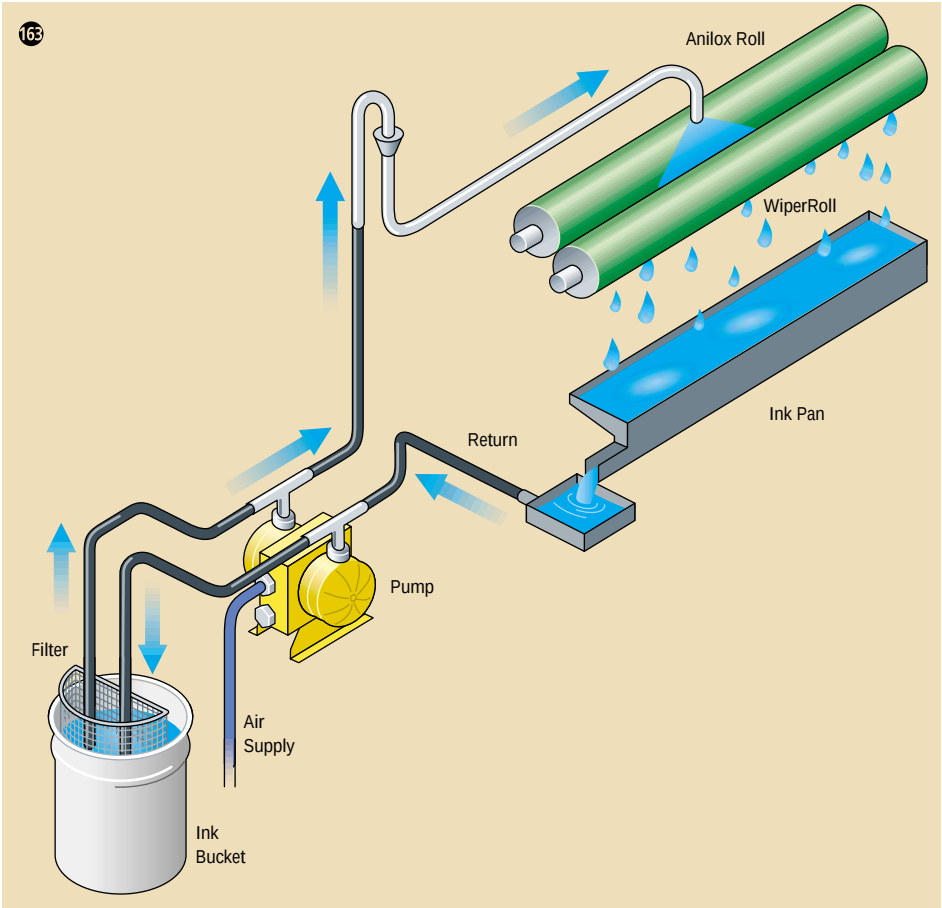
The ink distribution system should be set up to maintain a constant, uniform supply of ink during the pressrun (*Figure* 163).

Ink the Print Stations

The next step in the setup procedure is to ink up the print stations. The following procedure details a typical print station inking:

1. Double-check the color in the ink container to verify that it is the color to be placed in that print station.
2. Circulate the ink in the ink pump through the supply hose back into the pump to remove air from the system.
3. If an ink pan is being used, align the ink pan and lock down the hold-down mechanism. Ensure that the pan will not rub on the ends of any rolls or the surface of the plate cylinder.
4. Connect the return hoses from the ink pan to the ink pump, making sure they are routed around any moving parts. If using submersible pumps, return hoses must be slightly submerged in the ink of the ink-pumping unit to help avoid foaming with water-based inks.

163 An ink distribution system should be configured to maintain a constant, uniform supply of ink during the pressrun.



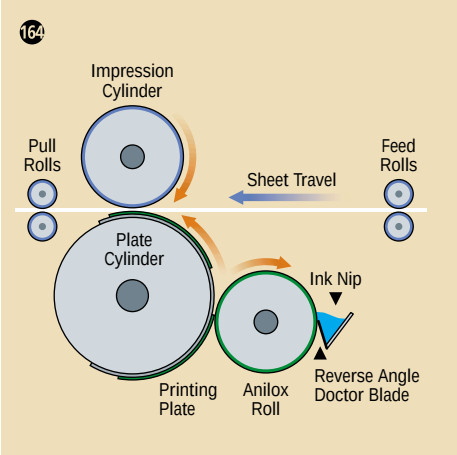
5. Connect the supply hose from the pump to the ink-distribution system.
6. Pump the ink into the distribution system.
7. After the ink has been pumping for a time, check the pH and viscosity. These measurements are done to ensure that the ink is at its running parameters before the pressrun begins. If the ink does not meet specifications, it should be adjusted and rechecked until it does.

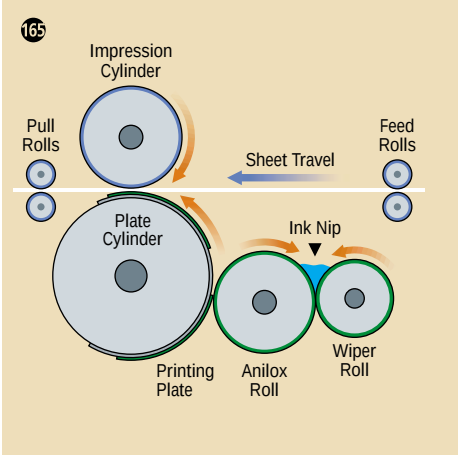
Set the Fountain Roll and/or Doctor Blade

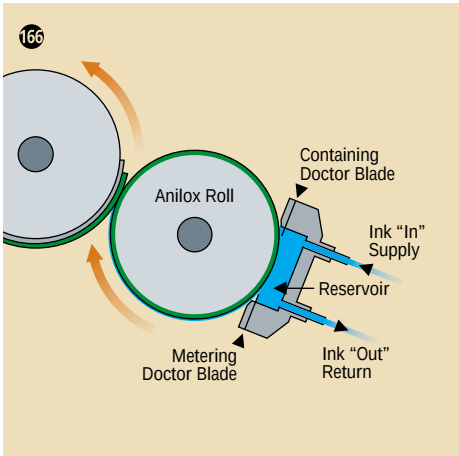
Once the ink is in the fountain and is within its recommended running pH and viscosity parameters, the anilox roll may be inked.

