Gravure, Flexography & Screen Printing

'L' Scheme Syllabus

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GRAVURE, FLEXOGRAPHY
AND
SCREEN PRINTING

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PREFACE

This book covers all the topics in a clear and organized format for the Second year Diploma in Printing Technology students as prescribed by the Directorate of Technical Education, Chennai, Tamilnadu. It is confidently believed that this book furnishes the students the necessary study material. The topics covered were neatly illustrated for better understanding of the students.

The book's step-by-step lessons in large, eye pleasing calligraphy make it suitable for both direct one-to-one tutoring and regular classroom use. The book is prepared in normal everyday English and is free from professional jargon characteristic of so many reading instruction books.

All of the lesson pages were carefully designed to eliminate distraction and to focus the pupil's full attention on the work at hand.

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UNIT - I – BASIC PRINCIPLES

PRINTING PROCESSES - PRINCIPLES

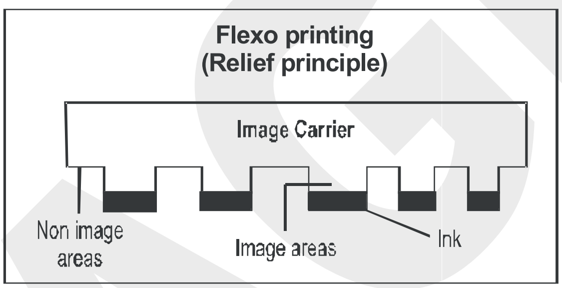
Lithography, letterpress, flexography, gravure and screen are the major conventional machine printing processes. Each of these processes is separate and distinct, because of the different operation of the planographic, relief, intaglio and stencil types of printing.

Image carriers in the form of plates, cylinders or stencils can be created either by exposing the assembled films onto a light sensitive image area which is then processed, or by laser engraving, digital or chemical transfer.

All printing image carriers have two separate surfaces - an *image* or printing area and a *non-image* or non-printing area. The image or printing area accepts the ink by mechanical or chemical means but the non-image area does not accept or retain ink.

1.1.A. PRINCIPLES OF FLEXOGRAPHY PRINTING PROCESS

In flexographic (Relief) printing the printing elements i.e., image area are in raised form. When the printing plate is inked, the ink adheres to the raised image area (printing parts) and is then transferred under pressure onto the printing substrate. In flexography a flexible, soft rubber or plastic plate is employed. - *see Figure*.



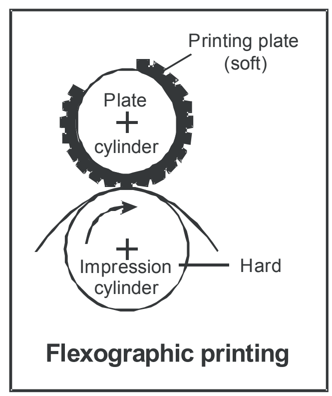


Figure 1: Flexography (Relief) printing

The principle on which a flexographic printing unit works is illustrated in figure-1. The low-viscosity ink is transferred to the printing plate via an anilox roller that is evenly screened with cells, the so-called screen roller/anilox roller (screen width 200–600 lines/cm, ceramic or hardchromed metal surface). The rubber or plastic plate is attached to the printing plate cylinder. Ink is transferred to the printing substrate by the pressure of the impression cylinder. The use of a blade (together with the ink supply system) on the screen roller has a stabilizing effect on the printing process resulting from even filling of the cells on the screen roller.

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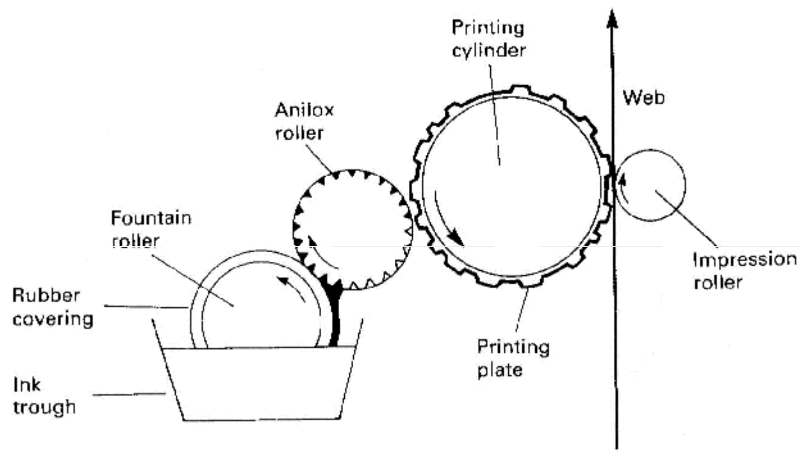
Structure of Flexography image carrier



Flexographic printing - ink metering by anilox roller.

Using the *flexible (soft) printing plate* and the appropriate ink (low viscosity) for the printing substrate, it is possible to print on a wide range of absorbent and non-absorbent printing substrates. With the rubber plates in exclusive use earlier, only a low to moderate printing quality of solid motifs and rough line drawings could be achieved. For today's higher-quality requirements, especially in the printing of packaging, photopolymer wash-off plates are used, such as "Nyloflex" from BASF and "Cyrel" from DuPont. These allow screen resolutions of up to about 60 lines/cm (150 lines/inch).

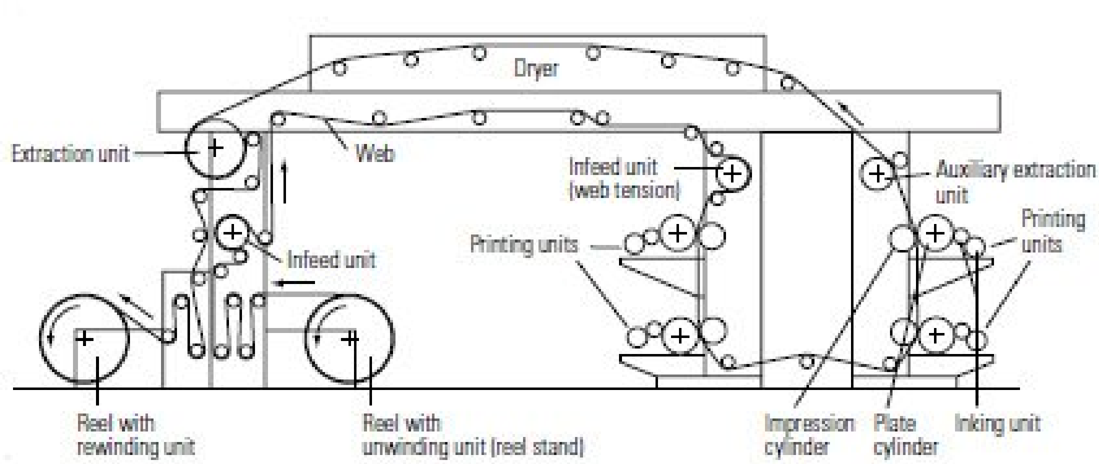
1.1.A. Flexographic Printing Process:

Flexography is a process in which the printing image stands up in relief. Liquid inks are used which may be solvent-based, and dries mainly by solvent evaporation. Water-based inks are also widely used, and UV-cured systems for printing with UV inks are being introduced.

A low printing pressure is essential to the process because of the combination of very fluid inks and soft, flexible printing plates that are used. The process has several distinctive features.

- Liquid inks are used that dry rapidly by solvent evaporation, thus enabling fast printing speeds to be achieved on non-absorbent materials such as films and foils.
- ‘Soft’ and flexible relief printing plates are employed that can be mounted and registered on a plate cylinder and proofs can also be obtained. Individual plates can easily be changed or rectified, and a portion of a plate can be removed to enable items such as price or expiry date to be changed.
- The application of ink to the surface of the printing plate is by means of a screened (Anilox) roller. The result is a simple ink feed system that consists of not more than two rollers, or perhaps a single roller and doctor blade (s).
- Although most flexographic printing is roll to roll, the machines enable changes in the print repeat length to be made simply.

1.1.B. MAIN SECTIONS OF FLEXOGRAPHY PRINTING MACHINES (PRESSES)



Multi-cylinder flexographic printing press

All flexographic presses are made up of four basic sections typically mounted in succession between sturdy side frames.

1. Unwind section
2. Printing section
3. Drying section
4. Rewind section

1. Unwind Section :

Most of the substrates come in the form of roll or webs. Firstly they are fed through infeed draw rolls, which pulls the web into press section. Now the speed of the web and press speed should be synchronized ‘to provide correct tension & register control. If the speed is more in unwind section, it is controlled by unwind breaking. An unwind section may also include a nest of internally heated steel rolls, or the rolls used for infeed tension control may be heated for a secondary purpose. This purpose is to 'open' the surface of heavily glazed or 'tight' papers by preheating, thus rendering the surface more receptive to printing ink. Preheating in this manner is also beneficial with some plastic materials, as it 'normalizes' the web, making it flatter and reducing the tendency to wrinkle.

2. Printing Section:

A single color station with the four essential rolls are fountain roller, inking roller, printing plate cylinder and impression cylinder - is sufficient to constitute a press. The majority of printing presses are multi-colour; from two to eight colors in printing section. In some presses these color units are arranged horizontally, in-line, similar to a rotogravure press. Much over common is an arrangement, unique of flexography, in one or more 'stacks'with a single stack of two to four color units, each color unit arranged vertically one above another. An arrangement of color units similar to a rotary letterpress, around a single, large, common impression cylinder is also common. This arrangement is called a central impression (CI) press.

The printing unit consists of the following three basic parts:

a. Inking unit
b. Plate cylinder
c. Impression cylinder

a. Inking Unit:

The function of the inking system is to meter out a fine and controlled film of liquid ink, and apply this to the surface of the printing plate.

It typically consists of an ink trough, a rubber-covered fountain roller, and a screened (Anilox) inking roller into which cells of uniform size and depth are engraved. The fountain roller lifts ink to the nip position, where it is squeezed into the cells in the screened inking roller and by a shearing action, ink is removed from the roller surface. The ink in the cells is then transferred to the surface of the printing plates. To regulate ink film thickness in printing, screened ink (anilox) rollers are available which have screens ranging from 40 to 200 cells/cm. These may be engraved or etched on metal or ceramic. The engraved cells are generally square in shape (although many other shapes are available now) with sloping side walls.

When printing halftones, the cells per centimetre of the anilox roller needs to be about 3.5 times the halftone screen ruling. The number of cells and their size regulate the volume of ink transferred. Further regulation of the ink is achieved by varying the surface speed of the fountain roller, by altering the pressure between the fountain roller and screened roller, and also by altering the hardness of the rubber covering on the fountain roller. Despite these controllable factors it is still the basic characteristic of the anilox roller which determines the ink supply to the plate. The anilox roller is a crucial factor in achieving good-quality flexo printing.

b. Plate Cylinder:

The plate cylinder is usually made from steel. The printing plates, which have a thickness of up to a few millimetres are secured to the cylinder with double-sided self-adhesive material.

c. Impression Cylinder :

The impression cylinder is also made from steel. The substrate passes between the plate and impression cylinders, which generate light printing pressure. The ink is transferred from the cells in the screened ink roller to the plate surface, and then to the substrate, during which it reaches virtually a uniform film.

For high-quality flexographic printing the components of the printing unit must be engineered to very tight tolerances (measured in tenths of thousandths of an inch). The ability to manufacture to these standards is one of the factors which has contributed to the growth of flexographic printing to produce higher-quality products.

<u>3. Drying Section:</u>

The Drying section require an after-drier to remove the remaining solvent from all the colours before the web can be wound in to a roll. The drying section may also require between printing units on multi color presses to permit the necessary printing of color on color. The removal of solvents can be accomplished in several ways, hot air drier is the most common. However revolutionary method of drying are being investigated.

An exhaust system conjunction with the after dryer prevents a build of solvent laden air that might become an explosive hazard. In between color hot air dryers it is essential that the exhaust exist the warm air supply, otherwise the location of these dryers in the very minimal space between color units would result in warm air being blown on to the inking rollers and plate cylinders. Premature ink drying would seriously interfere with the inking of the plates and printing of their image on to the web.

<u>4. Rewind Section:</u>

This section is identical to the unwind section in most respects but with some significant differences. It need to be nothing more than a shaft in plain bearings holding the winding roll by means of core chucks. However, there is one important difference. The unwind shaft is braked to add necessary tension as the press pulls the web off the roll. The rewind shaft must be driven.

<u>Drying Systems</u>

The most common type dryer is the forced hot air system. There are various sources for heating the air but usually it is natural gas. Steam and electric heat exchangers are also used. It is important to define ink drying in order to better understand the function of a drying system. The drying of ink on any substrate is basically the process of attempting to eliminate the solvents from the ink.

Water or solvent molecules are held together by their potential energy bond. These molecules are not static but are always moving at a high speed and colliding with each other.

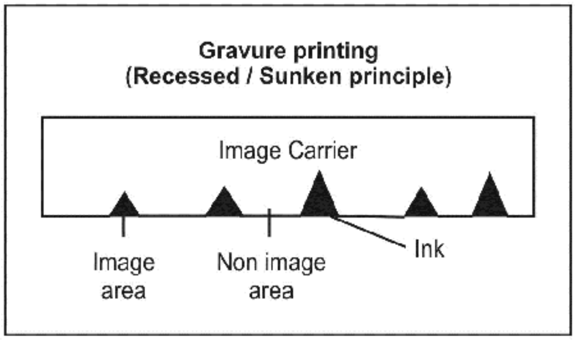
The higher the temperature of these molecules, the greater their kinetic energy, and the faster their speed of travel. If these molecules can absorb sufficient energy from hot air or other heat sources, it is, possible for them to break their potential energy bond and at this point start to evaporate. Once evaporation has started, a new set of conditions arise. The molecules now in a gaseous state, must pass through a laminar layer of air that is present with a moving web. These gas molecules must be removed quickly to prevent their return to the ink surface; and heat and fresh air must be continually fed to the surface to continue the evaporation process. The basic purpose of most drying systems is to induce a faster evaporation rate of the solvents by first heating the solvents, and secondly by continuously supplying a fresh supply of non solvent laden air to the ink surface in order to absorb the evaporating solvents.

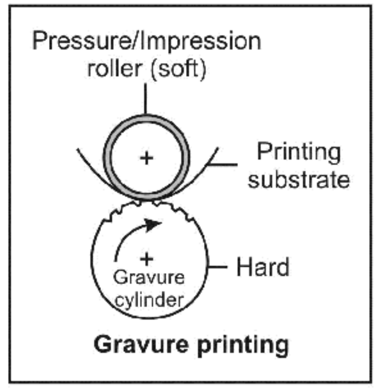
Whether the flexographic press be a stack central impression cylinder, or in-line type, all drying systems are designed to dry the ink between each color station as completely as possible before the next layer of ink is applied. After the web has been printed it travels to a final drying oven to complete the solvent removal. On earlier drying systems, it was common to use one heat source for heating the supply air, one fan *source* for blowing and supplying the air to both the between-color and final oven, and one exhaust fan to exhaust the solvent laden air from both the between-color and final oven. Today, dual drying systems are generally used. There is a separate burner, control, and supply fan for both the between-color and the final oven drying section. The advantage of the dual drying system becomes apparent when printing is done on cellophane materials. After the initial trapping at the color station the final oven must perform the added function of providing ink adhesion by fusing the ink to the cellophane coating. This can be accomplished readily in the dual systems by increasing the oven heat.

There are many different styles of between color drying covers, but all aim at delivering the maximum amount *of* air with the highest possible jet velocity over the longest web travel possible. There is, however, an optimum goal for designing a jet in order to get the maximum heat transfer with high velocity air. This relation is between the air velocity, the jet opening, jet spacing, and the distance of the jets to the web. High velocity air can be defined as air movement that is always higher than 10,000 FPM when measured at a sufficient distance from the jet orifice to simulate the position of the web.

Many presses combine different drying methods. For instance, in the after-oven various temperature and velocity zones may be combined. Also, different heat sources can be combined for different drying applications. Chill rolls are used to cool the printed web back to room temperature to prevent blocking. Single or multiple rolls in either single wall or double wall construction are presently used. It is also common to cool the non-printed side of the web first.

1.2.A. PRINCIPLES OF GRAVURE PRINTING PROCESS





In this type of printing, the printing areas are in recess - that is, on a lower level than the non-printing surface. The recesses are filled with ink and surplus ink is removed from the non-printing surface by doctor blade. The substrate is then pressed against the printing cylinder to transfer the ink onto it - *see Figure*. The main examples of gravure printing are Rotogravure printing and, in the area of arts and crafts, copper plate engraving and die-stamping (also security printing).

Gravure is the process which uses the intaglio principle. The shortest ink train is found in the gravure process as the gravure cylinder actually revolves in a bath of ink. The doctor blade removes excess ink, but leaves ink in the thousands of engraved cells in the copper cylinder.

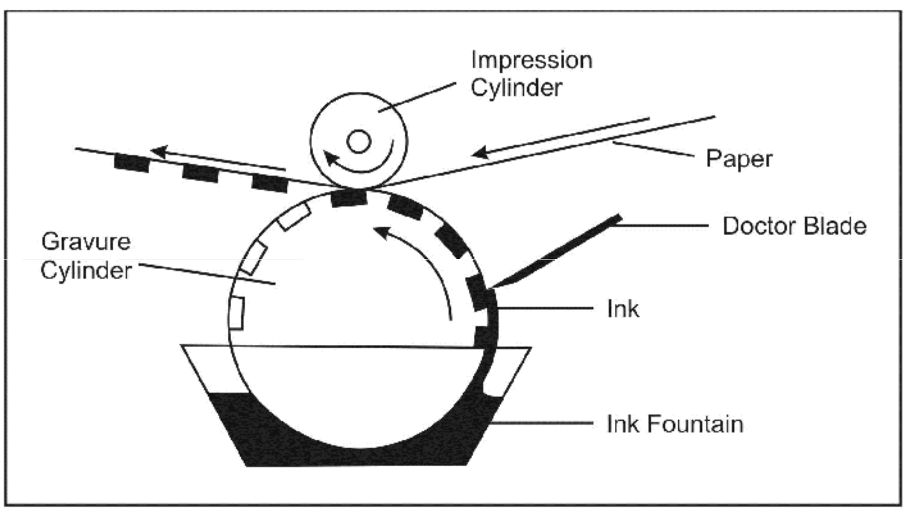


Figure: Gravure printing

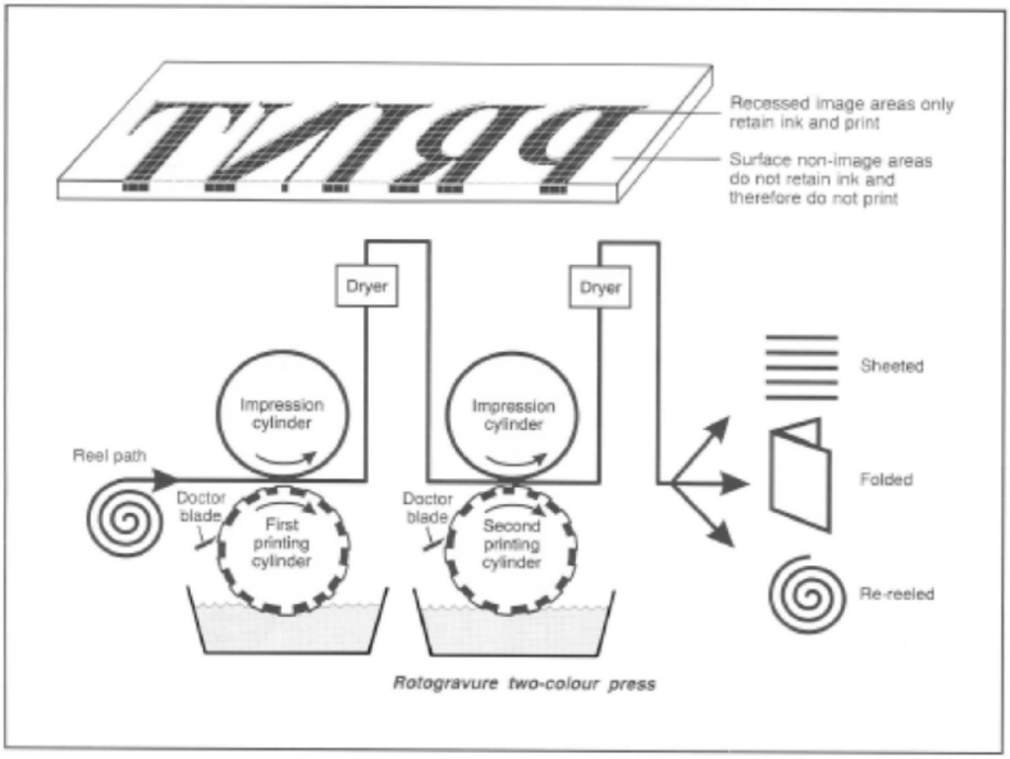


Figure: Two-colour Rotogravure press

The distinctive feature of gravure printing technology is the fact that the image elements are engraved into the surface of the cylinder. The non-image areas are at a constant, original level. Prior to printing, the entire printing plate (non-printing and printing elements) is inked and flooded with ink. Ink is removed from the non-image (by a wiper or blade) before printing, so that ink remains only in the cells. The ink is transferred from the cells to the printing substrate by a high printing pressure and the adhesive forces between printing substrate and ink.

Rotogravure printing is used for the economical production of long print runs. *Gravure printing forms* are usually cylindrical. A special feature of industrial *rotogravure printing* is the fact that a whole cylinder is used per color separation. This means that in a four-color press four separate cylinders have to be changed for each new job. Consequently, a company that has a lot of repeat jobs is forced to store a large number of cylinders. Depending on the printing format, gravure printing cylinders are generally rather heavy and require special conveying and handling gear systems.

<u>1.2.A. INTAGLIO / GRAVURE PROCESS</u>

In this process a metal plate usually copper is used as a image carrier. Here, copper etching or hand engraving is carried out to form an image. Ink is applied over the image areas, excess inks are wiped off. A sheet is laid over the plate and pressure is applied. Ink from recessed area is transferred to paper according to the width and depth of engraved lines.

Photogravure:

Photogravure is an intaglio process. Image areas are deeply etched below the surface of the copperised surface of printing cylinder. Liquid ink is filled in the recessed image areas and a doctor blade wipes the surface clean free from surplus ink. The cylinder is pressed on paper or other material for transferring the inked image.

Gravure Printing:

Gravure is the photographic version of the original “Intaglio” process and Gravure is a process which follows the intaglio principle.

In Gravure process, the printing image is engraved into a cylinder in the form of cells. The engraved cells are filled with ink and excess ink on the cylinder surface is wiped off by doctor blade. Printing is achieved by passing the substrate between the gravure cylinder and an impression roller under pressure.

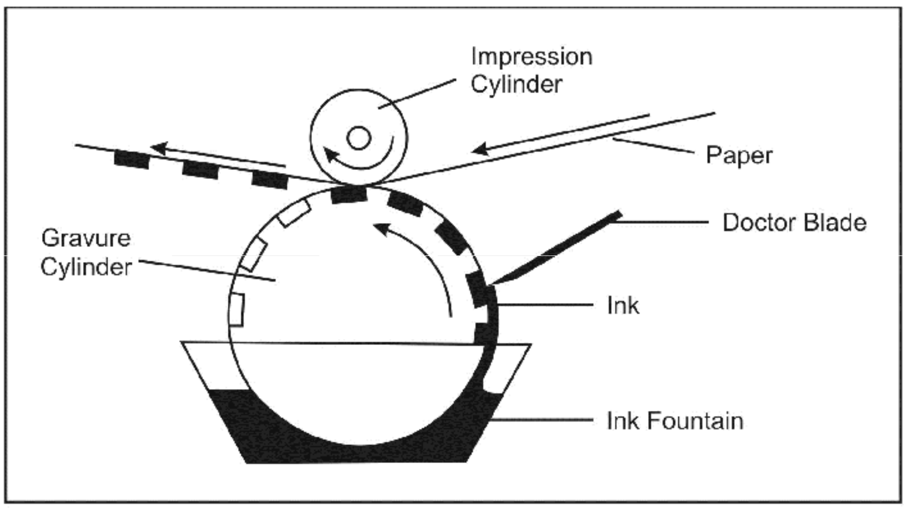


Fig.: Gravure Printing Unit

Gravure processes has a much wider application than letterpress or offset as it prints, from a low viscosity liquid ink. Coating, varnish, adhesive, hot carbon or anything that will flow on a cylinder can be printed by gravure. Plastic sheeting, curtains, linoleum, upholstery metallic foils, paper and boards can be printed. The finished materials can be passed through in-line machines for punching, cutting, folding, etc. Gravure has advantages in carton making.

Thick film of gold ink can be printed. Deep brilliant glossy solids by the slide of delicate tones of postal shades can be laid down by gravure. Printing with 100, 120, 150, 175, 225, 300 lines screens are possible. Printing using 175 line screen is popular. The greatest etching depth is 1 to 2 / 1,000 of an inch or 25 / 1000 to 50 / 1000 mm. The ratio of cell wall thickness to cell width 1:2.25 or 1:2.5 for paper and board and 1:3 for solid areas on foil and plastic is recommended. Width increases with cell depth and cell wall becomes thinner. Ink from deep cell spreads more. The dense areas merge into one another screen pattern. Highlight cells accept little ink.

Gravure is popular for picture reproduction. Small type printing is a problem. For type matter rinco process of gravure is popular.

1.2.A. ADVANTAGES, LIMITATIONS (DISADVANTAGES) AND CHARACTERISTICS OF GRAVURE PROCESS

Advantages of Gravure:

1) The final printed images are of excellent visual quality. Due to its intaglio character, the closeness of the printing areas and different thickness of ink, gravure print displays the pleasing effect of a continuous tone image.
2) Photogravure is an exceptionally fast printing method on almost all kinds of paper and materials. Press speed attainable in web-fed presses for paper: 1,000 fpm (Feet Per Minute) ; Film and Foil: 300 to 600 fpm. Sheet-fed presses: 3000 sheets per hour.
3) The printed sheet is usually dried, when it leaves the press, due to the volatility of the fluid ink.
4) Gravure cylinders yield very large number of impressions and under proper handling even yield several millions copies. Chrome-plated copper cylinder can print 1.5 million revolutions without re-chroming; and can print 12 to 20 million revolutions before making new cylinders, depending on material printed.
5) Rotogravure ink, based on, fluid ink can be formulated for printing on a, variety of printing stocks - paper, paperboard, plastic films, metal foils, textiles, etc.
6) The supplementary operations like cutting, punching, creasing and stripping are done “In-line”, the end product are fabricated at the same speed at which printing press runs.
7) Cheaper paper stock can be used on gravure presses compared with other processes.
8) Quality reproductions at low cost is possible.
9) Large presses with a web width of 144inch are used for printing of vinyl floor covering.
10) Virtually, there is no make-ready involved while printing on a Gravure press.

Limitations of Gravure :

1) Length of time to prepare and etch a cylinder. Generally, it required between three and four hours from the time resist has been applied to the copper surface until the printing form is ready to be proofed.
2) The high initial cost incurred in the cylinder preparation.

3) Type, Text matter and fine line illustrations do not reproduce as sharply in gravure as it is reproduced in offset chiefly because the rotogravure screen gives a “sawtooth” edge to vertical lines and horizontal lines while using gravure screens.
4) Minimum economical run is said to be 50,000 copies.
5) Once the cylinder has been prepared, very limited alterations or revisions alone can be made without having to prepare a new cylinder.
6) Air conditioning of the plant is necessary due to the inherent nature of the process.

Characteristics :

1) All gravure text matter as well as pictures must be screened.
2) Generally the gravure cylinder itself is etched and acts as the image carrier.
3) Gravure prints from a design below the surface of the plate or cylinder.
4) Gradations of tone are obtained by etched cells to different depths, so that more or less ink is carried by the cells and transferred to the paper according to their depth.
5) The use of the “Doctor blade” in the printing press (to remove ink from non-printing areas).
6) An interesting possibility of gravure press is the fact that a simple basic principle allows the use of cylinders of different diameters, without complicate changes in the unit gearings.
7) A continuous tone positive is used for exposing on the carbon tissue.

1.2.B. MAIN SECTIONS OF GRAVURE PRINTING MACHINE:

All gravure machines consist of following main sections:

1) Unwind section
2) Printing section
3) Drying section
4) Rewind section

1. Unwind Section :

Most of the substrates come in the form of roll or web. First web is fed through infeed draw rolls, which pulls the web into press section. Now the speed of the web and press speed should be synchronized to provide correct tension & register control. If the speed is more in unwind section, it is controlled by unwind breaking. An unwind section may also include a nest of internally heated steel rolls, or the rolls used for infeed tension control may be heated for a secondary purpose. This purpose is to ‘open’ the surface of heavily glazed or ‘tight’ papers by preheating, thus rendering the surface more receptive to printing ink. Preheating in this manner is also beneficial with some plastic materials, as it ‘normalizes’ the web, making it flatter and reducing the tendency to wrinkle.

2. Printing Section :

The printing unit of gravure machine consist of following :

a) Ink duct
b) Printing cylinder
c) Doctor blade
d) Impression cylinder

a. Ink Duct

In olden days open ink trough was used. There is no control of solvent evaporation and ink is not well agitated, it was unsuitable for high speed machines. Where there is a pump which continuously agitate the ink and pump it to the ink trough in which printing cylinder rotates. Excess ink is returned back to the tank from ink trough.

Due to this enclosed system solvent evaporation is reduced. This enclosed system also employs viscosity control of the ink. In this system whenever the ink is returned from ink trough, it is filtered and solvent is added to maintain the viscosity of ink.

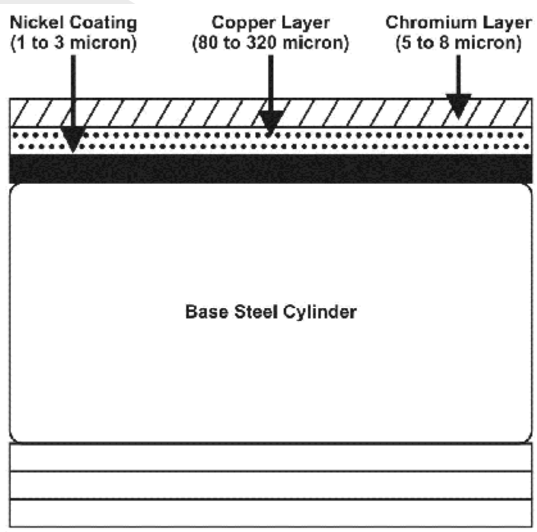
Further to this enclosed inking system a spray system is also used for very high speed machines, where ink pump delivers the ink to nozzles pointing at the cylinder. The nozzle surface is always kept wet. It will never dry out. This system also fully enclosed.

b. Printing Cylinder:

Basically, a gravure press is still the simplest of the printing machines. Publication presses have cylinders as big as 102 inch with a diameter of about 17 inch. Generally publication presses are not built to permit inserting of cylinders varying in the diameter.

Presses for package printing can handle cylinder varying in their diameter within a given range. When variable diameter cylinders are customary, the nature of the jobs controls the dimension. Cylinders for packaging vary greatly in size from the very small, about 7 inch long by 2 or 3 inch diameter up to massive cylinder length of 80 inch or more long with a diameter of about 17 inch.

Presses with a printing width of 200 inch (5 meters) and above are used for speciality printing, like printing of vinyl floor covering.



Gravure Printing Cylinder

Copper Plates

Gravure plates are made from rolled copper. The ends of the plate must be carefully bent to fit in to the clamps on the cylinder. The plate covers only parts of the cylinder circumference since the plate cylinder must house the clamping system. This uncovered section must be filled in with a "gap cover" or "segment" to provide a bearing surface for the doctor blade. These type of presses (using a gravure plate) are becoming absolete.

Copper Cylinder

Gravure cylinders can be made of iron, steel, copper or aluminium. Ends are usually fabricated with steel bar and plate, or steel shaft pressed through the cylinder body. Sleeves cylinders are metal tubes housed in the machine on mandrels. It is only necessary to produce a sleeve or tube with this system, for subsequent mounting on a machine mandrel. The sleeve is generally made of steel base and deposited with copper, to a diameter slightly larger than the required size. It is then turned and polished in a lath to obtain the correct diameter and perfect stage. This system is not recommended for multi-unit web-fed presses and for large-run package printing.

In the Ballard process, a thin skin deposit of copper is loosely adhered to the bulk of the cylinder surface, but is firmly attached at the bar ends. After printing, the copper skin is removed by cutting and then pulling off. The advantages of Ballard process are elimination of grinding of the old etching and allowing exact size cylinders for color works. The thin film of copper is approximately 0.006 inch thick and is deposited in about one and a half hours. This type of cylinder is used for printing of short-run magazine and packing. On an average, to deposit one square foot of copper for 0.001 inch thick, the requirements of copper is 0.74 oz.

Solid cylinders are invariably used on web-fed presses. The thickness of the copper deposit varies depending upon the circumference, length and construction of the cylinder. The copper deposit ranges from 0.015 to 0.050 inch thick, and copper is deposited slightly more than the required thickness. Afterwards the cylinder is taken out and brought to the required diameter by turning it on a lathe and then it is polished to a high luster. The accuracy of the cylinder is maintained within a tolerance of + or – 0.0005 inch.

c. Doctor Blade :

The printing cylinder is flooded with ink and before impression is made on the paper, the excess ink from the cells and on the non-printing surface of the cylinder is removed by the scraping action of a flexible sheet blade, known as "Doctor Blade". As the cylinder turns, and just before the paper makes contact with it, this doctor blade, made of fine Swedish steel (.008 inch thick) wipes off all the excess ink. The doctor blade, precision ground and hand coned (after use), is held against the cylinder under pressure, and scrapes the cylinder surface absolutely dry.

This doctor blade is assembled in such a way to ride on the surface of the cylinder and remove the surplus ink, without damaging the surface of the printing image area cells. This doctor blade is assembled as near as possible to the nip pressure, to avoid any ink evaporation and drying of ink in cells. Usually the thickness of the blade is 0.15mm to 0.25mm. The main blade is supported by backing blade of 0.76 mm thick.

The doctor blade is usually set in such a angle that must wipe excess ink from the non-image areas. If the blade angle is more steep, it gives cleaner wipe. If the blade angle is shallow it wipes less ink. Blades are ground with a bevel edge and the angle of bevel is one of the factors influencing the printing result. Doctor blades are normally made to reciprocate up to 6cm. The reciprocate action of blade makes better wiping of ink and disperse the paper fibers and any foreign particles.

High speed presses are equipped with pre-doctoring blade. This allows an ink film of 0.5mm to final doctor blade. Due to this pre-doctoring blade pressure on the second (final) doctor blade is reduced and cylinder wear is less, printed results are less affected by speed.

d. Impression Roller:

This has a steel core with hard rubber covering to bear the heavy pressure. The rubber covering is of 12 to 20 mm thickness. Its hardness is from 60^{o} to 100^{o} shore. If the substrate is too rough and more compressible then hard rubber is used. Plastic films are normally printed with soft roll and with low impression pressure.

In general the pressure applied between impression roller and printing cylinder is higher than any other processes. The impression roller is oftenly supported with third roller called “BACK UP” to overcome the impression roller deflection and give sufficient pressure in the center. Another technique is “flexible” roll which can be adjusted to even out the pressure across the width of the web.

Now a days impression rollers are employed with electrostatically assisted ink transfer. To overcome the printing problem “speckle” (individual cells not printing on rough papers and noncompressible papers even if it is coated one). In this special roller during the turning (rotation) high voltage is generated. This electric field encourages the ink to leave the cells and transfer to the paper even the contact is imperfect.

3. Drying Section:

The Drying section require an after-drier to remove the remaining solvent from all the colours before the web can be wound in to a roll. The drying section may also require between printing units on multi color presses to permit the necessary printing of color on color. The removal of solvents can be accomplished in several ways, hot air driers being the most common.

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4. Rewind Section:

This section is identical to the unwind section in most respects but with some significant differences. It need be nothing more than a shaft in plain bearings holding the winding roll by means of core chucks. However, there is one important difference. The unwind shaft is braked to add necessary tension as the press pulls the web off the roll. The rewind shaft must be driven.

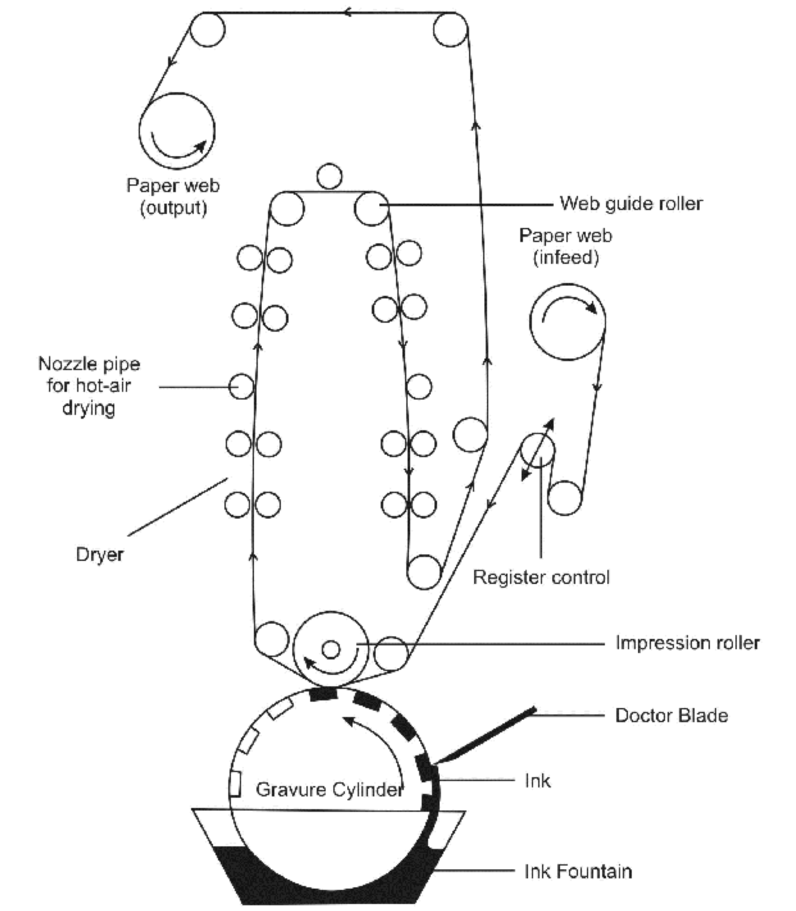
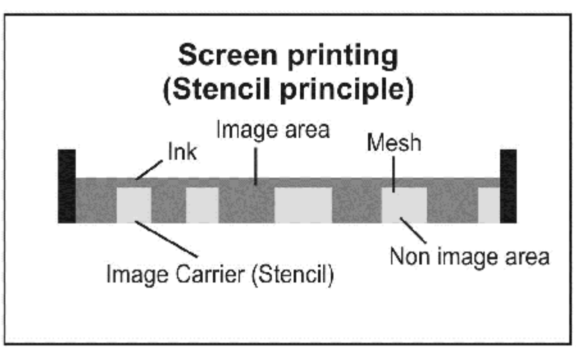
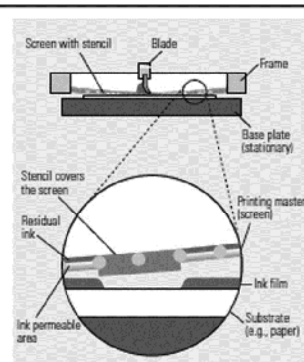


Fig. Schematic illustration of a gravure printing unit (KBA)

1.3.A. PRINCIPLES OF SCREEN PRINTING PROCESS





Screen printing (schematic diagram)

Screen Printing : In this type of printing, the image and non-image areas are carried on a mesh (woven) screen, the image areas being open or 'unblocked' in the form of a stencil. The non-image areas are formed by 'blocking out' the mesh by coating (*see Figure 4)*. The paper is placed under the screen. After the screen is lowered into contact with the paper, ink is passed across the upper surface of the screen. Where the screen is open, ink goes through to the paper beneath.

Screen printing is an example of the stencil printing process.

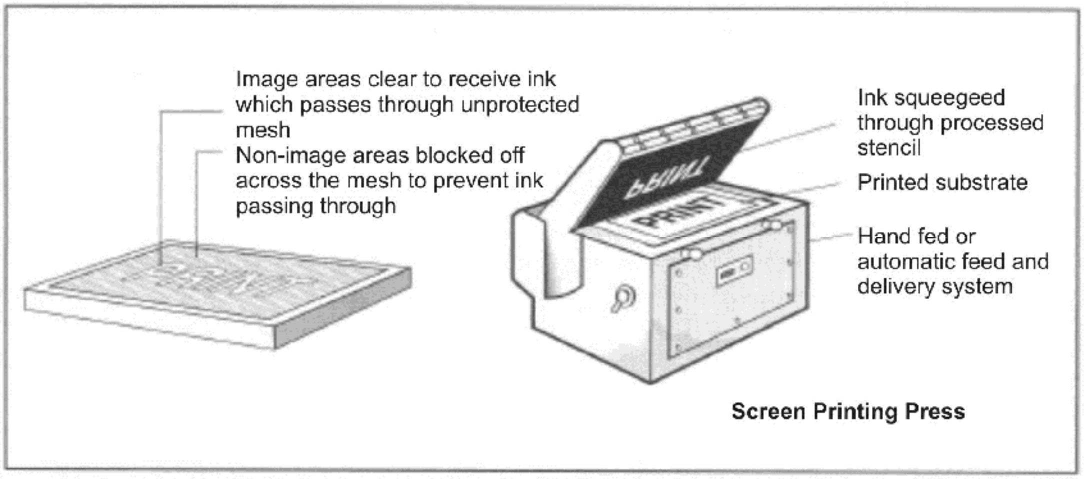


Figure 4: Stencil printing

Screen printing is a process in which ink is forced through a screen. The screen printing stencil serves as a printing plate. The screen is a fine fabric made of natural silk, plastic, or metal fibers/threads. Plastic or metal fabric is generally used nowadays. Ink is imprinted/transferred through the image-specific, open mesh that is not covered by the stencil. The screen printing plate is therefore a combination of screen and stencil.

It is the material, the fineness of the screen (the number of screen threads per centimeter of fabric length), the thickness of the screen, the distance between the top and bottom sides of the screen, and the degree of opening of the screen (the degree of screen opening areas as a percentage describes the ratio of the total of all mesh openings to the entire surface of the fabric) that determine the printing properties and quality of the fabric (screen). Fabrics can be obtained in levels of fineness from 10 to 200 fibers/cm. The most frequently used fabrics are those between 90 and 120 fibers/cm.

The screen work and printing of very detailed illustrations necessitate the use of very high levels of fabric fineness that are matched to the resolution requirements of print image reproduction. For screen work, fabric fineness (threads/cm) should be around three to four times greater than the screening of the print image (lines/cm) – therefore nine to sixteen different screen dot area surfaces per screen cell.