When using a two roll system (*Figure* 164), the fountain roll is adjusted to squeeze against the anilox roll. Once the press is started, the rubber roll is adjusted to evenly squeeze the ink off the anilox using the minimum amount of pressure. This pressure setting is checked by backing the fountain roll off until the operator can see the nip flood with ink. Then the operator squeezes back in with both sides of the rubber roll, making sure they are even, until the flooding on the surface goes away. By doing this several times, the ink wipe is set.

When setting a station with a doctor blade (*Figure* 165), the doctor-blade assembly is set into its holder and then slowly tightened down until it touches the anilox. As the blade is tightened to the anilox, the operator will notice that the ink will meter from the center of the anilox roll outward to the ends. When







164 In a two-roll system, the fountain roll should contact the anilox with the minimum amount of pressure necessary to evenly squeeze ink off the anilox.

165 When using a doctor-blade assembly, the blade should be placed in its holder, then slowly tightened until it touches the anilox.

166 A chambered doctor-blade system must be installed before the ink pump is turned on.

the ink is metered off of the ends of the anilox roll, the wipe is set. Similar to the procedure for setting fountain roll pressure, the doctor blade should be backed out and brought back in to the anilox several times in order to set the wipe with the minimum amount of pressure. Overtightening the doctor blade can cause the blade to fold under the pressure, causing the ink to dry due to the friction and heat buildup behind the blade. If ink drying occurs, the dried ink pigments can cause damage to the anilox roll.

If the press is equipped with a chambered doctor-blade assembly (*Figure* 166), the assembly is installed before the pump is turned on. The ink wipe should be set in the same manner as a single blade.

Adjust Print Impression

Print impression is measured in thousandths of an inch with a micrometer. The amount of pressure needed to transfer ink to the surface of the board is dependent upon the following:

- printing plate caliper;
- substrate porosity;
- board grade;
- ink transfer characteristics; and
- substrate texture.

On some presses, the impression setting is adjusted automatically by means of computerized controls. The computer may be programmed for settings of various board calipers. On other presses, the operator must manually set the impression by following scales for the approximate setting. In either case, the operator must fine-tune the setting to achieve the minimal pressure needed to transfer ink.

Print impression should be set as light as possible since excessive impression will crush the board's flutes and cause box compression-strength failure. Excessive impression may also cause fine print to distort and reverses to fill in. The actual impression needed on a board is determined by running boards through the press at run speed instead of jog speed. A portion of a board is

cut out, calipered and saved in order to measure feed roll crush. The remainder of the board is fed through the press. The thickness of the unprinted area of the board is measured and compared to the saved piece to determine any difference in caliper. Correct print pressure is checked by comparing the caliper of the printed area to the caliper of the unprinted area. Once the feed-roll pressure and print-impression pressure is adjusted, the printed images are registered to the board and to the other colors.

Check Colors to Standard

Once the press is set up and all settings are complete, the printing must be checked for accuracy against the color standard that was approved by the customer in the design stage of the job. A color standard may be an ink sample on the board being printed, a GCMI color chip or a printed sample from a previous run.

All visual color-matching should take place in a viewing booth designed for this purpose. This type of booth provides a standardized light source with a neutral gray background to eliminate color variations caused by the lighting conditions during the color-matching process.

A sample of the print should be compared to the color standard to ensure that the printed job meets the customer's requirements. The operator should check to make sure the color is printing at the correct density (lightness and darkness) either visually or with the use of a densitometer. If the color is not printing at the correct density, the anilox may be changed to achieve a density match with the standard. For slight density changes that are needed, the ink viscosity may be changed by adding water, or the ink may be extended to reach the color standard.

The ink hue should also be checked visually in a light booth or with the aid of a spectrophotometer. If changes in hue are needed, the operator should add the correct ink bases to reach the color standard. All of the information from the color-matching process should be documented so the job can be reprinted without additional downtime.

Press Setup Checklist

Before the pressrun begins, most companies require that a press setup checklist be filled out. A checklist ensures that all the details of the job setup are covered and documented for any future runs. Information on the checklist may include:

- ink pH and viscosity;
- print location;
- ink color;
- stock;
- copy accuracy;
- feed-roll impression;
- print impression;
- pull-roll impression;
- print clarity;
- plate condition; and
- anilox configuration.

Setup time is expensive, especially when it must be redone. Proper setups and constant verification of the product during the pressrun saves time and money.

PRESSRUN PROCEDURES

The attention to detail that marked the setup process must carry over into the pressrun. The next section describes maintenance that takes place once the press is running.

Monitor Ink pH and Viscosity

In order to maintain the ink's color-to-standard match throughout the pressrun, pH and viscosity must be monitored. Without monitoring, the color will vary, resulting in inconsistent product. Ink pH and viscosity must also be monitored to ensure proper trapping between colors, good ink resolubility, good print quality and correct ink drying between

print stations, especially if the press does not have between-station dryers.

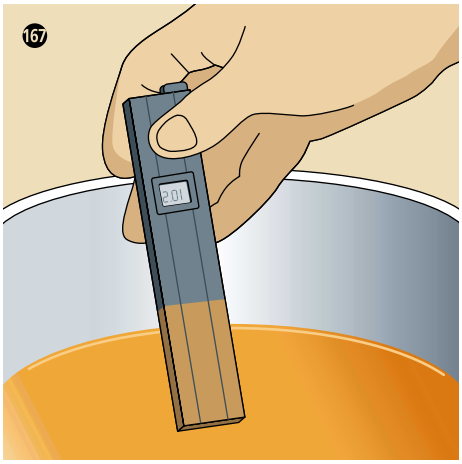
Water-based inks should be run in a specific pH range to keep them working efficiently. The pH ranges vary by ink manufacturer and the requirements for the job. Generally, water-based inks are in the pH range of 8.0 to 9.3. When the pH of a water-based ink falls too low, the ink will begin to body and thicken, eventually causing rewetting problems and dirty printing. If the pH is too high, the viscosity of the ink will be too low, causing drying problems. Color variations and print defects caused by pH levels can be eliminated by maintaining pH within its recommended range.

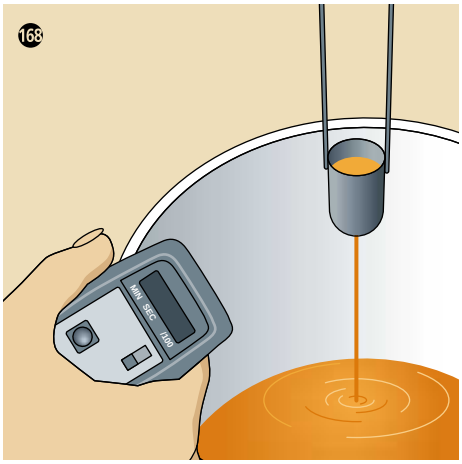
A pH meter is the instrument used to read pH levels (*Figure* 167). These instruments should be calibrated to a buffer solution with a known pH on a regular basis.