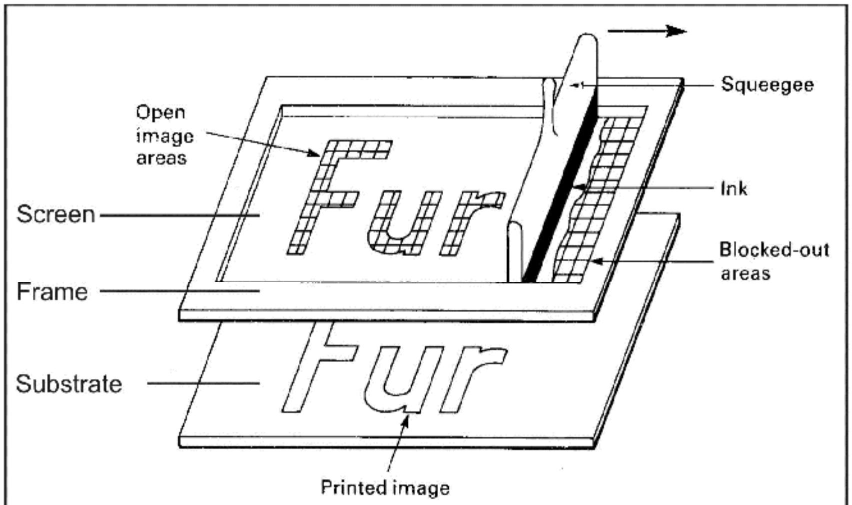
The *stencil* on the fabric defines the actual print image. The stencil is on the side of the screen opposite the side on which the squeegee (blade) works, to avoid damage and wear to the stencil. Manual stencils, which can be produced as drawn or cut stencils and transferred to the underside of the screen, are used for simple solid-area print work.

1.3.A. SCREEN PRINTING PROCESS

Screen printing (formerly called silk-screen printing) is a stencil process whereby ink is transferred to the substrate through a stencil supported by a fine fabric mesh of silk, synthetic fibres or metal threads stretched tightly on a frame. The pores of the mesh are 'blocked-up' in the non-image areas and left open in the image area. This image carrier is called the screen.

During printing the frame is supplied with ink which is flooded over the screen. A squeegee is then drawn across it, forcing the ink through the open pores of the screen. At the same time the substrate is held in contact with the screen and the ink is transferred to it. The principle is shown in Fig.

Because of their simplicity, screens can be produced cheaply and this makes it an attractive process for short-run work. Furthermore, since the image is produced through a screen rather than from a surface the impression pressure is very low. This makes it ideal for printing on fragile boxes or awkward shapes.



Basic screen press arrangement.

Irrespective of the type of machine the printing procedure is generally the same. A working supply of ink is placed at one end of the screen and the screen is then raised so that the stock may be fed to register guides or grippers on a base. The screen is then lowered and a rubber or plastic squeegee drawn across the stencil to produce the print. Ink replenishment is undertaken as necessary.

On most flat-bed machines the base to which the substrate is applied is of a vacuum type. This prevents the stock sticking to the screen and being lifted by tacky inks. To a certain extent the thickness of the ink film printed can be controlled by the pressure, sharpness and angle of the squeegee blade.

The more upright the blade the thinner the deposit of ink. Thus, in general, fine work requires a more upright blade. However, the type of ink, stock and machine govern the blade setting also.

1.3.A. Advantages of Screen Printing Process

One of the major advantages of the screen process is the ability to obtain prints on non-flat objects. For example, printing on bottles or other cylindrical objects is achieved by using a press of the cylinder type described above but the object to be printed is placed in the machine where the impression cylinder is shown. After each impression the bottle is removed and another unprinted one substituted. There are few limitations on size or shape. Special screens and jigs are produced for printing on shaped objects such as cups with handles or tapering cylinders, and screens with high elasticity combined with shaped squeegees are used for conforming to irregular objects. Print heads can also be bolted to automatic production lines, so that printing becomes a part of the total production process of such objects as filled polythene bottles.

1.3.A. APPLICATIONS OF SCREEN PRINTING

i. Screen Printing on Flat Surfaces

Posters and Graphics Printing in Short Print Runs.

Large-format posters in particular can be produced relatively conveniently in fairly small print runs. The quite thick ink film produces coloring that is very brilliant and resistant even with halftone color impressions.

Traffic Routing Systems and Signs. Large printing surfaces for high resistance inks are found with traffic signs and routing systems. The requirements they impose are best met using screen printing.

Vehicle Fittings and Instrument Dials. With vehicle fittings a narrow tolerance range of the translucency of the impression is required in addition to its precision. For example, it must be possible for control lights to light up in precisely defined colors.

Printed Circuit Boards for Electronics. Due to its simplicity and flexibility, screen printing is an important process during the development of printed circuit boards for electronic circuits. Accurate printing onto copper-laminated hard paper or glass-fiber reinforced epoxy board with etching allowance, solder resist, or assembly designations in the necessary coating thickness is only possible in large quantities with screen printing. Restrictions are, however, imposed on the latter as a result of the extreme miniaturization of components and printed circuit boards.

Photovoltaic. Special conductive pastes are used to print on photo resistors and solar cells, which serve as the contact points for current transfer. In doing so, particular importance is placed on high coating thickness in areas that are, at the same time, extremely small and covered with printed conductors, in order to optimize the efficiency of the energy production with the solar cells as fully as possible.

Compact Discs (CD). Screen printing is one of the major processes for printing on CDs. Pad printing and more recently even offset printing are also used.

Textiles. The depth of the ink absorption in textiles calls for a large volume of ink to be supplied and screen printing is the preferable process for applying it. Clothing, canvas shopping bags, webs of material, and so on, can be printed in both flatbed and rotary screen printing.

Transfer Images. Screen printing is frequently used to produce transfer images for ceramic decoration. These images are put together from ceramic pigments for firing. The pigment's grain size necessitates the use of a screen mesh that is not too fine. After detachment the images are removed from the base material and placed on the preburned bodies by hand. A recognizable feature of these ceramic products is the thick layer of ink. The images can be placed above or below the glazing.

Decorative Products, Labels, Wallpapers. Seamless decorations such as textile webs, wallpaper, and other decorative products, as well as labels often require rotary printing combined with reel material. Special machines are designed for this. Rotary screen printing with sheet material is used primarily for higher print runs.

Surface Finishing. *Transparent varnish* can also be applied using screen printing technology (for spot varnishing, in particular) *to finish* the printed product as add on value to attract the customers.

ii. Screen Printing on Curved Surfaces

Almost any body that has an even, convex and concave (to a limited extent) not too structured surface can be printed using screen printing. There are virtually no restrictions with regard to the material of the body to be printed on. Ceramics can be printed directly with screen printing. Ceramic pigment inks can be used for subsequent baking or just a low durability varnish applied to the glazed product. It is not always possible to print directly onto plastic components. Surface treatment, for example involving flame treatment, corona charging, or the application of primer is often necessary to ensure that the ink adheres.

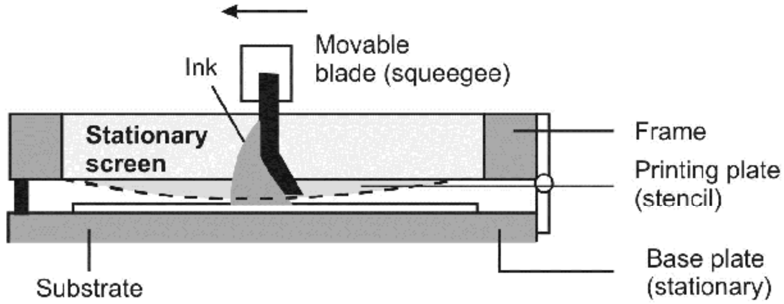
Bottles. Glass bottles with a baked finish or pretreated plastic bottles for the food and domestic products sector are printed using the screen printing process.

Toys. Toys, such as balls, and so forth, can be printed in full in several operational steps.

Glasses. The screen printing process is often used for drinking glass decoration, with thick coatings of all inks and also gold being applied.

Advertising Media. The type of advertising medium that can be decorated or provided with some other overprinting by the screen printing process ranges from cigarette lighters or ballpoint pens to pocket knives and pocket calculators.

1.3.B. MAIN SECTIONS OF A FLATBED SCREEN PRINTING MACHINE



Printing principle: flat-to-flat (flatbed)

Following are the parts of a screen printing press of hand operated one:

1. Frame
2. Base
3. Screen fabric
4. squeegee

<u>(1) Frame:</u>

The frame serves as a support for the screen fabric. It can be made from wood, metal or any other rigid material.

a) Wooden frame:

Wood used for screen printing should be soft, straight, grained and should resist the moisture and temperature. Wooden frame are easy to handle and assemble. The cost of the wooden frame is less than metal frame. Leveling is also important for wooden frames. Coating the wooden frame by a two-component lacquer protects the wood from water and solvent. Pine or popular wood is usually used for making frames. Before making a frame, wood is seasoned. The corners of the frame is joined by miter, end lap, or spline joints. Angle and corner irons are sometimes used to reinforce the corners of a large screen printing frame.

(b) Metal frames:

Steel is used for screen frames as its rigidity, life is more when comparing the wooden frames. For corrosion protection, steel frames are galvanized or coated with lacquer, sometime with stored varnish. These steel frames are available as rectangular or square section. For easier handling of large frames, steel is replaced by aluminium alloy, but care must be taken in providing rigidity. Also aluminium frames are corrosion – proof when comparing steel frames. Leveling of metal frame is very important. This leveling is done on a special leveling slab. Before mounting the fabric, sharp edges and pointed corners should be well rounded to avoid the tearing of fabric.

<u>(2) Base :</u>

This is the surface upon which the substrate to be printed is positioned and held. It is usually made from a thin sheet of plywood or hardboard or table. This is longer than the frame used. Loose-pin built hinges serve to hold the frame and base together.

(3) Screen Fabric :

The screen fabric is a woven material. It is a tightly stretched across the frame. This Screen fabric serves as a carrier for stencil. The selection of fabric for particular work plays a major role. Following are the types of fabrics.

a) Silk:

Silk is a natural fiber produced by the silk worm. Hand cut and indirect stencils adhere well to silk fabrics. However this silk is not dimensionally stable. Size variation can occur due to change in temperature and humidity. Therefore silk is unsuitable for jobs requiring critical registration.

(b) Polyesters:

Polyesters such as darcon, Terital and polylast are man-made synthetic materials containing cellulose, resins and hydrocarbons. Polyesters fabrics are woven very uniformly and possess good dimension stability. They are extremely strong and used for long runs. A major disadvantage is that indirect photographic stencil will not adhere so good as like in silk.

(c) Nylon:

Nylon is also a man-made synthetic material having uniformly woven fabrics. This fabric is strong and durable and can be used for long run jobs. Unlike polyesters, nylon fabrics lack dimensional stability. Nylon fabrics will go on stretched and react to temperature & humidity changes. So before mounting a nylon fabric on frames, it should be wet firstly and stretched very taut, to maintain the good registration.

d) Metal fabrics:

These types of fabrics are used for only special application. Unlike the synthetic fabric, it does not absorb moisture and is therefore unaffected by changes in humidity. Also it is unaffected by temperature. As it has very good dimensional stability it is used for very precision printing like printed circuit board or very specialized application. Usually “Stainless Steel wire” is used as a metal fabric.

Stainless steel will retain its tension almost indefinitely, where as all synthetic meshes-show a tendency to loose tension with use. Also stainless steel mesh allow more volume of ink to pass through. As it is electrically conductive it can be used for printing thermoplastic inks. Stainless steel screen printing fabrics are more expensive than synthetic material.

(4) Squeegee :

The squeegee performs a very important function in screen printing. It is used to force the ink through the screen mesh and stencil on to the printing stock below. Squeegee blades are made from high quality natural rubbers and synthetic material. Polyurethane squeegee blades are now- a-days used widely due to their resistance property to abrasion so there is no need for sharpening or reshaping.

Squeegeees are normally supplied in three grades : Hard, Medium, Soft. The hard and medium grades are used for printing thin film inks, the soft grade is used for printing on to non-absorbent materials such as metal & glass. During the printing action the squeegee is moved across the screen and force the ink to pass through the mesh opening.

ADDITIONAL RELATED TOPICS

ADVANTAGES AND LIMITATIONS (DISADVANTAGES) OF PRINTING PROCESSES

Flexography Printing

- ***Advantages***
  - Changes to plates can be made relatively easily and cheaply, by just replacing the required parts of the overall image areas
  - Ideally suited to printing reel/web-fed substrates with in-line press finishing
  - An environmentally friendly process as it tends to use few chemicals, in fact is often operated as an entirely water-based process in terms of consumables, such as plate processing, inks and cleaning fluids
  - Simple, generally easy to use process
  - Variable cylinder cut-offs allow greater flexibility on the length of images that can be printed.
- ***Limitations (Disadvantages)***
  - Cannot print screen halftones as fine as offset printing, requiring a smooth to coated stock to reproduce good screen detail
  - Not economic for sheet-fed printing, therefore unsuitable for short-run general commercial printed products such as booklets and leaflets
  - Although print quality has improved considerably in recent years, it is still not as high as offset lithography.

Gravure Printing

- ***Advantages***
  - A printing process giving full colour values in reproduction, with rich tonal effects, particularly in monochrome
  - High production speeds is of great advantage in periodical, magazine, catalogue and colour supplement work printing, where very long runs are often required

- High quality printed results, especially in colour work, on relatively inexpensive grades of substrates which cannot be matched by other printing processes
- Variable cylinder cut-offs allow much more flexibility on available pagination range for publications compared to heat-set offset litho.

➢ ***Limitations (Disadvantages)***

- Printing cylinders very expensive
- Alterations to plates or cylinders impracticable
- Type matter and fine-line detail is broken up by the overall cell structure
- Make-ready / set-up costs expensive, which along with high costs of printing cylinders makes gravure unsuitable for short- or medium-sized run jobs.

Screen Printing

➢ ***Advantages***

- Suitable for short runs multi-colour jobs.
- Low preparatory costs
- Light colours can be printed satisfactorily on dark materials or deep colours
- Ideally suited for printing showcards, posters and unusual & irregular materials such as heavy gauge metal, plastic, glass, etc
- Lays down the heaviest ink film thickness of all the printing processes, resulting in enhanced results such as very high gloss varnishing and raised printing results when required.

➢ ***Limitations (Disadvantages)***

- Halftone subjects are limited to coarse screens
- Although automatic presses are now available, the process is still in the main restricted to short-run work
- Conventional inks requires some considerable time, plus use of space consuming racking, to allow the work to dry, leading to the increased use of UV inks.

VISUAL CHARACTERISTICS OF THE PRINTING PROCESSES

It is undoubtedly a considerable asset to be able to determine with reasonable accuracy the printing process or processes by which an item of printed matter has been produced.

There are a number of characteristics or clues which, if they can be discerned, make identification of the process possible, but not necessarily simple. Indeed, there are some jobs where it is very difficult to identify the relevant process or processes, even to those having considerable experience, and the use of a powerful magnifying glass or 'linen tester' is of considerable value.

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Figure 5 and the comments which follow have been prepared to assist in this process.

Offset Printing

- Overall, smooth and even printed result
- Very wide range of substrates including coarse textures, can be satisfactorily printed, even when very fine halftone illustrations are reproduced
- Tonal effects obtained by the use of mechanical tints or halftones.

Flexography Printing

- Thickening of design under pressure, along with a general outline to the printed areas in the form of a visible halo, especially around the outer edges
- Tonal effects obtained by the use of mechanical tints or halftones
- Fine-screen halftones must have substrate with a coated surface
- Printed samples often obtained from processed material in reel-form such as self-adhesive labels, plastic and paper wrappings.

Letterpress Printing

- Thickening of design under pressure, along with a general outline to the printed areas in the form of a visible halo, especially around the outer edges
- Slight embossed effect usually detectable on reverse of sheet, especially with sheetfed printing.
- Tonal effects obtained by the use of mechanical tints or halftone dot
- Fine-screen halftones must have substrate with a coated surface.

Gravure Printing

- Wide range of tonal values is possible, giving an effect of continuous tone-like quality (especially in four-colour process work)
- Because of the screen pattern or cell structure, which appears over the whole of the printed image, fine-line work and text matter appear rough/broken at the edges when examined with a magnifying glass
- Under a magnifying glass the ‘screen pattern’ in conventional gravure is seen to be of a regular square formation (showing uniform cells).

Screen Printing

- Thickness of ink film is usually more apparent than in other processes, especially where solid colours are printed upon one another.
- Because of the use of relatively coarse screen meshes, forming the support for the stencil, small lettering and fine-line work tends to break up round the edges and this can be identified when examined with a magnifying glass.

- Halftone subjects are generally reproduced with a fairly coarse screen, although with water-based UV inks 54 lpc (in excess of 133 lpi) resolution is now possible.

JOB SUITABILITY

SUITABILITY OF PRINTING PROCESSES TO DIFFERENT CLASSES OF WORK

Each of the printing processes has particular properties, characteristics and associated costs which make it more suitable for certain classes of work than others.

It has to be acknowledged, however, that there is a considerable amount of common ground where two or more printing processes may regularly be used to produce a certain printed product - eg - books printed by offset litho, flexography and letterpress, newspapers by offset litho (cold-set) and flexography, reel-fed labels by flexography and letterpress, periodicals printed by sheet-fed, heat-and cold-set web offset, also web-fed gravure.

The comments made below are given as a general guideline rather than a definitive statement on the suitability of different printing processes to different classes of work.

Flexography Printing

This is predominantly a reel/web-fed process, suited mainly to specialist or niche printed markets such as reel-fed labels, newspapers, flexible packaging such as food wrappings, carrier bags and rigid packaging such as cartons and collapsible corrugated cases.

Gravure Printing

Sheet-fed Gravure printing

Suited to specialist work such as printing on metallised and other substrates to produce high quality decorative effects in gold, silver and fluorescent colours.

Web-fed Gravure printing

This main application covers a wide range of general commercial products. Gravure is especially suited to work in four-colour process on relatively cheap, smooth mechanical papers in quantities of 250 000 or more, such as magazines, mail order and catalogues. In addition there are a wide range of specialist products such as security printing including stamps and cheques; board packaging products such as folding box cartons for food and cigarette industries, also printed video cases; flexible packaging such as printed cellophane and polythene used in food wrapping, display and protection.

Screen Printing

Sheet-fed Screen printing

As the process is best known for its ability to print a thicker ink film than any other printing process this makes it ideal for printing light coloured inks on dark coloured materials, also onto awkward, rough surfaces, uneven and moulded shape surfaces. Examples include posters, showcards, printed circuits, T-shirts, printing on cloth, vinyl, metal, glass and plastic, etc.

Rotary/web-fed Screen Printing

Specialist area of the process used for self-adhesive labels, scratch-off lottery tickets, packaging, transfer printing, fabric printing, security printing, direct mail and high quality greetings cards with die-cutting and additional finishing requirements.

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UNIT: I – BASIC PRINCIPLES

PART - A - 1 Mark Questions

1. Name the printing process which utilizes intaglio principle.

Gravure prinitng process

2. What is direct printing process?

If the image is directly transferred from the image carrier to the substrate, then it is called direct printing process.

Eg: Letterpress, Flexo Gravure & Screen printing process are direct printing processes.

3. State the functions of doctor blade in gravure printing. / What is doctor blade?

Doctor blade is a thin, flexible steel, plastic or composite blade that passes over gravure cylinder to wipe off excess ink before impression is made on to the substrate.

4. What is the image carrier used in Gravure printing?

Copper Cylinder

5. How do flexo and gravure inks dry?

Flexo and gravure inks dry by eveporation of solvents.

6. Name the main sections of gravure printing machine.

i. Unwind section,
ii. Printing section - Gravure cylinder, Ink Trough, Doctor Blade, Impression Roller,
iii. Dryer section,
iv. Rewind section.

7. What is the earlier name of flexography printing process?

Aniline printing process

8. State the purpose of anilox roll in flexo printing machine. / What is anilox roller?

Anilox roll is a mechanically or laser engraved metering roll used in flexo presses to meter a controlled film of ink from the fountain roller to printing plates.

9. Name the main components of Flexography printing unit.

Ink fountain roller, Anilox roller, Plate cylinder, Impression cylinder.

10. Name the main sections of flexography printing machine.

i. Unwind section,
ii. Prinitng section - Fountain roller, Anilox roller, Plate cylinder, Impression cylinder,
iii. Dryer section
iv. Rewinding section.

11. What is the principle of Screen printing process?

In this type of printing, the image and non-image areas are carried on a mesh (woven) screen, the image areas being open in the form of a stencil. The non-image areas are formed by 'blocking out' the mesh by coating. The paper is placed under the screen. After the screen is lowered into contact with the paper, ink is passed across the upper surface of the screen. Where the screen is open, ink goes through to the paper beneath.

12. Name the various frames used for screen printing process.

Wooden frame, Metal frame

13. State the different fabric materials used for screen printing.

Silk, Polyester, Nylon, Metal fabrics

14. What is the function of squeegee?

Squeegee is used to force the ink through the screen mesh and stencil on to the printing stock kept below.

15. What is the earlier name of screen printing process?

Silk screen printing

16. Name the major printing processes.

Offset, Letterpress, Flexography, Gravure and Screen printing processes.

17. Write briefly the principles of Gravure Printing process.

In this type of printing, the printing areas are in recess - that is, on a lower level than the non-printing surface. The recesses are filled with ink and surplus ink is removed from the non-printing surface by doctor blade. The substrate is then pressed against the printing cylinder to transfer the ink onto it. The main examples of gravure printing are Rotogravure printing and, in the area of arts and crafts, copper plate engraving and die-stamping (also security printing).

18. What is Intaglio printing?

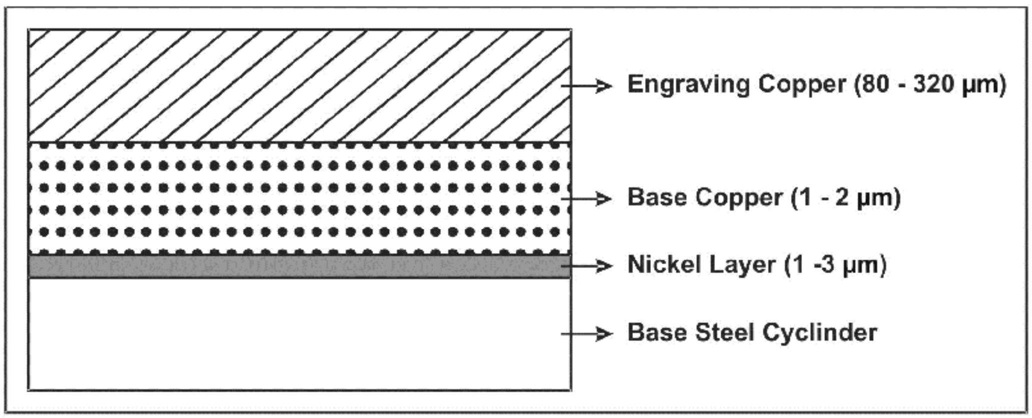
In this process a metal plate usually copper is used as a image carrier. Here, copper etching or hand engraving is carried out to form an image. Ink is applied over the image areas, excess inks are wiped off. A sheet is laid over the plate and pressure is applied. Ink from recessed area is transferred to paper according to the width and depth of engraved lines.

19. What is ESA?

Now a days impression rollers are employed with electrostatically assisted (ESA) ink transfer. To overcome the printing problem "speckle" (individual cells not printing on rough papers and non- compressible papers even if it is coated one). In this special roller during the turning (rotation) high voltage is generated. This electric field encourages the ink to leave the cells and transfer to the paper even the contact is imperfect.

20. State briefly the construction of gravure cylinder.

Basically the gravure cylinder is made up of steel. Over the steel core cylinder, a nickel layer coating of 1 to 3 μm is applied. Then the cylinder receives a base copper layer of 1-2 μm. Then the application of another layer i.e., engraved copper layer of 80 to 320 μm is applied over the base copper layer.



Construction of Gravure Cyclinder

21. What are the characteristics of prints produced from gravure printing?

- Because of the screen pattern or cell structure, which appears over the whole of the printed image, fine-line work and text matter appear rough/broken at the edges when examined with a magnifying glass.
- Wide range of tonal values is possible, giving an effect of continuous tone-like quality (especially in four-colour process work).
- Under a magnifying glass the 'screen pattern' in conventional gravure is seen to be of a regular square formation (showing uniform cells).
- The final printed images are of excellent visual quality. Due to its intaglio character, the closeness of the printing areas and different thickness of ink, gravure print displays the pleasing effect of a continuous tone image.

22. Describe briefly the principles of Flexography printing process.

In flexographic (Relief) printing the printing elements i.e., image area are in raised form. When the printing plate is inked, the ink adheres to the raised image area (printing parts) and is then transferred under pressure onto the printing substrate. In flexography a flexible, soft rubber or plastic plate is employed.

23. How the ink metering is done by Anilox roll in flexographic printing?

A screened (Anilox) inking roller into which cells of uniform size and depth are engraved. The fountain roller lifts ink to the nip position, where it is squeezed into the cells in the screened inking roller and by a shearing action, ink is removed from the roller surface. The ink in the cells is then transferred to the surface of the printing plates.

24. Explain briefly the principles of Screen printing process.

Screen Printing : In this type of printing, the image and non-image areas are carried on a mesh(woven) screen, the image areas being open or ‘unblocked’ in the form of a stencil. The non-image areas are formed by ‘blocking out’ the mesh by coating. - *see Figure*. The paper is placed under the screen. After the screen is lowered into contact with the paper, ink is passed across the upper surface of the screen. Where the screen is open, ink goes through to the paper beneath.

GLOSSARY

Aniline

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

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.

Driving Side

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

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.

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.

Infeed

A mechanism designed to control the forward travel of the web into the press.

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.

Intaglio

An engraved or etched design which is below the surface as cells in an anilox roll or gravure cylinder.

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.

(Extra Questions) – 3/4/6 marks

1. Write briefly about the image carriers used for gravure printing.

Gravure image carrier

Copper plates

Gravure plates are made from rolled copper. The ends of the plate must be carefully bent to fit in to the clamps on the cylinder. The plate covers only parts of the cylinder circumference since the plate cylinder must house the clamping system. This uncovered section must be filled in with a "gap cover" or "segment" to provide a bearing surface for the doctor blade. These type of presses (using a gravure plate) are fast becoming absolete.

Copper cylinder

Cylinders can be made of iron, steel, copper or aluminium. Solid (Integral) cylinders are invariably used on web-fed presses. The thickness of the copper deposit varies depending upon the circumference, length and construction of the cylinder. The copper deposit ranges from 0.015 to 0.050 inch thick, and copper is depostted slightly more than the required thickness. Afterwards the cylinder is taken out and brought to the required diameter by turning it on a lathe; then it is polished to a high luster. The accuracy of the cylinder is maintained within a tolerance of + or – 0.0005 inches. (In the cylinder, image areas are on a sunken (lower) level than the non image areas).

2. Write notes on doctor blade.

The printing cylinder is flooded with ink and before impression is made on the paper, the excess ink from the cells and on the non-printing surface of the cylinder is removed by the scraping action of a flexible sheet blade, known as "Doctor Blade". As the cylinder turns, and just before the paper makes contact with it, this doctor blade, made of fine Swedish steel (.008 inch thick) wipes off all the excess ink. The doctor blade, precision ground and hand coned (after use), is held against the cylinder under pressure, and scrapes the cylinder surface absolutely dry.

3. Write notes on dryers in flexographic presses.

The Drying section require an after-drier to remove the remaining solvent from all the colours before the web can be wound in to a roll. The drying section may also require between-color driers between printing units on multi color presses to permit the necessary printing of color on color. The removal of solvents can be accomplished in several ways, hot air current being the most common. However revolutionary method of drying are being investigated.

An exhaust system conjunction with the after dryer prevents a build of solvent laden air that might become an explosive hazard: In between color hot air dryers it is essential that the exhaust exist the warm air supply, otherwise the location *of* these dryers in the very minimal space between color units would result in warm air being blown on to the inking rollers and plate cylinders. Premature ink drying would seriously interfere with the inking *of* the plates and printing *of* their image on to the web.

4. Write notes on screen fabrics used for screen printing.

Screen Fabric :

The screen fabric is a woven material. It is a tightly stretched across the frame. This Screen fabric serves as a carrier for stencil. The selection of fabric for particular work plays a major role. Following are the types of fabrics.

a) Silk:

Silk is a natural fiber produced by the silk worm. Hand cut and indirect stencils adhere well to silk fabrics. However this silk is not dimensionally stable. Size variation can occur due to change in temperature and humidity. Therefore silk is unsuitable for jobs requiring critical registration.

(b) Polyesters:

Polyesters such as darcon, Terital and polylast are man-made synthetic materials containing cellulose, resins and hydrocarbons. Polyesters fabrics are woven very uniformly and possess good dimension stability. They are extremely strong and used for long runs. A major disadvantage is that indirect photographic stencil will not adhere so good as like in silk.

(c) Nylon:

Nylon is also a man-made synthetic material having uniformly woven fabrics. This fabric is strong and durable and can be used for long run jobs. Unlike polyesters, nylon fabrics lack dimensional stability. Nylon fabrics will go on stretched and react to temperature & humidity changes. So before mounting a nylon fabric on frames, it should be wet firstly and stretched very taut, to maintain the good registration.

d) Metal fabrics:

These types of fabrics are used for only special application. Unlike the synthetic fabric, it does not absorb moisture and is therefore unaffected by changes in humidity. Also it is unaffected by temperature. As it has very good dimensional stability it is used for very precision printing like printed circuit board or very specialized application. Usually “Stainless Steel wire” is used as a metal fabric.

5. State the functions of squeegees in screen printing.

The squeegee performs a very important function in screen printing. It is used to force the ink through the screen mesh and stencil on to the printing stock below. Squeegee blades are made from high quality natural rubbers and synthetic material. Polyurethane squeegee blades are now- a-days used widely due to their resistance property to abrasion so there is no need for sharpening or reshaping.

Squeegeees are normally supplied in three grades : Hard, Medium, Soft. The hard and medium grades are used for printing thin film inks, the soft grade is used for printing on to non-absorbent materials such as metal & glass. During the printing action the squeegee is moved across the screen and force the ink to pass through the mesh opening.

6. What are the applications of screen printing process.

Sheet-fed Screen printing

As the process is best known for its ability to print a thicker ink film than any other printing process this makes it ideal for printing light coloured inks on dark coloured materials, also onto awkward, rough surfaces, uneven and moulded shape surfaces. Examples include posters, showcards, printed circuits, T-shirts, printing on cloth, vinyl, metal, glass and plastic, etc.

Rotary/web-fed Screen Printing

Specialist area of the process used for self-adhesive labels, scratch-off lottery tickets, packaging, transfer printing, fabric printing, security printing, direct mail and high quality greetings cards with die-cutting and additional finishing requirements.

PART - B: 12 Marks Questions

1. Describe the principles of Gravure printing process with suitable diagrams.
2. Explain the principles of flexographic printing process with necessary skectches.
3. Explain the principles of screen printing process with suitable diagrams.
4. Describe the main sections of Gravure printing machine with skecthes.
5. Explain the main sections of Flexographic printing machine with diagrams.
6. Describe the main sections of screen printing machine with necessary sketches.

UNIT - II – IMAGE CARRIER PREPARATION

2.1. FLEXOGRAPHIC IMAGE CARRIER PREPARATION

Flexographic Plate

The first plates developed for flexographic printing were made of natural or, more commonly, synthetic rubber, and were manufactured much like letterpress plates. Although photopolymer plates are now widely used in flexographic platemaking, rubber still has its adherents, primarily because of its economy, its simplicity, and its compatibility with ink solvents that cannot be used with photopolymer plates.

Structure of Flexographic Plate

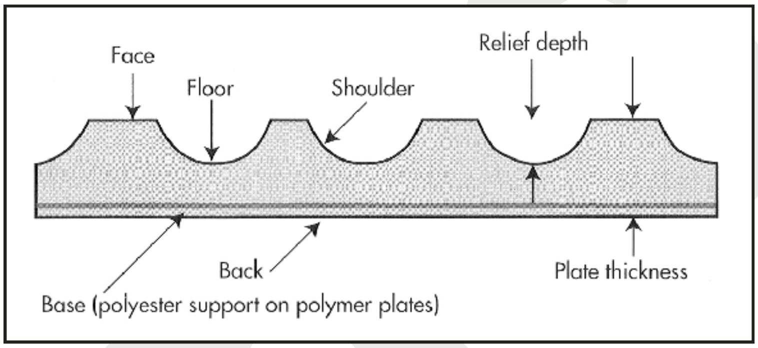


Figure - Structure (physical parts) of the flexographic printing plate

The terminology used to describe the plate is detailed in the above figure. The **face** is the image that prints. It must be smooth and have sharp edges. The **shoulders** will be as straight as possible where they meet the face. Ideally they will angle out from the face to provide support to fine lines and small halftone dots. The **floor** is the nonimage area. The distance between floor and face is **relief depth** and is critical to the relief principle. Contrary to standard practice, large relief depths are unnecessary as proven by the newspaper printers and leaders in narrow-web printing, both of whom print with relief depths of as little as 0.015 inch.

The **back** or **base** of the plate, in the case of photopolymers, is a polyester sheet and provides dimensional stability. It may also be metal as with many newspaper plates and plates mounted to cylinders magnetically. Rubber plates, with limited exceptions, have no stable backing.

The **total plate thickness** is determined by the space between the cylinder and the pitch line of the gear where the transfer of image to substrate is achieved. Thin plates are between 0.025 inch and 0.045 inch, and are found most commonly in news and narrow-web label applications. Others are slowly moving in this direction.

Plates between 0.067 in. and 0.125 in. are very common in most industry segments, with the exception of corrugated. There it is still common to find plates between 0.150 in. and 0.250 in. Trends in almost all flexographic applications are to thinner plates, which are found to hold better resolution and print with less gain.

There are several kinds of image carrier used in flexography

1. The traditional rubber plate
2. Photopolymer plates
3. Laser-engraved rubber plates or rubber rollers.

Flexographic plate composition must match to some extent the type of ink to be used and to the substrate to be printed. Both rubber and photopolymer plates are used.

2.1.1. RUBBER FLEXOGRAPHIC PLATES PREPARATION (IN BRIEF)

Natural and synthetic **rubber plates** were the first type of flexo plates developed, and they are still used for some applications. The process of producing a rubber plate is not far different from the process used to produce photoengravings used in the hot type letterpress process (figure).

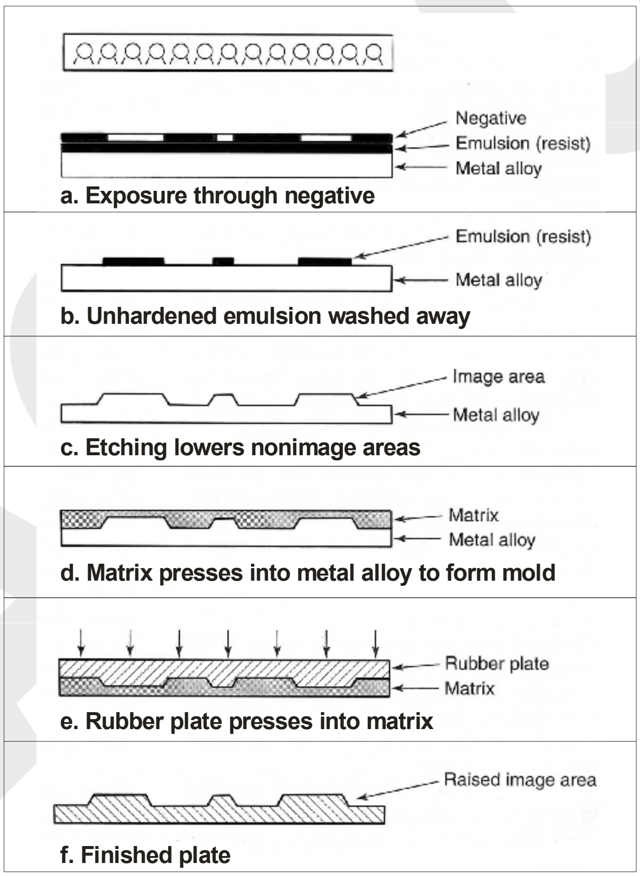


Figure: Steps in producing a rubber plate

i. Preparation of Original Plate

A sheet of metal alloy coated with a light-sensitive emulsion is first placed in a specially designed vacuum frame. The emulsion is not only light-sensitive, it is also an acid resist.

A negative is placed over the emulsion and light is passed through the negative. The acid resist hardens where light strikes the emulsion (image areas).

During processing, the unhardened resist in the non-image areas is washed away, leaving hardened resist only on the image areas. The metal alloy is then etched, which lowers the non-image areas and leaves the image areas raised. The remaining resist is washed off.

ii. Preparation of Mold or Matrix

The completed engraving is then moved to a molding press where a matrix (mold) of the engraving is made by pressing matrix material against the engraving with controlled heat and pressure. The matrix material sinks into the metal engraving to form the mold.

iii. Preparation of Rubber Plate

The rubber plate is made from the matrix by pressing a rubber sheet into the matrix, again under controlled heat and pressure.

Preformed sheets for rubber plates are available in a variety of thick nesses. The thickness depends on the job to be printed and the press to be used.

The major disadvantage of rubber plates is that they are more costly to make than photopolymer plates. Also, because they are made from an engraving, any plate problems identified during proofing must be corrected by remaking the engraving, which further increases the expense of the process.

2.1.2. PHOTOPOLYMER FLEXOGRAPHIC PLATES

Photopolymer plates are made from light-sensitive polymers (plastics). When they are exposed to ulta violet light, they undergo polymerization, or the chemical conversion of many small molecules into long-chain molecules. The result is that they will be harder and more insoluble in exposed areas and softer in unexposed areas. **Photopolymer plates** eliminate many of the disadvantages of rubber plates. There are two basic types of photopolymer plates used in flexographic platemaking - Sheet photopolymer plates & Liquid photopolymer plates.

2.1.2.a. SHEET PHOTOPOLYMER FLEXOGRAPHIC PLATES PREPARATOPN (IN BRIEF)

Sheet photopolymer plates are supplied in a variety of thicknesses for specific applications. These plates are cut to the required size and placed in an ultraviolet light exposure unit (figure). One side of the plate is completely exposed to ultraviolet light to harden or cure the base of the plate.

The plate is then turned over, a negative of the job is mounted over the uncured side, and the plate is again exposed to ultraviolet light. This hardens the plate in the image areas.

The plate is then processed to remove the unhardened photopolymer from the nonimage areas, which lowers the plate surface in these nonimage areas.

After processing, the plate is dried and given a postexposure dose of ultraviolet light to cure the whole plate.

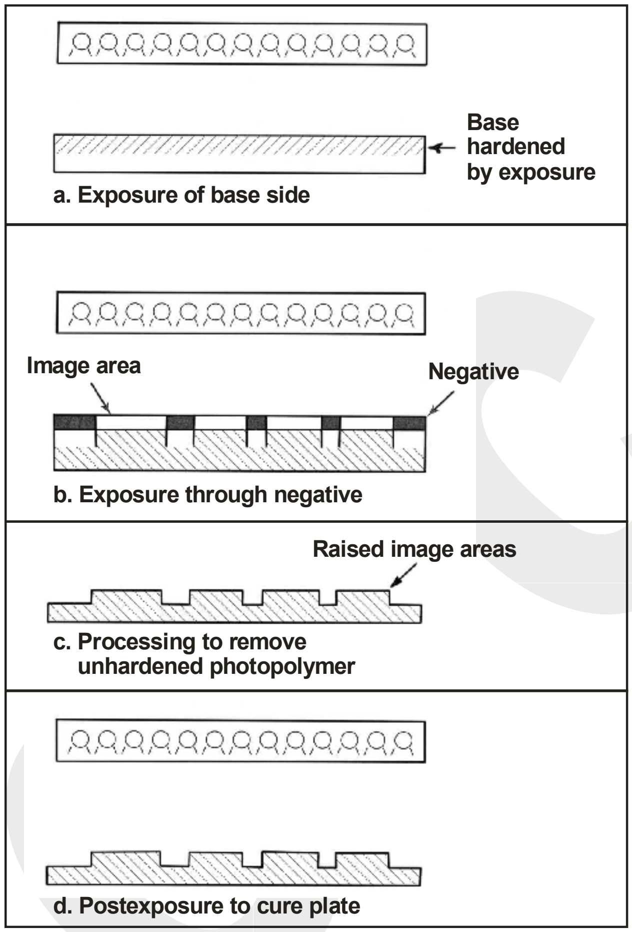


Figure: Steps in producing a sheet photopolymer plate

2.1.2.b. LIQUID PHOTOPOLYMER FLEXOGRAPHIC PLATES (IN BRIEF)

Liquid photopolymer plates are made in a special ultraviolet light exposure unit. In this process, a clear plastic protective cover film is mounted over a negative transparency which is placed emulsion side up on the exposure unit (figure a).

A layer of liquid photopolymer is then deposited by a motorized carriage over the transparency and cover film. The carriage deposits the liquid evenly over the cover film and controls the thickness of the deposit. While the carriage deposits the liquid, it also places a substrate sheet over the liquid (figure b).

The substrate sheet is specially coated on one side to bond with the liquid photopolymer and to serve as the back of the plate after exposure.

Exposure is made first on the substrate side of plate. This exposure hardens a thin base layer of the liquid photopolymer and causes it to adhere to the plate substrate. A second exposure through the negative forms the image on the plate (figure c). As with sheet materials, the image areas are hardened by this exposure. The non-image areas, however, remain liquid.

Processing removes unwanted liquid in the non-image areas to leave raised image areas. A post-exposure is then made to cure the whole plate (figure d).

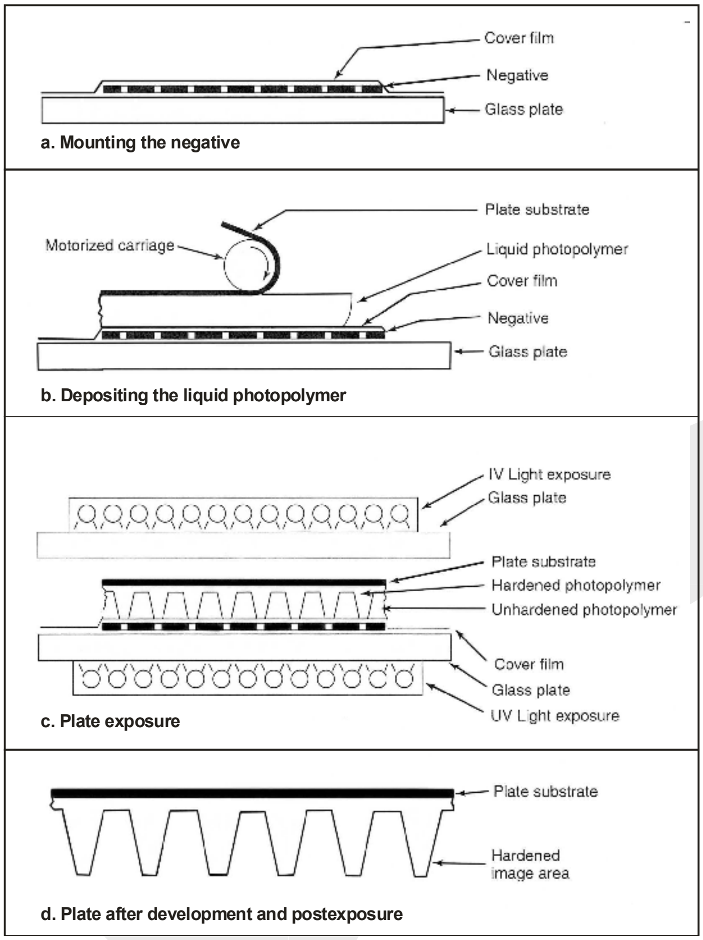


Figure: Steps in producing a liquid photopolymer plate

2.1.3. LASER ENGRAVING

Rubber suitable for flexographic printing can be engraved by laser techniques. The equipment will handle black and white positive copy for line work, and screened negatives or positives for halftone work. Screen rulings of 47 lines/cm (120 lines/in) are possible, and is expected to improve to 60 lines/cm. Engraving by this method can be done on either separate pieces of rubber, or rubber rollers. The ability to engrave rollers is unique, and an advantage in the printing of continuous designs. Because flexographic printing is done from an image in relief it is essential that the shank of the image has a steep angle and is smooth. A suitable depth in the non-image area is also essential.

2.1.1. RUBBER PLATES PREPARATION (in detail)

Steps in Rubber Plates preparation

Rubber plates are made by a series of steps starting with a negative, specially sized and distorted for the specific rubber being used. Since the rubber molding process includes two steps where heat is involved, the changes in size caused by heating and cooling materials must be compensated.

i. Preparation of Original pattern plate

The negative is exposed onto the light-sensitive coating of the metal or photopolymer pattern plate. A variety of materials including magnesium, lead type, copper, and hard photopolymer are imaged to make the original pattern plate. Magnesium is the most commonly used pattern plate material. Hard photopolymer is gaining in use because of its preferred interaction with the environment and the workplace.

The pattern plate is processed into a hard, letterpress-type relief plate. This becomes the "original" relief plate that will be duplicated in rubber for use in flexographic printing. Metal pattern plates are developed after exposure to remove the acid-resistant coating. The plate is etched with acid to the desired depth. This determines the relief depth of the final rubber plate. Then the plate is inspected and flaws are removed to prepare it for making the matrix, a mold.

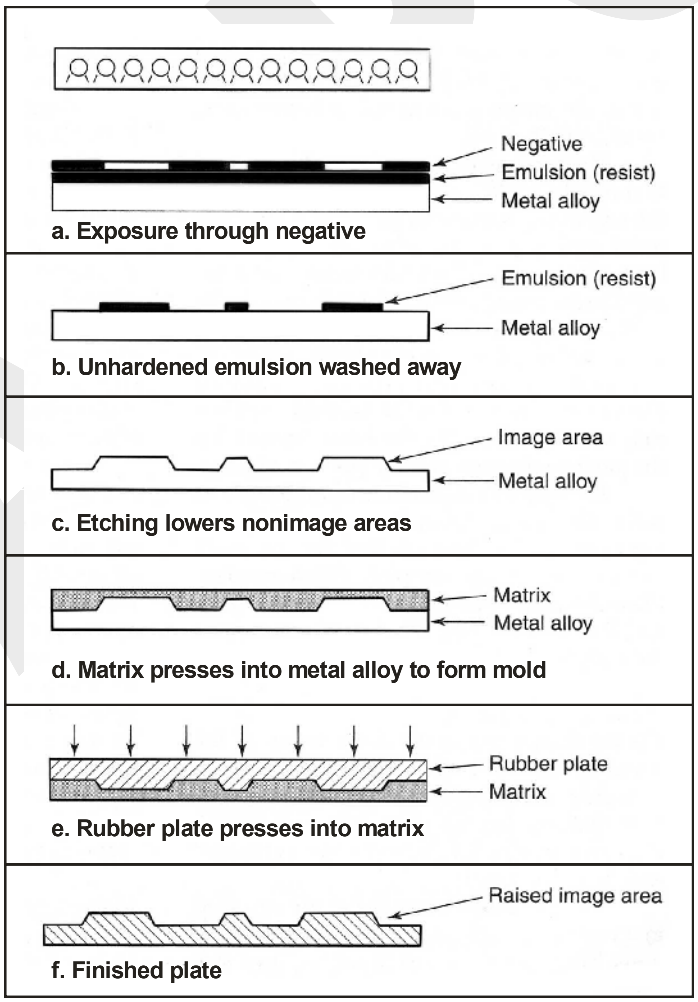


Figure: Steps in producing a rubber plate

ii. Preparation of Matrix / Mold

The rest of the rubber platemaking process takes place using a precision vulcanizer, or molding press. Figure below shows a vulcanizer and a diagram of its key parts.

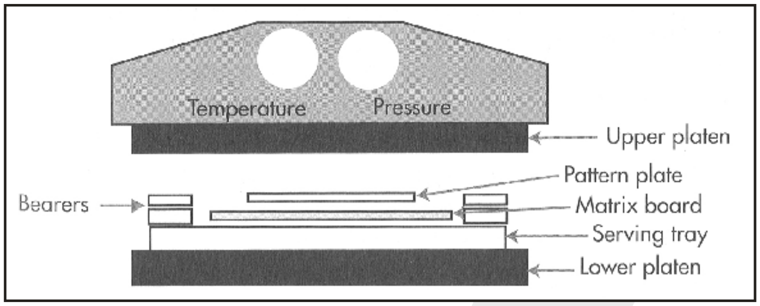


Figure: A Volcanizer (top) and a diagram of its key parts (bottom)

Matrix board, sometimes called bakelite, is cut to size, brushed to be sure it is free of foreign particles, and inserted face up into the molding press. The pattern plate is placed on top, image side down, and pressed under heat and pressure into the matrix board. Thickness control bearers are placed along both sides of the molding surface, called the serving tray, to control the thickness of the matrix. The matrix is a thermal plastic resin and cellulose material. The resin provides a smooth hard surface for molding the rubber plate. The matrix is molded to a specified floor thickness, the thickness between the face of the image and the back of the matrix board. Figure below shows the assembly of pattern plate, matrix, cover sheet, and the thickness control bearers.

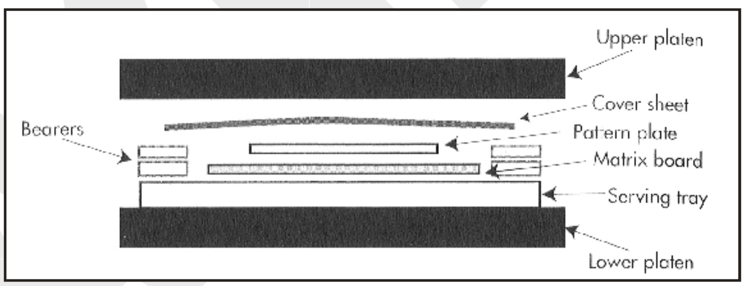


Figure: The assembly of pattern plate, matrix, and cover sheet and the thickness of control bearers

iii. Preparation of rubber plate

After checking the floor thickness and uniformity of the matrix it is placed back into the molding press, image side up, for molding the duplicate rubber plate. It is a duplicate because it is a copy of the pattern plate. In fact it is a third-generation plate, the first and second generations being the pattern plate and the matrix. The gum, which becomes rubber when vulcanized, is placed over the matrix. A cover sheet is placed on top of the gum to protect the upper platen of the molding press from any buildup of material. The exact total thickness of bearers is positioned at the left and right of the serving tray and the entire assembly is inserted into the heated plate molder. The bearers are calculated exactly to determine the thickness of the plate. The heat and pressure from the molding press soften the gum while hydraulic pressure pushes it into every part of the matrix. The assembly of matrix and gum is held for a specific time at 307°F until it is completely vulcanized, changed to rubber.

Quality checks often reveal slight irregularities in total plate thickness and uniformity. Small amounts of unevenness in rubber plates are often corrected by a grinding procedure.

2.1.2.a. SHEET PHOTOPOLYMER PLATES PREPARATION (in detail)

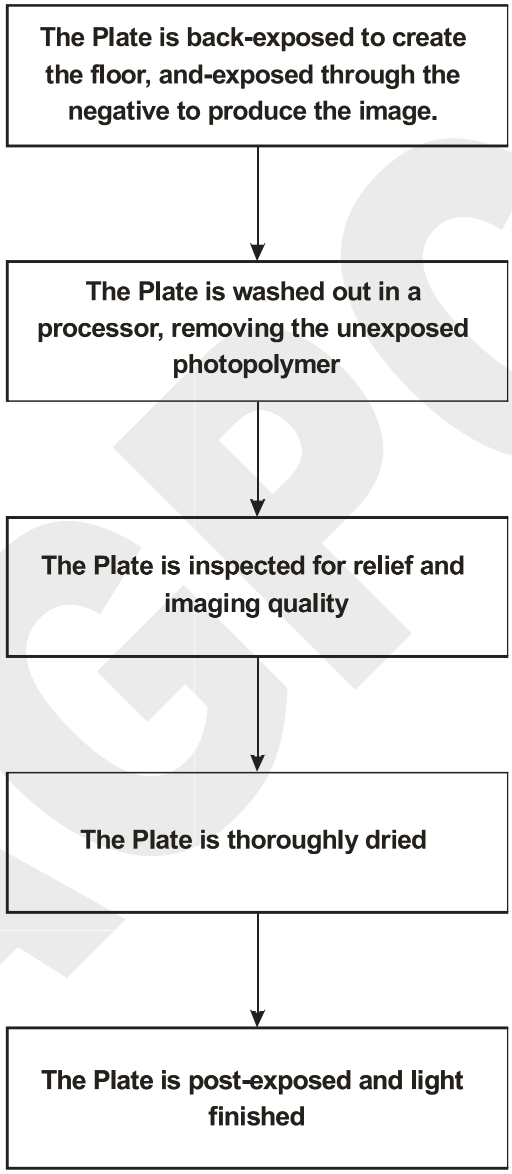


Figure: Production flow of the sheet photopolymer platemaking process

As the name implies, photopolymer plates are light-sensitive, and the platemaking procedures employ multiple exposures to light to determine their relief depth and shoulder angles. The workflow figure shown above describes the sheet photopolymer production flow. The raw materials are either in a liquid or a precast sheet form. Figure below describes the sheet type of plate, available in a wide variety of sizes from small (12 x 15 inches) up to 50 x 80 inches and possibly larger today; change is constant.

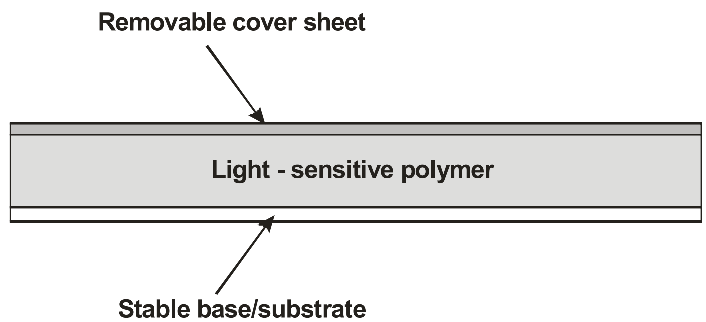


Figure: The sheet type of plate, which is available in a wide variety of sizes.

There are many sizes and types of exposure devices. The diagram in shown below is just one typical exposure system. The procedure for exposure and processing is simple.

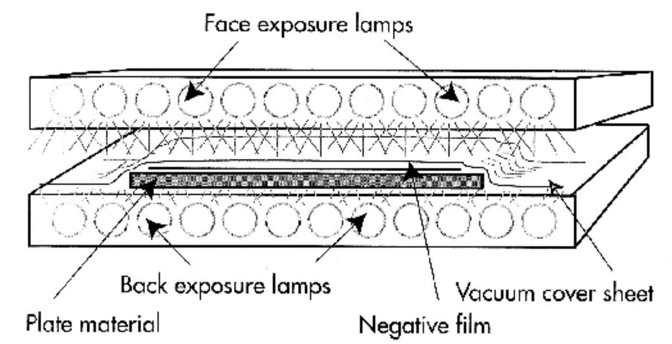


Figure Schematic of a typical exposure system.

i. Back / Base (Plain) Exposure

The plate material has a base and a face side. The base side is determined by the firmly attached polyester sheet. This provides the plate with dimensional stability. The base resists size changes and cannot be stretched during handling, particularly mounting. The first exposure is made through the base. Its duration determines floor thickness. Since total plate thickness is a specification of the sheet plate as it is supplied, floor thickness is the determiner of relief depth. Relief depth is a major factor in determining print quality. The longer the back exposure, the thicker the floor. Back exposure also affects the length of the face exposure.

ii. Main (Face) Exposure with negatives

The face side of the plate also has a polyester sheet, but it is easily peeled off prior to imaging. Face exposure is the imaging exposure made through the negative held in contact by a vacuum and a flexible drawdown sheet. The length of the face exposure determines the shoulder angle, which controls support of the image. Fine lines will be wavy if there is insufficient face exposure. Very small highlight dots will fail to image or be weak and move during impression without enough face exposure. Stochastic images require more face exposure to image the highlight “spots” since they are farther apart, somewhat independent of adjacent spots. Too much face exposure causes excess dot gain, particularly in highlights and quartertones.

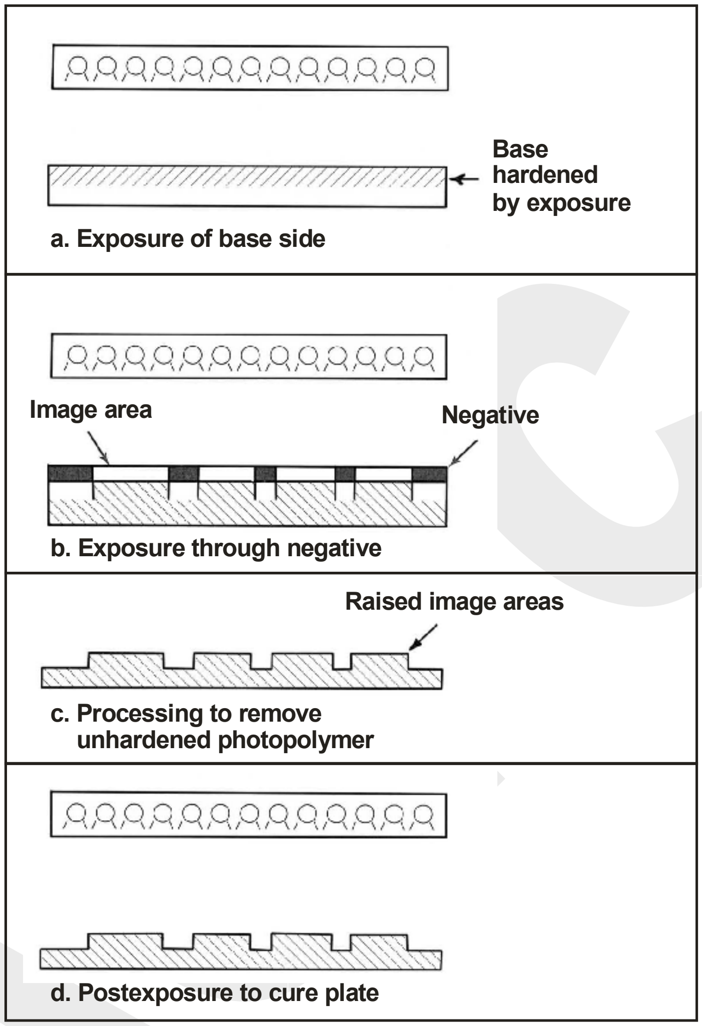


Figure: Steps in producing a sheet photopolymer plate

iii. Washing out the non image areas

Once the plate is exposed the material has been rendered stable or insoluble. The unexposed material is still a soluble monomer. It is processed by simply dissolving in an appropriate solvent or detergent. The plate is also scrubbed with brushes during washout to speed the process by removing the unexposed material as it is dissolved. Solvent-washed plates require a blotting step to assure all solvent and plate material are removed from the printing surface. This is a simple but critical part of the platemaking process. Any foreign material left on the face of the plate causes noticeable defects in the printed image.

Solvent-washed plate material absorbs some of the solvent, and time is required while drying for this material to escape from the plate. Detergent-washed plate materials don’t absorb liquid and thus require less time for drying. Dryers provide hot air and exhaust for rapid removal of moisture and vapors.

iv. Post Exposure

After the plate is processed and dried, it requires post exposure to cure all remaining unexposed material and finishing to eliminate a tackiness on its surface. While there are alternative methods, finishing is usually done by a UV light finishing process.

2.1.2.b. LIQUID PHOTOPOLYMER PLATES PREPARATION (IN DETAIL)

The figure below illustrates the process of making a liquid photopolymer plate. Liquid polymer plates are made following exactly the same exposure and processing steps of sheet photopolymer plates. The difference is that the parts of the plate come as separate items to the liquid platemaking department. The base, or substrate, of the plate is a sheet of polyester. One side has a matte surface to assure its firm attachment to the polymer resin. The polymer is in liquid resin form comparable to honey in appearance and consistency. There is a thin plastic cover sheet used to keep the resin off the negatives during exposure.

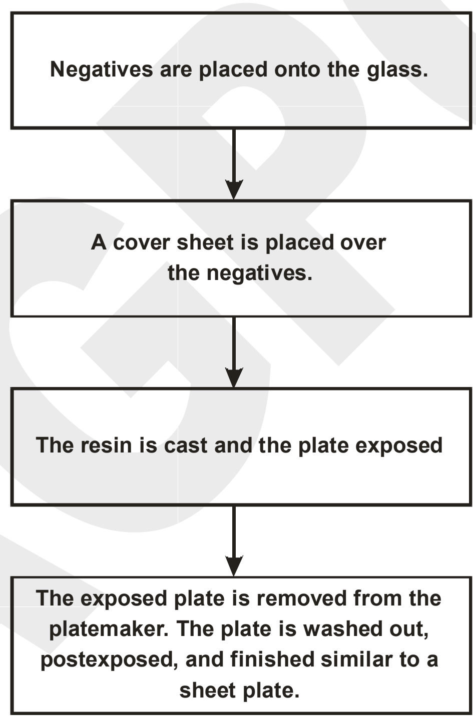
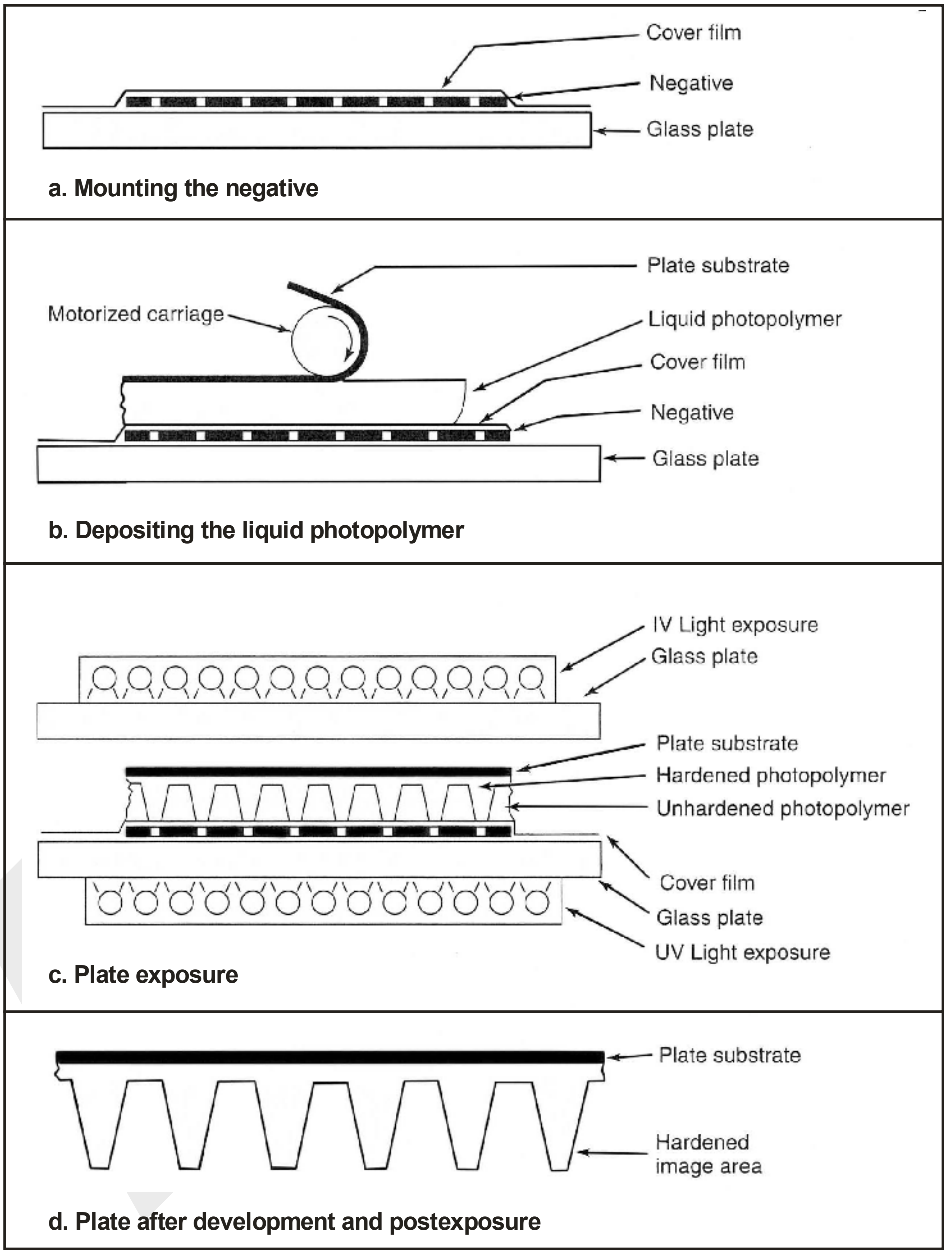


Figure: The process of making a liquid polymer plate.

i. Preparation of liquid photopolymer layer

While there are many features of liquid platemaking systems, the basic process is the same. The operator positions the negatives, emulsion up, on the lower glass which is cleaned before every plate is made. A very thin cover sheet is pulled over the negatives and drawn down with vacuum.

The resin supply carriage moves across the negatives, pouring a metered quantity of resin and simultaneously laying down the polyester base of the plate. As soon as the carriage is clear of the plate area the top of the machine is closed and vacuum is applied between the top and bottom glasses. This is done to assure the plate completely fills the space between the two glasses. This space is the critical plate thickness and determines plate uniformity required for quality flexographic printing.



Steps in producing a liquid photopolymer plate

ii. Exposure

The exposures are made. First the back exposure lamp is switched on. As with a sheet system, this is timed to establish the floor thickness (and relief depth) while also increasing the sensitivity of the resin to the face exposure. While the back exposure is being made the face exposure is started from the bottom lamps. This exposure is made through the negatives and determines the imaging and the shoulder support of the plate.

iii. Washing out

When the exposures are complete the unit is opened and the plate is removed. The cover sheet is discarded and unexposed resin reclaimed. The plate is placed into the processor washout unit; the processor washes out all the unexposed resin using a heated detergent and water solution.

iv. Post Exposure

Once washed out, the plate is rinsed and moved to the finishing unit where it is post exposed and finished simultaneously, in a special solution to remove the tackiness and to leave the plate ready to be used once it has been dried. Drying is done only to remove water from the surface since there is no absorption into the plate.

v. Finishing

Liquid platemaking departments almost always reclaim a significant amount of the unexposed resin before the plate is washed out. This is done by placing it on a vertical surface where, after removal of the cover sheet, a high-velocity air knife is passed down over the plate causing the unexposed resin to roll off into a catch basin. This resin is used again in the platemaking process, saving both material cost and pollution of the washout and subsequent wastewater.

DIGITAL FLEXOGRAPHIC PLATES

Currently there are several varieties of direct-to-plate, or digitally imaged flexographic plates. As with all printing processes, the motivation is to eliminate film imaging costs and improve throughput. Of course, improvements in quality are also expected.

2.1.3. LASER ENGRAVING ON RUBBER ROLLERS

The first direct-to-plate process was laser engraving rubber. In the process gum is vulcanized and precisely ground to final plate thickness. It is then mounted to a drum and rotated in front of a CO_2 laser. The nonimage area is burned away leaving the image in relief and the plate ready for mounting (see Figure 8-11). Laser-engraved rubber plates have precisely controlled shoulder angle, and resolution as high as 120-line halftone screens can be produced. One of the most appealing applications of this technology is the production of continuous-pattern images. Conventional plates always leave a gap of line where the two ends of the plate come together on the cylinder. Continuous patterns are laser-engraved onto rubber-covered rollers. Rubber is vulcanized to roller bases and ground to the exact repeat length. This roller is then laser-imaged. Gift wrap and wall covering often require uninterrupted patterns, and laser imaging is a popular solution. This process also eliminates any plate mounting and the cost of potential register flaws that go with mounting.

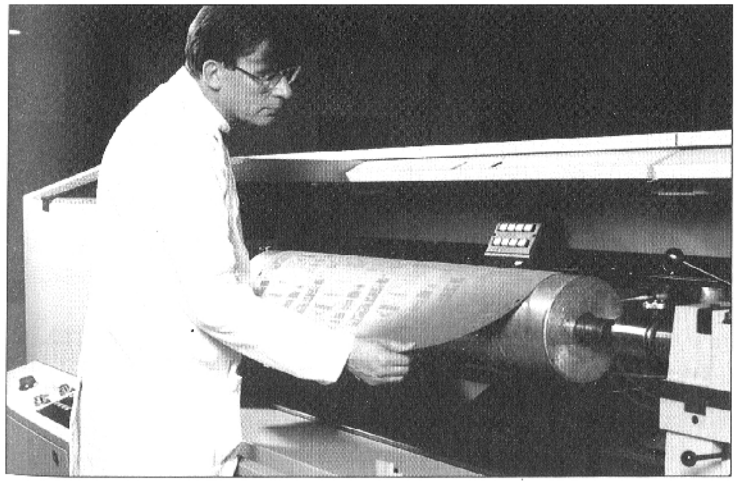


Figure: Operator examining a laser-engraved rubber plate.

COMPUTER TO PLATE FOR FLEXOGRAPHIC PRINTING

As explained in detail in sections 1.3.2.1 and 2.3.3, flexography is a relief printing technology, in which a flexible (soft) printing plate is pressed against a hard impression cylinder. Three different imaging systems are available for computer to plate in flexographic printing:

- laser imaging of the mask (high quality),
- laser engraving/ablation (up to approximately 600 dpi, mostly used for rubber plates),
- direct imaging with very high energy UV light (quality suitable for newspaper printing).

The first computer to plate systems for flexographic photopolymer plates were shown at DRUPA 95. They work on the external drum imagesetter principle and a Nd: YAG laser is used for *imaging the mask*. The plate is held on the drum by vacuum. The Barco company's "Cyrel Digital Imager" system may be taken as an example (fig. 4.3-14). This system is suitable for DuPont Cyrel plates with a format of up to 1067mm x 1524mm. In full format with 48 lines/cm screen, imaging takes approximately 35 minutes. Addressability is a maximum of 4000 dpi.

Low laser power suffices to image the laser-sensitive black coating on the photopolymer plate. The black coating is vaporized in areas corresponding to the image, consequently serving as a film for the subsequent UV exposure (details of the composition and function of these plates are given in sec. 4.3.9, see fig. 4.3-30). After imaging, these plates undergo conventional exposure on the reverse and image side (main exposure) with UV light and are then developed or further processed. In 1997 a computer to plate system suitable for both flexographic and some thermal-sensitive offset plates was introduced for the first time by Misomex, the "Omnisetter." A light source consisting of twenty thermal laser diodes (wavelength 830 nm) is used as the imaging system here.

In flexographic computer to plate systems for producing relatively soft rubber printing plates, the recessed, ink-free parts of the printing plate are removed directly by laser energy (*laser engraving*). The ablated particles are removed by suction. High-power lasers (such as 1–2.5 kW CO_2 lasers) are used for this activity. The laser engraving of gummed rollers for continuous printing has been possible since the seventies.With the maturing of computer technology, computer to plate became available as early as the end of the eighties.

UV direct imaging is available as the “UV Laser Platesetter” from Napp Systems. By means of high-power UV laser light the polymerisation needed for producing the flexographic plate is carried out directly pixel by pixel.

Laser engraving on polymer plate

The second direct-to-plate system simply substitutes a polymer plate for the rubber and, as above, images the polymerized material by laser burning away the unwanted polymer in nonimage areas.

The other two direct digital imaging approaches are digital-photographic hybrids. They both employ digital masking of light and conventional photographic exposure and washout processing. The first of these was first introduced by DuPont at DRUPA 95. It uses a laser to ablate (remove) a mask (black or other light stopping coating), which is applied on top of a conventional photopolymer plate. The plate material is supplied with the light-stopping mask. It is mounted onto a drum in the laser ablation unit and rotated in front of the laser. The laser removes the light mask leaving the image area open to pass light during the exposure step. The plate now has a negative built into it. It is placed on the standard exposure unit and given the same exposure as used on conventional plates. The benefit to the process is, of course, that there is no need to produce film. The lack of a negative does eliminate any issues of dust from film and halation due to contact problems, so quality is clearly improved. Without the negative and drawdown sheet, diffusion of light is also eliminated and, thus, resolution improved. This is particularly valuable in the lightest highlights. As with most new technologies, the early applications show little if any financial benefit. There has been little or no difference in throughput with single laser machines. Market realities should lead to future economic benefits for the consumer flexo printer. This digital approach is also used to image photopolymer on sleeves providing a “seamless” plate if necessary. This, of course, eliminates all plate mounting and the register issues that often result.

The third direct digital approach is the same as used by screen printers to apply graphics to photographic screens for many years, It employs an inkjet imager that applies a light-stopping mask to the sheet flexo plate. Once imaged, the plate is exposed and processes as any other sheet-type plate. This system is far less expensive but also limited in its early form by the capability of inkjet imaging.

2.2. GRAVURE IMAGE CARRIER PREPARATION

HAND ENGRAVING AND PRINTING:

There are several methods of hand engraving and etching. These terms are used interchangeably, but actually should not be. To engrave is to cut an object with a tool and to etch is to remove by chemical-acid means.

Both engravings and etchings are true intaglio methods of reproducing images. Lines are cut or etched below the non image surface of the image carrier. The image carrier made of copper, steel, or plastic, is then inked over the entire surface. The ink is wiped from the non-image high portion, leaving the lines filled with ink. The image carrier is then pressed against a paper receptor to transfer the image.

GRAVURE IMAGE CARRIERS:

The three main types of gravure image carriers are 1) flat plate 2) wraparound plate, and 3) cylinder.

Flat plates are used on special sheet-fed presses that produce stock certificates and other highgrade limited-copy materials.

Wrap-around plates are used to print art reproductions, books, mail order booklets, calendars, and packaging materials. The wrap-around plate is thin and flexible and attaches to a cylinder similar to one on an offset-lithography press. They can be used economically only on short runs (30,00 copies or less). They cannot produce a continuous design or pattern because of the area needed to clamp the plate to the cylinder.

Cylinder image carriers are the most common within the industry; Preparation of a gravure cylinder is a most critical process and each step in its production must be done with exacting care if quality results are expected.

GRAVURE CYLINDER MANUFACTURE

With the exception of sheet-fed gravure printing, which is now found only rarely, web-fed gravure printing requires a gapless *gravure cylinder*,onto which the image is applied directly,by means of etching or engraving. For this, the cylinder must be prepared in a costly mechanical and galvanic process.

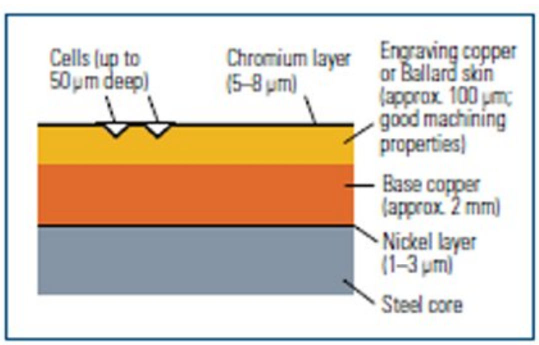


Fig. 1.3-12 Structure of a gravure cylinder

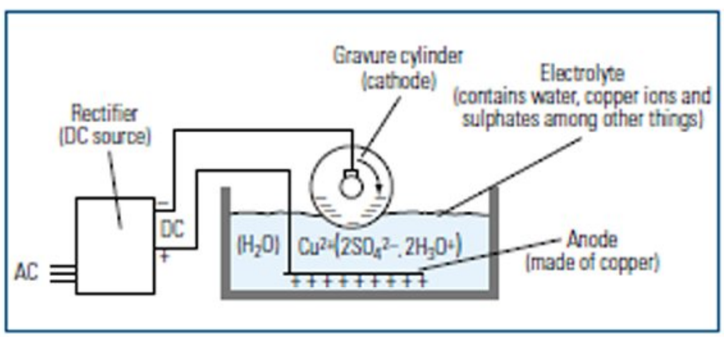
In its basic design, the gravure cylinder consists of a thick-walled steel tube with flanged steel journals. To increase the stiffness of this hollow cylinder, some of the cylinder journals are drawn inwards and are supported inside the tube on additional steel discs. All of these joints are welded during the manufacture of the gravure cylinder so that a solid roller body is created, which still has to be balanced so that there are no vibrations when running at high speed (typically up to 15 m/s) in the printing press.

The cylinder receives a base copper layer on its surface, which, among other things, serves to achieve the specified diameter of the finished gravure cylinder. For the application of another copper layer (figs. 2.2-3 and 2.2-4), which varies from print job to print job, there are several methods that are described in the following sections [note: the top copper layer is twice as hard (Vickers hardness approximately HV 200) as the base copper, so that this copper layer has good cutting properties as regards the electromechanical engraving process]:

• *The thin layer method* (fig. 2.2-4a):

The base copper layer is coated with an engravable copper layer (approximately 80 µm) in an electroplating process (fig. 2.2-3). This thin layer only allows a one-time engraving. The advantage of the thin layer technique is that all the gravure cylinders of one type have the same diameter dimensions and less mechanical surface treatment is required after the electroplating process than with thick layer processes (see below). The removal of the engraving (after dechroming) is achieved by dressing or milling the copper. After this, a new copper layer is applied. (In the special process known as copper recycling, the copper layer is removed in an electroplating reversal process. In this process, an additional nickel barrier layer of approximately 25 µm between the base copper and engraving copper is necessary.) The thin layer technique is used in some 35% of cases, whereby the copper recycling method only accounts for some 5%.

Fig. 2.2-3
Electroplating of a gravure cylinder; the copper ions Cu^{2+} settle down on the cathode (gravure cylinder) and form a copper layer



• *The Ballard skin method* (fig. 2.2-4b):

This method is also a thin layer process (one-time use of the engraving copper layer). The base cover is electrically covered with a removable copper skin (80–100 ¼m), whereby a special layer between base copper and Ballard skin ensures that the Ballard skin can be peeled off the gravure cylinder after printing. The Ballard skin method is employed in approximately 45% of cases.

• *Heavy copper plating (thick layer technique*; fig. 2.2-4c):

An approximately 320 ¼m thick layer of engraving copper is applied onto the base copper in an electroplating process. This thickness of the layer permits engraving for approximately four print jobs. After each print job, a layer of approximately 80 ¼m is removed in a multi-stage mechanical process (milling, grinding). The former image is thus removed. When the engraving copper is used up, a new copper layer (hard) is applied by means of electroplating. This method is employed in about 20% of cases. With all methods the cylinders are always *hard chromeplated* after etching or engraving to reduce wear and tear. Therefore chemical chrome deplating with hydrochloric acid must be undertaken prior to removal of the image carrying layer.

The *process sequence for preparing an Engraving Cylinder* is generally as follows:

- removing the used gravure cylinder from the gravure printing press;
- washing the gravure cylinder to remove residual ink;
- removing the chrome layer;
- removing the copper image-carrying layer, eitherchemically, by means of electroplating, or mechanically;
- preparing the copper plating process (degreasing and deoxidizing, applying the barrier layer if the Ballard skin method was employed);
- electroplating;
- surface finishing with a high-speed rotary diamond milling head and/or with a burnishing stone or a polishing band;
- etching or engraving (producing the image on the gravure cylinder);
- test printing (proof print);
- correcting the cylinder, minus or plus (i.e., reducing or increasing the volume of cells);
- preparing the chrome-plating process (degreasing and deoxidizing, preheating, and – if necessary – sometimes polishing);
- chrome-plating;
- surface-finishing with a fine burnishing stone or abrasive paper;
- storing the finished cylinder or installing it directly in the gravure printing press.

Today, all these operations are performed, more or less fully automated, in production lines, whereby overhead traveling cranes and in some cases the transportation of the gravure cylinder from station to station is carried out by automated guided vehicle (AGV) systems.

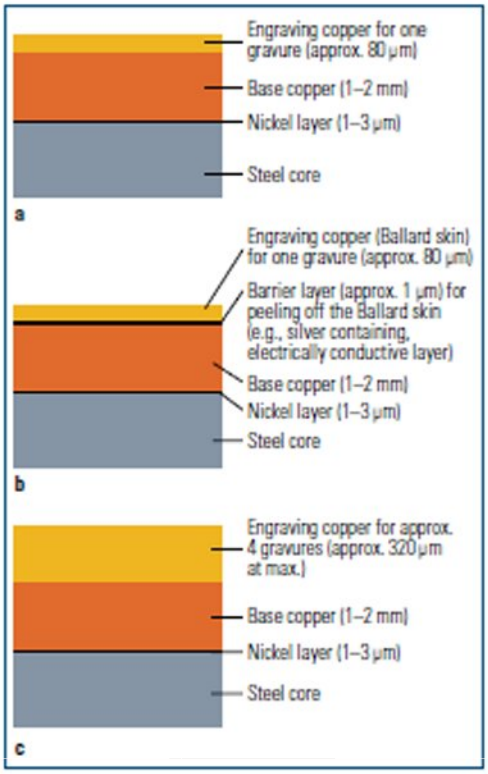


Fig. 2.2-4
The various methods of copper plating the gravure cylinder.
a Thin layer method;
b Ballard skin method;
c Thick layer method

GRAVURE CYLINDER IMAGING

In addition to an image-carrying function, the *screen structure* of the gravure cylinder surface has the significant task of guiding and supporting the doctor blade. The blade supports itself on the cell walls, which demarcate the cells. The continuous-tone-like graduation in the image of conventional gravure (etching) is achieved through the various depths of the cells.

However, there is a mixed form, the variable area and depth gravure process, in which the cell diameter and depth of the cells are altered for the continuous tone graduation

Variable area gravure printing without cell depth variation (corresponding to the dot size variation in offset and letterpress printing) has gained little significance.

Electromechanical engraving with diamond stylus (variable area and depth gravure) is the dominant process. Only seldom is etching still used as an imaging process in gravure printshops. Despite this, and in the interests of thoroughness, a short description of this process is given below.

GRAVURE ENGRAVING

Collective term for the various means of engraving or etching the image onto the gravure cylinder. Gravure, unlike most other printing processes, prints from depressed, inkfilled cells produced on the surface of a copper-plated cylinder. The ink in the cells is then transferred to the desired substrate.

The four basic means of engraving the image into a gravure cylinder are

i. the diffusion-etch process or carbon tissue or conventional method
ii. the directtransfer process or halftone gravure process
iii. electromechanical engraving, and
iv. the laser-cutting process.

I. CONVENTIONAL CYLINDER PREPARATIONS:

Conventional methods of cylinder preparation date back to the nineteenth century when the first commercial application of the intaglio mechanical principles took place. This early effort took into account the concept of a pattern of square dots, all the same size laterally arranged. The etched cells in highlight areas are very shallow, with the depth increasing in direct ratio to the incerase in tone. Tones are thus determined by the thickness of the ink film in the cells, rather than by the size of the dots. Principles of this form the basis for virtually all other gravure processes.

PREPARING OF GRAVURE CYLINDER BY CONVENTIONAL METHOD OR CARBON TISSUE METHOD

It is necessary to prepare film positives for gravure production.

Preparation of Originals

1. Prepare photographs, artwork, and type composition necessay for the images.

Film Processing

2. The type and artwork are photographed in a process camera to obtain the film negative.

3. The continuous-tone film negatives (those that contain no dots) are prepared from photographs that contain varying shades of gray.

4. The film negatives are then carefully retouched by the engraver to correct imperfections.

5. The retouched negatives are set up in proper position and a one-piece film positive combining all elements of the image, is made.

6. The engraver carefully inspects the film positive and retouches it to make final corrections and adjustments.

7. Several film positives are stripped together for the image to cover the entire cylinder.

8. Photographic proofs are made of the film positives and the engraver closely inspects them for needed correction.

Readying (Preparation) of the Cylinder :

During the time that the film positives are being prepared, the surface of the gravure cylinder is prepared to accept the iamge. The cylinder must be carefully prepared before the etched image is placed onto it.

9. The thin coating of copper, containing the image used on the previous printing job, is removed. This is done on a special gravure cutting lathe.

10. A new coating of copper must be placed on the cylinder surface. To do this the cylinder is placed into an electroplating tank coated with copper to approximately 0.005 inch over the specified finished diameter.

11. The cylinder is accurately centered in a high-precision lathe and is cut to a fine finish with a diamond tool to within 0.002 inch.

12. The cylinder is placed on a special grinder and super finished to the exact specified diameter and smoothness. It is now ready to receive the image.

Exposing the Image :

The entire image is screened in the gravure process. This includes the type, artwork, and photographs. Special gravure screens containing 150 to 300 lines to the inch are used. A sheet of carbon tissue, coated with a layer of orange-colored light sensitive gelatin on a paper backing sheet, is placed in contact with a gravure screen. Both items are placed in vaccum frame.

Exposure with Gravure Screen :

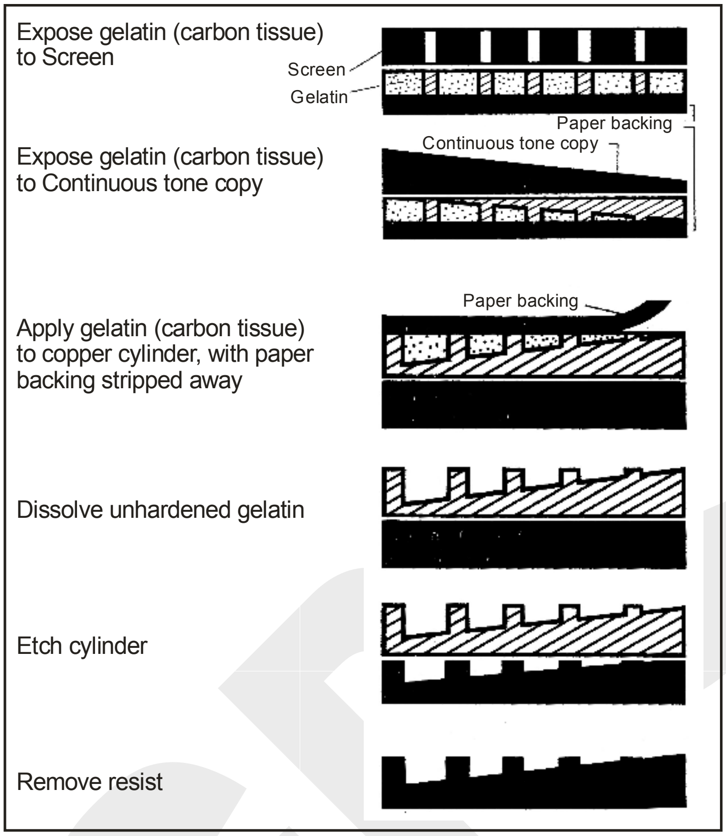
13. The carbon tissue is exposed to strong arc lamps through the screen. The transparent lines of the screen allow light to strike the carbon tissue, hardening it and making it insoluble to the etching solution which wil later be placed upon it.