To help control drying and to provide better trapping between colors, the pH value should decrease slightly from print station to print station, starting from the ink station closest to the in-feed and going to the out-feed section. Because the pH level controls the drying of water-based inks, this pH decrease helps the ink to dry properly before the next ink-down hits the board, providing better trapping between colors.

Because the pH level of water-based inks controls overall ink performance, pH should always be checked before viscosity. Adjustments made to viscosity alone may also change the pH, causing other print problems. The pH and viscosity of water-based inks should be checked every 30 minutes (*Figure* 168).

Water and amine are used to control viscosity in water-based ink systems. A stabilizing varnish may also be used, which is a water and amine combination that has been premixed to the correct percentages for the ink system being used. An addition of stabilizing varnish should lower the ink viscosity while maintaining the pH of the ink. Water alone will reduce the viscosity, but it may also reduce pH, and cause other print problems. Ink reducers may also be used to control viscosity. Adding small amounts of reducer should maintain correct viscosity. The viscosity level should never get so high that more than a pint of reducer is required to return the viscosity to the correct level. The careful control of pH and viscosity levels for water-based ink results in consistent color and uniform ink flow throughout the production run.





167 During the pressrun, pH can be quickly checked through the use of a pH meter.

168 One method of checking viscosity is by timing ink flow through a Zahn cup.

Adding Ink to the Fountain

During longer runs, the press operator may be required to add ink to the fountain or pump. This addition requires specific attention to detail. The following text details a typical ink addition procedure:

1. Double-check the ink to be added for correct color. Do not assume that an ink container is marked correctly.
2. Adjust pH and viscosity of the ink to be added. Viscosity of water-based inks should be five to 10 seconds higher than the ink in the fountain. Agitation of the ink will cause a viscosity drop of three to five seconds.
3. Add only enough ink to bring the level back to the optimum level.

The optimum level should be determined before the production run. It is based on the amount of ink coverage for a given color, which depends on the ink coverage for the job being printed. The big print areas that use more ink will require the ink pans to be filled more often than those that use little ink. Add fresh ink each hour to a low coverage area rather than filling up the fountain and adding only solvent or stabilizer for the whole shift. Fresh ink helps maintain the correct balance between colorant, resin, water and amine.

Ink loses printability and flow characteristics if only water and amine are added over a period of time. This loss is due to the depletion of the colorant and the resin in the ink. For the ink to work properly, and to avoid printability problems, press operators must know the following about the inks they are using:

- upper and lower working viscosity limits;
- solvents and additives to use;
- range of pH for water inks; and
- the maximum pigment load the ink can handle.

By maintaining the proper percentages of ink components, the color will be more consistent and fewer print problems will occur.

Checking Quality

Conducting quality checks during a pressrun is an important part of the printing operation. Once a job is set up and running, certain steps must be followed in order to maintain quality throughout the run.

Color Consistency. Visual color checks of printed samples should be done using a light booth in the same manner as the color check of the setup operation. More and more instrumentation is being used to verify color consistency. Specific tools such as densitometers, colorimeters and spectrophotometers have replaced simple visual color checks.

A minimum of one sheet every 15 minutes should be inspected during the pressrun for any variation in color away from the color standard. The sheet should also be inspected for other defects that would affect the final product.

Samples should be compared throughout the run to ensure that there are no color drifts. A color drift occurs when the color shifts in successive production samples. Color drifts are checked by laying consecutive samples on a white background in a fanned out arrangement. One of the most common causes of color drift is substrate variation. Samples should be cut for comparison, rather than folded or overlapped, to allow for more accurate comparisons.

Inspections and Quality Checks. During a pressrun, the operator should make ongoing inspections of the press and the job being printed. The following items are typical pressrun checks:

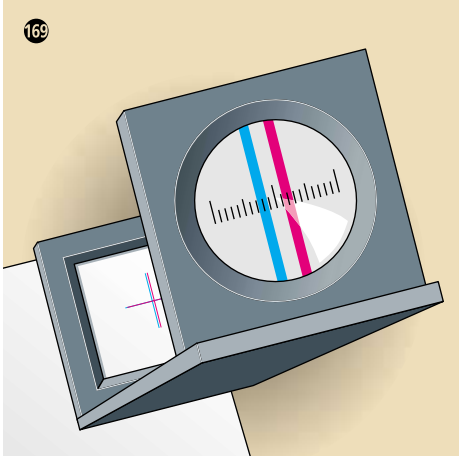
- Listen to the press for any unusual noises that may indicate a mechanical problem.
- Double-check the ink level in the fountain or pumping unit. When using a pump, check the ink flow to the pan.
- Monitor print quality during the pressrun.

Inspecting a print sample is the most accurate check of print quality. Operators should not rely on checking print quality on the moving sheet alone. Samples of the printed product must be checked visually with the

aid of a magnifier for poor registration, poor ink lay, color drifts and color match.

During the inspection, the operator should look for defects and variations in:

- print registration (*Figure* 169);
- cleanliness and sharpness of print;
- ink or impression misses;
- ink picking;
- flaws caused by plate lift, lint or other causes;
- print quality;
- board defects;
- tracking;
- fill-in;
- excessive pressures; and
- print-to-cut registration.



169 A loupe, or magnifier, will be of great assistance in print inspection.

General Housekeeping

When the press crew is not tending to other duties, general housekeeping work is always needed around the press. A conscientious operator and crew ensures that the work area is kept clean and in a workable condition.

The operator should also be conscientious about maintaining the machine. Any irregularities in the press such as strange noises, oil leaks or other unusual signs may signal an impending breakdown and should be investigated immediately. The operator should ensure that all lockout and tag-out procedures are followed when housekeeping is performed inside the press.

Production personnel should pay attention during the pressrun to make sure that all consumables are available in sufficient quantities. Stock and ink should be monitored in order to keep a steady supply available. It is important that the machine is not shut down due to a lack of these items.

Other items such as ink additives, rags, load tags, reports and machine logs should be monitored and replaced before they run out.

Prepare for the Next Job

Operators should begin the setup for the next job during the current pressrun. Work completed in advance of the changeover allows for a smoother and more efficient setup. The operator should review the upcoming job order and plan the best and fastest way to change over to the next job. Production personnel can find problems and solve them before the next setup begins by checking all the materials before the next set up.