Exposure with film positive (image) :

14. The screen is removed from the carbon tissue and the film positive is placed over the tissue. The tissue is again exposed to light source through the film positive. The gelatin sensitized coating of the carbon tissue hardens in proportion to the amount of light that passes through the positive. In highlight or lightest areas the gelatin is hardened to the greatest amount; in shadow areas (darkest) it is hardened to the least.

Mounting the carbon tissue on cylinder

15. The exposed carbon tissue, containing the complete image, is transferred carefully to the copper cylinder. It is important to place the tissue in exactly the correct position on the cylinder.



The transfer machine places approximately 1,300 pounds of pressure per square inch on the carbon tissue to make it adhere properly to the copper cylinder.

Peeling off paper back from carbon tissue

16. After the carbon tissue has been adhered to the cylinder, the paper backing is removed and hot water is used to wash away unhardened gelatin remaining where the light did not penetrate. Large nonimage areas of the cylinder are “staged out” (hand painted with asphaltum) to resist the action of the etching solution. The cylinder is now ready for etching.

Etching the Cylinder :

17. The cylinder is carefully removed from the transfer machine to the etching trough. The etching solution (ferric chloride solution) can be either poured onto the rotating copper cylinder or placed in an etching machine that allows the cylinder to rotate constantly in a bath of acid. The etching solution penetrates the gelatin and attacks the copper.

The etching depth of the copper is determined by the thickness of gelatin in each rectangular dot. Because the gelatin is thickest within the highlight area of the image, it takes a longer period of time before the etch penetrates it. The depth of the etching within that area is therefore vey slight. Within the shadow area of the image there is only a small amount of gelatin to protect the cylinder, and the etching solution quickly attacks the copper and etches to greater depth. The shadow cells are etched to approximately 38 microns in depth; highlight cells to 3 or 4 microns. Cells of depth between these extremes represent the middle tones. (25 microns = 0.001 inch.)

18. The cylinder is carefully inspected microscopically after it has been etched for a period of time. If any flaws appear it is possible to re-etch to corect the defect.

PROOFING AND FINISHING THE CYLINDER:

19. The cylinder is proofed on a special gravure press after inspection. The proof results are compared with the original copy. If flaws are found in the cylinder, it is possible for the finisher to hand-correct them.

20. A thin chrome plating is done over the copper cylinder surface after it is considered to be perfect. The chrome is much harder than the copper and offer better resistance to wear for many more copies. The cylinder is now completely prepared and is ready to be placed on the printing press.

OTHER METHODS OF CYLINDER PREPARATIONS:

Several variations in methods of preparing the gravure cylinder are now practiced. Each method of special technique has special advantages, and also disadvantages. The major difference between these processes and the conventional gravure process is that in the former the square dots vary in size as well as depth. This allows a wider range of tonal values.

GRAVURE CYLINDER PREPARATION

II. HALFTONE PROCESSES

1. DOUBLE POSITIVE SYSTEM-HALFTONE GRAVURE:

This is similar to the conventional process except that instead of exposing the carbon tissue to a gravure screen and then a continuous tone positive, ***it is exposed to a continuous tone positive and a screened positive.*** The screened positive is made from the continuous tone positive by contact using a special contact screen and duplicating film (to yield a positive directly). The screened positive has dots of varying area, but ones which never join up completely because a cell wall pattern is always present. Etching is similar to before, using baths of ferric chloride of different strengths or a single-bath etching technique. The result is a cylinder in which ***different tones are made up of cells which vary in both depth and width.***

The advantage of this technique is that etching is easier to control and the cylinder has greater tolerance to wear on long runs. This is because the highlight cells have smaller width but much greater depth so will not be affected by wear. Speckle can be a more prominent problem with this type of etch.

2. HALFTONE GRAVURE PROCESS OR DIRECT - TRANSFER PROCESS

Another technique will ***produce cells which vary only in width and are all the same depth. Carbon tissue is not used and only a single halftone positive is used.*** A light-sensitive coating is applied directly to the cylinder, exposed to the positive and developed. Etching can be done in a one-bath etch. The Acigraf process is the most widely used process of this type although other methods based on powderless etching (as in letterpress platemaking) and electrolytic etching have been tried.

Also called the Single-Positive System, the direct transfer process is, like the diffusion etch process, a chemical etching process. The primary difference is in the composition of the resist, which replaces the carbon tissue with high-contrast, high-resolution photo polymer emulsions.

The emulsion is applied (by a spray, ring coaler, or other means) directly to the copper-plated surface of the gravure cylinder itself. A single screened positive is brought into contact with the emulsion on the cylinder and exposed to ultraviolet light. As in the diffusion-etch process, the exposed (nonimage) areas become hard, while the unexposed (image) areas remain soft.

A solvent is used to wash away the unexposed resist, and the photopolymeric resist produces cells that print with smoother edges than cells etched by electromechanical engraving. Etchant is applied, as before, and engraves cells at a rate that varies according to the thickness of the resist.

The film positive is carried by clear mylar belts between the emulsion of the gravure cylinder and a mercury-vapor lamp, which enables the engraver to expose the resist in a circumferential fashion. The direct-transfer process is also quicker than the diffusion-etch process, taking only about 4-10 minutes to etch a cylinder.

Despite the quickness and ease of the previous forms of chemical engraving, they have been replaced for the most part by newer techniques, primarily by the electromechanical process, while newer digital computer-to-laser systems are making inroads into the gravure engraving process.

III. ELECTRONIC / ELECTROMECHANICAL ENGRAVING OF GRAVURE CYLINDERS:

Present procedures for producing gravure cylinders are time consuming and demand several skilled personnel. Electronic engraving machines reduce the amount of production time and labour.

Electromechanical engraving appeared as a commercial process in the late 1960s and has almost completely replaced earlier chemical processes. In its simplest form, the engraving machine has three basic parts:

i. a scanning head and cylindrical drum for mounting copy, or a digital input device;
ii. a control panel and power supply;
iii. an engraving head and cylinder mounting station.

This is a technique that was developed by the Hell organization in Germany, who have produced a range of Helio-Klischograph machines for several types of work such as consumer magazines and packaging.

These machines, which are similar to a lathe in general layout, use a diamond stylus which is shaped in a very precise way, to engrave cells shaped like inverted pyramids, 2 to 50 microns deep. As the cylinder rotates the stylus moves in and out of the copper surface cutting between 2800 and 5000 cells per second, although 3200 cells per second is typical. For deeper cells the stylus penetrates deeper into the copper so that the area at the top of the cell becomes greater as well as the depth. Cells in adjacent rows are staggered by half a cell so that they nestle together, with a screen angle of 45. For colour work the screen angle must, of course, be varied to avoid moire patterning. This is done by altering the cylinder rotational speed in relation to the frequency of the cutting tool in a carefully calculated fashion. In this way, compressed or elongated cells are produced with screen angles at 30 or 60.

The composition of the copper on the cylinder is important to achieve a consistent cutting action. If the copper is too soft, the chips of copper produced by the cutting tool do not come out of the surface cleanly, and tear leaving splinters of copper on the cell edges. Variation in hardness can lead to variation in depth of cut, and hence cell volume. The best copper hardness is in the range 200 to 220 Vickers.

The use of mechanical engraving has become widespread since, by comparison with etching methods, it is controllable, and also lends itself to direct output from computer pre-press systems. The inverted pyramid shape of the cells promotes good ink release and a lower cell volume can therefore print an equivalent density.

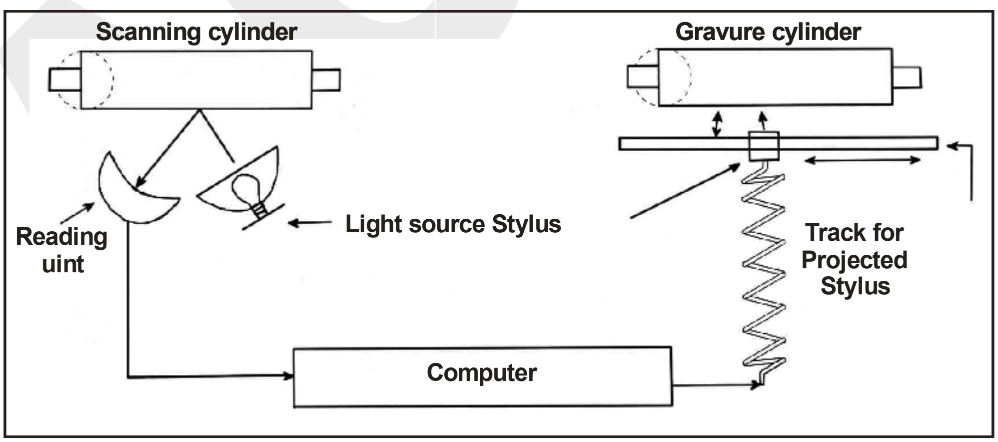


Diagram of the electromechanical process

The operations involved in electromechanical engraving are significantly shorter compared to the etching process. Nowadays, they are normally controlled directly with the data recorded in prepress. In this way the mounting of a scanning original on a separate scanning drum that runs synchronously with the engraving machine is also no longer needed.Hence, the engraving machine only consists of a lathe-like device, into which the prepared gravure cylinder is mounted. The engraving procedure is similar to a rotating cutting process, but the cut is intermittent (stylus frequency).

The gravure cylinder rotates during engraving at a constant surface speed (depending on the screen at approximately 1 m/s).At the same time the diamond stylus of the engraving head moves at a high frequency (4–8 kHz). The diamond penetrates the copper at different depths and produces the cell.

The cells are equidistant from each other in the circumferential direction (direction of engraving) due to the continuous circumferential velocity and the engraving frequency. Engraving of neighboring tracks is semi-staggered. The lateral repeat length corresponds to the forward motion of the engraving head per cylinder revolution in the shaft direction of the gravure cylinder.

Depending on the width of the web to be printed, up to sixteen engraving heads (typically eight) with styli are used for publication gravure printing. The burrs on the copper surface are usually removed by a *scraper* which is fixed to the engraving head during the engraving process. The cylinder must therefore only be lightly polished before it is used for a test print in a proofing press, corrected manually in accordance with this, and then finally *chrome-plated*.

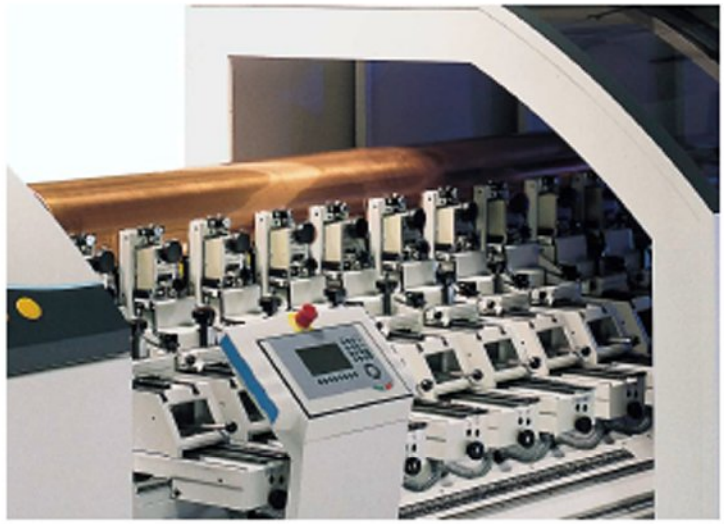
IV. LASER ENGRAVING/LASER CUTTING PROCESS

In the past, there have been numerous attempts to make engraving faster and cheaper. One possibility lies in the implementation of *non-contact methods*, such as electron or laser beam. In individual cases, laser engraving is already in practical usage today. In the year 1995, a direct engraving process using a laser was brought onto the market (“Laserstar”by Max Dätwyler AG), where a solid-state laser engraves a *zinc layer*. The cell shapes produced are similar to those of etched cells (the process operates at 70 kHz engraving frequency). The engraved cylinder is chrome-plated after a grinding and cleaning process.Dressing of the gravure cylinder after printing is carried out using similar chemical, mechanical, and electroplating methods as with a copper cylinder. Basically the step of copper plating (to permit engraving copper) is replaced by a process of electroplating zinc.

Laser engraving opens several new doors for gravure printing. The unwanted saw tooth effect with fine fonts can be reduced. Alongside this, there is the possibility of working with frequency-modulated screens.

Indirect laser engraving processes use a light-sensitive black layer that is applied onto the copper of the gravure cylinder.The laser removes this layer in accordance with the image (on the basis of already available digital data files). The gravure cylinder is then etched (e.g., “DIGILAS” by Schepers-Ohio).

Fig. 2.2-7
Engraving machine for electromechanical stylus engraving with up to 16 engraving heads (HelioKlischograph K 406-Sprint, HELL Gravure Systems)



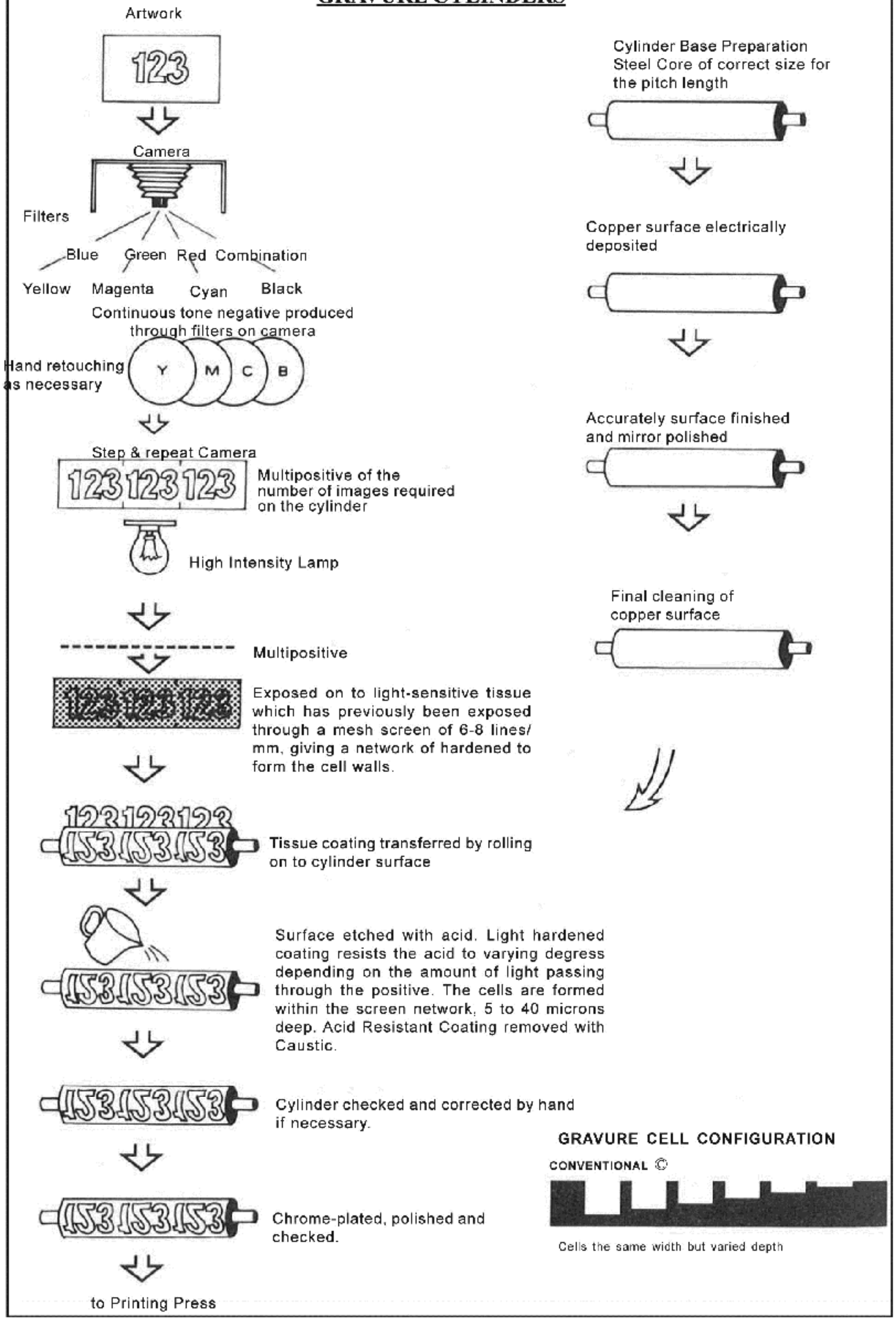
V. COMPUTER TO CYLINDER FOR GRAVURE PRINTING

Direct digital control of mechanically *stylus engraving devices* has been possible since about 1985 in gravure cylinder production.This means that the data comes directly from the computer and not from a scanned analog copy (bromide), (see fig. 1.3-14). Thus computer to cylinder technology is far more widespread in gravure printing than computer to plate technology in offset printing.

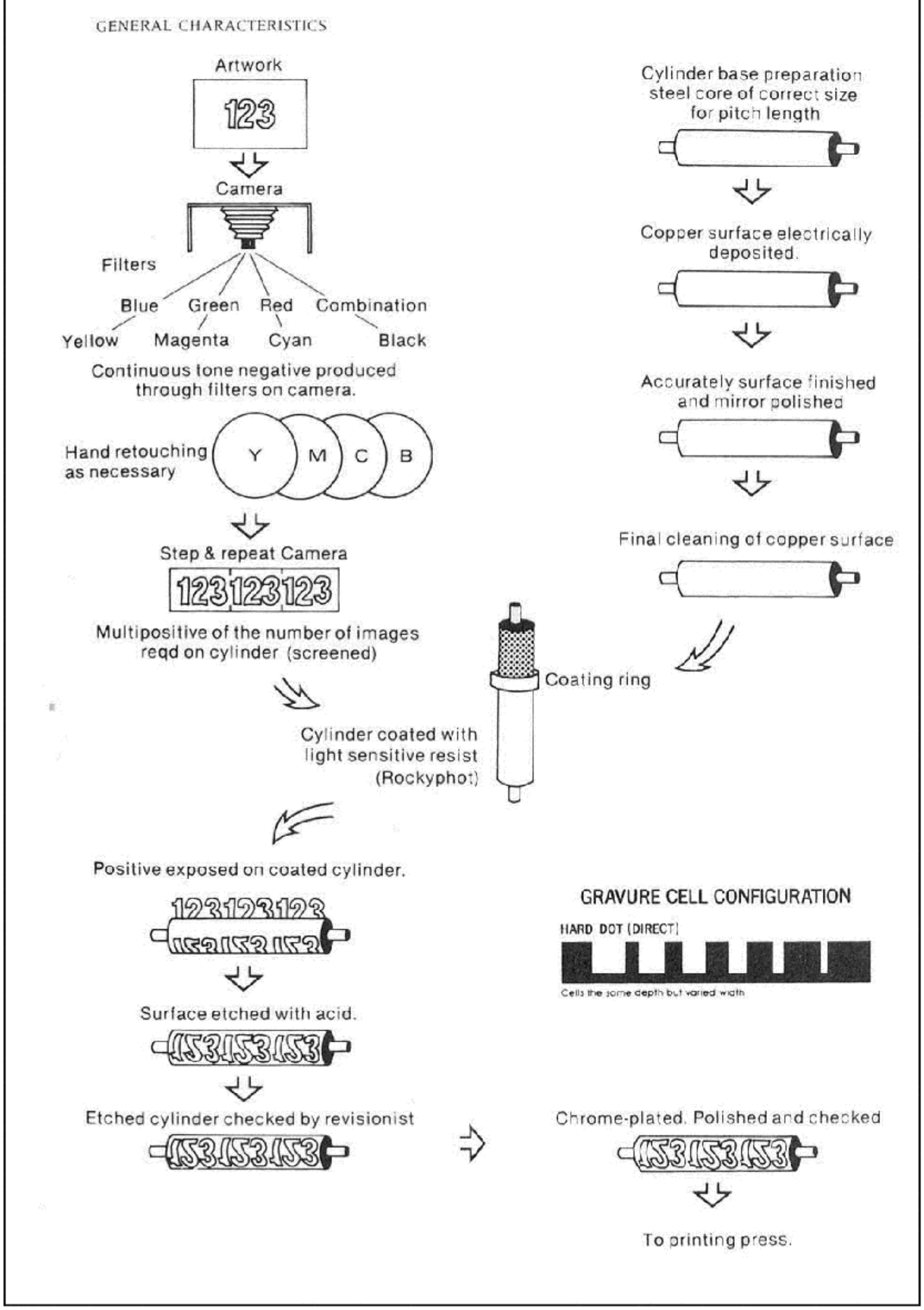
Electrons or laser beams have been tested in conjunction with various base materials for *direct engraving* by applying heat energy to the base material. Electron beam engraving has worked very efficiently.However, it is too expensive as a result of the costly vacuum technology. Thus, for economic reasons, no system has yet been marketed. A fully automated gravure system using laser beams, the “Laserstar” from Max Dätwyler, was presented at DRUPA 95. In this, however, the cylinders have to be coated with zinc (instead of copper) because of its better absorption capacity, particularly at 1064 nm (Nd:YAG). This entails high expenditure on conversion of the other cylinder preparation processes.

Fig. 4.3-15
Computer to cylinder for gravure cylinder stylus engraving (HelioKlischograph K406, HELL Gravure Systems)

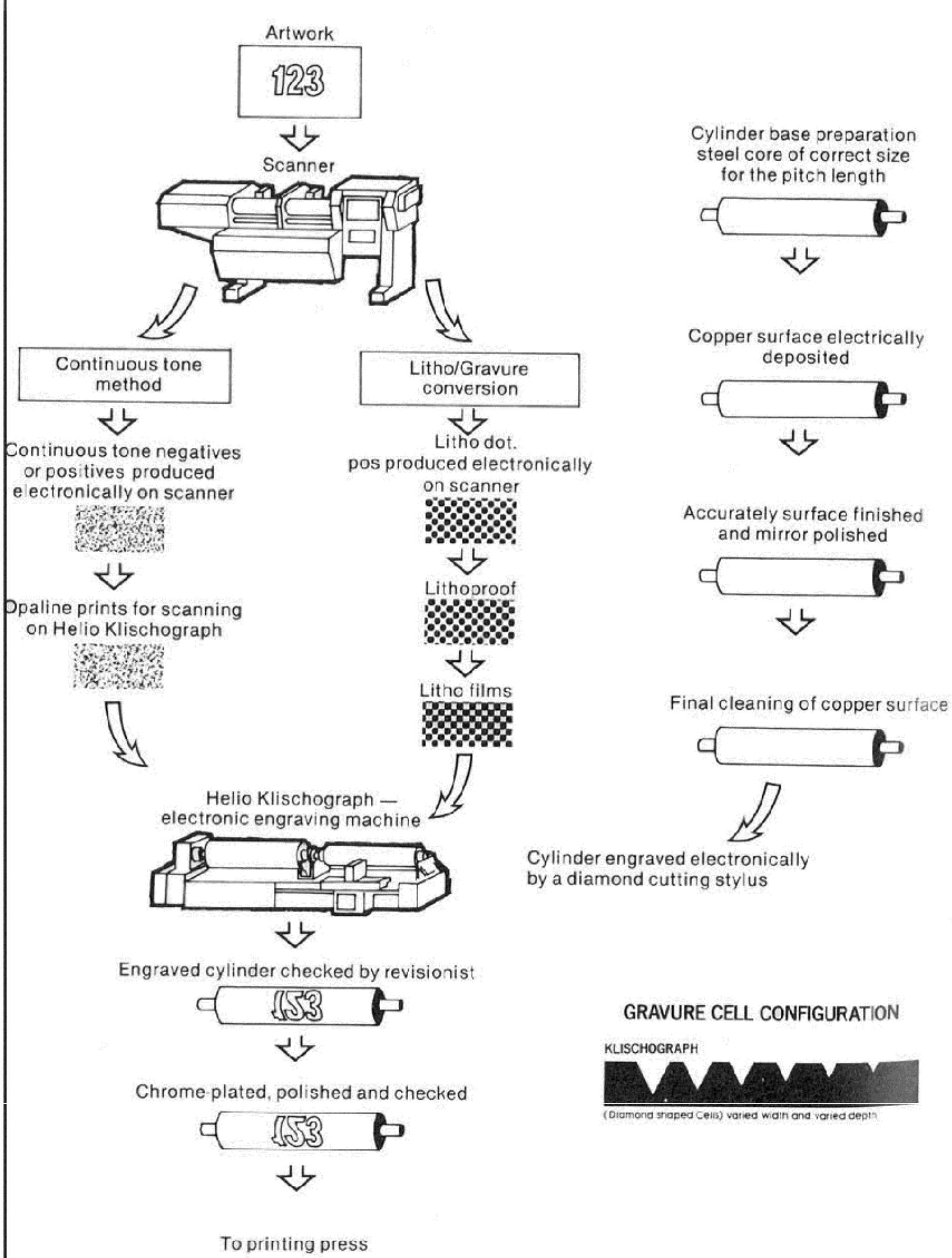
CONVENTIONAL METHOD OR CARBON TISSUE METHOD OF PREPARING GRAVURE CYLINDERS



HALFTONE METHOD OF PREPARING GRAVURE CYLINDERS



ELECTRONIC ENGRAVING METHOD OF PREPARING GRAVURE CYLINDERS



Summary of Current Technology

The gravure engraving process today includes chemical engraving, usually employing a method called direct transfer, electromechnical engraving and recently-introduced laser technology.

i. Electromechanical Engraving

Electromechanical engraving freed gravure image processing from carbon tissue transfers and chemical etching. This method of cylinder preparation uses a diamond stylus that vibrates at more than 4500 times per second, cutting a diamond-shaped cell in the copper-plated cylinder. The input information that drives the diamond stylus is generated by a scanner or by a digital file.

The physical volume of the electromechanical cell is approximately 30% less than the chemically-engraved cell, but other factors play a part in overcoming this difference. The inverted diamond shape of the cell provides a superior ink release compensating for the reduced cell volume.

In the solid areas of the image, the diamond stylus can be programmed to cut a channel between the cells. The channel enhances the flow of ink from the cells and produces a smoother coverage in the solid areas.

ii. Direct Digital engraving

Direct digital engraving refers to the filmless transfer of the image from a digital file to the image carrier via an electromechanical engraver. In a filmless environment, all image corrections are done in the digital file, eliminating the need to correct film and/or cylinders. This significantly reduces the time required for the manufacturing cycle and produces consistent quality. A duplicate cylinder can be made from the digital data, thus minimizing the variables inherent in the use of film. This process can be repeated as often as required. This is a great advantage for packaging and product gravure printers who often repeat the printing of a design for years.

iii. Laser Engraving

Recently introduced laser engraving technology is being Beta-site tested at the time of this writing. Although laser and electron-beam technologies were researched in the 1970s, they were always deemed too expensive for commercial use. The newest entry into tile engraving market has developed a new alloy that can be plated and machined using existing equipment currently handling copper. The laser engraver is designed to be six times faster than existing electromechanical equipment. The equipment is also designed to integrate efficiently into existing production environments capable of sharing the same prepress technology. We expect that commercial results and the adoption of laser technology will be completed in the next couple of years.

iv. Electron-Beam Engraving

The Hell company developed electron-beam engraving techniques in Germany in the late 1980s. This technology, working in a vacuum, could engrave cells at speeds reportedly up to 1,50,000 cells per second in a copper image carrier using digital imaging information as input. After early field testing, the equipment was withdrawn from the market because it was too expensive to be competitive in the commercial market. An interest remains in electron-beam technology. As other technologies advance, it may again become a viable option for gravure engraving.

Cylinder Proofing

Proofing of the engraved gravure cylinder is a critical part of the prepress process. All cylinders engraved by chemical etching or electromechanical engraving using analog scanning are proofed either on a multiunit proof press for publication cylinders or on a Single-color proof press for packaging and product cylinders. The proofing process is performed on the actual substrate to be printed, with inks that are comparable to the final pressrun, except they are slower drying to facilitate cleanup. As more and more engravings are generated from digital information, the need for press proofing is being reduced.

Proofs printed by digital printers directly from the digital data are increasingly common in all three gravure market segments.

v. Halftone Gravure

The Gravure Association of America published Publication Halftone Specifications for Gravure in 1988. They have been updated periodically to reflect advancements in gravure prepress technology. One of the most significant advances in gravure technology was the successful use of digital input in the form of halftones, to drive electromechanical engraving machines. This eliminated gravure’s dependence on continuous-tone film. These specifications made it possible to use the same film for both gravure and offset.

2.3. IMAGE CARRIERS USED FOR SCREEN PRINTING

Negative and Positive making:

Line and halftone positives are needed to prepare photographic screens. These positives are obtained by photographing line and continuous tone copy.

In every printing unit, whether the work is done by hand or by machine, they employ a screen as a means of holding the design to be printed. The screen consists of a wooden frame, metal frame or plastic frame. Metal meshes are used for high precision jobs. The stainless steel mesh is usally fitted in a metal frame with the use of vacuum pressure.

Preparation of a Screen Frame

The most common frame used is made up of soft, straight, grained, dried soft wood such as white pine or walnut or any other wood which is light in weight and strong. The thickness and width of the sides of the frame varies depending upon the size of the screen.

Attaching the Screen Fabric to the Frame

The screen fabric may be attached to the wooden frame by means of nails or stapplers to the underside of the screen. Care should be taken so that the threads of the fabric run parallel to the sides.

Metal Screens

Metal meshes are used when thousands of impressions are to be printed from a screen and for high precision work or where the ink employed is unsuited for fabric screens.

Ceramic ink or dye, could destroy synthetic fabrics after a relatively smaller number of impressions.

Metal meshes are made of very fine threads of uniform diameter and their strengths are also classified by their numbers. The numbers denote the mesh variety or number of openings per square inch. The most common metal screen used is stainless steel, although phospher bronze and copper meshes are also used. Wire or metal screen are very durable but they do bend and crack, where as silk is resilient and gives more value than working with screens made of metal.

Screen Fabrics

The printing screen contains uniform mesh openings and blocking material or a masking medium applied to the fabric which provides the design to be printed.

The meshes or the bolting cloth must have uniform strong and fine threads. It must be durable and it must be woven in such a way that the threads are parallel and will not be mis-positioned. The mesh or the bolting cloth variety used for screen process work is identified by a number. Smaller the number the coarser the mesh, that is the larger the openings in the fabric. The numbers ordinarily employed vary from 120 mesh to 400 mesh, that is the number of weaves vary from 120 to 400. The mesh number is usually followed by one or more X's. It indicates the strength of the mesh or fabric, for example the 120 XXX is stronger than number 120XX, and the number 120 X is weaker than 120XX. 120 mesh can be used by the beginner for most purposes and the quality is recommended for quality works because it has more twisted fibres than the plain number 120. Coarser meshes give a heavy deposit of ink when printed and takes a longer drying period. In these meshes fine details cannot be obtained in printing.

New meshes should be washed with warm water (about boiling temperature). After it is attached to the frame, soap or detergent can be used for washing. Washing not only cleans the fabric for the photographic film to adhere properly, but also results in roughening of the fabric. Meshes are available in different widths and is generally sold by meters or yards and the cost varying with width, classification and quality of the fabric. All screens should be cleaned immediately after use with proper solvents. If ink is allowed to remain on the screen, it will dry and harden, thus shortening the life of the fabric.

VARIOUS METHODS OF PREPARING IMAGE CARRIERS FOR SCREEN PRINTING

There are several methods of preparing printing screens, most of which have become standardised. These methods enable the printer to reproduce any type of copy, including fine details in line drawing, single and multi colour halftone pictures for reproduction.

To a great extent, the versatility of screen printing is made posible by the varied printing screens which are used. These screens first of all must withstand enamelling lacquers, synthetic inks, ceramic inks, water based inks, textile dyes etc., that are forced or pushed through the screens. In addition each screen must be resistant to normal handling and to atmospheric conditions. Variations are due to wear and tear in printing. It must withstand the cleaning solvents employed to clean the screens for future storage and use ; and when necessary it should be possible to remove the screen completely from the screen fabric for future use.

The printing screens are prepared by hand or photographically. The actual printing is made possible by blocking out the unwanted parts of the screen or those areas that are not to print and keeping open only those parts in the screen that are to be printed, or areas through which the ink is to be squeegeed. There are many types of printing screens and each having its own methods of preparation. Four general types have been developed. They are

i. **the knife cut printing screen,**
ii. **photographic printing screen,**
iii. **the wash out or etched screen and**
iv. **the block art printing screen.**

The first printing screens consisted of simple stencils which were attached to the screen fabric, screen printing has sometimes been reffered to as stencil printing due to this reason. Any printing screen can be used for single colour or multi-colour work. Regardless of the type of printing screen employed a screen has to be prepared for each colour that is to be printed.

<u>Preparing the Screen by Knife-cut Stencil Method</u>

The first printing screen used in the early days of screen printing consisted of knife cut or paper cut out or stencils representing the design or originals to be prited. These were adhered to the fabric with adhesives such as glue, shellac and paste or the cut outs were just held in place on the underside of the screen by the tackiness of the ink employed in printing. Then shellacked papers and lacqured papers were employed because they were easier to attach on the screens and the result was much better.

- The present day printer employs a synthetic film as a stencil.
- The method of cutting is by using a sharp knife blade.
- Placing the stencil film over the master drawing, the stencil is pasted on the four corners by adhesive tapes. The film side of the stencil is in contact with the design. The emulsion should face the user.
- The required areas are cut carefully.
- After completing the cutting, image areas are removed leaving only the non image areas to block out the screen.
- Now the stencil is placed below a screen and solvent of the particular type mostly thinner is rubbed with a cotton waste from the top. This should be done slowly in all the areas of the stencil. First the thinner should be applied with one waste and rubbed on with another. This process should be repeated to all the areas of the stencil film.
- After drying for a few minutes, the backing film is peeled off.
- Now the screen is ready for blocking out the non image areas and to carry out the printing.

I. PHOTOGRAPHIC METHODS OF MAKING SCREEN IMAGE CARRIERS

2.3.1. PREPARING THE SCREEN BY GELATINE PROCESS ("DIRECT" METHOD)

The photographic methods of making screens are greatly responsible for the tremendous growth of the industry. These have encouraged printers to step into fields which would have been impossible for them to enter in with handcut screens.

It is possible to print fine details, illustrations and to separate colours photographically from a coloured original and then print the colours to produce prints on varied surfaces. This enables to do one, two, three or four colour works by screen process printing. All proofs from engraving or from other printing processes can be used, enlarged, reduced and printed. Screen process printing produces a more distinct and concentrated colour effect than it is possible to attain with photographic plates used in other printing processes.

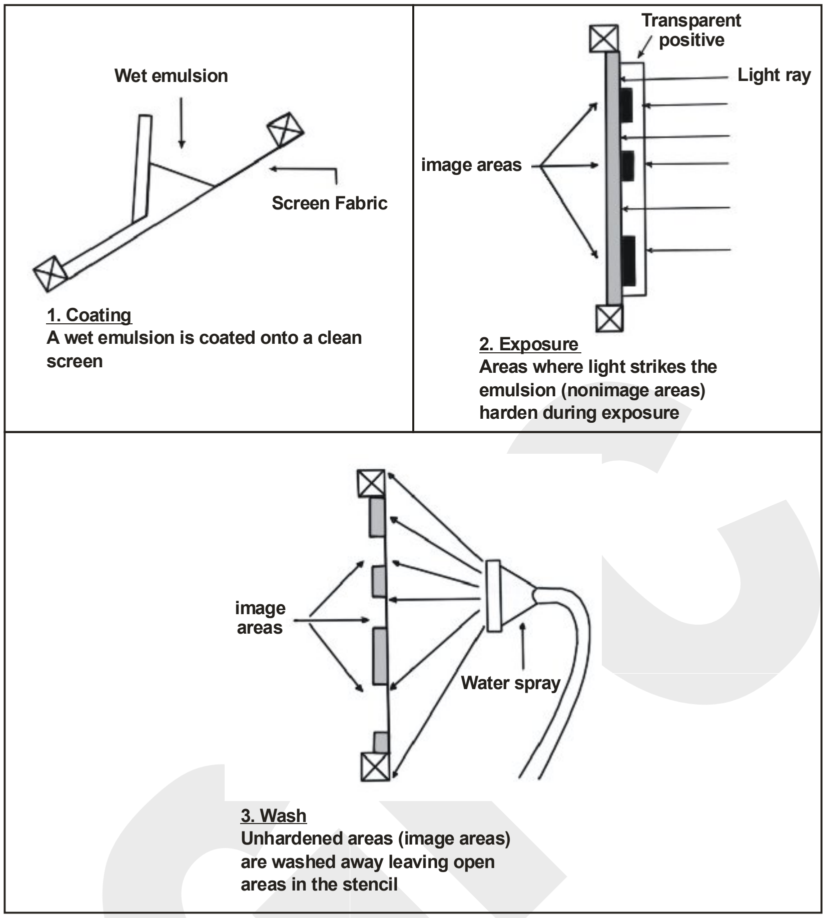
Although the method of photographic screen making is not difficult to carry out, it took a vast amount of experimentation and research by experts and suppliers to develop this phase of the graphic arts. The first photographic screen was made in United States.

Photographic screen process printing deals with the arts and processes employed in the production of photographic printing screens which are used for photography and screen printing as a combition of light energy or chemical energy to make the printing screens. It is based on the principle that substances such as gelatine, albumin, polyvinyl alcohol (PVA) or glue when coated or mixed with light sensitive salts such as potassium bichromate or ammonium bichromate harden upon exposures to light. Those parts of the screen which are covered (sensitized) so that no light strikes them during the period of exposure will not become hardened. The hardened or exposed parts will remain insoluble in water, while the unexposed parts can be washed or etched out in water. The substance or compound which makes the emulsion or coating sensitive to light is known as a sensitizer.

The Process

In the present day market the gelatine or gum is sold in commercial names such as Silk coat, Red star etc.

- The method of preparing a sensitized emulsion is as follows
  Emulsion - composed of polyvinyl chloride, a gelatin - based substance,
  Sensitizer 2% (Ammonium Bichromate),
  Few drops of liquor Ammonia (3 to 4 drops)
- The above proportion may be increased or decreased accordingly when larger or smaller quantities are required.
- The emulsion thus prepared is coated to the cleaned screen with a scale or a sharp edged squeegee in a dark room. The emulsion becomes light sensitive after the addition of Ammonium Bichromate.
- The coated screen is dried with a fan in the dark room.

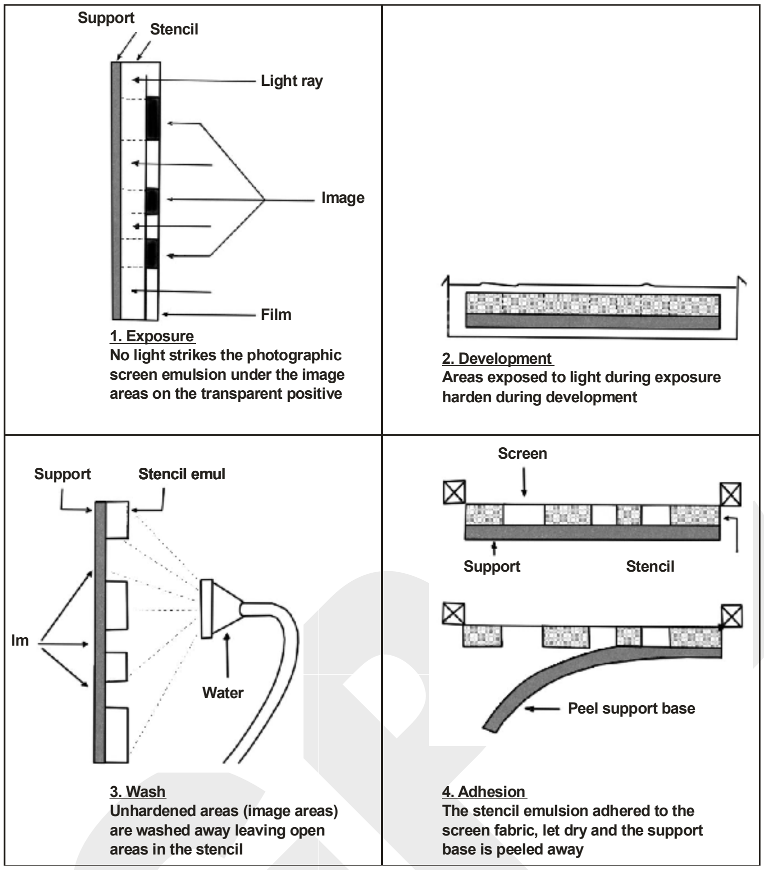


Direct screen stencil process

- After drying the required positive is placed readable side in contact with the under side of the screen.
- The screen is then exposed to a light source, where light will go through the transparent parts of the positive but not through the opaque parts of the positive.
- Thus leaving some parts of the sensitized emulsion exposed and some parts where the light does not strike which will be washed away with the water when developed and produced as openings in the stencil.
- When the emulsion is dry, the screen is ready for printing.

2.3.2. SCREEN MAKING BY PHOTO SENSITIVE FILMS (5-STAR FILM) METHOD ("INDIRECT OR TRANSFER METHOD)

The photographic screen process printing is made from an emulsion which is coated on a strong translucent or tranparent backing sheet such as Vinylite (for perfect accuracy in large printing or small printing screens and when many colours are to be printed). The film with the plastic backing sheet will prove very effective especially in hot and humid conditions. Contraction of the plastic backing sheet is negligible and therefore the registration of different colours is easier.



Indirect screen stencil process

Usually the thin emulsion coating which is carefully applied on the backing sheet under cotrolled condition consists of the colliodal gelatine, pigment and plasticizer for imparting softness and flexibility to the coating.

The film should be stored according to the manufacturers directions. It is ordinarly sold in tubes and may be left in these tubes in cool, dry places for a long time when not in use. The film should be stored in total darkness.

The technique of film cutting deserves careful consideration. Skill in cutting is developed through persistent practice.

The Process

Cut the five star film to required size and in excess of the positive’s size. Be sure that the hands are free from grease or perspiration. Keep the film well covered, especially after it is stripped to avoid dust or damage. Examine the cut film closely for ‘mistakes’, omissions and presence of foreign matter. Keep the film side in contact with the readable side of the positive.

- Then place it in a contact box so that light will pass through the positive and strike the five star film. Then expose it to sunlight or artificial light source. The exposure time varies from design to design, from 1 minute 10 minutes in some cases.
- After exposing remove the five star film from the contact box and place it in a tray, care should be taken so as not to expose it to actinic light. Then pour a diluted

solution of Hydrogen peroxide, that is, one part of Hydrogen peroxide mixed with three parts of water. Develop the film for about one minute. Remove the Hydrogen peroxide solution from the tray and pour warm water, over the film. Now the image areas wil open up. After all the image areas have been opened up, cool down the film by pouring cold water.

- Then adhere the developed film on the back side of the screen with the films emulsion side in contact with the screen.
- Keep the screen flat by placing it over some pile of papers. Then from the top place a blotting paper to blot out excess water. Allow the screen to dry either with a drier or allow it to dry naturally.
- When the screen is completly dry, peel off the backing transparent film of the 5 star film. Now the screen has a stencil which will allow the ink to pass through, only on the opened up areas.
- Cover the screen on the non-image areas. Bloack out unwanted areas with opaquing solutions like lacquer, gum, photographic opaque or any other blocking out medium recommeded.
- The screen is now ready for printing.