Stock for the next job should be located and inspected to be certain it is the proper stock, the correct size, and is in good condition. The stock grade, test and flute should be inspected to ensure that it is correct. Variations should be reported before the set up begins.

The ink required for the next job should be located and inspected to ensure that it is the correct formula and available in sufficient quantities. Color standards should be reviewed to help determine print station selection and anilox roll requirements.

Tooling and plates for the upcoming job should be checked prior to the setup to make sure the tooling is available and the plates are in good condition.

CLEANUP PROCEDURES

Most jobs require some degree of cleanup upon the completion of a run. Inks for the next run are often different, which requires that the

press equipment be washed. Since the press is profitable only when it is in production, an efficient cleanup program is needed. A correct wash-up procedure minimizes downtime between jobs and maintains the press in good working condition. Cleanup procedures vary by company and brand of equipment.

When a color change is required for the next run, the old ink must be washed out of the machine and replaced with fresh ink of the new color. Depending upon the direction of the color change (from light to dark or dark to light), the time required to do the wash-up will vary. Without a thorough wash-up, dark colors will contaminate the lighter ink colors.

Printing plates should be cleaned and rinsed after a production run and prior to being placed in storage.

Cleaning Equipment and Materials

Operators should ensure that all needed cleanup equipment and materials are at the press before the press goes down for cleanup. It is important for the ink to be cleaned up as soon as possible after the machine goes down so that the water-based ink is more soluble and can be washed up with water and a high pH soap. Dried water-based ink is very difficult to remove.

The follow cleaning equipment and supplies should be on hand:

- warm water (120° F);
- rubber gloves ;
- eye protection;
- clean rags;
- cleaning solutions;
- brass brush for chrome anilox rolls;
- stainless-steel brush for ceramic anilox rolls;
- soft-bristled brush for plates; and
- coating material (such as vegetable shortening) for corrosion protection on weekend cleanups.

Opening the Machine

Upon completion of the run, the press is opened for cleanup. Company lockout or tag-out procedures must be followed when working inside the machine.

Conserve Ink

In an effort to conserve ink, the ink pan is often lowered and the liquid ink squeegeed down the ink-return hose and back into the ink pump before a wash-up begins. The return hose is then switched to the wash-up container or drain and the wash-up process begins.

Manual Cleanup

The following procedure details a typical manual cleanup after the ink has been drained from the pan. Company procedures may vary depending on the specifications of the machine.

1. Turn off the ink pump and disconnect the power supply to stop the ink flow.
2. Pump cleaning solution through the entire system. This pumping makes the entire system easier to clean.
3. Remove the ink supply hose from the deck.
4. Stop the rotation of the rubber roll.
5. Release the pressure between the rubber roll and the anilox roll.
6. Move the ink-return hose from the ink pump to the wash-up container.
7. Reset pressure between the anilox and rubber roll and restart their rotation.
8. Flood the anilox and rubber rolls with wash-up solution as they slowly turn. The solution will remove ink from the surface of the rolls. Several passes over the rolls with fresh solution may be needed to throughly remove the ink.
9. Release the pressure between the anilox roll and rubber rolls on one end only.
10. Wipe the anilox roll. Begin on the side with the released pressure. Use a folded rag or shop towel soaked with cleaning solution. If water-based ink is being washed up, it is best to keep the

fountain roll and anilox roll wet until the ink is washed off. It is very difficult to clean off water-based ink after it has dried on the rolls.

11. When the end of the roll is reached, release the pressure on the remaining end. Finish wiping the anilox roll.
12. Clean the rubber roll the same way as the anilox roll.
13. Stop the rotation of the rubber roll and thoroughly clean both ends of the anilox and rubber roll.
14. Go over each roll with clean, warm water to remove any soap residue from cleaning water-based ink. The print station of a two-roll system contains pinch points between various rolls. These pinch points are referred to as inward nips (*Figure* 170). The person cleaning the print station must use extreme care in this area, because it is easy to catch a rag or finger in the nip.
15. Remove and clean the ink filter.
16. Reassemble the station.

Cleaning the Plates

Clean the plates with cleanup soap and water to remove any dried ink. The plate should be scrubbed with a soft-bristled brush and cleanup solution. It should then be blotted dry with a rag. Rubbing the plate with a shop towel should be avoided, as it can damage the plate surface. After the plate is cleaned, it may be removed from the plate cylinder. The operator should make note of any plate damage or defect so that new plates may be prepared for upcoming runs.

Chamber-bladed Station Cleanup

The following procedure details a typical cleanup of a chamber-bladed system:

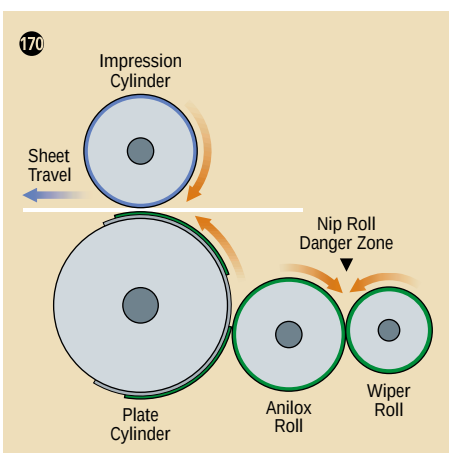
1. Disengage doctor-blade assembly from anilox.
2. Lock the blade assembly into the cleanup position using the appropriate safety mechanism.
3. Clean the anilox roll by passing a folded clean rag, soaked in cleanup solution, along the entire face of the rotating roll.
4. Scrub the anilox with a brush. Use brass bristles for chrome rolls, steel for ceramic rolls.
5. Turn off the anilox drive motor and wash both ends of the anilox thoroughly.
6. Remove any ink buildup off the sides of the anilox.
7. Make a final pass with a clean damp rag, followed by a clean dry rag.

Extreme caution is required when cleaning the anilox roll when a doctor blade is being used. The cleanup person must be aware of the location of the blade to avoid accidentally bumping it while cleaning. Doctor blades are extremely sharp and can cause severe injury.

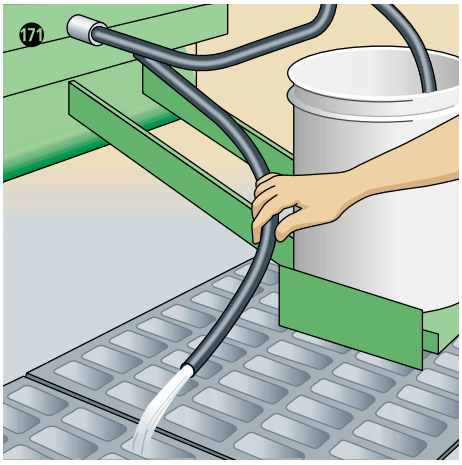
Doctor-blade Assembly Cleanup

Cleaning the doctor-blade assembly requires direct contact with the doctor blade. Cut-resistant gloves should be worn to minimize the risk of injury. In some cases, the blade assembly is removed from the press for cleanup. The following procedure details a typical cleanup for a doctor-blade assembly:

1. Soak a shop rag or towel in cleaning



170 The area between two rolls is known as the inward nip. When cleaning, one should be careful not to catch a rag or finger in this area.



171 Ink residue from an automatic wash-up system should be dumped into the plate waste drainage system for treatment.

solution and wipe the inside and outside of the assembly. Also wipe both sides of the blade. Light pressure will reduce the chance of the blade cutting through the rag.

2. Check the condition of the doctor blade. Carefully remove blades that show excessive wear or damage. Properly dispose blades.
3. Continue cleaning the blade assembly with a soaked rag until most of the ink on the assembly is gone. Complete a final pass with a clean damp rag to remove any last traces of ink.

Ink Pan Cleanup

After washing the doctor-blade system, the ink pan must be cleaned. The following procedure details a typical ink pan cleanup:

1. Put the pan into position for washing. Scrape any liquid ink into the drain hole.
2. Place a rag at the bottom of the ink pan and saturate it with cleaning solution.
3. Pass the damp rag over the entire interior of the ink pan to rewet the dried ink. Concentrate on areas where ink buildup exists, rewetting the rag as needed.
4. Wipe the ink pan dry using a second rag when all ink buildup is removed. Only a haze should remain.
5. Dampen another clean rag with cleaning solution to remove the remaining pan haze. Immediately use a dry rag to give it a final shine.
6. Use the two rags to clean the outside of the pan and deck cover.
7. Remove the ink return hose. Wipe any remaining ink out of the drain hole.

Automatic Wash-ups

Automatic wash-up systems are built into some machines. They have a fixed sequence of operations that are done automatically for the operator. The system may be used during setup, between orders, or at the end of a run or shift.

When the automatic wash-up system is engaged, the ink is automatically drained from the system into the ink bucket and saved for future use. After the ink is drained from the inking system, the press operator removes the ink bucket from the platform. Water or clean-up solution is then automatically circulated, and often pressure sprayed, throughout the entire system.

Water and ink residue is then removed from the inking system automatically. The residue is dumped into the plate waste drainage system for treatment (*Figure* 171).

Automatic wash-up systems basically perform the same steps listed in the section describing manual wash-up of the ink station. It is important to remember that automatic wash-up systems do not scrub the anilox roll, and therefore, do not eliminate this cleanup step.

Mark Ink Containers

The containers holding the ink used during the run should be marked with the correct ink color or number. Any additives, bases or solvents that were added to the ink, and their quantities, should be noted on the containers. Container labels are often covered by ink spilling down the side of the bucket. If a spill

occurs, attach a new label or identify the bucket in some other manner.

Weekly Cleanups

In some situations, the press may not require a complete wash-up because the colors being run from job to job are similar and contamination is not a major problem. In this case, some of the press components are only cleaned thoroughly on a weekly basis.

At least once a week, following the normal wash-up, the anilox roll should be scrubbed with a brush made for this purpose. Operators should remember to use a brass brush for chrome rolls and a stainless-steel brush for ceramic coated rolls.

The ink pan under the rolls should be cleaned weekly. In many cases, the ink pan is not removable, so the cleanup must be done around the rolls and doctor-blade assembly. It is common to coat the inside and outside of the pan with a thin layer of material (one that is approved by the ink company) to keep ink from drying on the metal. Vegetable shortening is often used.

Other machine parts and components should be cleaned. Keeping the press and press area clean not only maintains the appearance of the plant, but leads to a safer work place and a better press performance record.

Appendix A

PRESSROOM TROUBLESHOOTING CHART

DEFECT/INDICATOR	PROBABLE CAUSE	CORRECTIVE ACTION
PADHESION, INK		
■ Ink fails to adhere to substrate. ■ Fails tape test. ■ Fails crinkle test. ■ Fails rub test.	1. Improper ink formulation/chemistry. 2. Insufficient heat and/or air volume in main dryer. 3. Low treatment level of substrate. 4. Excessively reduced ink viscosity, binder destroyed. 5. Surface of substrate may be contaminated. 6. Surface of substrate may require special application.	1. Check ink for correct type and grade for substrate being run. 2. Increase heat and/or air volume in main dryer. 3. Check surface of substrate for adequate treatment level. 4. Restore and maintain ink viscosity at optimum point. 5. Apply wash-coat prior to printing. 6. Apply primer prior to printing.
BINDING		
■ Intermittent dark lines of varying widths running in the web direction of printed image.	1. Irregular web tensioning, substrate moving independent of plate movement. 2. Gear bottoming off pitch line. 3. Intermittent plate slur. 4. Excessive ink viscosity. 5. Noncompressible stickyback. 6. Low durometer plate materials.	1. Reduce web tension. Clean and lubricate driven and undriven rollers. Check web tensioning mechanisms for proper operation. 2. *See defect "Gear Marks."* 3. Run bearers. 4. Reduce ink viscosity. 5. Use cushioned stickyback. 6. Use higher durometer plate materials.
BLEED		
■ An under color wetting into an over color in a trapping or overprinting application. ■ Diffused or migrating colors in a dried/cured ink film.	1. Under color drying too slowly or over color drying too fast. 2. Poor physical property resistance.	1. Improve under color drying rate by reducing viscosity and/or ink film thickness. Use a faster or slower solvent as required. Adjust or check between station dryers. (Preceding colors must be dry enough to receive subsequent colors laid down.) 2. Use proper ink formulation and pigment grade selection.