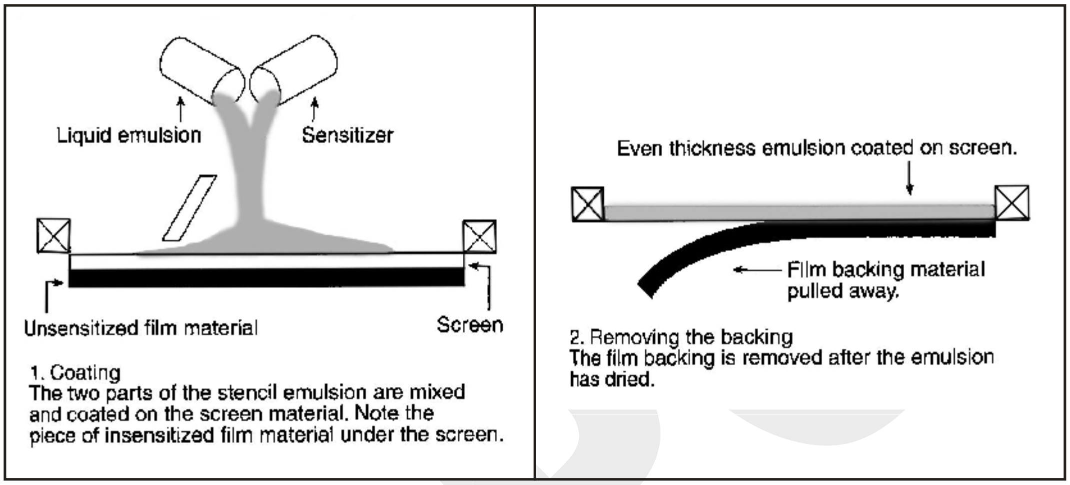
2.3.3. CHROMALINE FILM METHOD OF SCREEN MAKING ("DIRECT/INDIRECT METHOD)

This film combines the advantages of the strength of gelatin method and the sharpness of the photographic method. Hence it is a hybrid film. With this type of film we can print fine details and halftone reproductions including colour separation work. This film can be used for long runs and are not easily damaged.

The method of preparing the screens are as follows:

- Prepare the gelatin or silkcoat solution and sensitize it with Ammonium Bichromate to 100 grams of silkcoat solution. Add 2% of Ammonium Bichromate. Thin the solution till it becomes like honey.
- Cut the chromaline film (dark blue in colour) to the required size.
- Place the screen over the chromaline film emulsion side. Pour the sensitized solution over the screen. Using a squeegee give an even coat of the solution over the film. Remove the excess solutions which appear on the sides of the film with a waste. Dry the screen under a fan. Carry out this process in a dark room.
- After the film is dry peel off the backing of the chromaline film.
- Place the positive's readable side in contact with the emulsion of the chromaline film. The positive may be held rigidly by pasting cello tapes at the corners. Give sufficient backing on the printing side of the screen, so that the screen is slightly above the table level. Place a rigid glass on top of the screen.
- Now expose the screen to a light source. The exposure time varies from 30 seconds to 3 minutes for a bigger design. This condition is with a powerful carbon arc lamp. It may vary for other sources of light. The exposing may also be done with the use of a contact box in which the screen can be placed inside.

- Take out the screen, remove the positive and dip the screen in a tray of water; slightly agitate the screen. Now the image areas will open up.
- Instead of dipping in a tray of water it can be developed by placing it in a sink and spraying water with a tube with moderate pressure.
- The screen is dried in natural atmospheric conditions after blotting out the excess water.



Direct/indirect screen stencil process

II. COMPUTER TO SCREEN FOR SCREEN PRINTING

Computer to screen is the digital production of image carriers for screen printing in which the print image data, controlled directly via the computer, are output onto the stencil or screen [4.3-5]. Most computer to screen systems work using the ink jet technology, in which either heated wax or ink is applied to the screen.

First the screen must be lined with a closed layer/emulsion (stencil material). The print image is applied to this coating using ink jet ink (as a film substitute). This is then followed by the usual exposure to cure the stencil material. The uncured ink-covered areas of the coating are then washed off with water. After drying, the stencil/screen plate is ready for printing. Addressability is about 600 dpi (systems with 1000 dpi are being developed). In large format applications (e.g., 2 m *x* 3 m, which is now about the maximum format for computer to screen) a resolution of 150 dpi usually sufficient, with screen ruling of 18 to 20 lines per cm becoming possible. An example of an ink jet-based computer to screen system is shown in figure 4.3-16.

The shortest stencil production method is the direct exposure of the emulsion-coated screen by laser beam. The laser beam destroys the emulsion in the image area. The emulsion is cured on the non-printing areas (UV light). This method is only suitable for metal mesh and not for the customary polyester mesh. It is only used in exceptional cases, mainly in textile and tile printing.

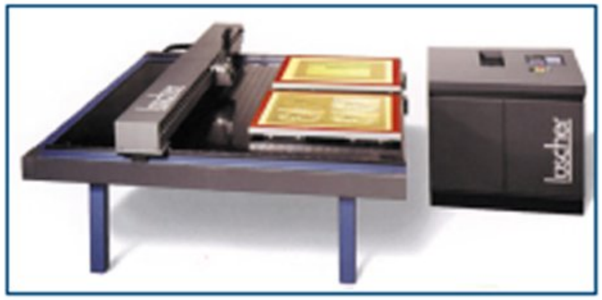


Fig. 4.3-16
Computer to screen system for imaging with ink jet (mini-JetScreen, Löscher)

III. OTHER STENCIL AND SCREEN PRODUCTION OPTIONS ARE:

1. Cutting on a cutting plotter

Stencils can be cut directly out of the appropriate films by means of graphics and CAD programs. They are then transferred and stuck onto the screen. The process used here is comparable to hand-cut stencil production.

2. UV projection for oversize formats

Projectors that expose the photosensitive stencil material with UV light (fig. 2.4-7) are used to save on film costs, or so that comparatively very large screens can still be exposed with manageable film formats.

3. Ink jet process

Some manufacturers supply ink jet systems (Piezo Drop on Demand Systems) that spray a UV impermeable ink (or wax) onto a conventionally coated screen in accordance with the print image (fig. 2.4-8). The sprayed-on ink replaces the film (having the effect of a positive film). The UV exposure cures the unmasked parts of the stencil. The ink/wax, with ink jet produced film is removed in the subsequent development process and the uncured areas are washed off.

4. Rotary screen production

The nickel-based flat plates are stuck or welded or clamped to the appropriate end pieces to produce rotary screen plates (fig. 2.4-9). In decorative printing, for example, *seamless rotary screens* are made using electroplating techniques (fig. 2.4-10).

5. Screen printing plates produced from electroformed screens (Stork)

Electroformed screens (flat and rotary) made from nickel are primarily used for rotary screen printing (figs. 2.4-9 and 2.4-10). There are several *stencil making* options for this type of screen:

- The screen is first coated with a photopolymer, which then undergoes conventional (film) exposure and washing off.

AGPC

- The screen is coated with a photopolymer as in the previous example and imaged by the ink jet process, then exposed and washed off.
- The photopolymer-coated screen is completely exposed/cured and the appropriate image perforations are then burned into the polymer with a CO2 laser.
- The screen is enclosed in a special polymer and this is then developed directly with a laser (488 nm). Unexposed parts are washed off by chemical means.

AGPC

UNIT: II - IMAGE CARRIER PREPARATION

Part – A (1 Mark Questions)

1. State the type of image carrier used for flexographic printing.

Relief image carriers.

2. What are rubber plates?

Rubber plates made from natural and synthetic rubber were the first type of plates developed for flexographic printing. Rubber plates are prepared from mould or matrix. The mould is prepared from the original relief metal plate.

3. What do you mean by relief depth?

The distance between the floor and face of the flexographic (relief) plate is known as the relief depth.

4. What is matrix?

A matrix is a mould made from an engraving or a metal relief master into which softened rubber is pressed for rubber plates preparation. Matrix is composed of thermoplastic resin and cellulose material.

5. State the purpose of back exposure given to flexo plates.

Back exposure is done to harden or cure the base of the flexo plate. Back exposure determines floor thickness and relief depth of the flexo plate.

6. What do you mean by face & floor of the plate?

Face: The physical past of the flexographic printing plate that holds the image to be printed is called the face of the plate.

Floor: The non image area of the flexographic plate is called the floor of the plate.

7. What is vulcanization?

The process in which gum is cured and changing its physical properties to rubber.

8. Mention the layers of photopolymer plates.

i. Stable base / Substrate layer.
ii. Light sensitive photopolymer plates.
iii. Removable cover sheet layer.

9. State the type of image carrier used for gravure printing.

Recessed or sunken image carrier.

10. What are the various methods of copper plating the cylinder?

a) The thin copper layer method (approximately 80 µm of copper)
b) The ballard skin method (removable copper skin of 80 to 100 µm)
c) The heavy copper plating method (approximately 320 µm of copper)

11. Name the various layers of imaged copper cylinder.

Stainless steel base cylinder, nickel layer, base copper layer, engraving copper layer, chromium layer.

12. What is gravure scope?

A microscope used to examine engraved gravure cylinder or Anilox roller cell as a means of evaluating cell depth, the cell opening, and cell wall thickness.

13. What is carbon tissue?

Carbon tissue is light sensitive material attached to gravure cylinders, used as a resist during the chemical etching process. Carbon tissue consists of layers of gelatin, dye, photosensitive material, and a paper or plastic backing.

14. What is electroplating process?

The electro deposition of an adherent metallic coating on an electrode for the purpose of securing a surface with properties or dimension different from those of base material.

15. Define etching.

This is the process of dissolving unevenly a part of the surface of a metal using an acid or other corrosive substance.

16. What is sleeve?

This is tubular part of a base cylinder, which can be mounted on a shaft.

17. What is the chemical used for etching gravure cylinder?

Ferric chloride solution.

18. State the purpose of chrome plating gravure cylinder.

A thin chrome plating is done over the copper cylinder in order to protect the cylinder surface from wear and tear caused by the wiping action of doctor blade.

19. Name the various halftone processes available for gravure cylinder preparation.

i) Double positive system halftone gravure.

ii) Halftone gravure process or direct transfer process.

20. What are screen fabrics?

In screen-printing, screen fabric is the material used to make the screen to which the stencil is attached and through which the ink is transferred. Screen fabrics include such substances as silk, polyester fibers, nylon, and metal wires.

21. What is direct stencil?

A light –sensitive liquid emulsion that squeezed into the screen fabric and becomes stencil when contact exposing and processing are done on the screen.

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22. What is emulsion?

A solution that contains light-sensitive diazo or bichromatic components used in the direct stencil method in screen-printing.

23. What is indirect film or transfer film?

A light sensitive gelatin emulsion coated on a polyester or plastic carrier sheet that is exposed to a film positive and chemically processed into a stencil before being adhered to the stretched screen fabric. After the stencil is dry, the carrier sheet is removed.

24. What is mesh?

The open space between the woven threads of screen-printing fabric through which the ink passes during printing.

25. What is photo stencil?

A stencil in which image and non-image areas are produced photographically is called a photo stencil.

26. What is a scoop coater?

A tool for coating screen-printing fabrics with photosensitive emulsions for making photo stencils.

27. What is serigraphy?

A fine art screen-printing reproduction of an original artwork is called serigraphy.

28. What is tension meter?

A precision instrument used to measure the surface tension of the stretched screen fabrics.

29. State the various image carriers used for Flexographic printing.

a. Rubber Plates
b. Photopolymer plates
    i. Sheet Photopolymer plates
    ii. Liquid photopolymer plates
c. Laser – engraved rubber plates or rubber rollers
d. Laser engraving on polymer plates
e. Computer to photopolymer plates.

30. What are photopolymer plates?

Photopolymer plates are made from light – sensitive polymers (plastics). When they are exposed to light, they undergo polymerization, or the chemical conversion of may small molecules into long – chain molecules. The result is that they will be harder and more insoluble in exposed image areas and become softer in unexposed non image areas.

There are two basic types of photopolymer plates used in Flexographic plate making – sheet photopolymer plates and liquid photopolymer plates.

31. State the purpose of post exposure given to flexo plates.

After washing off the plate has to be dried thoroughly in order to evaporate any wash – off agent that has penetrated relief layer. Post exposure is done to harden all parts of relief completely. In this state, the plate has a sticky surface, on which dust and dirt would collect. This stickness disappears as a result of exposure to UV- light or after immersion in a bromine solution.

32. State the thickness of different range of photopolymer plates available.

Single layer sheet photopolymer plates are available in thickness fro 0.76mm to 6.35 mm. Thicker sheet photopolymer plates are available in thickness from 4 to 5 mm.

33. What are the various cylinder preparation methods available for gravure printing?

a. Conventional or carbon tissue or diffusion-etch method
b. Halftone Process
    i. Double positive system halftone method
    ii. Halftone gravure or direct transfer process
c. Electromechanical engraving process
d. Direct digital (Computer to cylinder for gravure printing) engraving process
e. Laser engraving process
f. Electron beam engraving process

34. What are image carriers?

Any plate, film, cylinder or other surface which contains an image are called image carriers. Image carriers receive ink, and transfers it to the substrate to be printed.

Eg: Gravure cylinders, Flexo photopolymer plates, screen stencils, offset plates, letterpress blocks.

35. What is integral shaft and mandrel shaft?

Integral Shaft: A cylinder base design in which the supporting shaft is permanently attached to the printing cylinder.

Mandrel Shaft: A cylinder that is not permanently mounted on a shaft and can be removed.

36. What is engraving?

Engraving is a printing principle whereby an image area lies beneath the surface of a plate and the non image areas exist on the plate surface. Ink is applied to the plate and then wiped from the surface, leaving the ink in the recessed image areas. Pressure applied to the substrate transfers the image.

37. What are the various gravure cell configurations available?

Conventional Process - Cells having the same width but varied depth

Halftone gravure or direct transfer process - Cells having the same depth but varied width

Electromechanical engraving Process - Cells having the varied width and varied depth.

38. What is Ballard skin copper plating?

This method is also a thin layer copper deposition process (one – time use of the engraving copper layer). The base copper layer is electrically covered with a removable copper layer (80 to 100 µm), where by a special layer between base copper and Ballard skin ensures that the Ballard skin can be peeled off from the gravure cylinder after printing. The Ballard skin method is employed in approximately 45% of cases.

39. State the advantages of laser gravure engraving process.

i. Laser engraving opens new doors for gravure printing.
ii. The real advantage of this process is the speed of 30,000 cells per second.
iii. The unwanted saw tooth effect with fine fonts can be reduced.
iv. There is also the possibility of working with frequency modulated screens with laser engraving process.
v. The laser engraver is designed to be six times faster than the existing electromechanical equipment.

40. What are the advantages of direct digital engraving?

In Direct digital engraving, all image corrections are done in the digital file, eliminating the need to correct film and/or cylinders. This significantly reduces the time required for the manufacturing cycle and produces consistent quality. A duplicate cylinder can be made from the digital data, thus minimizing the variables inherent in the use of film.

41. State the advantages of electron beam engraving.

This technology, working on a vacuum, could engrave cells at speeds upto 1, 50,000 cells per second in a copper image carrier using digital information as input.

42. What are the various screen stencils available for screen printing?

Following are the various types of screen printing stencils available and each having its own methods of preparation.

1. The knife cut printing screen,
2. The photographic printing screen,
3. The washout or etched screen, and
4. The block art printing screen.

43. What is mesh count and mesh opening?

Mesh Count: The number of openings per linear inch in any given screen printing fabric. The higher the number, the finer the weave of the screen fabric.

Mesh Opening: In screen printing, a measure of the distance across the space between two parallel threads, expressed in microns.

44. What is monofilament, and multifilament?

Monofilament: A single strand of synthetic fiber that is woven with others to form a porous screen fabric.

Multifilament: Many fine threads twisted together to form a single thread of synthetic fiber that is woven with others to form a porous screen fabric.

GLOSSARY

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.

Cure

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

Deep-relief Powder Molding (DRPM)

The rubber plate-making process where the finished plate relief is more than 0.125".

Matrix

An intermediate mold, made from an engraving or type form, from which a rubber plate is subsequently molded.

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.

Vulcanization

A curing process to change the physical properties of a rubber.

Part – B (6/12 Marks Questions)

45. Describe the structure of flexographic plate with diagrams. (6 marks)

46. Describe briefly the preparation of rubber plates for flexographic printing with figures. (6 marks)

47. Explain briefly the preparation of sheet photopolymer plates with necessary diagrams. (6 marks)

48. Describe briefly the preparation of liquid photopolymer plates with suitable sketches. (6 marks)

49. How will you prepare flexographic plates by laser engraving method? (6 marks)

50. Explain the principles and procedures involved in computer to plate technology for flexographic printing. (6 marks)

51. Explain the steps involved in preparation of rubber plates with necessary diagrams. (12 marks)

52. Describe the steps involved in preparation of sheet photopolymer plates with suitable sketches. (12 marks)

53. Explain the steps involved in liquid photopolymer plates preparation with suitable diagrams. (12 marks)

54. Describe the process sequence for the preparation of copper cylinder. (6 marks)

55. Explain the various methods of copper plating the gravure cylinder. (12 marks)

56. Explain the steps involved in preparation of gravure cylinder by carbon tissue method with necessary diagrams. (12 marks)

57. How will you prepare gravure cylinder by double positive system halftone gravure. (6 marks)

58. Describe the steps involved in gravure cylinder preparation by direct transfer process with suitable sketches. (12 marks)

59. Explain the steps involved in electromechanical engraving of gravure cylinders with necessary diagrams. (12 marks)

60. How will you prepare gravure cylinder by laser engraving process? (6 marks)

61. Describe the working principles of computer to gravure cylinder system. (6 marks)

62. Write the advantages of direct digital engraving process, and laser engraving process of gravure cylinders. (12 marks)

63. Write notes on(i) Electron – beam engraving of gravure cylinders (6 marks)

    (ii) Gravure cylinder proofing. (6 marks)

64. Explain the preparation of screen printing stencils by direct method with sketches. (12 marks)

65. Describe the steps involved in preparation of screen stencils by indirect method with necessary diagrams. (12 marks)

66. How will you prepare screen-printing stencils by Direct / Indirect method. Support your answer with diagrams. (12 marks)

67. Explain the working principles of computer to screen printing systems. (12 marks)

68. Write notes on screen fabrics used for stencil preparation. (6 marks)

UNIT - III – FLEXOGRAPHY PRINTING

3.1. TYPES OF FLEXO INKING SYSTEMS

Flexography can be distinguished from other printing processes by its inking systems. The metering roller is known as the anilox roll, and it is the primary determiner of ink film thickness. It determines uniformity and consistency.

Developments in anilox rolls continue to be at the heart of process improvement. The laser-engraved anilox permits use of doctor blades, which together provide consistent image uniformity over long runs and over long periods of time. All of this is essential for repeatability and predictability. Today flexography is competitive with all processes, largely due to the modern anilox roll technology.

INK METERING

In every printing process there must be a method to meter the quantity of ink. One must control the film thickness of ink in order to use the least amount of ink required for proper density/darkness and solid uniformity or coverage.

The surface of the anilox roll is covered with tiny cells, all equally spaced and of the same depth and shape. The cells are specified by the number of cells to the linear inch and the depth of the cell, or its volume.

Anilox cells are often described as fine or coarse, depending on the cell count. A roll having 200 cells per inch is rather coarse, one with 400-500 cells per inch is average, and one having over 700-800 cells per inch is considered fine. Figure 3.1 shows that cell count alone does not reveal all one needs to know about the ink delivery capacity of the anilox roll.

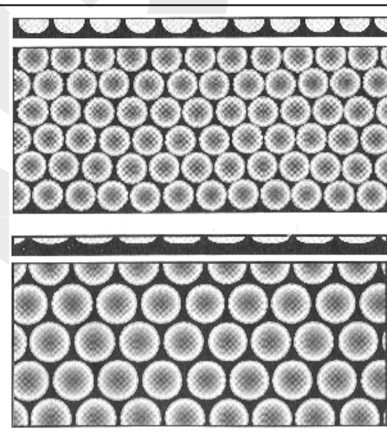


Figure 3.1 - Cell count alone does not reveal all one needs to know about the ink delivery capacity of the anilox roll. A 360-line anilox roll with a deep cell (top) can carry more ink volume than a coarser 200- line roll (bottom) with very shallow cells.

A 360-line anilox with a deep cell can carry more ink volume than a coarser 200-line roll with very shallow cells. Therefore, when specifying an anilox one must always define the cells per inch or cell count, and either cell depth or volume.

Cell dimensions are specified in microns. A micron is a millionth of a meter. To appreciate this, consider that there are 25.4 microns in 0.001 inch. Volume is measured in bcms, “billion cubic microns” per square inch (an interesting measurement combining a mixture of metric and English units).

A volume of 1.0-2.0 bcm is a low volume, probably used for fine screens/halftones on smooth substrates. A volume of 4.0 bcm is a middle-of-the-road anilox roller while a 7.0 bcm roll is found where bold solids are being printed on a very rough and absorbent surface. To increase or decrease the amount of ink in flexography, one changes to another anilox roll that carries the desired amount.

The anilox roll is at the heart of the flexo process. There are several common forms of ink metering systems found on flexographic presses.

TYPES OF FLEXO INKING SYSTEMS

1. Two-roll ink metering system

The old standard system is called the **“two-roll system”** (Figure 3.2 top). The anilox receives a flood of ink from the fountain roll which is suspended in a pan of liquid ink. The fountain roll is run in tight contact against the anilox roll. The fountain roll turns slower than the anilox, creating a wiping action. This causes most of the surface ink to fall back into the fountain, leaving only the ink inside the cells on the anilox roll. The ink in the cells is then transferred to the plate as they come in contact. In the two roll system, the efficiency of the wiping action is affected by the durometer of the rubber fountain roll. A harder, higher durometer like 80 wipes the surface (lands) of the anilox more efficiently than a soft roll with a durometer of 50. (The lands are the tops of the walls between cells which support the rubber roll or doctor blade and define the cells.)

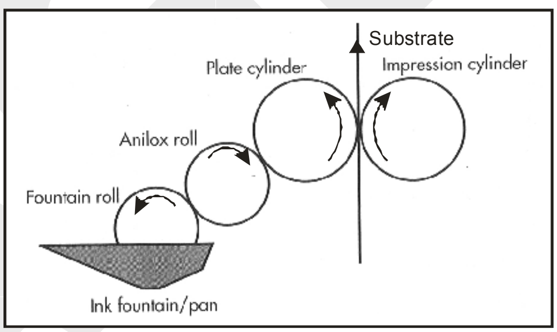


Figure 3.2 - Two roll ink metering system.

i. Ink Fountain

The anilox roller is a chrome- or ceramic-covered roller whose surface contains small, engraved pits or cells (typically from 80-1,000 cells per inch).

The pressure between the fountain roller and the anilox roller is set so that the excess ink pools up at the top of the nip between them. The difference in revolution speed of the two rollers (the fountain roller typically turns at a slower rate than the anilox roller) causes a wiping effect of the anilox roller. The goal is to ensure that only the ink stored in the engraved cells on the anilox roller’s covering is transferred to the plate. The difference in speed also eliminates a problem in flexography called mechanical pinholing (sometimes also called ghosting, and related to mechanical ghosting found in offset lithography), in which ink is not replenished uniformly to the surface of the anilox roller, causing the texture of the roller to be transferred to the substrate.

2. Modified two-roll with a doctor blade ink metering system

The second metering system is a modified two-roll with a doctor blade. The rubber fountain roll is backed away so it floods the anilox with ink. The doctor blade is set at a reverse angle to the direction of rotation of the anilox. This reverse-angle doctor blade is engaged with just enough pressure to wipe the surface areas clean of all ink. This produces a much cleaner wipe than the two-roll system. Figure 3.3 bottom illustrates the two-roll with doctor blade ink metering system.

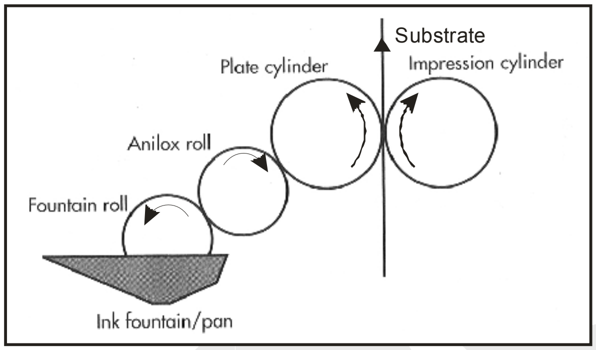


Figure 3.2 - Two roll ink metering system.

3. Reverse angle doctor blade ink metering system

A third configuration of the metering system is the simple doctor blade design (see Figure 3.4) where the anilox roll is suspended directly in the ink fountain (removing the need for a fountain roller) and the reverse angle doctor blade shears off the excess ink letting it fall back into the ink fountain.

Here the ink metering is performed by a doctor blade (a strong strip of steel, plastic, or other material) that is placed between the fountain and the nip between the anilox roller and the plate cylinder. The angle and pressure of the doctor blade ensure a controlled and uniform ink metering.

A drawback of all these designs is the open ink fountain and exposed anilox. This permits free evaporation of the volatiles into the pressroom environment and the resulting change in ink viscosity (thickness) which affects printability. Ink fountain covers are often used on large presses to reduce this effect and to keep out dust and other foreign airborne particles that contaminate the ink. Because of the in-line converting operations going on during the pressrun, dust is an important element to be controlled.

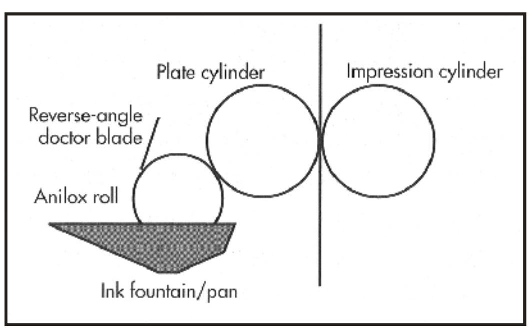


Figure 3.4 - Reverse angle doctor blade ink metering system.

4. Chambered doctor blade ink metering system

The last common print station design is the chambered doctor blade system. As shown in Figure 3.5 the ink fountain is replaced with an assembly mounted against the anilox roll. On one side of the chamber there is a reverse-angle doctor blade that performs the metering function. The other side of the chamber is sealed by a containment blade, which keeps the ink from escaping or leaking out of the chamber. The ends of the chamber are sealed with gasket-like materials. Ink is pumped into the chamber and usually returned by gravity to the ink sump. The chamber blade metering system keeps the ink enclosed at all times, reducing the loss of volatiles and maintaining the ink in a constant and clean condition.

Ink is pumped onto the surface of the anilox roller, where the top doctor blade is responsible for metering. This system is typically used on high-speed presses, and is popular due to the fact that, since the inking system is not exposed to the air, ink viscosity can be tightly controlled.

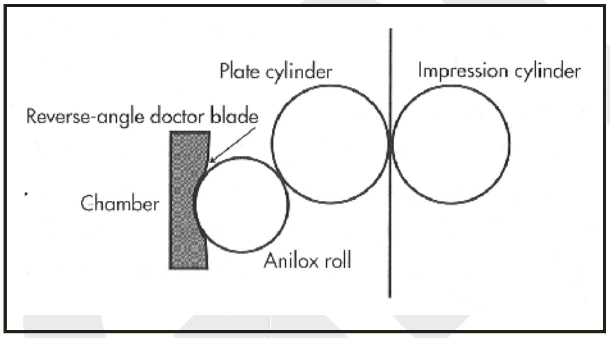


Figure 3.5 - Chambered doctor blade ink metering system.

Conclusion

Flexography is a process where a precisely engraved anilox roll prints a thin film of ink onto the raised surface of the plate, which offsets the ink onto the substrate. It is imperative that the same amount of ink is delivered hour after hour and job after job if the process is to be predictable and profitable. Although there are many two-roll (sometimes called roll-to-roll) metering systems, the doctor blade is clearly the choice for repeatability.

For some who prefer "art" over science, the two-roll system does allow the operator to vary the ink film. Of course, achieving the same variation on repeat orders poses a problem, complicated further when a different operator is at the controls.

The best of flexo printing requires precise doctor blade metering, and the chamber blade system is the system of choice, at least until something better is developed. The flexo press is easily retrofitted with the latest metering systems; many older machines still in sound mechanical condition are being retrofitted to bring them up to the print quality capacity of much newer presses.

3.2. TYPES OF ANILOX CELLS AND CLEANING SYSTEMS

THE ANILOX ROLL

The anilox roll is a uniformly imaged gravure cylinder. Figure 3.6 illustrates cells of two specifications, showing the depth and the opening. It also shows the land area critical to print quality, including solid uniformity and clean printing screens or halftones.

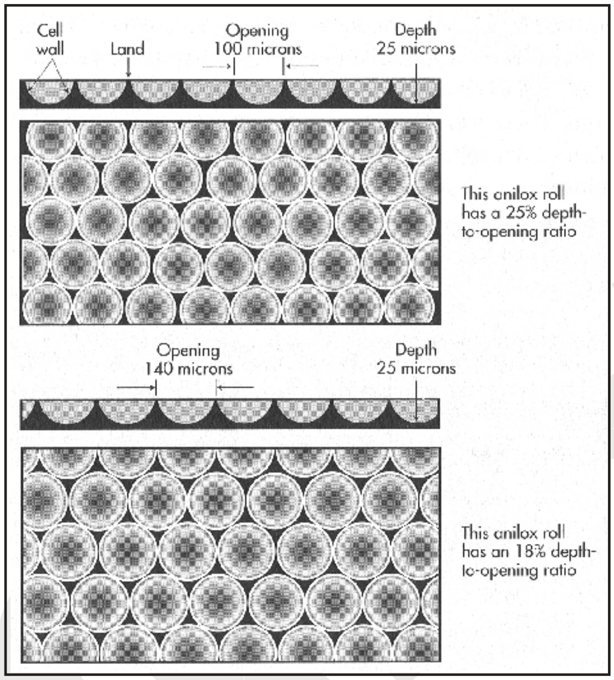


Figure 3.6 - Anilox rolls with cells of two different specifications. This shows the depth and the opening, and the land area, which is critical to print quality, including both solid uniformity and clean-printing screens and halftones.

The specifications of the cells in the anilox roll determine its capability for specific applications. For example, an anilox roll with 200 cells per inch, having a cell depth of 30-35 microns, will carry a volume of 7.5 bcm (billion cubic microns per square inch). This is a lot of ink. It would be like a six-inch paint brush, only good for very heavy applications of ink. You could paint a barn or rough siding with a six-inch brush and you could cover a very rough, absorbent kraft paper with a 200-lpi (lines per inch) 7.5-bcm anilox roll.

However, if you wanted to do fine work, like fine lines and 133line halftones on a smooth and coated paper you might want a 600lpi 1.6-bcm anilox roll. Determining the best anilox roll for a given production scenario is a MUST; first an explanation is required of the specifications and how they relate to the substrates to be printed and the variety of graphics required to be reproduced.

3.2.1 ANILOX ROLL SPECIFICATIONS

CELL COUNT

Cell count refers to the number of rows of cells per linear inch (specified to linear centimeters in the metric world—divide by 2.54 to convert). A cell count of 180 would be very coarse, found only in coating or low-end imaging applications where substrates are poor and quality is not a priority. A cell count of 360, once considered fine, is now a middle-of-the-road roll used in good work on absorbent paper and paperboard substrates. Today cell counts of 700 and above are commonly used for very high-quality imaging on smooth, high-holdout (not absorbent) substrates. This explanation places importance on the substrate in choosing an anilox roll. Images, however, are also very important in determining the cell count.

CELL DEPTH

Cell depth is the next specification and is just as important as cell count. These two specifications determine cell volume, which is the determiner of density in a given application. Figure 3.7 shows that three aniloxes of the same cell count may have very different volumes depending on the cell depth. It is volume that interests the printer. When specifying an anilox roll determine the cell count and volume to do the job and leave the depth to the anilox supplier.

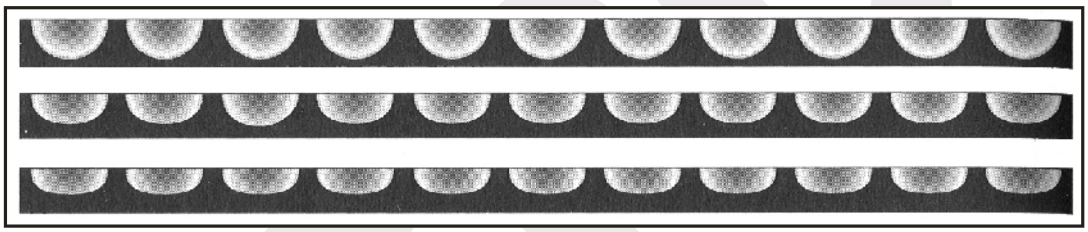


Figure 3.7 - Three anilox rolls at the same cell count may have very different volumes, depending on cell depth. The top roll shown here would have a 5-bcm volume, the botom has a 2.5-bcm volume.

CELL VOLUME

Cell volume is the key to coverage and uniformity of solids. More volume results in more ink and, thus, better coverage. However, too much volume of ink also results in dirty print. If there is too much ink to sit on top of the relief image of the plate, it will flow over the shoulders and result in dirty print.

High-resolution images require high-line, low-volume anilox rolls. There are rules of thumb for determining anilox cell count from halftone lines per inch. It is common to demand at least 3½ to 4½ times more cells on-the anilox than the lines per inch in the halftone. This is to prevent anilox moire, an objectionable pattern caused by the screen of the graphics interacting with the anilox screen pattern.

Figure 3.8 shows the importance of the cell count the ability to produce clean printing. It can be seen that a high-line count ("line count" and "cell count" are terms used interchangeably) roll has enough cell walls to support very fine screened images. A coarse cell will allow small percentage dots to fall inside cell, without being supported by a cell wall, and thus permit ink to flow around the image onto the shoulder of the dot. This causes "dirty print" or dots to join wherever a dot is unsupported by a land area. A high-line-count fine anilox roll will produce clean printing of fine screens and type.

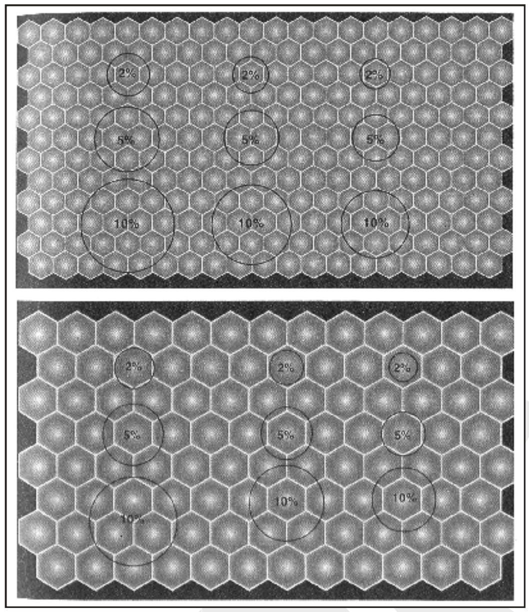


Figure 3.8 - The importance of cell count to the ability to print cleanly. The top shows a 900-line anilox roll with a 25-micron cell opening and 3-microncell wall; the bottomshows a 550-line anilox roll with a 42-micron cell opening and 4-micron cell wall.

The best anilox roll specifications yield just enough ink to deliver the required density and solid uniformity while not overinking the fine screens in the plate. This roll has enough cells to provide lands to support the finest image areas.

Cell angle can also be controlled. While traditionally the cells are angled 45° from the axis of the roll, it is possible to fit more cells into an area when they are aligned at 60°. Since this provides more cell openings and less land area, or space between cells, 60° rolls achieve better uniformity with less ink. The 60° angle is also better in avoiding moire with traditional graphic screen angles since it no longer falls in line with the most desirable image angle of 45°. Today most new rolls are purchased with 60° cell angle.

Sometimes a flexo printer concludes that the ideal roll is a very-high-line-count, even when printing on an absorbent substrate. The all that is needed is very deep cells to achieve the required volume. This introduces one last concept to be considered, depth-to-opening ratio. Figure 3.9 illustrates several depth-to-opening ratios. It shows that very high volumes might be engraved into an anilox of a high cell count. However, the bottom row illustrates that when the depth exceeds a certain point, no more ink is released to the plate. There is a range within which volume on the roll can be used to control in film on the printed substrate. Beyond that range, no additional ink can leave the roll and there will be no increase in density.

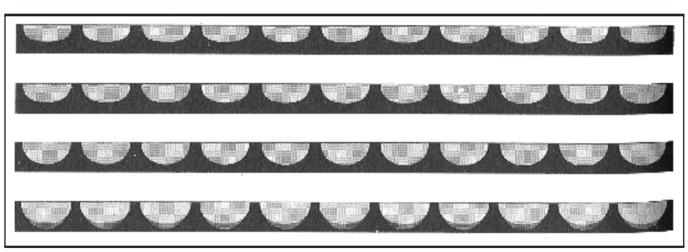


Figure 3.9 - Illustration of several different depth-to-opening ratios. Very high volumes can be engraved into anilox rolls. However, the bottom row illustrates that when depth exceeds a certain point, no more ink is released to the plate. Higher volume results in higher ink transfer, up to about 35% depth-to-opening ratio.

Until now the discussion might suggest that the anilox is the so determiner of ink film thickness. But this is far from the case. The ink itself is a major player. It has been assumed that the amount of liquid that is printed controls the dry ink on the product. Actually it is the amount of solids, particularly the colorant, or pigment. Figure 3.10 illustrates that one ink may require 40% more liquid be printed to result in the same density and solid uniformity. This, of course, would require a 40% higher volume anilox roll. Such an anilox would not print as clean. Therefore, when people talk of high-line-count low-volume aniloxes, you must realize they are also talking about inks with the maximum amount of pigment and the least amount of liquid necessary for transfer and adhesion.

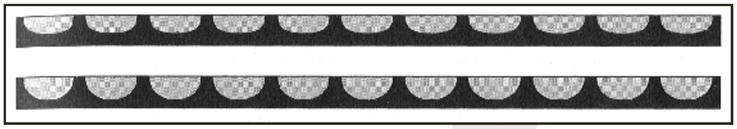


Figure 3.10 - One ink may require 40 % more liquid be printed to result in the same density and solid uniformity. This, of course, would require a 40 % higher-volume anilox roll, and would not print cleanly. In the illustration, the top anilox prints excellent density using a highly pigmented ink. The bottom anilox requires 40 % more volume to print the same density because the ink contains less pigment and more liquid.

3.2.2. TYPES OF ANILOX ROLL BASED ON CELL SHAPES:

Anilox Roll is engraved with tiny cells. They normally have an inverted pyramid shape. These cells or pockets when filled with ink from fountain roll carry up an exact quantity of ink to the printing plate. Choosing a proper anilox for the job is important for successful flexographic printing. If the cell count is more, the ink carrying is also less.

The Anilox rolls come in various sizes with various shapes of cells. Three basic shapes of Anilox roll cells are

i. Inverted pyramid shape cells
ii. Quadrangular shape cells
iii. Trihelical shape cells

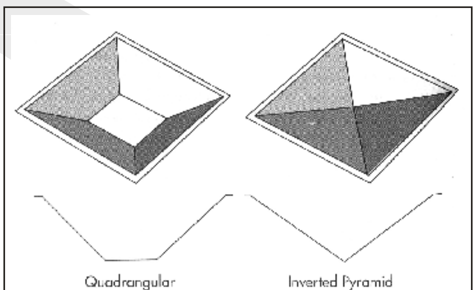
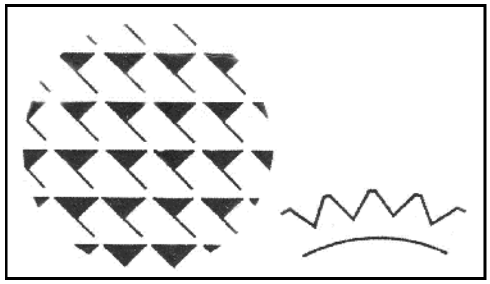
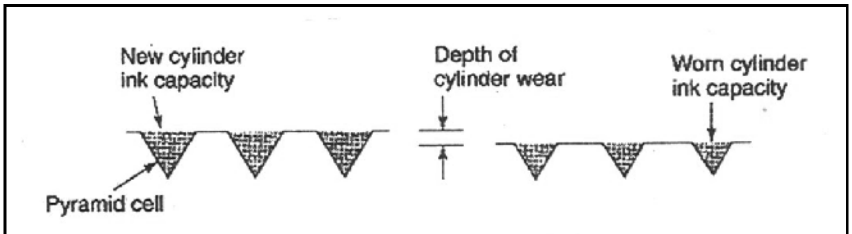


Figure 3.11 - The two most common cell shapes used in flexo printing, the quad and pyramid

i. Inverted pyramid:

Anilox roll with inverted pyramid shaped cells are recommended for all types of flexo inks as well as varnishes and coating.

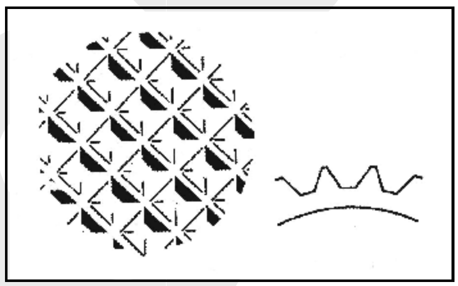


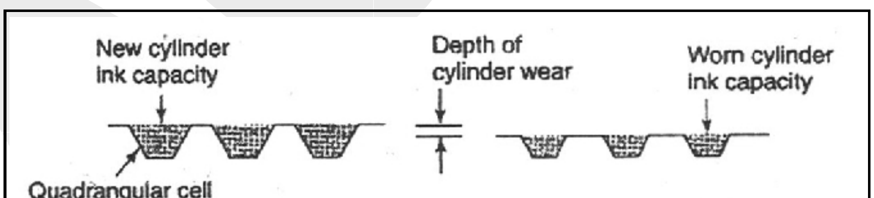


Pyramid cell ink capacity lost through cylinder wear

Quadrangular Cell:

Anilox roll with quadrangular shaped cells carry more volume of ink in comparison with inverted pyramid cells. These cells are oftenly used with reverse angle blade.

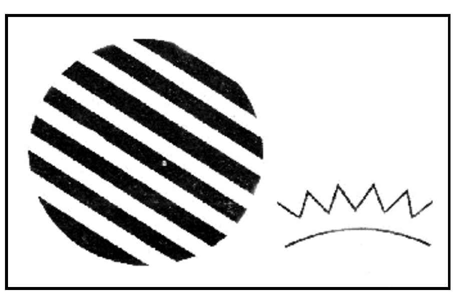




Quadrangular cell ink capacity lost through cylinder wear

Trihelical Cell:

Used to apply heavy viscous coating. This type of Anilox roll can be used with or without reverse –angle doctor blade.



Anilox rollers are normally engraved. After engraving they are copper finished then hard chrome plating is applied to increase their life.

3.2.3. TYPES OF ANILOX ROLLS BASED ON ROLLER SURFACES

i. LASER-ENGRAVED CERAMIC ANILOX ROLLS

Laser-engraved ceramic anilox rolls are the dominant type of roll being used today. This is a steel roll that has been machined to very precise dimensions and tolerances. It has a plasma sprayed chromium oxide surface built up to a thickness of 0.00~0.010 in. The cells are burned into the ceramic with a CO2 laser that literally vaporizes the coating, leaving a precise cell. The cell count and depth are computer-controlled, meaning that theoretically any specification can be set.