PRESSROOM TROUBLESHOOTING CHART *(CONT'D)*

DEFECT/INDICATOR	PROBABLE CAUSE	CORRECTIVE ACTION
BLOCKING		
■ Undesired adhesion between two surfaces.	1. Improper ink drying.	1. *See defect "Drying Too Slow."*
	2. Excessive pressure in rewind.	2. Reduce rewind tension.
	3. Excessive weight in stack.	3. Reduce stack height.
	4. Softening of pre-applied coatings.	4. Use solvents that do not attack prior coatings.
	5. Web rewound too warm.	5. Reduce web temperature by chilling within ±10° of room temperature or reducing dryer temperature.
	6. Web rewound with excess surface moisture.	6. Avoid rewinding excess surface moisture on web prior to rewind.
BRITTLENESS		
■ Ink film/substrate breaks or cracks when flexed.	1. Excessive heat or UV exposure level in drying/curing system causing a release of moisture and plasticizer from substrate or ink film.	1. Control web temperature. Reduce heat and/or increase volume of air through drying chamber. Reduce UV lamp power.
COLOR STRONG		
■ Excess ink transfer to substrate.	1. Excessive ink viscosity.	1. Reduce ink viscosity.
■ Excess color strength.	2. Excessive pigment load.	2. Add extender.
	3. Incorrectly specified anilox roll.	3. Select anilox roll with lower cell volume.
	4. Incorrectly specified fountain roll.	4. Select fountain roll with higher durometer.
	5. Light setting of fountain roll nip.	5. Increase fountain roll nip pressure.
	6. Doctor blade incorrectly set.	6. Adjust doctor blade to parallel with a minimum pressure setting.
COLOR VARIATIONS		
■ Inconsistent color throughout a press-run.	1. Lack of viscosity and/or pH control.	1. Maintain viscosity and/or pH control.
	2. Inconsistent press speeds.	2. Maintain consistent press speed.
	3. Variation in ink batches.	3. Mix adequate amount of ink.
	4. Color contamination.	4. Improve cleanup procedures.
COLOR WEAK		
■ Lacking color strength and body.	1. Excessive ink viscosity reduction.	1. Add fresh ink to restore viscosity.
	2. Excess extender varnish.	2. Add pigment concentrate (toner).
	3. Ink settled out.	3. Thoroughly mix ink in container before adding to fountain.
	4. Plugged anilox roll cells.	4. Thoroughly clean anilox roll.
	5. Incorrectly specified anilox roll.	5. Select anilox roll with higher volume.
	6. Incorrectly specified fountain roll.	6. Select fountain roll with lower durometer.
	7. Tight setting of fountain roll nip.	7. Decrease fountain roll nip pressure.
	8. Worn anilox roll.	8. Replace/refurbish anilox roll.

PRESSROOM TROUBLESHOOTING CHART *(CONT'D)*

DEFECT/INDICATOR	PROBABLE CAUSE	CORRECTIVE ACTION
CURING OF UV INK		
■ Ink fails to cure. ■ Ink offsets in rewound roll. ■ Ink picks on idle rollers. ■ Ink tracks through the press.	1. Low lamp power setting. 2. Weak exposure bulbs. 3. Dirty lamp reflectors. 4. Lamp focus incorrect. 5. Excessive press speed. 6. Excessive ink film thickness. 7. Lamp shutter not opening.	1. Increase lamp power setting. 2. Replace exposure bulbs. 3. Clean lamp reflectors. 4. Adjust lamp focus to optimal distance. 5. Reduce press speed. 6. Reduce ink film thickness. 7. Check lamp shutter assembly operations.
BLOCKING		
■ Undesired adhesion between two surfaces.	1. Improper ink drying. 2. Excessive pressure in rewind. 3. Excessive weight in stack. 4. Softening of pre-applied coatings. 5. Web rewound too warm. 6. Web rewound with excess surface moisture.	1. *See defect "Drying Too Slow."* 2. Reduce rewind tension. 3. Reduce stack height. 4. Use solvents that do not attack prior coatings. 5. Reduce web temperature by chilling within ±10° of room temperature or reducing dryer temperature. 6. Avoid rewinding excess surface moisture on web prior to rewind.
CURING OF, UV INK (INCIDENTAL)		
■ Ink curing prior to printing and UV lamp exposure on plates, rollers, etc.	1. Direct exposure to sunlight. 2. Exposure to general lighting sources.	1. Eliminate direct sunlight exposure. 2. Use UV filter covers on general lighting sources directly over press.
DOT GAIN		
■ An excessive increase in the size of a halftone dot from film to the printed image.	1. Excessive ink volume. 2. Excessive plate thickness. 3. High density stickyback. 4. Low ink viscosity. 5. Excessive pressure settings. 6. Poor ink metering application. 7. Damaged or worn press components. 8. Dirt on impression and/or plate cylinders.	1. Reduce anilox roll volume to a minimum while maintaining color requirements. 2. Use thinner plates. 3. Use cushioned stickyback. 4. Increase ink viscosity. 5. Reduce pressure settings to a minimum. 6. Use bladed ink metering application. 7. Check and replace damaged or worn gears, bearings or cylinders. 8. Clean impression and/or plate cylinders.

PRESSROOM TROUBLESHOOTING CHART *(CONT'D)*

DEFECT/INDICATOR	PROBABLE CAUSE	CORRECTIVE ACTION
DRYING TOO FAST		
■ Ink drying on plates and/or rollers and failing to transfer.	1. Improper use of solvents.	1. Use proper solvents.
	2. Low pH level.	2. Check pH and adjust to optimum point.
	3. Uncontrolled or unrestricted air movement in the vicinity of plates and rollers.	3. Eliminate excessive air movement in vicinity of plates or rolls by fans, open windows or doors. Balance air intake and exhaust flow for between station dryers.
	4. Failure to use fountain covers.	4. Use fountain covers.
	5. Improper ink formulation.	5. Use proper ink formulation for substrate being printed.
	6. Excessive preheat web temperature entering print stations.	6. Reduce preheat web temperature entering print stations.
	7. Pressroom environment consisting of high temperature and/or low humidity.	7. Control pressroom environment to ideal conditions.
DRYING TOO SLOW		
■ Ink fails to properly dry. ■ Ink pick-off or transfer to press rollers and/or subsequent plates. ■ Ink offsetting or blocking in rewind or stack. ■ Ink penetration of paper. ■ Tacky print surface.	1. Use of slower drying solvents.	1. Use faster drying solvents.
	2. Ink viscosity too high.	2. Reduce ink viscosity. Check viscosity approximately every 30 minutes.
	3. Inadequate or unbalanced drying equipment.	3. Use adequate and balanced drying system to accommodate normal press speeds.
	4. Improper ink formulation.	4. Use ink formulation having more hold-out capability.
	5. Excessive ink film thickness.	5. Reduce ink film thickness.
	6. Pressroom environment consisting of low temperature and/or high humidity.	6. Control pressroom environment to ideal conditions.
	7. Excessive press speeds.	7. Reduce press speeds.
FEATHERING		
■ Irregular string-like edges around print, often on trailing edges.	1. Excessive pressure settings.	1. Use minimum pressure settings for plate and anilox.
	2. Incorrect solvent balance.	2. Use correct solvent balance.
	3. Uncontrolled ink viscosity and/or pH range.	3. Maintain proper ink viscosity and/or pH range. Use fountain covers.
	4. Improperly set ink metering applications.	4. Readjust pressure settings of fountain roll nip or doctor blade assembly.
	5. Poor shoulder angles on plate.	5. Use a steeper shoulder angle on the plate with consideration for support.
	6. Dust on the substrate transferring to the plate.	6. Use web cleaning devices when necessary.
	7. Excessive static electricity present.	7. Use static eliminator bars.
	8. Dried ink on plates from startup or previous run.	8. Wash plates thoroughly after color OK and when order is completed.