The ceramic surface is extremely hard, which is very important to print quality. Since high-quality flexo printing is achieved with doctor-bladed ink metering systems, the rolls must not wear or repeatability would be impossible. While ceramic rolls do wear, it occurs over an extended period of production.

ii. CONVENTIONAL (OR) MECHANICALLY ENGRAVED CHROME ANILOX ROLLS

While today the vast majority of new rolls being purchased are laser engraved ceramic, there are still many rolls in the industry of the engraved chrome technology. These rolls, also called mechanically engraved, or simply “chrome,” are manufactured by a displacement process, the same as knurling. A hard, precise tool called a mill contains a male pattern of the cells (Figure 5-9). The mill is forced under tremendous pressure into the steel- or copper-covered steel roll. During several passes over the roll the cells are made deeper and deeper until the roll has reached full engraved depth. Just as ice dropped into a glass of water raises the level of water in the glass, this process displaces the metal up into the mill while the mill is pressing deeper into the surface. Since every cell is produced from the same “master” the conventional engraved chrome roll is a very uniform “gravure cylinder.” The roll is electroplated with a hard chrome to provide protection from wear, hence the name engraved chrome. Figure 3.11 illustrates the two most common cell shapes used in flexo printing, quad and pyramid.

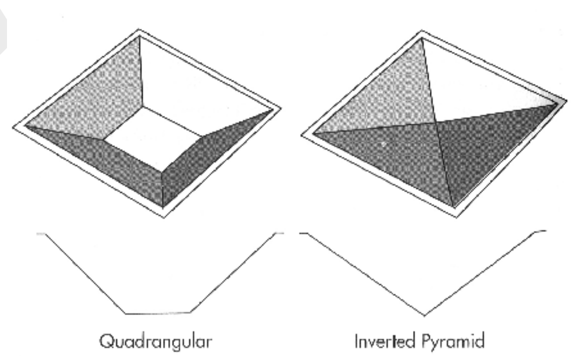


Figure 3.11 - The two most common cell shapes used in flexo printing, the quad and pyramid

Engraved chrome has limitations that helped to move the market to laser-engraved ceramic, the greatest being its lack of resistance to the wear caused by doctor blades. Since new cell specifications require a lengthy process, demanding very high craft skills, to make the engraving tool, it was not possible to perform quality improvement experiments in a timely and economical fashion. These two factors were major contributors to the early acceptance of laser engraving as an alternative approach to anilox roll production. In little over a decade the dominant roll of choice changed from engraved chrome to laser-engraved ceramic.

There are other types of anilox rolls. Conventionally engraved rolls can be plasma-sprayed with ceramic instead of chrome and yield better life. These rolls are called engraved ceramic. This approach, however, has never been widely adopted. Another approach to anilox cell production is electromechanical engraving. This method uses the same machines employed in the production of gravure cylinders. The Ohio Engraver and the Helioklischograph are the two most common tools to employ a diamond stylus in cutting precise cells into a copper surface. The copper is then electroplated for wear resistance.

One last technique known as random ceramic has been employed. This is a roll which is simply plasma-sprayed with chromium oxide particles. The coarser the particle the more ink carrying capacity. Like sandpaper, the rougher the surface, the more ink, and the finer the particles, the less ink. This is a simple system, not as uniform in its ink delivery, and is used relatively little compared to other types.

DEVELOPMENTS

Lightweight cylinders are now being used to replace the standard steel construction. Modern materials such as carbon fiber can be used to build the base roll without the weight of steel. These are much easier to handle, and shipping issues are reduced. The same is true of the use of sleeves, similar to those being used for plate cylinders. It is important to note that many new ideas continue to develop in this and other aspects of flexo printing, which is a sign of the atmosphere change and development that characterizes flexo technology.

3.2.4. TYPES OF ANILOX ROLL CLEANING SYSTEMS

i. Roll Cleaning System:

The level of cleanliness of anilox roll and indeed the ease of achieving, is one of the most important problems facing the flexo printer today. This is due to the rise in screen counts and the ever increasing requirement for quality improvements.

ii. Jet wash type system:

These are very simple mechanical device that utilize specific heated chemicals fired at the roll under high pressure. They are not generally not screen counts sensitive and will work over a range of screen counts. On the downside, their success is heavily reliant on the type and condition of the chemicals employed, which can be expensive, being applied at

50%by volume with water. Performance can drop dramatically as chemical becomes contaminated.

iii. Powder blasting system:

Generally single roll system, they use the impinging force of a particle to knock out the contamination and are supplied as either wet or dry systems. Work well up to moderate screen counts when the operator is fully lined and interested. Gaps between roll and nozzle, air pressure, feed rate and the feed itself all need to be monitored and controlled. Also these system can have an issue with ink. Powder is a total loss and can be used for on press cleaning, however this can be a messy process.

iv. Polymer bead blasting system:

The same rules apply as with powder blasting. The units work well with the correct beads up to moderate screen counts when the operator is fully trained but the units suffer from the same limitation as powder blasting. These cannot generally be used as on press system is that there is no waste to consider. There are couples of fringe systems that have entered the market over the last few years that deserve mention.

v. Dry ice system:

These as the name suggest utilize the dry ice to blast out the contamination. The equipment is also used as a general press cleaning system and although when properly used and controlled will clean the roll well but not enough is known about the longer term effects on the ceramic and the units are very noisy in operation. Again, there is no waste to consider with these systems.

vi. Laser Cleaning System:

These systems utilize generally the same laser used to cut the cells as to clean them. This vaporization of the contamination will render the roll clean but the systems are very expensive in comparison with other devices available and as it is generally the lower skilled operative that are left to clean the rolls, the question of skill level should be raised.

vii. Ultrasonics:

This system work by the flexing of the base of a filled tank at very fast rate. So fast, that on the downward stroke a vacuum is created under the water microns. On the upward stroke the vacuum is closed and pushed up into the fluid in the form of microscopic vacuum bubbles that collapse on contact with the roll surface, sucking out the contamination. When correctly controlled and combined with a suitable cleaning chemical (usually at 10%with water), this method will give excellent results. The system generally do not require a skill to operate and when used regularly are very quick and effective, however waste is a consideration, although this can be neutralized in certain circumstances and the volumes are low in comparison with jet wash system.

viii. Alpha sound:

This equipment utilizes ultrasound but, there are differences compared with ultrasonic cleaning systems generally available today for this purpose. This technology embraces and manipulates various frequencies and power levels to specifically target screen count ranges. Tight control over the base technology is the key and other various system features stop operator error and protect the roll. There is enough room in the marketplace for all the above roll cleaning methods but what is the best? That is the operator to decide.

3.3. SELECTION OF SUITABLE ANILOX ROLLER

CHOOSING THE ANILOX ROLL

There are always several, if not many, considerations to be made in the choice of anilox rolls.

1. **Substrate.** If only one substrate is to be printed then the choice is easy. Many times one anilox roll must be used for a range of substrates. This calls for the anilox which delivers the least ink required to achieve density and solid uniformity on the most absorbent of these substrates.
2. **Anilox cost.** If one roll costs $15,000-20,000 for a five-color press, one may have to settle on just one or two sets of rolls for all one's needs. This is especially true in the corrugated industry. Therefore, even to print a variety of substrates and types of graphics, a compromise must be found for economic reasons.
3. **Time.** Modern flexo presses generally provide for quick changes of anilox rolls; however, most presses in use today are not so equipped. This means that to optimize the anilox to the job at hand, the changeover times may be prohibitive, again, a compromise is necessary.
4. **Graphics.** It is common for customers or designers to specify graphics with fine screens on substrates of less than ideal surface. Since most jobs mix screens with solids this scenario presents problems. In this case the anilox will probably be chosen to achieve adequate solid density and uniformity while delivering more ink than necessary to the screens; another common compromise.
5. **Productivity.** While there are many influences on productivity one common example is the availability or lack of dryers. The classic case is in the envelope world where very high speeds are expected without availability of dryers. Drying relies more on absorbance into the paper. The substrate is also generally rougher than ideal so that viscosities (fluidity of ink) must b lower, more liquid, and thus anilox volumes higher in order to deposit sufficient pigment for density and uniformity. Bottom line: fine screens are likely to suffer.

These realities point to the value of planning all jobs with input from the entire production team. It is unrealistic to expect a customer and designer to understand so much. Since everyone seeks total success in any project, working together from the beginning will result in the best achievable results given the specific realities hand.

3.4. FLEXO PLATES - STRUCTURE AND MOUNTING TECHNIQUES

3.4.1. Structure of Flexographic Plate

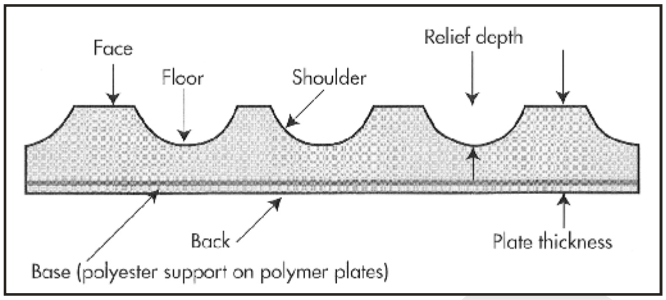


Figure 3.12 - Structure (physical parts) of the flexographic printing plate

The terminology used to describe the plate is detailed in the above figure. The **face** is the image that prints. It must be smooth and have sharp edges. The **shoulders** will be as straight as possible where they meet the face. Ideally they will angle out from the face to provide support to fine lines and small halftone dots. The **floor** is the nonimage area. The distance between floor and face is **relief depth** and is critical to the relief principle. Contrary to standard practice, large relief depths are unnecessary as proven by the newspaper printers and leaders in narrow-web printing, both of whom print with relief depths of as little as 0.015 inch.

The **back** or **base** of the plate, in the case of photopolymers, is a polyester sheet and provides dimensional stability. It may also be metal as with many newspaper plates and plates mounted to cylinders magnetically. Rubber plates, with limited exceptions, have no stable backing.

The **total plate thickness** is determined by the space between the cylinder and the pitch line of the gear where the transfer of image to substrate is achieved. Thin plates are between 0.025 inch and 0.045 inch, and are found most commonly in news and narrow-web label applications. Others are slowly moving in this direction.

Plates between 0.067 in. and 0.125 in. are very common in most industry segments, with the exception of corrugated. There it is still common to find plates between 0.150 in. and 0.250 in. Trends in almost all flexographic applications are to thinner plates, which are found to hold better resolution and print with less gain.

Flexographic Plates

A somewhat similar type of plate is a **metal-backed plate**, which molds and vulcanizes the rubber to a metal backing. Such plates, like some of those used on offset presses, have prepunched holes for accurate mounting on plate cylinder registration pins. Such plates tend to be easier to mount and more accurate than traditional adhesive-backed plates.

Several types of **remounted plates** are produced on a removable metal cylinder or sleeve that can be slid onto the plate cylinder. Some varieties also produce the plate on a mountable carrier sheet. **Magnetic plates** have the rubber surface applied to a magnetic backing material, allowing the plate to be mounted on the plate cylinder magnetically, which allows for easy mounting and removal, as well as register adjustment.

One particular alternative to flexographic plates is a design roll, which is a **printing cylinder containing a layer of rubber**. The image areas are engraved directly on the rubber-covered cylinder, commonly using lasers. They are used primarily when seamless printing is required, such as for gift-wrapping, linerboard, security paper, etc.

The printing plate material must be selected so that it will not be swollen, etched, or embrittled by the inks. **Printing plates are either flat and fastened onto the plate cylinder with adhesive or double-sided adhesive film, or they are produced in cylindrical form (e. g., *sleeve technology*).**

Photopolymers for flexographic printing plate production are available in liquid or sheet (solid) form, with the Sheet photopolymer plates becoming increasingly more prevalent.

Sheet photopolymer plates are nowadays supplied ready-for-use (e. g.,Nyloflex printing plates from BASF or Cyrel from DuPont). They **are available as single or multi-layer plates.**

SINGLE LAYER PHOTOPOLYMER PLATES

Single-layer plates consist of a relief layer (untreated photopolymer) that is covered with a protective film. A separation layer allows easy removal of the protective film.A polyester film on the reverse side of the plate serves to stabilize the untreated plate. The layer structure of a single-layer plate is shown in figure 2.3-7a.

Single-layer plates are made in thicknesses from 0.76mm (e. g., for printing on plastic bags, film, and fine cardboard products) to 6.35 mm (e. g., for corrugated board and heavy-duty bags made from paper and film). Screen frequencies of up to 60 lines/cm (150 lpi) can be achieved with plates less than 3.2 mm thick. The possible tonal range here is about 2–95%. Thicker plates (around 4–5 mm) are suitable for screen frequencies of up to 24 lines/cm (60 lpi)with a tonal range of approximately 3–90%.

MULTILAYER SHEET PHOTOPOLYMER PLATES

Multilayer sheet photopolymer plates for high-quality halftone printing are structured as shown in figure 2.3-7b. In their structure they combine the principle of relatively hard thinlayered plates with a compressible substructure. The base layer itself forms a compressible substructure for the relief layer and consequently absorbs deformation during printing; the image relief remains static, however. The stabilization film ensures that virtually no longitudinal extension occurs as a result of bending during mounting of the flat plate on the impression cylinder.A comparable improvement in print quality is also achieved when thin single-layer plates with compressible cellular film are stuck onto the plate cylinder.

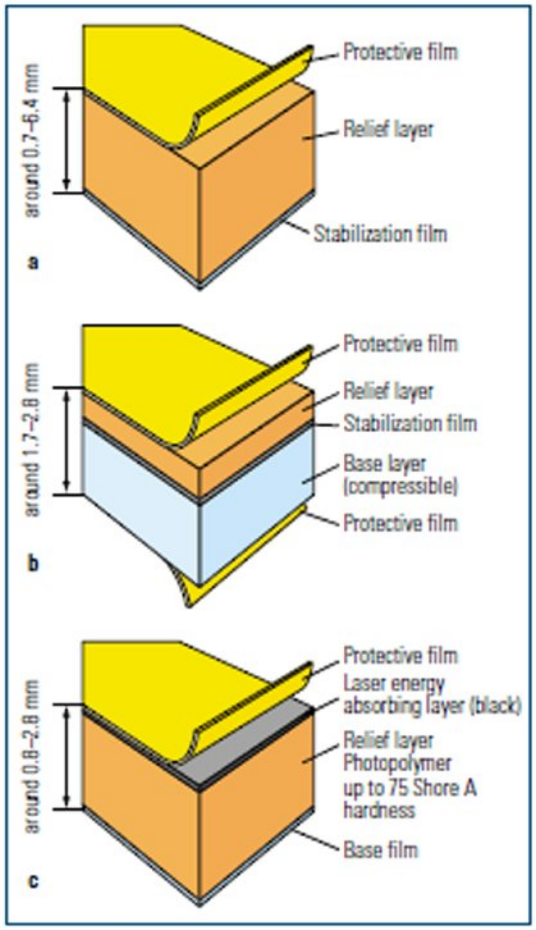


Fig. 2.3-7 Structure of the various flexographic plates.
a Single-layer plate (BASF);
b Multi-layer plate (BASF);
c Plate for computer to plate imaging systems (digiflex, BASF)
Note: 75 Shore A considerably softer than 75 Shore D for letterpress plate in fig. 2.3-4

3.4.2. FLEXOGRAPHIC PLATE MOUNTING

Regardless of the system of plates and cylinders, the register and impression are determined by this phase of production. Presses have lateral (across) and circumferential (around) register. All the accuracy within the image is determined by prepress, particularly plate mounting There are tools available today to make this step accurate and productive. There are still many, however, using older techniques which require greater allowance for register tolerance.

All involved in the production process need to be aware of the process capability being employed on the job at hand. This is just one more reason for making the project a team effort, involving all along the production chain to achieve the best possible results for the customer.

The plate, regardless of its origin, is part of a system. This system includes the plate, the stickyback or other mounting medium, and the cylinder, sleeve, or carrier sheet onto which it is mounted. Today there are many ways to assemble this system, and new approaches are being developed. The fundamentals, however, are constants valuable, and prerequisite to understanding the latest approaches.

PLATE MOUNTING FUNDAMENTALS

The plate mounting process is simply the precise positioning of the plate in the x and y axes. If the plates are mounted perfectly square, the running adjustments on the press permit easy registration on the run. Unlike offset lithographic presses, flexo presses with plates mounted directly to cylinders or sleeves permit no angle adjustments. They must be mounted perfectly square (Figure 3.13). In the case of corrugated and a few other exceptions where plates are mounted to carrier sheets, angle adjustments are possible. Making angle adjustments is, however, always cumbersome and costly.

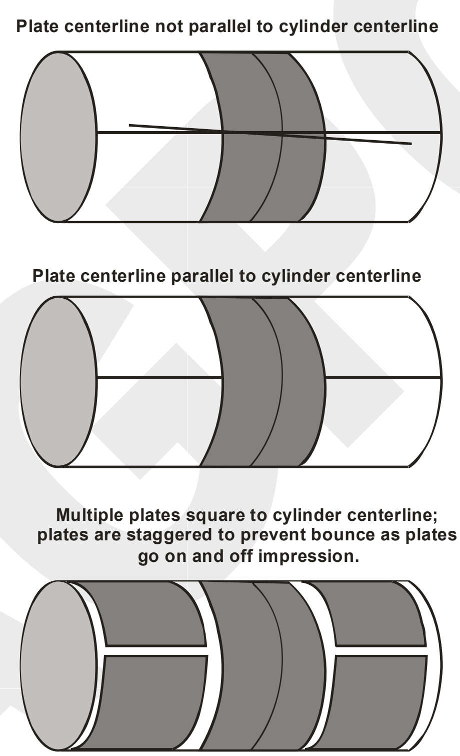


Figure 3.13 - The plate mounting process is the precise positioning of the plate in the x and y axis. Plates must be positioned squarely to the plate cylinder.

When jobs are run more than one-up, plates are either made in single pieces for each color of the entire job or one label at a time. In other words, a three-color job runs three images across and two around the cylinder could be plated with just three plates, each containing six images (3 across X 2 around), or it could be plated with 18 individual plates.

In the past flexo plates were always done as individuals, 18 plates for this scenario. This required very skilled mounters and often more than a shift just to mount the job. It also meant there were 18 potential mounting errors for this simple job.

Today, with large film output devices and platemakers, a job of this description would more likely be prepared with one large plate for each color. Now there are only three positioning tasks. There are also precision tools available to assure accurate location of each plate. The cost of plate mounting has moved from labor to tools and technology. This permits much shorter times to press and far less press downtime for repositioning plates that were poorly mounted.

STICKYBACK TYPE

Flexo plates mounting

Flexographic printing plates are usually secured to the printing cylinder by means of two-sided self-adhesive material. The plates are mounted on the plate cylinder and pre-registered in position on special equipment designed for this purpose. Several plate cylinders are normally available for one machine to enable pre-mounting of plates. This reduces the unproductive time on the machine to a minimum. A 'cushion-back' adhesive layer behind the stereo is sometimes used to compensate for any inaccuracies in the plate or press. However, in halftone printing this can lead to greater enlargement of highlight dots than would otherwise have been the case. The current best practice is considered to be to use the thinnest possible adhesive tape since the potential for introduction of thickness variation is then minimized.

Two-sided self adhesive tapes are also called as stickyback. Stickyback comes in selected thicknesses, densities, and hardnesses. Some stickybacks simply adhere the plate and may be as thin as 0.002 in. Other stickybacks are thicker, most commonly 0.015 in. and 0.020 in. thick. These are either rigid or cushioned.

Cushion stickyback is a foam material that aids impression uniformity. Consistent thickness of stickyback is critical to the job. Variation in stickyback is the same as variation in the plate thickness. Much research has been done to understand the ideal stickyback and plate combinations for selected types of images. The mounting tape has a major effect on the print quality of the product. To oversimplify, harder tape is best for solids and soft for fine screens. Since there is considerable interaction among graphics, inks, and substrates, the optimum choice is generally given serious thought. This is an area where top printers often find that one size does not fit all.

PLATE ALIGNMENT CONCEPTS

For the purpose of this text, all plate alignment systems will be grouped into three categories: i) optical, ii) register pins, or iii) videoscopes and microtargets. These are not clean divisions because some employ more than one concept.

i. OPTICAL DEVICES

Optical devices rely on simple visual alignment of the position marks on the plate with grids or layout lines. The simplest optical approach relies on scribed lines in the cylinder itself. The mounter simply lines up the vertical and horizontal center marks of the plate with the marks scribed into the cylinder. Simple? Yes; remember, all that is required is a plate mounted squarely on a cylinder. Other optical approaches enable the plate to be positioned squarely on a sheet or table and then transferred to the cylinder. Figure 3.14 illustrates one simple visual approach where the plate is aligned with a grid.

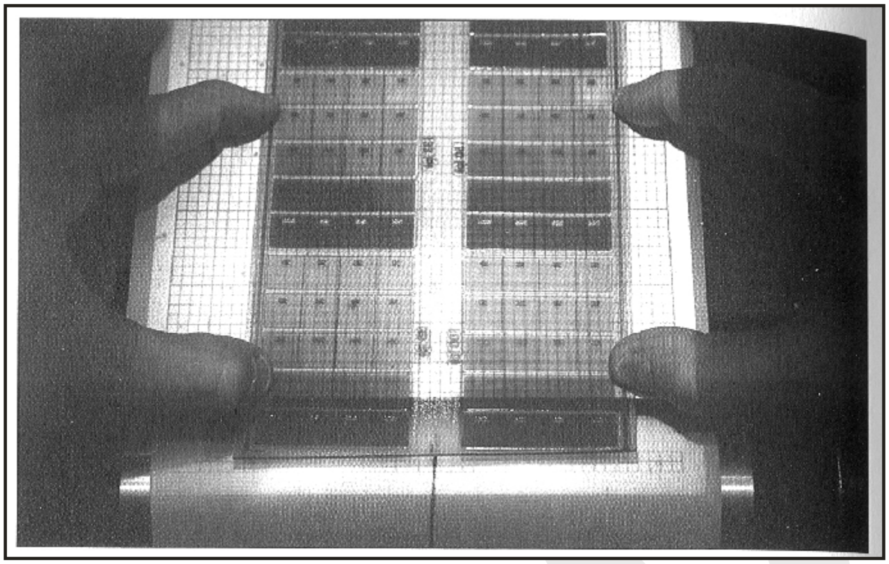


Figure 3.14 - A simple visual approach to mounting a plate

Devices called optical mounter-proofers have been used for many years. Two such mounters known by the names of their inventors, Harley and Mosstype (for Earl Harley and Samuel Moss), employ mirrors to enable the operator to line up the marks on the plate with a drafted position layout on the impression cylinder of the device.

The operator uses the drafting features of the machine to draw out the press/web layout. Then the operator inserts a print cylinder for one color into the machine and attaches a gear that in the “around the cylinder” position. If the plates are to be mounted three-around, after each plate is positioned the cylinder is turned exactly one third the circumference to mount the next plate. Each plate is positioned to hit exactly on the drafted lines.

To Check register, the plates are inked and an impression made onto the drafted sheet. After each cylinder is mounted it is inked and proofed, resulting in a paper-and-ink proof of the entire mounted job. The proof normally is checked both in mounting and the press department where it goes along with the cylinders for the pressrun.

Optical mounter-proofers require very skilled operators. It could take more than one shift to mount a six-color, complex job where many plates are involved. Bieffebi is another optical mounter-proofer based on the same principles.

Today these same “mounter-proofers” are often retrofitted with pin register systems or videoscopes to permit more critical alignment with far less skill and time. There are several retrofit options that permit modernizing older, yet still-valuable mounter-proofers. Figure 3.15 shows a typical mounter-proofer.

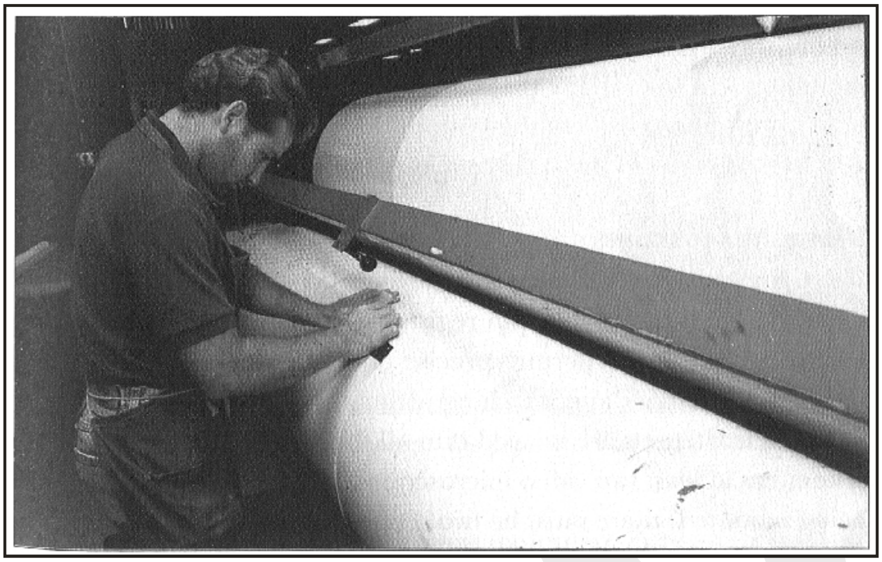


Figure 3.15 - A typical mounter-proofer

ii. PIN REGISTRATION SYSTEMS

The graphic arts industry has employed pins to align images for decades. Prior to sheet polymer plate materials, the use of register pins had to stop with the final film in the flexographic process. Today there are approaches using pins to line up images with play and plates with cylinders and carrier sheets.

Pin registration of images on film to the plate is achieved by drilling sheet photopolymer plate material with holes matched to holes in the final films. After back-exposing the plate material, the pins are placed through the holes and used to position the film during face exposure, just as is routinely done with litho plates. These same registry holes are then used for mounting onto the cylinders.

It is more common for plates to be made without regard to image position and then drilled for plate mounting with pins. This approach involves locating the imaged plate precisely using microscopes and tiny microtargets built into the image. Once positioned the plate is drilled for mounting. The plate is then located on pins, sometimes right on the cylinder or carrier. Pins are sometimes part a mounting device used to transfer the plate to the cylinder.

Figure 3.16 illustrates the concept of employing pins to position the plate for mounting. On the top the plate is precisely aligned and drilled with holes for register pins. On the bottom the plate is positioned on pin as it is transferred to the stickyback on the print cylinder.

Figure 3.16 - The pin-registration concept. The plate is drilled (top), hen pinned to the cylinder (bottom)

iii. VIDEO MICROSCOPES

Video microscopes represent the third approach. While these same tools are also used in some pin register systems, this concept by-passes drilling and simply permits precise positioning of the plate over the cylinder/carrier and attaching without any additional action. A pair of microtargets are imaged into all the plates. The mounting system has at least two video microscopes. If multiple plates are being mounted, there must be two scopes for each plate position. The plate is precisely located so the video crosshair is exactly on the microtarget. Once located, the plate is brought into contact with the stickyback. The position of the scopes is locked for all colors being mounted and documented for future mounting, or for remounting should a plate be damaged on press.

This is a very accurate and fast approach to mounting. It is so reliable that many printers no longer demand a proof from the mounted plates. This approach to mounting also has a perfect fit to modern digital prepress, which makes exact location of microtargets a routine part of the workflow. Figure 3.17 shows a Heaford videoscope plate register system. At the right the operator positions a plate while watching the monitor to see when it is perfectly aligned.

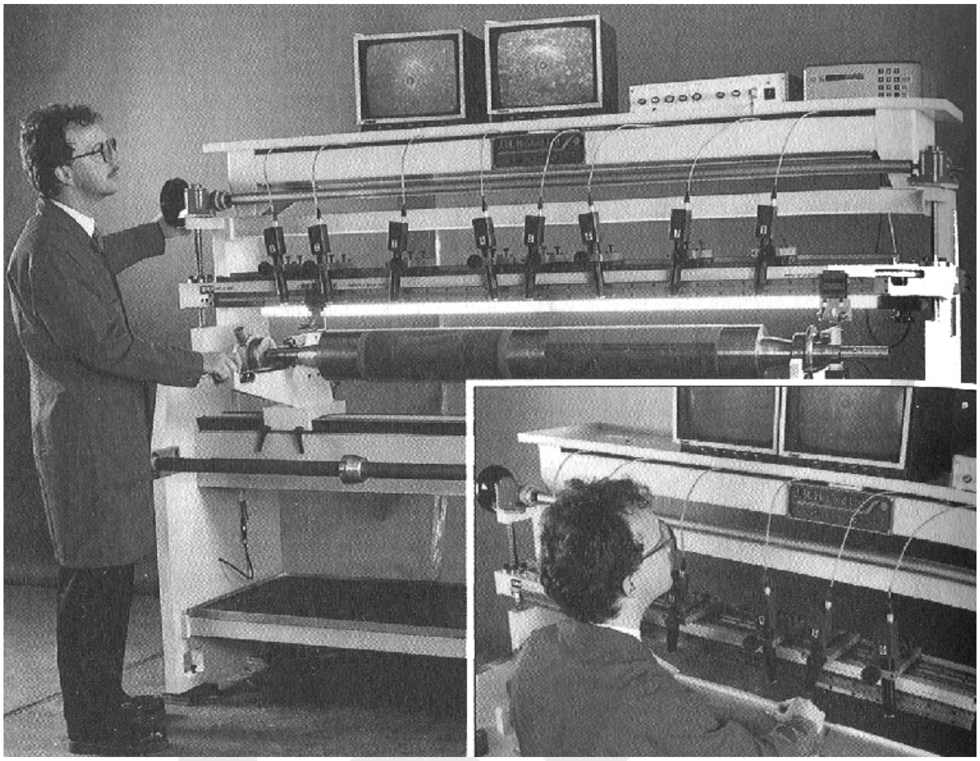


Figure 3.17 - Heaford videoscope plate register system

TYPES OF FLEXO PLATE CYLINDERS

There are three general cylinder approaches from which flexographers may choose when building their plate system. (See Figure 3.18.) They may be integral, demountable (small narrow-web examples shown), or lightweight sleeves.

Integral plate cylinders are the most expensive and, arguably, probably the most accurate and precise over their lifespan. The one-piece cylinder is made for a single repeat length, circumference, and has precision journals to hold gears and bearings. They are often unique to a given press. Since they are on piece, they have no tolerances for assembly and are subjected to le labor activity, meaning less chance for accidental damage.

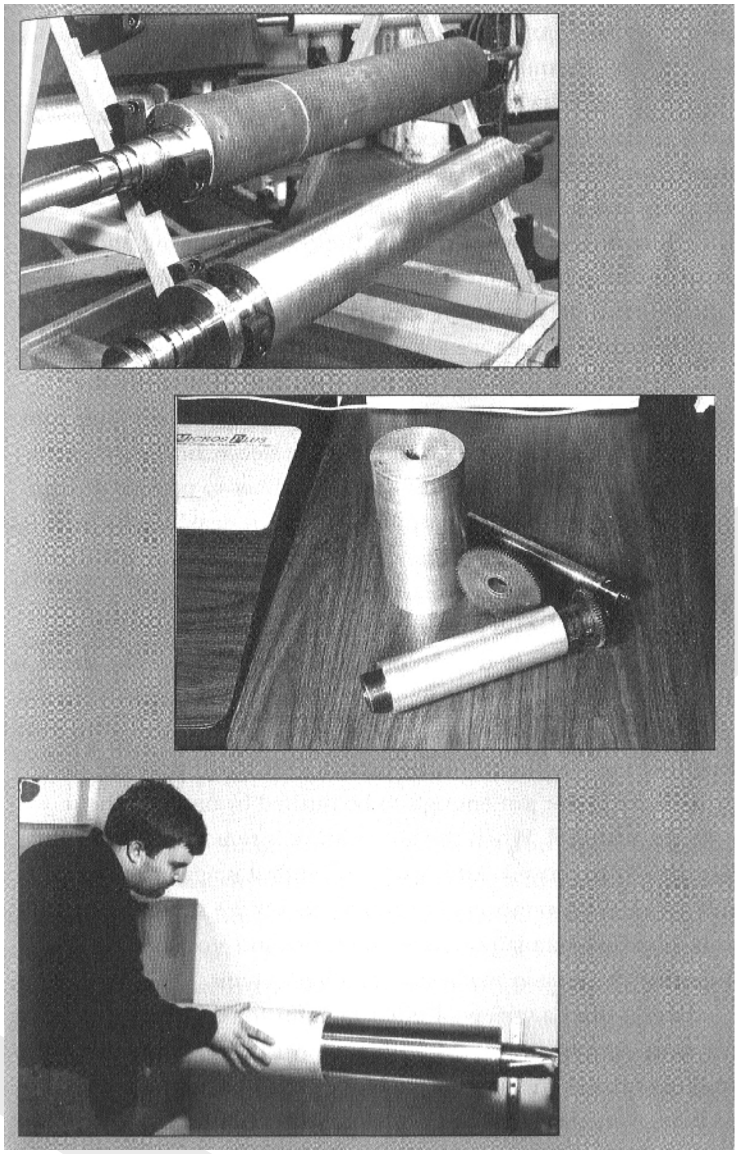


Figure 3.18 - Three different cylinder types: integral (top), demountable (middle), and Sleeve (bottom).

Demountable cylinder systems consist of a shaft or mandrel, art metal sleeves machined to specific repeat lengths. These steel or aluminum sleeves are installed for the specific job, and corresponding gears and bearings are installed at the time of mounting. Therefore only one set of shafts with precision bearing and gear journals is required for a wide variety of repeat lengths on a press. This system is the dominant approach in narrow-web applications,

Lightweight sleeves are a solution for the larger sizes of presses where the costs of cylinders are especially high and where the demount system still requires a lifting apparatus for handling. Jobs can be set up for mounting directly to the sleeve, or the sleeve may be covered with vulcanized and ground rubber to provide desired resilience qualities and to permit a range of repeat lengths from just a few mandrel diameters. Figure 3.19 illustrates how a single sleeve and mandrel size can accommodate a range of repeat lengths.

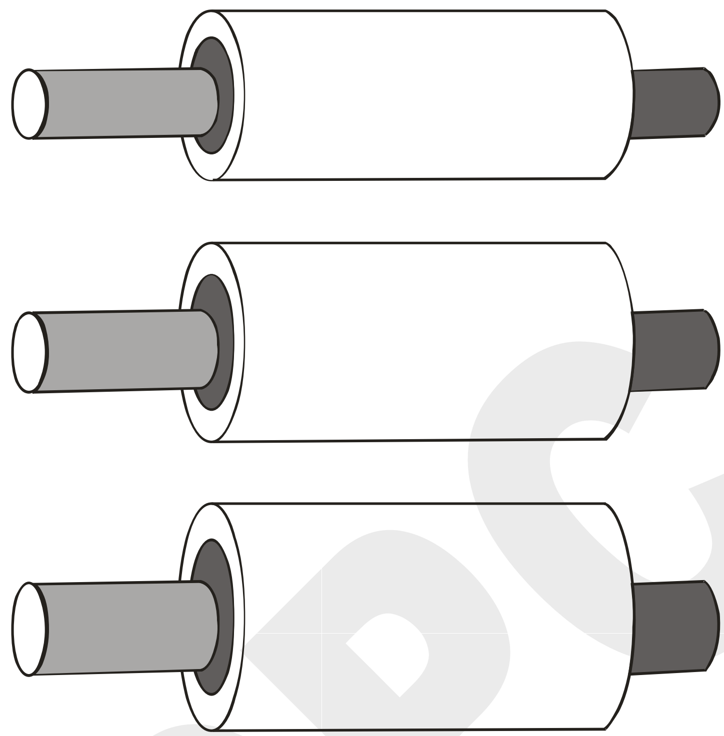


Figure 3.19 - A single sleeve and mandrel size can accommodate a range of repeat lengths.

To run light sleeves the press is equipped with hollow plate cylinder mandrels fitted with compressed air fixtures. The sleeve is slipped over the end of the mandrel by hand. Air is applied to the mandrel and passes through small holes positioned along the entire length of the mandrel. This air provides sufficient pressure to expand the sleeve just enough to be pushed by hand all the way onto the mandrel. When the air pressure is removed the sleeve is too tight to be moved. After use the mandrel is again pressurized and the sleeve is removed. Very large sleeves are still light enough to be handled manually, making their use and storage easy, and requiring the least in materials handling systems.

Sleeves offer a variety of other benefits for the creative. Among the most obvious advantages is the ability to leave jobs mounted for running on any one of a variety of presses. Jobs can be left mounted for reruns since less cost is tied up with cylinder inventory. This also results in substantial savings in plate mounting and in remaking plates damaged during removal and storage. Jobs can be mixed on a pressrun by mounting more than one narrow sleeve on a mandrel.

Where a converter runs repeat and standard items, this makes it possible to offer short runs without unrealistic waste of press capacity. They are also popular where continuous digitally imaged pattern rolls are used.

The sleeve allows much less expensive inventory of patterns for repeating jobs and costs of handling and shipping to the laser engraver are substantially reduced. Sleeves are also a convenient vehicle for trying out new plate thicknesses without investing in an inventory of cylinders. Since they can be easily built up to various thicknesses they are useful as tools for process improvement.

3.5. SLEEVE TECHNOLOGY, DIRECT LASER ENGRAVING

3.5.1. SLEEVE TECHNOLOGY

The principle of sleeve technology consists of a thin-walled metal sleeve, the inside diameter of which is dimensioned so that the sleeve can be expanded under compressed air and pushed axially onto the plate cylinder. Once the compressed air has been turned off, the sleeve sits firmly on the plate cylinder by force fit. Before being pushed onto the plate cylinder, the entire outer surface of this sleeve is covered with plate base material. The cylindrical plate is directly imaged using lasers in a round imagesetter. With this process the longitudinal extension that takes place during conventional mounting and the inaccuracies connected with the attachment of the block do not occur.

There are two modes of procedure for sleeve technology:

- Covering the sleeve with a laser exposable plate cut exactly to the size of its cylinder casing, in which case the sleeve has a seam.
- The use of seamless sleeves which have been already fully prepared by the manufacturer with the relief layer (e. g., BASF digisleeve).

3.5.2. DIRECT LASER ENGRAVING

In flexographic computer to plate systems for producing relatively soft rubber printing plates, the recessed, ink-free parts of the printing plate are removed directly by laser energy (*laser engraving*). The ablated particles are removed by suction. High-power lasers (such as 1–2.5 kW CO2 lasers) are used for this activity. The laser engraving of gummed rollers for continuous printing has been possible since the seventies.With the maturing of computer technology, computer to plate became available as early as the end of the eighties.

UV direct imaging is available as the “UV Laser Platesetter” from Napp Systems. By means of high-power UV laser light the polymerisation needed for producing the flexographic plate is carried out directly pixel by pixel.

LASER ENGRAVING ON RUBBER ROLLERS

The first direct-to-plate process was laser engraving rubber. In the process gum is vulcanized and precisely ground to final plate thickness. It is then mounted to a drum and rotated in front of a CO2 laser. The nonimage area is burned away leaving the image in relief and the plate ready for mounting (see Figure 3.20). Laser-engraved rubber plates have precisely controlled shoulder angle, and resolution as high as 120-line halftone screens can be produced. One of the most appealing applications of this technology is the production of continuous-pattern images. Conventional plates always leave a gap of line where the two ends of the plate come together on the cylinder. Continuous patterns are laser-engraved onto rubber-covered rollers. Rubber is vulcanized to roller bases and ground to the exact repeat length. This roller is then laser-imaged. Gift wrap and wall covering often require uninterrupted patterns, and laser imaging is a popular solution. This process also eliminates any plate mounting and the cost of potential register flaws that go with mounting.

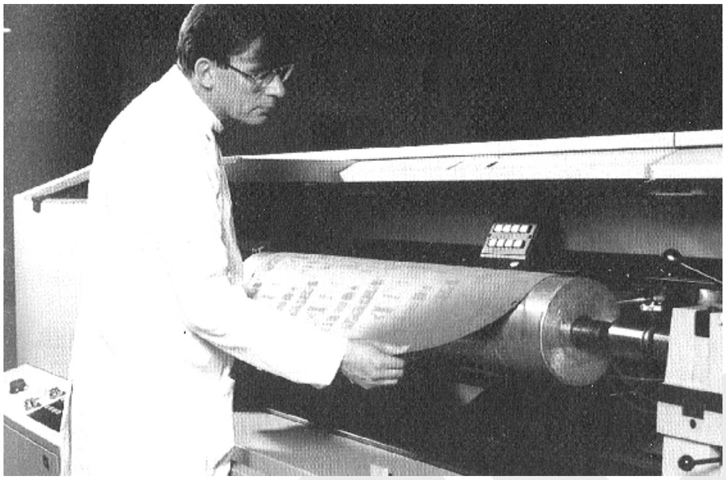


Figure 3.20 - Operator examining a laser-engraved rubber plate.

3.6. CORONA TREATMENT, FLEXO SUBSTRATES

SURFACE TREATMENT

Surface treating parts prior to printing ensures proper and complete ink adhesion and can often make the printing process run more efficiently. Some materials are impossible to print unless they have undergone surface treatment.

Materials having a low affinity for printing inks (low surface tension) can be modified to improve their printability. There are three general ways this is done.

3.6.1. CORONA TREATMENT

The most common method today is **corona discharge treatment**, which raises the printability by applying a high-voltage, high-frequency electrical charge to the web. Treatment levels fall off with time. Materials treated by the manufacturer for printability may eventually lose their treatment level to the point that they must be retreated before successful printing.

Wide-web printers of plastic bags and film laminates often have corona treaters on the infeed sections of their presses, allowing them to raise the dyne level immediately prior to printing. These treaters not only increase the surface area, but also burn away slip agents and dust, which further improves ink transfer and adhesion.

Surface treatment is frequently used in printing and other converting processes to alter the surface characteristics of a material. Treatment processes may be designed to improve a substrate’s wetting properties, which influence how well inks and coatings will flow out over the material’s surface. Treatments may also be used to enhance the bonding between the substrate and the applied material or eliminate static charges that have accumulated on the substrate surface. Surface-treatment technologies play a key role in preparing the surfaces of many commonly used packaging materials (paper, plastic, foil, etc.) for subsequent processing steps.

Most inks, paints, coatings, and adhesives resist wetting on the surface of virgin-plastic parts, which are newly thermoformed or molded items characterized by an inert, non-porous, low-energy surface. Virgin-plastic parts that screen and pad printers typically work with include items made from polyethylene, polypropylene, and other polyolefin's. These materials tend to be very slippery and feel greasy to the touch.

Another common method is **flame treatment**, whereby the web passes over gas burners which serve to clean and modify the surface resulting in improved printability.

The third approach is to apply a **printable coating**. This is most commonly done by the packagers of specialty pressure-sensitive laminates. The narrow web label manufacturer is called on to print a wide variety of specialty surfaces. The supplier to the narrow-web printer is a converter who buys these materials in large rolls, slits to the narrow-web sizes, applies adhesives to the back, and rewinds with a removable liner. This is the Simple structure of a pressure-sensitive label stock. These repackagers commonly apply printable clear coatings so the narrow-web printer can use his normal ink system.

Since there is a variety of materials and presses, the use of an in-line treater is often not practical or affordable. Narrow-web printers who specialize in certain nonporous substrate applications do treat or coat in-line to save on costs of special treating and packaging.

3.6.2. Flexo Substrates

Introduction

The materials on which we print are many and varied, due to the virtues and the versatility of the flexographic printing process. There is indeed almost no material which has not been or cannot be printed by it.

The kinds of materials on which we print are divided into several major groups as follows:

1. **Paper and paperboard stocks**
2. **Corrugated stocks**
3. **Films**
4. **Foils**
5. **Laminates**

1. PAPER AND PAPERBOARD STOCKS

Paper is made in many different weights and thickness and in a wide variety of densities and surface finishes. Thick papers are usually referred to as "paperboard". There is no definite point where paper becomes paperboard. The terminology usually depends on such factors as density, composition, end use.

"Basis weight" is the term used to define the weight of various grades of paper, referring to the weight of a ream of that grade.

Glassine

Glassine is paper made by prolonged "beating" or "hydrating" pulp, generally sulphite, down to a jelly-like consistency. The resulting sheet is very dense, and would be hard and brittle without the addition of softeners and plasticizers which act as lubricants to make the sheet more pliable.

Parchment Paper

Parchment papers are made by briefly immersing a web of unsized paper in a bath of sulphuric acid, then quickly washing out the acid.

Release-Coated Papers

Paper coatings with resin, lacquer or latex type binders are usually receptive to flexo inks, in fact, many enhance printability, although some coatings tend to decrease the absorbency of the paper surface so that ink trapping and drying problems are increased.

Paper Coating Material

Polyethylene is increasingly used as a paper coating material. If the polyethylene surface is to be printed, the same principles apply as in printing polyethylene films except that the paper adds dimensional stability and tensile strength. Polyethylene surfaces must be treated for a ink adhesion, and should be checked for such treatment prior to beginning the job.

2. CORRUGATED STOCKS

The printing surface of corrugated board has been almost exclusively of natural Kraft paper. Most of the basic recommendations for printing uncoated papers stock flexographically will therefore apply to the printing of corrugated board. There is also a growing demand for boxes whose printing characteristics have been altered by the use of various impregnating and/or coating materials to improve water resistance. These boxes are used to ship iced poultry, fish and these boxes are presently produced by several costly and separate operations.

3. FILMS

The following are types of films:

1. CELLOPHANES (plain and coated)
2. CELLULOSE ACETATE FILMS
3. ETHYL CELLULOSE
4. FLUOROHALOCARBON FILMS
5. METHYL CELLULOSE
6. POLYSTERS
7. POLYETHYLENE
8. POLYPROPYLENE

9. POLYSTYRENE
10. RUBBER HYDROCHLORIDE
11. VINYL CHLORIDE CO-POLYMERS
12. VINYLIDENE CHLORIDE
13. CO-POLYMERS

CELLOPHANES:

Cellophane is a clear, transparent, flexible, odourless, grease-proof, non-toxic, regenerated cellulose film widely used for packaging an endless variety of consumer products, and for miscellaneous other uses. Cellophane like paper is made from cellulose, of which the main source is wood. Cellophane is made by processing highly purified wood pulp into a transparent solution.

CELLULOSE ACETATE FILMS:

The group covered under the classification “acetate films” includes cellulose acetate, cellulose tri-acetate, and cellulose acetate butyrate. These are clear, transparent, odourless, tasteless, dimensionally stable films compounded from plasticized to the printer in thicknesses from 0.0005" to about 0.10".

Cellulose acetate films are relatively water proof, but are not at all moisture vapor proof.

ETHYL CELLULOSE:

Ethyl cellulose is a clear, transparent, flexible, odourless, tasteless, water-insoluble, heat-sealable film. The film may be produced in such a variety of modifications that it is difficult to give anything but a general description. Like the acetate films, only a small volume of ethyl cellulose film is printed.

FLUOROHALOCARBON FILMS:

This family of films, known by such trade names as ACLAR (Allied Chemical) and TEFLON (Dupont) are remarkably strong, chemically inert, flexible, thermoplastic, and possess several unusual properties of interest in some areas of the flexible packaging field.

Significant properties of these films include excellent clarity, zero water absorption, high tensile strength, non-flammability, high softening temperature, and very high chemical resistance, including little or no effect from most common acids, alkalis, solvents, oxygen, or ultra-violet exposure.

METHYL CELLULOSE:

Methyl cellulose is a methyl ester of cellulose, in film form, which is clear, transparent, odorless, tasteless, flexible, and water soluble. The latter characteristic would make its use advantageous in packaging “throw-in” packs of soaps, bactericides, etc., but very little of this type of film is printed.

POLYYESTER FILMS:

Polyester films are available in calipers ranging from a quarter of a thousandth of an inch (.00025") in thickness to as much as seven to ten thousandths.

1. As “metallic yarn” when vacuum metalized, laminated and slit into narrow widths.
2. As a tough surface laminate for paper paperboard, and foil, either clear or metalized, smooth or embossed,
3. Scuff panels on automobile doors.
4. Replacement for chrome decorative of functional panels.
5. Base for recording tapes.
6. As a tough, durable surface, or as a window in display packages requiring greater strength than available in other films.
7. Alone or laminated to other material for decorative paneling, shoes, pocket hooks, belts, lamp shades, etc.
8. For “boil-in” food pouches, permitting foods to be cooked in the package.
9. Vacuum packaging.

POLYETHYLENE:

Polyethylene is a thermoplastic, or heat softening resin formed by the polymerization of ethylene gas under high pressure and temperature. The polyethylene film or tubing extruded from this resin is relatively clear, transparent, odorless, tasteless, non-toxic, water and moisture-vapor proof, heat-sealable, elastic, durable and extremely flexible even at sub freezing temperatures.

Polyethylene resin, extruded into film form, is not printable until its surface is “treated” so that ink will adhere to it. Treatment adversely affects heat-sealability of polyethylene surfaces in proportion to the degree of treatment. Treatment can decrease tear and impact resistance of the film.

Polyethylene film is usually treated for printing in connection with the extruding operation by either of two methods. One of these methods called “flame-treatment” applies a carefully controlled gas flame to the surface of the film while the film is passing around as refrigerated roller to prevent it from softening due to the heat of the flame.

Polyethylene film to be printed varies between .0005" and 0.10" in thickness, with the most popular thickness range between 0.001" and .0015".

POLYPROPYLENE:

Polypropylene is so similar in apparent physical characteristics to some of the higher density polyethylene films that it is difficult to distinguish between them. However, polypropylene is superior to corresponding density polyethylene in grease resistance, gas transmission rate, impact, and tear resistance.

POLYSTYRENE:

Polystyrene is a clear, transparent, odorless resin formed by carefully controlled polymerization of highly purified styrene, sometimes known as vinyl benzene. As a film it is unplasticized, semi-rigid, semi-flexible, weak in strength, brittle, is easily attacked by ink solvents, and has poor heat sealing characteristics. Although it is a low cost material, it is rarely used as a film, a notable exception being the packaging of fresh tomatoes.

4. ALUMINIUM FOILS:

Aluminium foils are thin, continuous sheets or webs of metallic aluminium or aluminium alloys which may be flexible, semi-rigid, depending upon their thickness and temper or hardness. They may be unmounted metal or the metal foil may be supported by various films, paper, or paperboard, using adhesives, waxes, or plastics for bonding. Most aluminium foil used in the flexo printing and packaging industries ranges from .0002" in thickness to as much as .005" or .006".

Aluminium foil is made by hot or cold rolling aluminium goes in between hardened, polished steel rollers into progressively thinner gauges until the desired thickness is achieved.

Pure elemental aluminium and aluminium alloys are both used in making foils for packaging, depending mainly upon the desired properties, but practically all foils contain at least 97 percent pure aluminium.

The properties of aluminium foils are substantially those of the pure metal itself. It is non-absorbent, odor-free, non-toxic, completely opaque, and impervious to most solvents, oils, fats, waxes, foods and gases.

Aluminium foils are used in a wide range of familiar applications ranging from insulation through military packaging to gift wraps, household use, a wide variety of food packages and cigarette, ice cream, candy wrappers and the heavier gauge, more or less rigid “cook-in/severe-in” food containers. Foils which have been adhesive-mounted or wax-mounted to various papers and similar stocks are widely used for bags, packages, wrappers, cans and other containers, while the most complex laminated structures made with foil, papers, films, and plastics are finding increasing uses in pouches and assorted packages for all kinds of foods, drugs, and chemicals.

5. LAMINATES:

Laminates, rather than a single substrate, are used where product or end use requirements are such that they cannot be met by a single material. Further, these same stringent conditions may require a different ink than would normally be used for the surface of the laminated structure alone.

Since laminated materials are obviously more expensive than any of their single plies, waste is a much more important factor than in printing single webs. It is, therefore, important to keep waste to a minimum.

3.6.2. SUBSTRATES

There are hundreds of specific substrates printed by the flexo process. This discussion centers on the most common materials and attributes of substrates in general. It deals mostly with those attributes critical to printing. While there are many specific substrates, the printing attributes of this spectrum of materials and surfaces are relatively few.

Printing is a surface application of fluid; therefore, the important elements are appearance, including color, gloss, and smoothness, and receptivity to transfer and adhesion. The smoother the surface, the better the image resolution. The whiter and brighter, the better the range and color of the reproduction. The higher the affinity for ink, the easier the printing and the better the adhesion.

The substrate is the key determiner of the printing system and thus the key to the appearance, as well as structural performance, of the product. Decisions regarding substrate are determiners of final visual and thus market success.

A generic list of substrates commonly printed flexographically might include paper, paperboard, corrugated, films, laminates, foils, and metal. There are many specific types of papers with different weights and thicknesses, surfaces, strengths, and appearances for their particular end uses.

Paperboard is thick paper, used for the spectrum of packaging and specialty applications. Some paperboard is white throughout, but many packaging materials are only white on the surface where appearance is important. If you examine the inside of many cartons you will see the nonvisible side is brown if composed of natural kraft, or gray if made from a mixture of recycled cellulose wood fiber. These materials are often specifically engineered to provide superior strength.

Corrugated board is a structure formed of three liners: the inner and outer surfaces, and the fluted medium in the middle. The outer liner is the one with surface properties so critical to print performance. The corrugated middle layer is called the medium. Its purpose is entirely strength.

Films are commonly referred to as plastics. There are many films, but the most common are polyethylene, polyester, polypropylene, and PVC, known as vinyl. Films may be opaque or clear. Clear films are popular for the “no label look” used on clear glass and plastic containers and windows of cars and businesses.

Many films are manufactured with multiple layers. These can be used to get combinations of properties, like strength, barriers to moisture and oxygen, and appearance. Multilayer materials are produced by coextrusion and by lamination.

Coextrusion is achieved by heating and feeding different raw materials into separate chambers of the extrusion die. This actually creates the material in a multilayer form. **Lamination** combines more than one material, joining them by heat or adhesive. **Extrusion lamination** creates a multilayer structure by extruding a material onto a moving web.

Pressure-sensitive (PS) materials are laminates of a different type, Pressure-sensitive labels are coated with adhesive, peeled from the liner carrier, and applied to the product. Figure 3.21 shows the basic structure of pressure-sensitive material. The customer can specify the face stock, which may be virtually any type of paper or film. The adhesive may be very aggressive to stick on dirty or greasy surfaces or very weak to permit easy removal of the label made for temporary use.

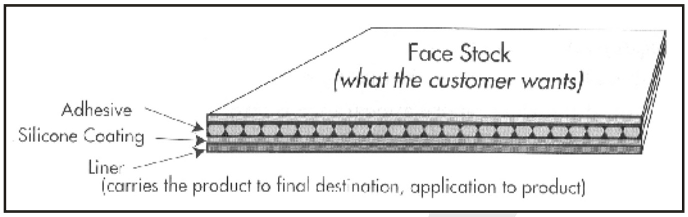


Figure 3.21 - The basic structure of pressure-sensitive material

The liner may be paper or film and is silicone-coated to prevent the adhesive from sticking, thus preventing easy transfer from the liner to the product. The narrow-web industry relies on a broad spectrum of PS substrates to serve needs from industrial to Consumer product labels and even stickers popular among the younger set.

Metal, usually in a very thin form **called "foil,"** is popular for its appearance and its opacity. It not only has the sheen and appeal of the metal look, but lends this to a spectrum of transparent colors when printed. It is also commonly used as a cover-up label because it is totally opaque. If a mistake is made in pricing, for example, a label with a layer of foil under the face stock is marked with the corrected price and placed over the error.

3.6.3. PROPERTIES OF SUBSTRATES USED FOR FLEXO PRINTING

PRINTABILITY

All substrates may be categorized as **porous (absorbent)** or **nonporous (not absorbent)**. Paper and paperboard substrates are porous. They absorb liquid and are easily printed with any type of ink system. They have a high affinity for liquid. This affinity for ink is known as surface tension. High surface tension means good printability. Dynes per centimeter is the unit of measurement of surface tension.

Substrate printability is rated by applying liquids of calibrated surface tension to the substrate. If the liquid has a surface tension of 40 dynes, and it wets a substrate that would not wet out with a liquid of 38 dynes, the substrate has a surface tension of 40 dynes.

Paper has such a high affinity for ink that it generally is not measured. Synthetic films and foils, however, are nonporous. They have a low affinity for liquids. Low surface tension means poor printability. If you wet a plastic bag or aluminum foil and shake it off, most of the water is gone. Unless specially treated for printing, films and foils have surface tensions—dyne levels—in the low thirties. In general surface tension needs to be above 38 to 40 dynes for printability by standard methods.

SMOOTHNESS

Another major factor affecting print quality is smoothness. The smoother the surface the better the imaging quality. Smooth surfaces require a minimum of ink to achieve required density and solid, uniform coverage. Minimum amount of ink are always best for clean printing of high-resolution images like fine screens, fine lines, and tiny type.

Paper manufacturers are continuously at work to achieve smoother surfaces on their papers to improve printability. The long-time measure of paper smoothness is the Sheffield. Brown kraft paper might have a Sheffield smoothness of 300, while a sheet of coated solid bleached sulfate (SBS)—a standard paperboard used in folding cartons-might measure 50. Coated offset paper for high-quality labels might have a Sheffield of 20.

A more recently developed tool is the EMVECO stylus-type smoothness tester. The fine point of the stylus is dragged over the surface. As it responds to the variations in that surface it plots them on a graph and calculates values for frequency and volume. It has been developed to provide a better prediction of printability.

GLOSS

Surfaces are also described by their level of shine. Described as glossy, dull, or matte, these qualities have considerable effect on quality of printed pictures. Smoothness and gloss are created by coating and calendaring or polishing.

Coatings are most commonly composed of clay and sometimes titanium dioxide. These coatings are used to fill the porous, fibrous surface of paper and paperboard. If they are further polished, they develop a very high sheen or gloss. The more glossy, the higher the apparent density and the longer the range of tones from black to white.

These surface attributes also relate to the visibility of smudges and fingerprints. Packaging and consumer items look “used” or handled when such smudges are visible.

WHITENESS AND BRIGHTNESS

An important substrate surface attribute is its whiteness and brightness. These two attributes are closely related but not the same. **Whiteness** is the degree which the surface reflects all colors of the spectrum. A perfect white would reflect 100% of the additive light primaries red, green, and blue.

Brightness is the quantity of the light striking the surface which is reflected. If a surface reflects all the incident light, its brighter than one that reflects only 85%. Reflectance is sometimes enhanced by fluorescing brighteners that reflect UV wavelengths. Since UV is at one point in the spectrum, these brighteners have an adverse effect on whiteness.

In general, substrates that are very bright also tend to be very white. Whiteness and brightness along with smoothness and gloss all are required for the highest quality color reproduction.

PICK RESISTANCE

The last surface attributes of particular importance to the flexo printer are cleanliness and strength or pick resistance. Lint and dust come from loose fibers in paper and clay coatings that are brittle and shatter when slit, either at the paper mill or in-line during printing and converting. These particles are frequently picked up by the flexo plate and show on repeating images as dirty print and voids or white specs. Certain substrates are very subject to these problems. Thin ink films show these problems even more than thicker films. For this reason some corrugated printers prefer printing more ink than ideal print quality would require.

The best solution, short of cleaner material manufacture, is the installation of cleaners in-line on the printing press. Varieties of electrostatic, mechanical, and vacuum devices are available for this purpose. Figure 3.22 shows the same sheet of corrugated board printed with low volume and with a more suitable volume of ink. The difference in appearance demonstrates the critical requirement of either cleaning or covering dusty board.

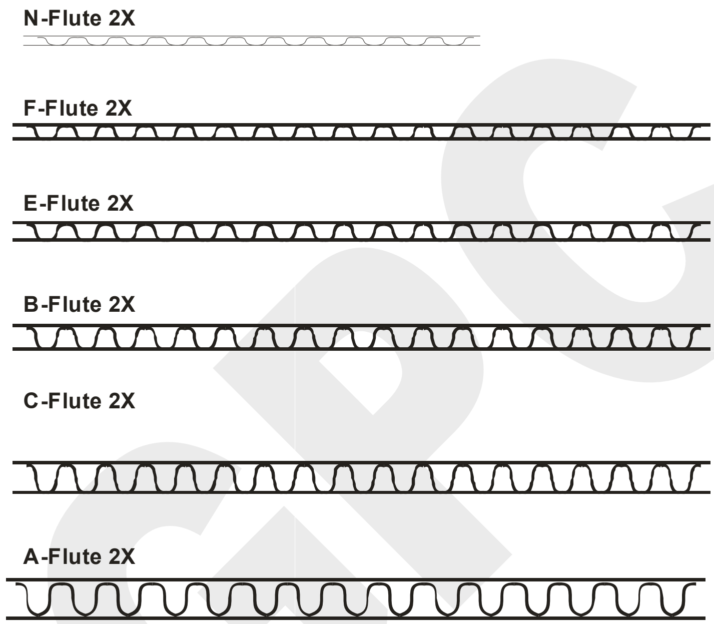


Figure 3.22 - Several different flute boards

Pick resistance is the strength of the surface, which keeps it front being pulled apart by the tack or stickiness of the ink. Since flexo uses a liquid ink, compared to offset and letterpress, tack is very low. This, and the ability to adjust viscosity, makes flexo a superior process to print on low-strength surfaces. This is why flexo is the choice for tissues and paper toweling, both of which are low in surface strength.

<u>THICKNESS</u>

The thickness of substrates is another attribute that can be of considerable importance in printing. Thickness of paper is specified in basis weight, the weight in pounds of 500 sheets of the basic size. Basic size is determined by the most common use of the paper. For example, bond or writing paper is most commonly used in 8½ x 11 inch sheets cut from the standard or basic size of 17 x 22 inch. One of the most common weights is 16-lb. bond. This means that 500 sheets of 17 x 22 inch paper weigh 16 pounds. 24-lb. bond paper is a thicker gauge, and 13-lb. bond is very thin. When a label printer orders pressure-sensitive label stock, the basis weight of the face stock and the liner must be specified.

Paperboard, on the other hand, is specified by gauge in points or thousandths of an inch. 10-pt. “board” is 0.010 in. (ten thousandths) thick. Small folding cartons may be as thin

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as 10-pt., while large cartons for packaging heavy objects may be 24-30 pt. (0.02-0.030 in.) thick. Linerboard used to make corrugated board is specified in still another method, weight in pounds per thousand square feet, Ib/msf.

Corrugated board is a structure. Its thickness is specified by flute design. The most common board for transporting consumer goods is B-flute. The boxes at the grocery store, for example, are B-flute (0.104 in. thick). Bigger boxes that carry heavier objects may be C-flute (0.146 in. thick), or A-flute (0.165 in. thick). Small containers may be E-, F- or N-flute (0.050 in., 0.030-0.045 in., and 0.015-0.025 in. thick respectively).

The thicker the board the larger the space between the flute tips and the more washboard the surface. When printing on C-flute it is common for the print to have dark lines along the flute tips where the board is thicker and harder.

The thinner the corrugated board the more level the surface and the less likely there will be objectionable flute marks in the print. The thin boards are very popular for retail packaging in warehouse and club stores. Due to the small fluting, they accept very high-quality graphics with screens commonly as fine as 100-120 lines per inch and even finer at times. This permits flexo printing directly on boards having high-holdout liners at quality levels to rival litho labels, which must be applied in a separate operation.

Figure 3.22 shows the actual size of A-, B-, C-, E-, F-, and N-flute boards. This makes it easy to see how corrugated converters would be seeking markets that have been folding carton or paperboard markets in the past. Corrugated has superior strength, especially when stacking packages, compared to paperboard. The thin corrugated board is now being printed on sheetfed offset presses configured for heavy paperboard printing applications.

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UNIT: III – FLEXOGRAPHY PRINTING

PART - A - 1 Mark Questions

1. Name the different flexo inking systems.

i. Two-roll ink metering systems
ii. Modified two-roll with a doctor blade ink metering system
iii. Reverse angle doctor blade ink metering system
iv. Chambered doctor blade ink metering system

2. Name the anilox cell shapes used in flexo printing.

i. Inverted pyramid shape cells
ii. Quadrangular shape cells
iii. Trihelical shape cells

3. What are the various anilox rolls available based on roller surface?

i. Laser engraved ceramic anilox rolls
ii. Conventional or Mechanical engraved chrome anilox rolls

4. Name the different layers of sheet photopolymer plates.

i. Stable base or substrate layer
ii. Light sensitive photopolymer layer
iii. Removable cover sheet layer

5. State the purpose of Corona treatment.

Corona treatment is done to eliminate static charges that have accumulated on the substrate surface. This treatment raises the printability by applying a high-voltage, high-frequency electrical charge to the web.

6. What is a sleeve?

Tubular component that can be mounted on a mandrel, sleeve cylinder is an alternative to an integral or one piece cylinder.

7. Name the various Flexo plate alignment systems.

i. Optical plate alignment systems
ii. Register pins plate alignment systems
iii. Videoscopes and Microtargets plate alignment systems.

8. Define Cell count of flexo anilox roller.

Cell count refers to the number of rows of cells per linear inch. A cell count of 180 would be very coarse, found only in coating or low-end imaging applications. A cell count of 360, once considered fine, is now a middle-of-the-road roll used in good work. Today cell counts of 700 and above are commonly used for very high-quality imaging on smooth, high-holdout (not absorbent) substrates.

9. Define Cell depth of flexo anilox roller.

Cell depth is the next specification and is just as important as cell count. These two specifications determine cell volume, which is the determiner of density in a given application. When specifying an anilox roll determine the cell count and volume to do the job and leave the depth to the anilox supplier.

10. Define Cell volume of flexo anilox roller.

Cell volume is the key to coverage and uniformity of solids. More volume results in more ink and, thus, better coverage. However, too much volume of ink also results in dirty print. High-resolution images require high-line, low-volume anilox rolls. It is common to demand at least 3½ to 4½ times more cells on-the anilox than the lines per inch in the halftone.

11. What are the various anilox roll cleaning systems?

i. Jet wash type System
ii. Powder blasting system
iii. Polymer bead blasting system
iv. Dry ice system
v. Laser cleaning system
vi. Ultrasonics
vii. Alpha sound

12. Name the various technologies available for mounting flexo plates.

i. Plate mounting using optical devices.
ii. Plate mounting using pin registration systems
iii. Plate mounting using video microscopes and microtargets.

13. What are the advantages of direct laser engraving of flexo plates?

Laser-engraved rubber plates have precisely controlled shoulder angle, and resolution as high as 120-line halftone screens can be produced. One of the most appealing applications of this technology is the production of continuous-pattern images. Conventional plates always leave a gap of line where the two ends of the plate come together on the cylinder. Continuous patterns are laser-engraved onto rubber-covered rollers. Gift wrap and wall covering often require uninterrupted patterns, and laser imaging is a popular solution. This process also eliminates any plate mounting and the cost of potential register flaws that go with mounting.

14. Draw the structure of multiplayer sheet photopolymer plates.

Multilayer sheet photopolymer plates for high-quality halftone printing are structured as shown in figure 2.3-7b. In their structure they combine the principle of relatively hard thinlayered plates with a compressible substructure. The base layer itself forms a compressible substructure for the relief layer and consequently absorbs deformation during printing; the image relief remains static, however. The stabilization film ensures that virtually no longitudinal extension occurs as a result of bending during mounting of the flat plate on the impression cylinder.A comparable improvement in print quality is also achieved when thin single-layer plates with compressible cellular film are stuck onto the plate cylinder.

15. State the different modes of procedure for flexo sleeve technology.

There are two modes of procedure for sleeve technology:

- Covering the sleeve with a laser exposable plate cut exactly to the size of its cylinder casing, in which case the sleeve has a seam.
- The use of seamless sleeves which have been already fully prepared by the manufacturer with the relief layer (e. g., BASF digisleeve).

16. Name the different types of substrates used for Flexographic printing.

The kinds of materials on which we print are divided into several major groups as follows:

1. Paper and paperboard stocks
2. Corrugated stocks
3. Films
4. Foils
5. Laminates

GLOSSARY

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.

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.

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 moistureproof, etc. Cellophane gained widespread use in the early 1930s and is credited with helping the flexo printing process to flourish.

Corona Treatment

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

Doctor Roll

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

Extrusion

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

Gear Marks

A defect in flexographic printing appearing as uniformly spaced, lateral variations in tone corresponding exactly to the distance between the gear teeth.

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.

Laminate

1. A product made by bonding together two or more layers of material or materials;
2. To unite layers of materials with adhesives.

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.

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.

PART - C: 12 Marks Questions

1. Explain the different types of flexographic inking systems with necessary diagrams.
2. Describe the various types of anilox roll cells with suitable sketches. Write about the anilox roll cleaning systems.
3. Explain the various considerations to be made while selecting suitable anilox rollers.
4. Describe the structure of flexographic plates with necessary sketches.
5. Explain the various Flexographic plate mounting techniques.
6. Describe the direct laser engraving of flexo plates. Write about the principles of sleeve technology.
7. Explain the various substrates used for flexo printing.
8. Describe the Corona treatment process.
9. Write short notes on (i) Anilox roller (ii) Sleeve Technology (iii) Flexo substrates.

UNIT - IV – GRAVURE PRINTING

4.1. STRUCTURE OF GRAVURE CYLINDER

Gravure Cylinder

The quality of the final gravure image depends first on the construction of the cylinder. Almost all cylinder cores are made from steel tubing. Some packaging printers prefer extruded, or shaped, aluminum cores because they are much lighter, less expensive, and easier to ship than steel. A few companies use solid copper cylinders, but steel remains the most popular core material.

A steel cylinder is used when printing with adhesives or other corrosive materials. In most gravure printing, however, a thin coating of copper is plated over the steel core of the cylinder to carry the image. Copper is easier to etch than steel and can be replaced easily when the job is finished.

Parts of Gravure Cylinder

There are five important parts to identify on a gravure cylinder (figure below).

- Axis
- Shaft
- Diameter
- Circumference
- Face length

The **axis** is the invisible line that passes through the center of the length of the cylinder. The **cylinder shaft** is the bearing surface as the cylinder rotates in the press. If you look at the end view of a cylinder, the shaft appears as a circle. The **diameter** is the distance across the circle, through the center of the shaft. The **circumference** is the distance around the edge of the end view. The **face length** is the distance from one end of the cylinder to the other, along the length of the cylinder.

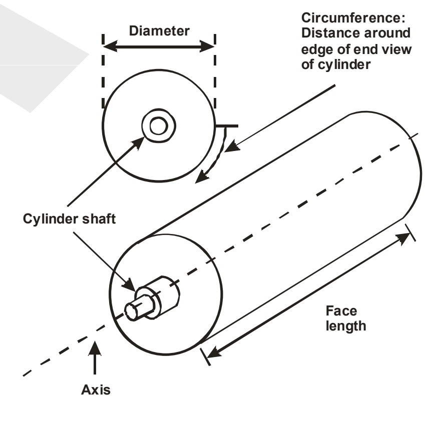


Fig. Parts of a gravure cylinder.
The most commonly identified parts of a gravure cylinder are axis, shaft, diameter, circumference, and face length

The face length of the cylinder limits the width of paper to be printed. The circumference limits the size of the image. One rotation of the cylinder around its circumference is called one impression. Continuous images can be etched on a cylinder without a seam so the design is repeated without a break. Wallpaper designs are commonly printed by gravure.

Gravure cylinders are built using many different sizes. The face length is always the same for each press to match the press sheet size but varies in diameter and circumference to closely match the cut-off size of the specific job. There are two basic cylinder designs (figure below).

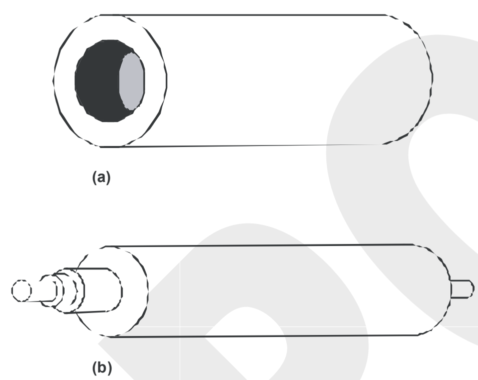


Fig. Two forms of gravure cylinders.
There are two basic forms of cylinder construction: mandrel (a) and integral shaft (b)

- **Mandrel**
- **Integral shaft**

A **mandrel cylinder** (sometimes called a sleeve or cone cylinder) is designed with a removable shaft. Most holes are tapered so that the shaft can be pressed into place and then removed easily.

In the **integral shaft design**, the shaft is mounted permanently on the cylinder. The cylinder is formed first, and then the shaft is either pressed or shrunk into place. The shaft is attached permanently by welding and remains in place for the life of the cylinder.

Integral shaft cylinders are more expensive than mandrel cylinders but are generally considered to produce high-quality images. This is because they produce greater support across the length of the cylinder during press runs than hollow mandrel cylinders.

Copper Plating and Polishing

Electroplating is the process of transferring and bonding very small bits (called ions) of one type of metal to another type of metal. This process takes place in a special liquid plating bath. The ions are transferred as an electrical current passes through the bath. The longer the current flows, the more new metal that is plated to the cylinder.

The first step in the gravure electroplating process is to clean the surface of the cylinder thoroughly. The cylinder is cleaned by brushing or rubbing it with special cleaning compounds and then rinsing it with a powerful stream of hot water. Some plants use special cleaning machines for this purpose. The goal is to remove all spots of grease, rust, or dirt so that a perfect coating of copper can be applied over the entire cylinder surface. Cylinder areas that will not be plated. such as the ends, can be coated with asphaltum or other staging materials, which covers and protects its clean surface.

To electroplate a cylinder, the cylinder is suspended in a curved tank and rotated through the plating bath (figure below). The electrical current is allowed to flow from the copper anode (the plating metal) through the bath to the cylinder (base metal). Zinc sulfate, copper sulfate, or cyanide solutions are common plating-bath liquids. Six-thousandths of an inch (0.006 inch) to thirty-thousandths of an inch (0.030 inch) is the common thickness range for the copper layer on a gravure cylinder.

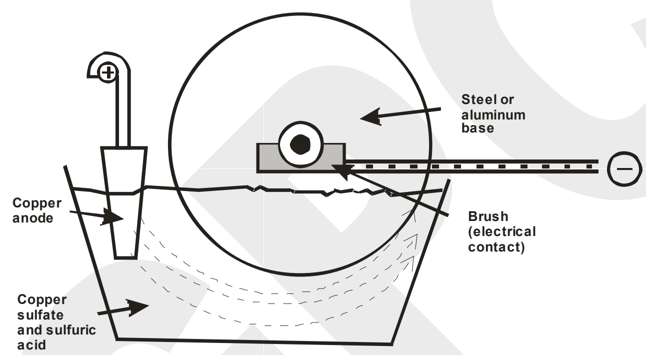
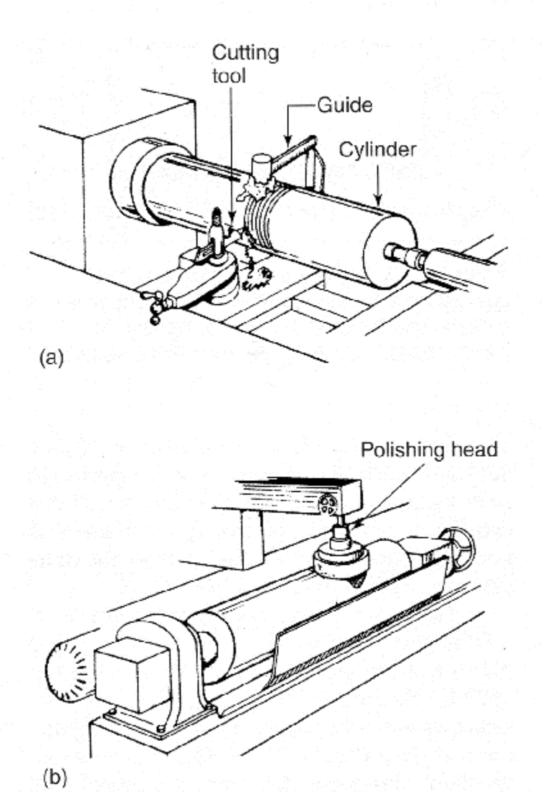


Fig. Diagram of the electroplating process.
An electrical current passes from the copper anode through the plating solution to the steel or aluminum cylinder until the desired thickness of copper is plated on the cylinder.

A newage gauge is a device used to test the hardness of copper. Copper hardness is measured by pushing a diamond point into the copper surface. The diagonal length of the opening created by the diamond point is measured and then compared with the amount of force required to push the diamond into the copper. The result is expressed in diamond point hardness (DPH). Most printers look for a DPH between 93 and 122.

The last step in constructing a gravure cylinder is to bring the diameter (and circumference) of the cylinder to the desired size and at the same time create a perfect printing surface. The cylinder must not only be round and balanced perfectly, it must also be perfectly smooth and uniform across its length. If the cylinder is not uniform, the doctor blade will not be able to remove excess ink from the nonprinting surface.

The newly plated cylinder is mounted in a lathe and prepared for final turning. Some plants use a diamond cutting tool to bring the cylinder into rough dimensions; they then use separate grinding stones to polish the cylinder’s surface (figure below). Other plants use specially designed precision machines that both cut and polish the cylinder at the same time. With these machines, cylinders can be cut within one ten-thousandth of an inch (0.0001 inch) of the desired size and surface. After the final turning, the cylinder is ready for image etching).



Final turning of a plated cylinder. (a) The cylinder is first cut to rough dimensions. (b) Then it is ground or polished to final size.
Courtesy of Southern Gravure Service.

Reusing Cylinders

Gravure cylinders can be reused many times. One way to reuse a cylinder is to cut away the old image on a lathe. This involves removing only two-thousandths to three-thousandths of an inch of cylinder surface. The cylinder is then replated with copper and recut or reground to its original diameter.

Another way to reuse a cylinder is to simply dissolve the cylinder's chrome coating (added as the final step in cylinder preparation to protect the soft copper on the press) and to then plate over the old image with new copper. The replating process fills the image areas above the original cylinder surface. Excess copper is then cut or ground away, and the cylinder is returned to the desired diameter size.

Ballard Shell Cylinders

The Ballard shell process is a special technique used by some publication printers that allows easy removal of a copper layer after the cylinder has been printed. The cylinder is prepared in the usual manner, including copper plating, except that it is cut twelve thousandths to fifteen-thousandths (0.00012 to 0.00015) of an inch undersize in diameter. The undersized cylinder is coated with a special nickel separator solution and is returned to the copper plating bath. A second layer of copper is then plated onto the cylinder over the first layer. The cylinder is then cut or ground to the desired size, given an image etch, and printed.

The difference between most gravure cylinders and Ballard shell cylinders is seen when the cylinder has been printed and is ready to receive another image. The second copper layer can be simply ripped off the ballard shell cylinder base. A knife is used to cut through the copper to the nickel separator layer, which allows the shell to be lifted away. The cylinder can then be cleaned, a new nickel separator solution can be applied, and another shell can be plated to receive the image.

EXTRA

GRAVURE CYLINDER

With the exception of sheet-fed gravure printing, which is now found only rarely, web-fed gravure printing requires a gapless *gravure cylinder*,onto which the image is applied directly,by means of etching or engraving. For this, the cylinder must be prepared in a costly mechanical and galvanic process.

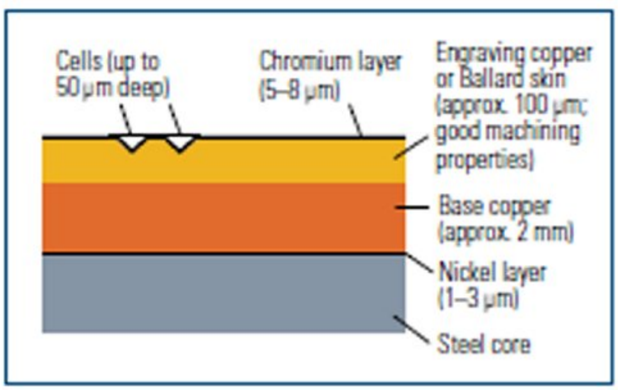


Fig. 1.3-12 Structure of a gravure cylinder

In its basic design, the gravure cylinder consists of a thick-walled steel tube with flanged steel journals. To increase the stiffness of this hollow cylinder, some of the cylinder journals are drawn inwards and are supported inside the tube on additional steel discs. All of these joints are welded during the manufacture of the gravure cylinder so that a solid roller body is created, which still has to be balanced so that there are no vibrations when running at high speed (typically up to 15 m/s) in the printing press.

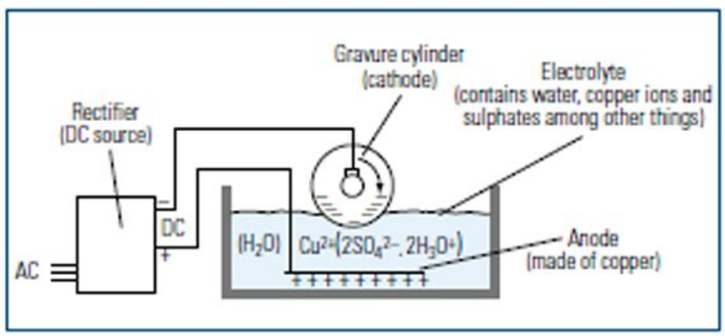
The cylinder receives a base copper layer on its surface, which, among other things, serves to achieve the specified diameter of the finished gravure cylinder. For the application of another copper layer (figs. 2.2-3 and 2.2-4), which varies from print job to print job, there are several methods that are described in the following sections [note: the top copper layer is twice as hard (Vickers hardness approximately HV 200) as the base copper, so that this copper layer has good cutting properties as regards the electromechanical engraving process]:

<u>Various methods of copper plating the Gravure Cylinder</u>

<u>• *The thin layer method* (fig. 2.2-4a):</u>

The base copper layer is coated with an engravable copper layer (approximately 80 µm) in an electroplating process (fig. 2.2-3). This thin layer only allows a one-time engraving. The advantage of the thin layer technique is that all the gravure cylinders of one type have the same diameter dimensions and less mechanical surface treatment is required after the electroplating process than with thick layer processes (see below). The removal of the engraving (after dechroming) is achieved by dressing or milling the copper. After this, a new copper layer is applied. (In the special process known as copper recycling, the copper layer is removed in an electroplating reversal process. In this process, an additional nickel barrier layer of approximately 25 µm between the base copper and engraving copper is necessary.) The thin layer technique is used in some 35% of cases, whereby the copper recycling method only accounts for some 5%.

Fig. 2.2-3
Electroplating of a gravure cylinder; the copper ions Cu^{2+} settle down on the cathode (gravure cylinder) and form a copper layer



<u>• *The Ballard skin method* (fig. 2.2-4b):</u>

This method is also a thin layer process (one-time use of the engraving copper layer). The base cover is electrically covered with a removable copper skin (80–100 ¼m), whereby a special layer between base copper and Ballard skin ensures that the Ballard skin can be peeled off the gravure cylinder after printing. The Ballard skin method is employed in approximately 45% of cases.

<u>• *Heavy copper plating (thick layer technique*; fig. 2.2-4c):</u>

An approximately 320 ¼m thick layer of engraving copper is applied onto the base copper in an electroplating process. This thickness of the layer permits engraving for approximately four print jobs. After each print job, a layer of approximately 80 ¼m is removed in a multi-stage mechanical process (milling, grinding). The former image is thus removed. When the engraving copper is used up, a new copper layer (hard) is applied by means of electroplating. This method is employed in about 20% of cases. With all methods the cylinders are always *hard chromeplated* after etching or engraving to reduce wear and tear. Therefore chemical chrome deplating with hydrochloric acid must be undertaken prior to removal of the image carrying layer.

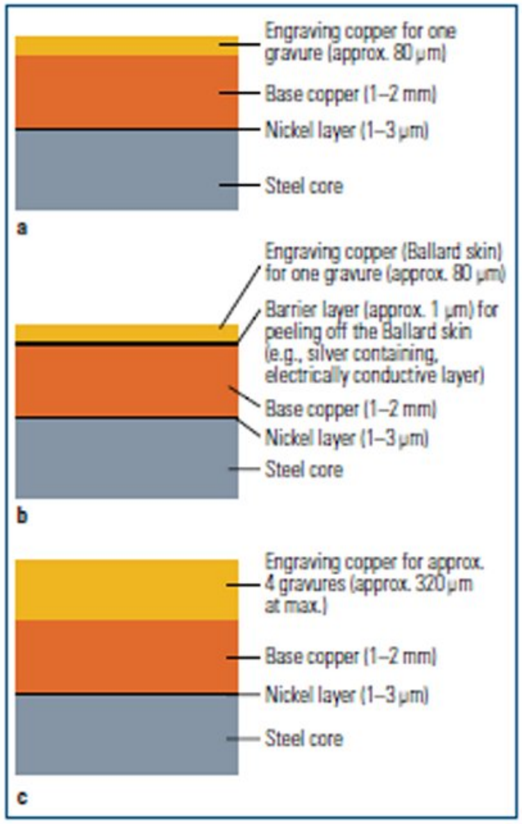


Fig. 2.2-4
The various methods of copper plating the gravure cylinder.
a Thin layer method;
b Ballard skin method;
c Thick layer method

<u>The *process sequence for preparing an engraving cylinder* is generally as follows:</u>

- removing the used gravure cylinder from the gravure printing press;
- washing the gravure cylinder to remove residual ink;
- removing the chrome layer;
- removing the copper image-carrying layer, either chemically, by means of electroplating, or mechanically;
- preparing the copper plating process (degreasing and deoxidizing, applying the barrier layer if the Ballard skin method was employed);
- electroplating;
- surface finishing with a high-speed rotary diamond milling head and/or with a burnishing stone or a polishing band;
- etching or engraving (producing the image on the gravure cylinder);
- test printing (proof print);

- correcting the cylinder, minus or plus (i.e., reducing or increasing the volume of cells);
- preparing the chrome-plating process (degreasing and deoxidizing, preheating, and – if necessary – sometimes polishing);
- chrome-plating;
- surface-finishing with a fine burnishing stone or abrasive paper;
- storing the finished cylinder or installing it directly in the gravure printing press.

Today, all these operations are performed, more or less fully automated, in production lines, whereby overhead traveling cranes and in some cases the transportation of the gravure cylinder from station to station is carried out by automated guided vehicle (AGV) systems.

4.2.1. GRAVURE DRYING SYSTEM

The ink used for gravure printing has a low viscosity, so that the ink in the cells can run out properly and be transferred onto the paper. This low viscosity is principally achieved by using a high proportion of *solvent* with low boiling point in the ink. To dry the printed ink, the solvent must evaporate in a high velocity air dryer after leaving the printing nip.