PRESSROOM TROUBLESHOOTING CHART *(CONT'D)*

DEFECT/INDICATOR	PROBABLE CAUSE	CORRECTIVE ACTION
FILL-IN		
■ An accumulation of excess ink on and around the printing plate surface — especially with relation to small type and screen halftones.	1. Excessively fine type or screen for anilox roll selection.	1. Select higher line, screen lower volume anilox roll.
	2. Excessive pressure settings.	2. Use minimum pressure settings for plate and anilox.
	3. Uncontrolled ink viscosity and/or pH range.	3. Maintain proper ink viscosity and/or pH range. Use fountain covers.
	4. Improperly set ink metering applications.	4. Increase pressure settings of fountain roll nip or doctor-blade assembly.
	5. Incorrect solvent balance.	5. Use correct solvent balance.
	6. Excessively sized particles of ink pigment.	6. Improve grind and pigment dispersion.
	7. Lack of relief height in plate.	7. Increase relief height in plate.
	8. Low fountain roll durometer.	8. Use higher durometer roll.
FOAMING		
■ Ink foams in fountain.	1. Excessive agitation of ink in fountain.	1. Reduce flow rate of ink pump.
	2. Lack of defoaming agent in formulation.	2. Add defoaming agent to ink.
	3. Contaminated ink.	3. Replace with fresh ink.
	4. Excessive ink viscosity.	4. Reduce ink viscosity.
GEAR MARKS		
■ Parallel lines of misprint.	1. Gear bottoming off pitch line.	1. Adjust overall plate package thickness to pitch line.
GHOSTING		
■ A faint image of design transferring to the printed image or non-image area.	1. Ink starvation.	1. Change diameter of plate cylinder or change speed differential of fountain roll to anilox roll. Change anilox roll specification to a higher volume. Increase ink flow to chambered doctor blade.
	2. Improperly cleaned metering roll.	2. Thoroughly clean anilox and/or fountain roll.
HALO		
■ An unwanted line surrounding a printed image.	1. Excessive pressure settings.	1. Use minimum pressure settings for plate and anilox.
■ Printed image appears double-edged.	2. Plate cupping.	2. Make new plates and new plate matrix or engraving. Avoid cupping.
	3. Plate durometer too hard.	3. Use recommended plate durometer for printing given materials.
	4. Stickyback too thin or too firm.	4. Use compressible stickyback.
	5. Plate cylinder running out of round.	5. Check plate cylinder for T.I.R.
	6. Excessive plate grinding.	6. Reduce amount of plate grinding.

PRESSROOM TROUBLESHOOTING CHART *(CONT'D)*

DEFECT/INDICATOR	PROBABLE CAUSE	CORRECTIVE ACTION
HICKEYS		
A small, solid print area encircled with a white halo.	1. Dust on the substrate transferring to the plate.	1. Wash plate, use web cleaning/static eliminator devices if necessary.
	2. Excessive ink tack.	2. Reduce ink tack level.
INK MOTTLING		
Spotted or irregular appearance of solid print area.	1. Excessive reduction of ink viscosity and/or pH level.	1. Add fresh ink and maintain optimum viscosity and/or pH range.
	2. Excessive anilox roll cell land areas.	2. Examine condition of anilox roll cell lands. Replace anilox roll if necessary.
	3. Contaminated ink.	3. Replace with fresh ink.
	4. Mottled pattern in surface of plates.	4. Remake plates if mottled appearance is evident on surface. Examine plate mold for like pattern of mottle.
	5. Foreign matter collecting on surface of plates.	5. Wash plates thoroughly.
	6. Dirty or pitted impression cylinders.	6. Clean impression cylinders thoroughly of inks, waxes and all other foreign matter.
	7. Uneven or irregular substrate surfaces.	7. Increase opacity of the ink. Reduce durometer of plate material.
	8. Ink lacks proper flow characteristics.	8. Consult ink supplier for reformulation.
MISREGISTER		
One part of design not correctly positioned with another.	1. Plates not mounted in register.	1. Remount plate in register. Review plate mounting and make-ready procedures.
	2. Incorrect web tension.	2. Adjust tension controls appropriately for substrate being printed.
	3. Incorrect drive-roller adjustment.	3. Check drive roll parallel for constant side-to-side pressure and center wear condition.
	4. Excessive web temperatures.	4. Reduce dryer temperatures.
	5. Failure to center press register compensators before putting job in press.	5. Center individual advance/retard running registers and side-to-side register compensators before manually keying in job register.
	6. Idle rolls dragging or running intermittently.	6. Replace or lubricate idle roller bearings.
	7. Press out of alignment.	7. Realign press.
	8. Gauge variations in substrate.	8. Replace substrate.

PRESSROOM TROUBLESHOOTING CHART *(CONT'D)*

DEFECT/INDICATOR	PROBABLE CAUSE	CORRECTIVE ACTION
MOIRÉ		
Undesirable interference pattern in process printing.	1. Improper screen angles.	1. Screen angles of each color should be 30° apart. The yellow should be 15° between two colors, in most cases the cyan and black. Actual angles are based on imagesetter designated screening, providing the nominal screening rule is placed at least 7.5° away from the anilox screen angle.
	2. Anilox screen count too similar to plate screen count. For example, a 165 line anilox used with an 85 line screen plate can cause moiré because of harmonic 85 x 2 = 170, too close to 165 line.	2. Select an anilox screen count of at least three to four times the plate line screen count.
ODOR		
Undesirable odor in printed substrate.	1. Retained solvents, amines or monomers.	1. Balance solvents and check for proper solvent use. Use correct UV ink chemistry. Check and adjust main dryer/UV lamp operation. Increase between station dryers/UV lamps. Reduce press speed to increase dryer/UV lamp dwell time.
OFFSETTING OR SET-OFF		
A transfer of ink to the side of the substrate opposite where it was printed.	1. Ink not dry at rewind or stacker.	1. *See defect "Drying Too Slow."*
	2. Trapped solvents or amines.	2. Reduce ink film to minimum acceptable thickness.
	3. Excessive pressure in roll.	3. Reduce rewind tension.
	4. Excessive weight in stack.	4. Reduce height in stack.
	5. Films treated on both sides.	5. Run minimum rewind tension. Apply offset powder to web before rewinding. Overprint with non-blocking varnish if necessary.
	6. Films with plasticizers subject to migration.	6. *See No. 5.*
PICK-OFF/INK		
Ink transferring to subsequent plates and rollers.	1. Ink drying too slow.	1. *See defect "Drying Too Slow."* Increase between station dryer temperature and/or air flow.
	2. Excessive plate impression setting.	2. Use minimum plate impression pressure.

PRESSROOM TROUBLESHOOTING CHART *(CONT'D)*

DEFECT/INDICATOR	PROBABLE CAUSE	CORRECTIVE ACTION
PINHOLING		
Small holes in solid print area.	1. Physical surface of substrate is pitted, irregular or contaminated.	1. Consult your material supplier.
	2. Failure of ink to form continuous film.	2. Increase ink film thickness. Increase plate impression pressure to substrate. Add 2% to 3% anti-pinhole compound to ink. Check substrate for the appropriate treatment level.
	3. Ink drying too fast.	3. Use slower solvent or increase press speed.
	4. Excessive land areas on anilox roll.	4. Examine condition of anilox land areas. Replace anilox roll if necessary.
	5. Anilox roll cell engraving angle.	5. Specify 60° anilox roll engraving angle.
	6. Dirt on impression cylinder.	6. Clean impression cylinders.
PLATE SWELLING		
Plate dimensionally larger and softer.	1. Inks or solvents not compatible with printing plates.	1. Check inks and solvents being used for compatibility with your ink and plate suppliers.
	2. Residual solvent left in plate from processing.	2. Increase plate processing drying time.
POOR INK TRANSFER		
Insufficient ink being applied to substrate.	1. Ink viscosity excessively reduced.	1. Rebuild tack and color strength by addition of fresh ink or extender – or both.
	2. Plugged anilox roll.	2. Thoroughly clean anilox roll.
	3. Ink drying on plates.	3. *See defect "Drying Too Fast."* Reduce drying rate with slower solvent.
	4. Surface of substrate pitted or not ink receptive.	4. Verify ink formulation with ink supplier for given substrate. Add anti-pinhole compound. Check substrate for appropriate treatment level. Increase plate impression setting to the substrate.
	5. Improper pressure setting between fountain roll, anilox roll and plate.	5. Adjust pressure settings.
SEPARATION OR KICK-OUT, INK		
Curdling and thixotropic (similar to souring).	1. Presence of wrong solvent or excess diluting agent..	1. Add rich true solvent to return ink to proper balance.

PRESSROOM TROUBLESHOOTING CHART *(CONT'D)*

DEFECT/INDICATOR	PROBABLE CAUSE	CORRECTIVE ACTION
SKIPPING PRINT		
Voids in print image area.	1. Inconsistent plate caliper.	1. Check plate caliper for a variation of greater than ± 0.001". Secure new plates or do necessary makeready.
	2. Impression settings too light.	2. Increase impression settings for plate and/or anilox.
	3. Plate cylinder bounce.	3. Check T.I.R. of plate cylinder and impression cylinder. Observe the condition of shafts, journals, bearings and gears for cleanliness or excessive wear. Consider nature of artwork design.
	4. Failure to lock down print station.	4. Be sure printing stations are locked firmly in place when impression is properly set.
	5. Print station cocked or out of parallel.	5. Reset print station for side-to-side parallel.
SOURING INK		
Ink exhibits a thixotropic state with a loss of flow and tendency to curdle.	1. Excessive moisture in ink due to high humidity levels.	1. Add normal propyl acetate. Keep fountains and reservoirs covered.
STREAKS, SMEARS OR SPOTS		
Unwanted ink transfer on web or sheet.	1. Undissolved particles in ink.	1. Filter particles out of ink, clean up plates and anilox.
	2. Ink dripping onto web or sheet.	2. Check print station ink application and circulation system for overflow or leaks.
	3. Ink throwing off anilox roll.	3. Increase ink viscosity. Replace end seals or wipers.
	4. Ink not drying properly.	4. *See defect "Drying Too Slow."*
	5. Excessive foaming.	5. Add anti-foam to ink.
	6. Contact with the ink film and substrate.	6. Remove any objects contacting the ink film and substrate.
STREAKS IN WEB DIRECTION		
Continuous dark lines through print.	1. Damaged fountain or anilox roll.	1. Replace or refinish metering rollers depending on extent of damage.
	2. Nick in doctor blade.	2. Hone or replace doctor blade.
STRIATIONS		
Parallel thin lines or bands present in solid print areas.	1. Excessive ink transparency.	1. Reformulate for greater opacity level.
	2. Excessive ink viscosity reduction.	2. Replace or add fresh ink.
	3. Plugged anilox roll.	3. Clean anilox roll.
	4. Worn anilox roll.	4. Replace anilox roll.

PRESSROOM TROUBLESHOOTING CHART *(CONT'D)*

DEFECT/INDICATOR	PROBABLE CAUSE	CORRECTIVE ACTION
WEB WEAVE		
Web failing to track or follow a true course through the press.	1. Web guides not operating or properly set.	1. Check and clean web guides regularly per manufacturer's instructions. Set web guides and position cores so that web will unwind and rewind at an equal measurement from the end of the respective shafts.
	2. Press out of alignment.	2. Realign press.
	3. A roller or rollers out of alignment.	3. Realign roller or rollers.
	4. Build up of ink, tape or foreign matter on press rollers.	4. Clean all rollers of foreign matter.
	5. Excessive web temperature (film substrates).	5. Reduce web temperature.
	6. Gauge inconstancies with substrate.	6. Replace with new substrate.
WRINKLING		
Wrinkles in substrate.	1. Baggy substrate.	1. Tape rollers at web edge to draw out wrinkles.
	2. Equipment misalignment.	2. Adjust all roller alignment.

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