Previous systemss, such as counter flow/parallel flow drying systems and heating drums are no longer used. Today, *high-velocity nozzle dryers* are used. Radial fans route the air in pipes fitted closely above the web and equipped with circular or slot nozzles. The air hits the web vertically, and thus the fresh print. The effect of the impact turns the air around by 180° and returns between the pipes back to the radial fans to be fed back to the nozzle pipes. In front of the radial fans, a part of this circulated air is branched off and routed into a solvent recovery unit in order to prevent the concentration of solvents in the ambient air from rising strongly. This proportion of air is automatically replaced by fresh air or ventilation air.

In many cases, the modern high-velocity nozzle dryers can operate without the need for heating the air – air at room temperature is sufficient for the slightly volatile Toluene (solvent) to evaporate from the ink; the air is slightly heated due solely to its friction by circulation. If an additional heating unit is required, this is installed behind the exhaust of the radial fan.

Since not only the speed at which the air emerges from the nozzles, but also the length of the dryer plays a decisive role in determining the effectiveness of drying and therefore the maximum production speed (typically 15 m/s) of the gravure printing press, the dryers are placed on both sides and surround the entire printing unit. Therefore, the term “drying hoods” is often used. Depending on the type of solvent used, shorter drying units, which do not surround the entire printing unit, are sufficient (fig. below).

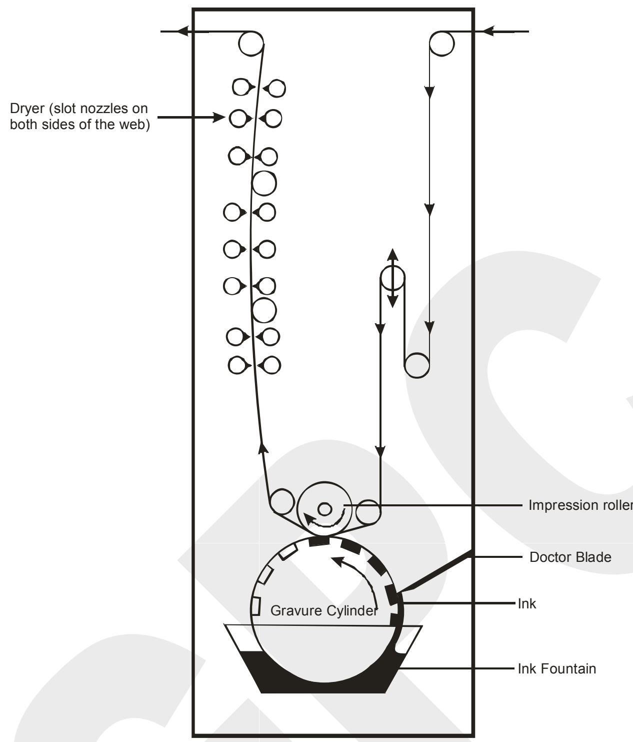


Fig. Dryer with slot nozzles

The paper web is blasted wit air on the front and reverse side from the slot nozzles because some of the solvent penetrates through the paper to the reverse side.

The solvent (normally *Toluene*) must be recovered for environmental and financial reasons. The solvent recovery unit consists of large vessels that are filled with activated carbon and through which the air charged with solvent is routed. In this process the solvent settles down on the activated carbon, whereby the air is freed from the solvent and simultaneously cleaned in an environmentally sound way. In order to release the solvent from the activated carbon for re-use, steam is sent through the activated carbon vessels in the “reversal process,” which washes out the solvent. Since the solvent has a lower specific gravity compared to water, it can be easily separated from condensed steam,as it separates itself from the mixture onto the surface.

4.2.2. Gravure Drying Chamber

As we use liquid ink in gravure press, it has to be dried before getting in to next unit or color. So it necessary to dry gravure printed substrates to avoid trapped odors and setoff etc.

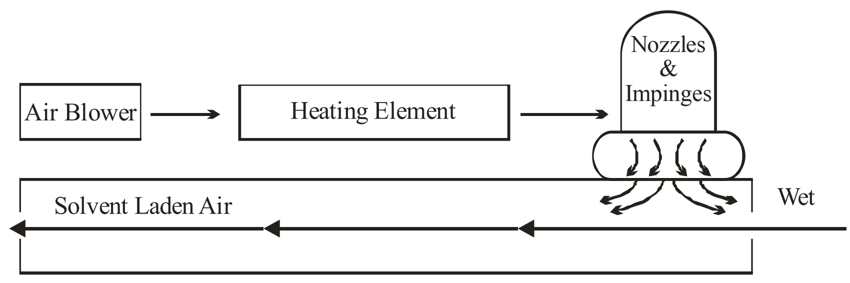


Fig : Drying System

Heat is applied over the substrates to evaporate the solvent from the ink. This heat is not only sufficient to dry the web. Because more heat will cause the web shrinkage and loss of detail. Heating is coupled with air of high velocity.

A fan is provided in a blower, which will blow the high velocity air through heating elements. These heating elements may be stream, electricity and gas. Now the mixed heat and air is passed or forced through the nozzles and impinges with a high velocity of about 4000 cubic feet per minute on to the web for effective ink drying.

From the dryer 50% air is sucked by blower and the remaining is vacated by exhausted fan. Now the same amount of the fresh air is passed to blower sucker whatever the exhausted air sent to atmosphere.

Gravure ink solvent is highly inflammable and become explosive when mixed with air in certain proportions. So minimum 10000 cubic feet of fresh air is added to 1 gallon of solvent evaporated in the dryer.

Each dryer has an exhaust duct containing a damper to control the amount of air exhausted and consequently the amount of fresh air is drawn in to the dryer.

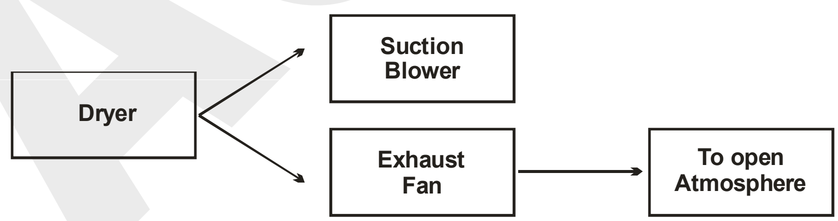


Fig : Process Flow in Dryer

The heat controls should be set to obtain adequate drying at the lowest possible temperature. 140 – 1500 F is ideal for cellophane or other plastic materials. 170 – 180 for paper and board. Following are the dryers used for different application

- Semi-Extended Dryer
- Extended Lacquer Dryer
- High Heat Flexo Graphic Dryer

All dryers' uses air as a heat transfer medium for varying types of inks, coating and liquids. In certain specialized job for drying and heating, infrared (IR), Ultraviolet (UV), Radio Frequency (RF), Microwave (MW) and Electron Beam (EB) drying methods are used.

4.2.3. GRAVURE SOLVENT RECOVERY SYSTEM

Solvent recovery system removes solvent fumes from- the dryer exhaust air and collects the solvent for reuse. Solvent recovery systems are excellent for multiple press operations where the solvents be selected for easy recovery and reuse. Publication gravure liters use solvent recovery systems almost exclusively. The recovered solvent costs only a fraction of the cost of new solvent and helps to offset the cost of the solvent recovery equipment.

Solvent recovery for packaging and product gravure operations more difficult because of the variety of solvents used in the ink and coating formulations. Recovered solvent requires further treatment before it can be reused. This often increases the cost above the cost of new solvent. Solvent recovery is very rarely cost effective for packaging and product printers running multiple solvents.

The purpose of a solvent recovery system is to remove evaporated solvents from dryer exhaust air and the press room air and collecting the solvent for reuse. During the recovery process, the solvent undergoes a number of transformations, described below.

Solvent-laden air is drawn from the dryer by large fans. The air is channeled through duct work to one or several adsorbers beds of activated carbon pellets. The pellets adsorb the solvent as the air forced through them. The cleansed air passes out of the adsorber and into the atmosphere.

After the carbon bed is reasonably saturated with solvent, steam is forced into the adsorber. This drives the solvent vapor backout of the carbon and into the steam.

The solvent vapor-steam mixture is then cooled and condensed into a liquid state. When this mixture is piped into a decant tank, the solvent and water separate into distinct layers solvent is lighter than water). The solvent is siphoned off the top into a collection tank, from which it is returned to solvent storage or reuse. The water layer is removed to a collection tank for disposal or reuse.

The nonpolar solvents used in publication gravure are essentially not miscible with water. Thus, the recovered solvent is water-free and can be reused directly. The recovered water, however, may contain traces of solvent which have to be removed by air stripping or liquid phase carbon adsorption.

Packaging and product gravure operations use polar solvents or mixtures containing polar solvents. These are atleast partially miscible with water, and does the recovery solvent contains water and the decant water condensate contains solvent. The degree to which the water has to be removed from the solvent before reuse depends on the nature of the solvent, and the ink system's tolerance for water. Purification of decant water is governed by the method of disposal and local regulations.

Solvent recovery is appropriate for multiple press operations where solvents are necessary, and where the solvents can be selected for easy recovery and re-use as a recovered mixture. The cost of the recovered blend, which can be reused with little doctoring, is only a fraction of the cost of buying new solvent.

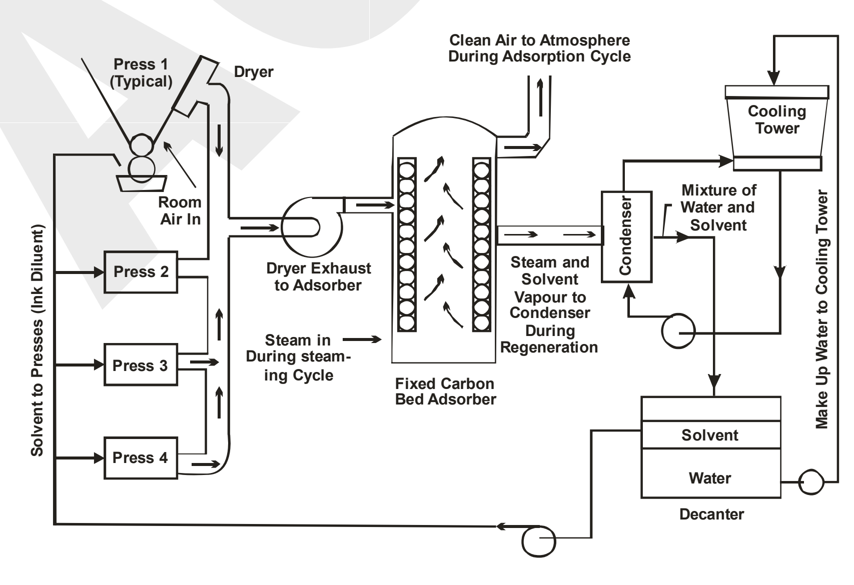
Dryers already in use have adequate drying capacity for use with a solvent recovery system. Small exhaust volumes are desirable in reducing the capital cost of the recovery plant. Indirect heating methods such as steam are desirable, since LEL controls can then reduce the exhaust air to minimum balance conditions when drying light loads. Dryers not in use, or handling water coatings, can be exhausted top the atmosphere.

Capture efficiency – the ability of the solvent recovery unit to get as much of the exhaust air as possible – needs to be good if solvents are to reach the recovery plant. The wet web entering the dryer should be enclosed as much as practical operation permits. The enclosure should be connected to the dryer so that the negative balance pulls air from the enclosure into the dryer. Traditionally, ducts at floor level called floor sweeps exhausted large amounts of air and the heavy solvent vapors. These can be replaced by lower volume ducts placed closer to the printing fountains and the smaller volume can be ducted to the dryer body or the exhaust duct. Some presses use their hollow frames as ducts to more efficiently capture vapors.

Higher LELs due to solvent Recovery

Higher operating LELs in dryers, such as those around 30%, have not adversely affected drying rates. Solvent vapors in air can surpass the lower Explosion Limit and even exceed the upper Explosion Limit (too rich to burn) and still be below the saturation limit. The only noticed adverse effect of high LELs is in odor retention. Two-zone dryers with the exhaust from zone 2 cascading back to zone 1 solves this problem. When reverse printing is required, dampers can automatically reverse the cascade direction.

Solvent recovery demands a look into “press stop” logistics. When a press stops, the exhaust air should be greatly reduced or stopped.



Gravure Solvent Recovery System

OTHER ENVIRONMENTAL-FRIENDLY SOLVENT REMOVAL / REDUCTION SYSTEMS

INCINERATION (THERMAL OXIDATION)

Incineration destroys high boiling solvents and other fumes that would contaminate a solvent recovery system. They can be built to accommodate a single press, and the heat from the incinerator can be reused. Energy sources for incinerators depend on the geographical location of the press. Where energy costs are a concern, incinerators equipped with a catalyst can operate at much lower temperatures. The catalysts include precious metals such as platinum and palladium. Certain materials run on the press can contaminate catalysts. When this happens, the catalyst must be replaced. The choice of incinerator must balance the initial cost of installation with the ongoing cost of operation.

LOW-VOC TECHNOLOGY

Low-voc technology deals with pollution control by formulating the ink with as little VOCs as possible. Inks that require “curing” rather than drying fall into this category. UV inks and coatings have been very successful in flexography and rotary letterpress printing. These inks contain Photoinitiators that cure when exposed to ultraviolet light, eliminating the need for any solvent capture or control. UV coatings are successfully used in gravure, but some problems still remain with pigmented inks.

Other forms of low-VOC technology include electron-beam (EB) technology, high-solids inks, and thermoplastic inks. All these technologies have been proven to have a certain degree of success in specialized applications.

We expect continued government pressure to reduce or eliminate the use of solvent in gravure operations. Gravure printers and allied industries have invested enormous amounts of capital with a great deal of success. Today’s capture efficiencies exceed 98%. Water-based ink has replaced solvent ink in applications that were ought to be impossible only five years ago. We expect continued Development in gravure ink technology and in equipment that will keep gravure in compliance with future regulations.

EXTRA

GRAVURE INK DRYING

Drying speed of gravure inks is affected by the evaporation rate of the solvents used to adjust viscosity. Ideally, the ink manufacturer will recommend a solvent blend that is compatible with the ink formulation and the evaporative rate necessary to dry the ink at production speeds.

NECESSITY AND FUNCTION OF DRYER SYSTEMS

Dryers are necessary for high-speed gravure printing because the web cannot run straight through multiple printing stations without making contact with other rollers. The ink must be dry enough not to stick to any rolls it contacts with the printed side of the web. Dryers would not be necessary if the press ran slow enough for the ink to air-dry.

The basic principles of drying are called the “three Ts”: time, temperature, and turbulence. **Time** is the most important. All liquids will dry when they are given enough time. The time that is required to dry the ink in relation to the web speed for the desired production determines the dryer length.

Temperature is an easy factor to control. Heat sources for gravure dryers include steam, gas, electric, thermic oil, gas/oil combination, and waste heat from an incinerator. The addition of heat quickly increases drying speed. Too much heat can cause the substrate to shrink, stretch, curl, or become brittle. Excess heat can also cause many ink and coating defects. If the ink film dries too fast, it can skin over (that is, dry on the surface), trapping moisture underneath. This condition can result in retained odors, as well as ink picking on subsequent rolls and blocking when the printed product is rewound or stacked.

Turbulence is the movement of air. Turbulence involves nozzle design, velocity, and air volume. The air turbulence at the web surface is very important. In the dryer, the speed or velocity of air movement and its direction can greatly affect drying speed. Uniform distribution of the air supply across the web is necessary for consistent drying.

Gravure dryers are designed based on the substrate, ink, and coating, specified by the printer. They must be easily accessible for cleaning and constructed to strict safety standards if the press is printing with volatile solvents. The solvent load must be the heaviest possible load for each print unit. Solvent load is the maximum gallons per minute of solvents to be evaporated. The press manufacturer estimates this number and designs the exhaust size so that it cannot be reduced below this level. The estimated solvent load is based on press width, press speed, square inches covered per pound of ink, average percent of printed coverage, percent solvents in the ink, and weight of a gallon of typical solvent. Most dryers that handle volatile vapors are equipped with an LEL (lower explosive limit) detector or control. It measures the concentration of solvent vapors in air as a percent of the level that will explode if exposed to a spark or flame. If the solvent concentration exceeds a safe level for operating, the press will be stopped automatically. The real value to using this system comes from reducing the exhaust volume on print units that are applying a small amount of ink, saving a considerable amount of energy.

Dryers are constructed so that airflow can be controlled in specific sections or “zones” of the drying unit. In a single-zone dryer, the temperature and airflow are the same throughout the unit. Multi-zone units can operate independently with individual temperature controls for the different zones and air recirculation from one zone to another within the unit. Multi-zone dryers are ideal for water-based inks, adhesives, and a variety of coatings.

A dryer is considered in neutral balance when the amount of air exhausted is equal to the amount of supply air necessary to meet the production requirements of the press. This condition is difficult to achieve and maintain. When the dryer draws a small amount of room air into the dryer along with the web, this creates a slight negative imbalance, which is an ideal operating condition. Positive balance occurs when dryer air spills into the pressroom, raising the level of solvent fumes and creating a generally unhealthy and uncomfortable condition.

WATER-BASED INK

Water-based inks contain little or no volatile solvent and do not constitute an explosive hazard. However, as relative humidity increases, water evaporates more slowly. To keep the humidity from increasing in a dryer, it is necessary to increase the amount of exhaust air. Increasing the turbulence where the air impinges on the printed web is more effective than increasing the temperature when drying water-based inks and coating. Excessive heat can cause extensible substrates to stretch and paper-based substrates to shrink, leading to register and tension control problems.

Press speed determines the amount of time the web is in the dryer. For high-speed printing with water-based inks, dryers are built with longer web paths to insure enough time to dry the ink.

ENVIRONMENTAL COMPLIANCE

The solvents used in most gravure ink formulations are designated as volatile organic compounds (VOC). When exposed to sunlight, VOCs contribute to the formation of smog and are therefore listed as hazardous air pollutants (HAP) by the Environmental Protection Agency. Regulations established on May 15, 1995 require that all presses emitting over 100 tons per year of solvent vapors have pollution control devices. The printer's options for pollution control includes low-VOC or water-based ink, solvent recovery, and fume incineration.

WATER-BASED INK

Water-based ink technology has been around since the 1960s. It is the least costly compliance option, but today's technology has many limitations. Water systems require as much as five times the amount energy that is required to dry solvent inks. Water inks have been successful in packaging and product applications where press speeds have a tendency to be slower than publication gravure press speeds. Acceptable print quality has been achieved on coated board, vinyl, aluminum foil, and lightweight papers.

4.3.1. DOCTOR BLADE - STRUCTURE, TYPES, MECHANISM

4.3. Doctor Blade

The function of the doctor blade is to wipe ink from the surface of the plate cylinder, leaving ink in only the recessed wells. A great deal of research has been done on materials, angles, and designs for doctor blades.

Several different materials are used for blades. The goal is to minimize blade wear and reduce heat generated by the rubbing of the blade against the turning cylinder. Plastic, stainless steel, bronze, and several other metals have been used with success. The most common blade material, however, is Swedish blue spring steel. Blades are usually between 0.006 inch and 0.007 inch thick. The blades must be relatively thin to reduce wear on the cylinder, but strong enough to wipe away ink.

Blade angle is another important consideration. The angle between the blade and the cylinder is called the counter (figure below). There is much debate about the proper counter for the best image quality. The best counter depends on the method used to prepare the cylinder. For example, with electromechanically engraved cylinders, image quality decreases as the counter increases. Most angles are set initially between 18 degrees and 20 degrees. After the blade is placed against the cylinder and production begins, however, the counter generally increases to around 45 degrees.

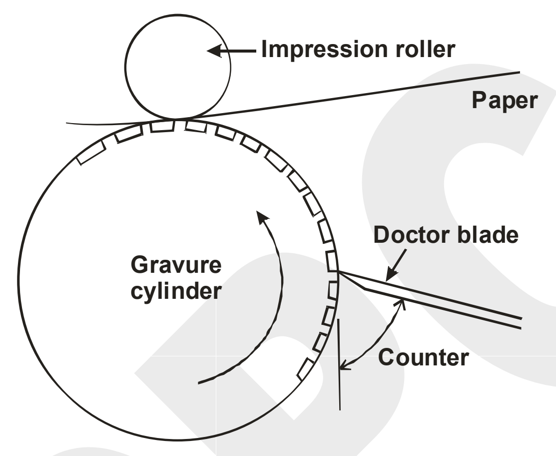


Fig. Diagram showing the counter.

The counter is the angle between the doctor blade and the cylinder surface.

One way to set the blade angle is by using the reverse doctor principle. With this approach the doctor blade is set at a large enough angle to push the ink from the surface (figure below).

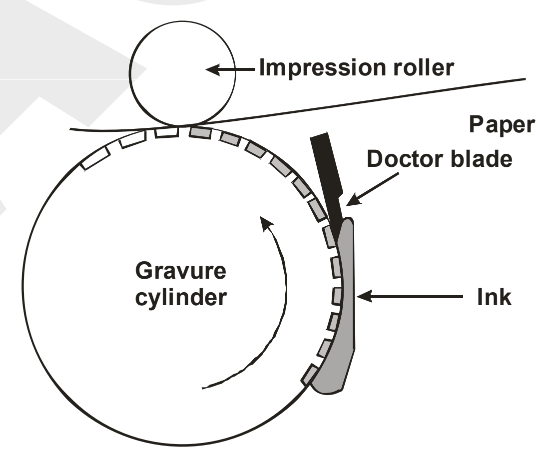


Fig. Diagram showing a reverse doctor blade.

A reverse doctor blade pushes ink from the cylinder surface

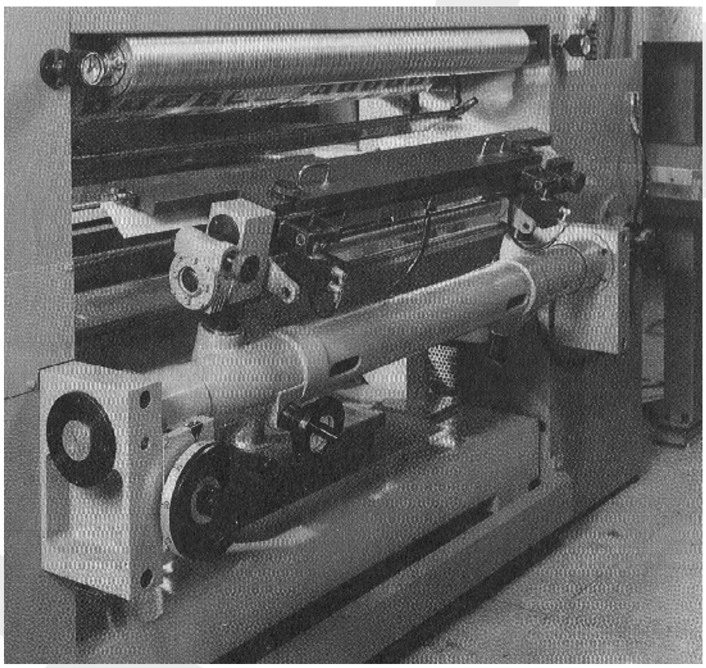
4.3.1. & 3. STRUCTURE AND MECHANISM OF GRAVURE DOCTOR BLADE

The doctor blade is a thin flexible strip, usually of steel, that is held parallel against the surface of the gravure printing cylinder. It removes the excess ink from the smooth, unengraved surface of the cylinder allowing the ink to be retained in the recessed cells.

The action of the doctor blade is fundamental to gravure printing and has been part of the process since the 18th century. Doctor blades are also used in coating applications, flexographic printing, and paper coating.

DOCTOR BLADE STRUCTURE OR ASSEMBLY

The doctor blade assembly is made up of the blade holder, the wiping blade, the backup blade, and the oscillation mechanism (see below).



Example of a doctor blade assembly.

The blade holder is specific to the press design. Presses intended for printing a broad range of cylinder sizes have blade holders with a wide range of adjustments. Publication and other presses that use cylinders of only a few diameters have a smaller adjustment range. In publication presses, the blade holders are fixed in the press, while in packaging and some product presses the holders are removable.

The doctor blade and backup blade, if one is being used, are inserted directly into a clamp that is part of the assembly. The holder is designed to keep the blade material flat and the edge parallel to the cylinder surface.

DOCTOR BLADE MATERIALS

A special, cold-rolled, hardened, and tempered strip of steel is the most commonly used material for gravure doctor blades. Several alloys are sold for doctor blades, the most popular for gravure doctor blades being electroslag refining or remelting (ESR). It is available bright polished or blue polished. There is no functional difference between the two.

If corrosion resistance is required, stainless steel blades are used. They are hardened and tempered and are more resistant to corrosion than carbon steel but not as durable. Other materials commonly used for special applications include polypropylene, Teflon, and nylon.

DOCTOR BLADE SPECIFICATION

Flatness and straightness are very critical for doctor blades, especially for blades exceeding 100 inch in length. Steel blade thickness varies from 0.004 inch to 0.015 inch and from less than an inch up to four inches in width. Commercial tolerances for thickness are +0.006 mm and +0.010 mm for width.

The backup blade is used to give the doctor blade additional support. When set up properly it creates a spring action when the doctor blade is applied to the cylinder. Stiffness can be adjusted by changing how far the doctor blade is extended beyond the backup lade. Excessive cylinder wear and premature blade wear will result if the blade setup is too stiff. If the blade setup is not stiff enough, there will be excess sensitivity to contact angle, pressure, and press peed. Backup blades are typically 0.010-0.015 inch thick.

WIPING ANGLES

Setting the blade refers to the action of bringing the doctor blade in contact with the engraved cylinder at the best angle and pressure necessary to completely wipe the excess ink from the cylinder. There are two important angles that the press operator must consider when setting a doctor blade, the set angle and the contact angle. The set angle is actually a reference angle. Some presses are equipped with instruments that can be used to achieve a pre-determined set angle. The contact angle is the net result of all the forces applied to the doctor blade when it is in operation. Manufacturers recommend a contact angle of between 55-65° for optimum wiping performance. When pressure is applied to the doctor blade at the start of the pressrun, a certain amount of force is required to keep the blade in contact with the cylinder. The ink being wiped from the cylinder surface can apply hydraulic forces against the blade causing it to lift up and away from the cylinder. To alleviate this condition, some printing units are equipped with pre-wiping, non-contact blades that reduce the hydraulic pressure created on high-speed presses.

DOCTOR BLADE WEAR

ADHESIVE WEAR

Gravure inks provide the lubrication necessary to minimize blade and cylinder wear. The doctor blade actually rides on a thin film of ink. The cylinder surface is not wiped completely, but is sufficiently cleaned so that the remaining ink film will not transfer to the substrate. Adhesive wear occurs when the ink film fails to separate the blade from the cylinder.

ABRASIVE WEAR

This type of wear takes place whenever hard foreign particles are present between the blade and the engraved cylinder. Potential sources of abrasive particles include ink pigment, dried ink, rust, paper dust, particles of paper coating, doctor blade particles, and chrome flakes from the printing cylinder. Gravure ink pumping systems are equipped with filters to remove potentially abrasive materials from the ink before they can cause damage to the blade or cylinder.

One of the most common print defects unique to gravure is the doctor blade streak. Despite the many precautions taken in press design and ink handling, occasionally a foreign particle will get lodged under the doctor blade, causing a streak. Proper blade oscillation can minimize this problem and reduce cylinder wear.

Cylinder finish is also a factor in print defects. A certain amount of roughness can actually improve lubricity and doctor blade performance. The best surface finish will take into account the type of ink and solvent being used, the press speed, and the substrate. The blade-to-nip distance also affects ink transfer and must be factored into any decision dealing with doctor blade and cylinder interaction.

4.3.2. TYPES OF DOCTOR BLADE

Several different doctor blade designs are used by gravure printers (figure below). The most popular are conventional and MDC/ Ringier. Care must be taken to keep the conventional design sharp and uniform. Most printers hone the blade by hand with a special stone and then polish it with a rough or emery paper to get a flawless edge while the MDC/Ringier design tends to self-sharpen. The MDC/Ringier design has a longer working life than the conventional form design and requires much less press downtime for blade cleaning and repair.

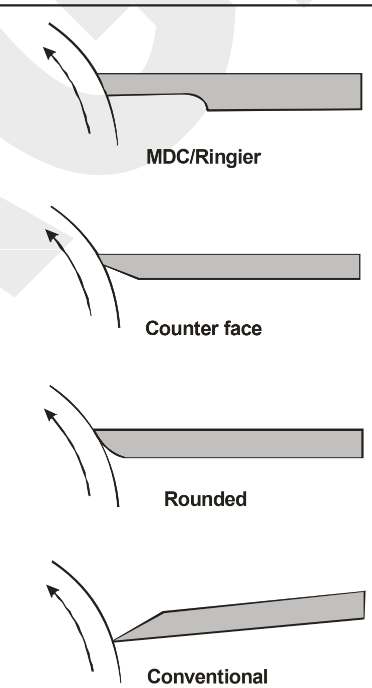


Fig. Examples of different doctor blade designs

The action of the doctor blade against the cylinder is of special concern. The blade rides against the cylinder with pressure. Pressure is necessary so that the ink does not creep under the blade as the cylinder turns. The most common method of holding the blade against the surface is by air pressure. The blade fits into a holder, which is mounted in turn in a special pneumatic mechanism. Most printers use a pressure of one and a quarter pounds per inch across the cylinder length.

Most doctor blades are not stationary, however. As the cylinder rotates, the blade oscillates, or moves back and forth, parallel to the cylinder. This oscillating action works to remove pieces of lint or dirt that might otherwise be trapped between the cylinder and the blade. Dirt can nick the blade. Nicks allow a narrow bead of ink to pass to the cylinder surface. Nicks are major defects that can ruin the image or scratch the surface of the cylinder.

A prewipe blade is commonly used on high-speed presses to skim excess ink from the cylinder (figure below). This device prevents a large quantity of ink from reaching the doctor blade and ensures that the thin metal blade wipes the cylinder surface perfectly clean.

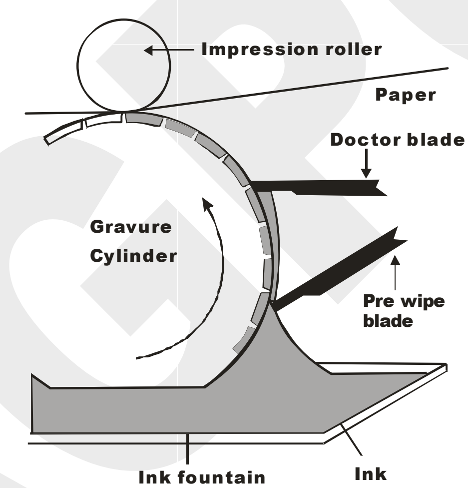


Fig. Diagram of a gravure cylinder showing prewipe and doctor blades.
Most presses use prewipe blades skin most of the ink from the cylinder before the cylinder reaches the doctor blade.

EXTRA

GRAVURE INKING UNIT

In gravure printing the ink must be applied into engraved cells of the gravure cylinder surface. For this the ink must have a very low viscosity (approximately 1 Pas) – it mainly consists of a solvent with a low boiling point (Toluene) and pigment- containing resins or resin-embedded pigments.

To fill the indented elements, that is, the etched or engraved cells, only requires an ink pan that is filled with gravure printing ink, into which the rotating gravure cylinder is immersed (fig. below). In order to prevent strong foam formation and splashing of the ink, a pan roller with a soft covering runs simultaneously in the ink pan. Due to friction, this roller runs more slowly than the gravure cylinder circumference. This allows the application of a homogenous ink film onto the gravure cylinder without splashing. Special splash guard plates on the gravure cylinder ends also prevent ink splashes at the cylinder edges and the superfluous ink falls into the ink trough beneath the height adjustable ink pan. From the ink trough, the ink flows into an ink tank positioned in front of the printing unit; there it is mixed with fresh ink, cleaned by filters, its viscosity is checked and it is pumped back into the ink pan.

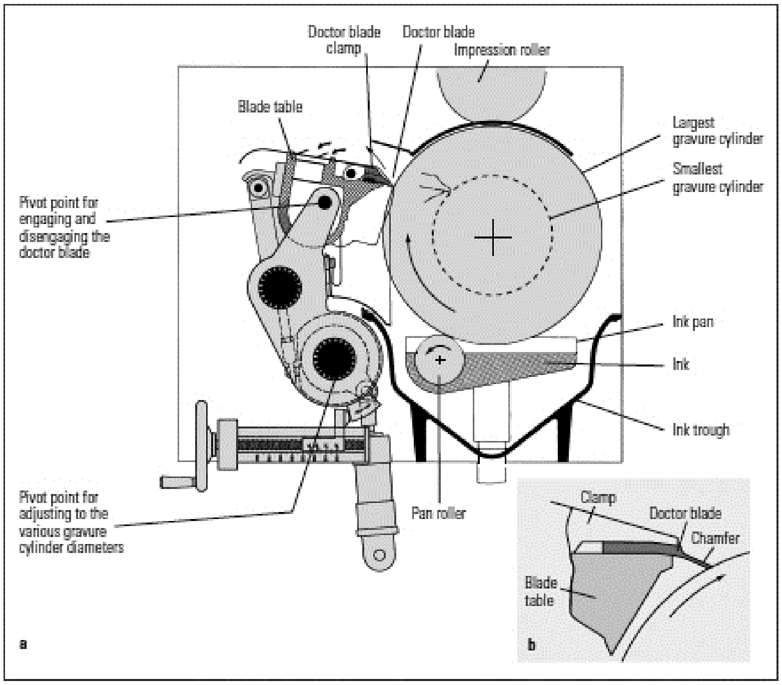


Fig. 2.2-14 Gravure inking unit.
a Principal structure;
b Doctor blade (detail). (KBA)

DOCTOR BLADE

Since the gravure cylinder also takes up ink on the non-printing areas when dipped into the ink pan, the superfluous ink must be removed from the gravure cylinder surface by means of a *doctor blade*. This blade is often referred to as the "soul" of gravure printing; its design is of immense importance. The blade itself simply consists of a thin, wear-resistant steel strip that is bent slightly and mounted in a blade holder (fig.b). Previously, a distinction was made between a thicker support blade, located above and set slightly further back, and the blade itself. Today, it is usual to use blades with thicker but shorter profiles. These are chamfered on their cutting edge (i. e., ground thinner, fig. b) and are fitted in a clip instead of a holder.

For *engaging and disengaging the blade* (pneumatic or hydraulic), two articulating, suspended machine elements (fig. a) are needed. The first is the blade table for throwing the blade on and off and for applying the blade pressure. The second is the blade frame, needed for adapting the blade to gravure cylinders of various sizes and also for swinging away the entire device when changing the gravure cylinder if two blade devices are needed for the *change-over operation* (i. e. the plate cylinder rotates in the opposite direction).

The blade must reciprocate to avoid *blade marks* (and thus the wear and tear of the blade) in the print. This can be achieved via a crank mechanism in the gear box from the longitudinal shaft or via a returning worm gear from a separate gear motor. Here, it is important that there is no rational transmission ratio to the gravure cylinder drive, in order to assure a constant shifting of the blade at any possible damaged areas on the gravure cylinder and thus prevent a cumulative abrasion of the same point of the blade.

The blade is subject to a high level of wear and must be changed regularly (normally with a new print job). The blade must be aligned exactly parallel to the gravure cylinder surface, assured today by the hydraulic blade clamping with pressure selection and self-alignment. The *angle of contact* is also important for a good result and is used as a control parameter with difficult images.

4.4 - IMPRESSION ROLLER - STRUCTURE, TYPES, MECHANISMS

4.4.1 & 3. STRUCTURE AND MECHANISM OF GRAVURE IMPRESSION ROLLER

The functions of the impression roll are to force contact between the web and the engraved cylinder, to create the necessary web tension between printing units, and to propel the web through the press.

The impression roll brings the substrate in contact with the engraved cylinder resulting in proper ink transfer. It is a friction-driven, rubber-covered metal cylinder. The impression roll is not geared to the press, but is driven by friction at the nip. It helps to propel the web through the press and set the web tension pattern between press units. Impression pressure is measured in pounds per linear inch (PLI). This is the average force per inch applied over the face of the impression roller. Depending on the hardness of the roll covering and the substrate to be printed, the PLI can range from fifty to several hundred pounds.

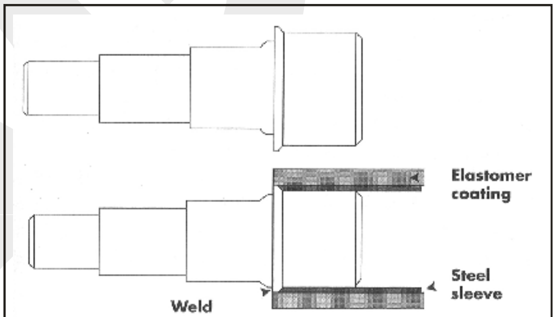


Fig. The typical impression roll consists of a tubular sleeve, supported at each end on bearings

DESIGN

The impression roll is made of a tubular sleeve covered with a rubber compound. Roll manufacturers have a wide variety of covering materials available depending on ink and solvent type, substrate, press speed, and the use of electrostatic assist. Roll covers include natural and synthetic rubber polymers and polyurethane.

DIMENSIONS

The impression roll has two main dimensions: core diameter (the outside diameter of the metal sleeve) and outside diameter (the diameter after the rubber cover has been added to the sleeve).

BALANCE

The impression roll must be balanced to eliminate excess vibration during press operations, much the same as the construction of the image carrier cylinder. If the impression roll is out of balance, excess vibration can cause a reduction of overall mechanical efficiency, uneven impression resulting in poor print quality, excessive wear on the bearings, and uneven web tension. Excess vibration can also cause wrinkling of the substrate, heat buildup, and possible failure of the roll covering.

SPECIFICATIONS

The manufacturers of impression rollers follow the recommendations of the press manufacturer. The following specifications must be determined by the printer:

- Cover material determined by press conditions
- Hardness (shore durometer) of roll
- Physical properties of cover materials, i.e., heat resistance, resiliency, abrasion resistance, chemical resistance, and compression set
- Trim, the shape of the rubber covering at the end of the roller

ROLLER PRESSURE

During printing, the pressure of the impression roll against the cylinder forces the substrate against the engraved cylinders, causing ink to transfer from the engraved cells to the substrate by capilary action. The press operator can adjust the pressure of the impression roller. Pressure can be varied to accommodate press type, engraving specifications, speed, ink formulation, substrate, and electrostatic assist.

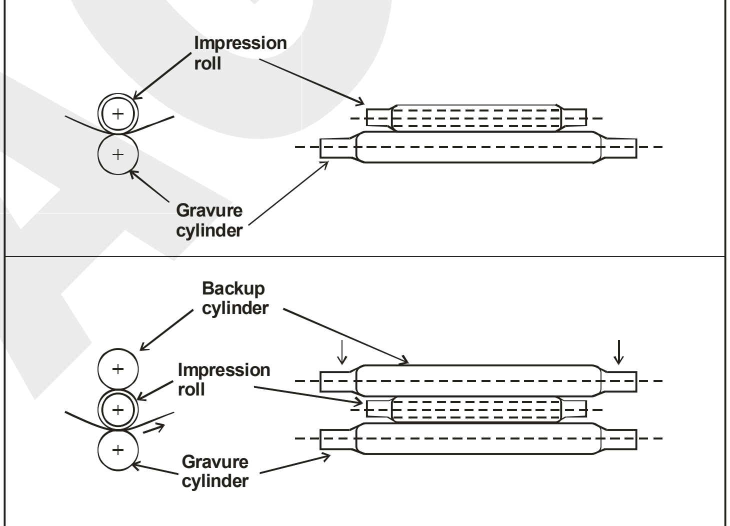


Fig. Two-roll (top) and three-roll (bottom) impression systems.

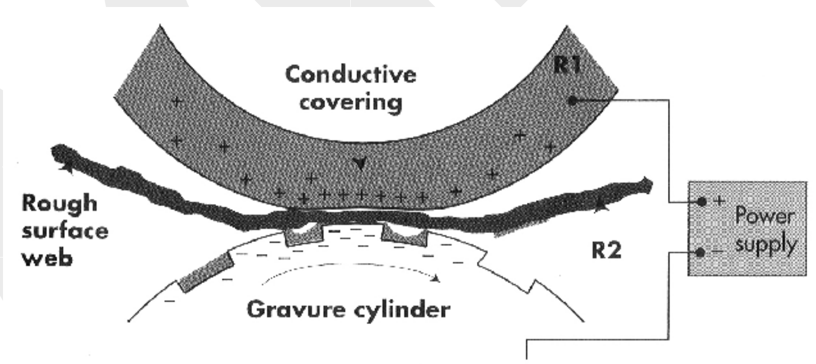
THE NIP

The nip is the point of contact between the impression roller, web, and engraved printing cylinder. The pressure applied at the ends of the impression roll must be distributed evenly along the entire length of the roller to create a consistent nip. The tendency of the roll to bend at its center when pressure is applied at the ends is referred to as deflection. Deflection is more likely to occur where the presses are wide (over 60 inches), cylinder circumference is small, and the press speeds are high. In other words, publication gravure and wide-web product gravure operations are subject to this problem. A number of systems have been designed to address the need for constant nip pressure. They fall into three general categories:

- Three-roller system consisting of the engraved cylinder, impression roll, and a backup roll.
- This design is limited to slower press speeds because it actually has two nips, which can create excess heat and limit the operational life of the impression roll.
- Two-roll system consisting of the engraved cylinder and a crowned impression roller.
- Two-roll system consisting of the engraved cylinder and an internally-supported impression roller.

Electrostatic Assist

In order for ink to transfer from the engraved cylinder, it must come in direct contact with the substrate. If the ink fails to contact the substrate, a print defect will occur. This is usually referred to as "missing dots" or "snowflaking." This condition is most likely to show up on rough substrates, particularly paper and paper board. Improving the smoothness is the obvious solution to the problem, but is not always possible or cost effective.



Basic schematic of the principles of electrostatic assist.

In 1966, the Gravure Research Institute developed a method of introducing an electric field to the nip area to help transfer ink from the engraved cylinder to the substrate. When voltage is applied across the impression roll, an electric field is generated between the impression roll and the engraved cylinder. This electric field produces an external force on the ink, pulling it toward the substrate. When the substrate leaves the nip, the charge dissipates.

This process is called electrostatic assist (ESA). The development of A paved the way for ultra-high-speed presses and the ability of e gravure process to print on rough substrates with good print results.

4.4.2. TYPES OF GRAVURE IMPRESSION ROLLER

As in every conventional printing process, in gravure printing there is also an *impression roller*. This cylinder must be sufficiently stable and as small as possible in its diameter to assure a narrow printing nip for a better (i. e., sharper) print of the gravure cylinder. Therefore, previously (prior to 1960), it was common to arrange the gravure cylinder, a smaller intermediate roller (impression roller), and a larger cylinder above one another in a three-roller system. (If the small intermediate roller were brought into contact with the gravure cylinder without the pressure from the large cylinder, there would be too large a deflection of the impression cylinder.Hence, the contact pressure in the center of the two cylinders would no longer be sufficient in the printing nip.)

The trend towards higher production speeds and the consequent need to reduce heat generation favored two roller systems, which led to the development of *deflection-compensated impression rollers* in the 1960s and 70s. Their design was based on rollers used in calenders (stack of rollers). Above it all, it was the “swimming roll” from the company E. Küsters and the “NIPCO roller” (fig. below) that became established in superwide designed gravure printing presses. In the case of the latter, small hydraulic cylinders, supported on a fixed, stationary body inside the impression cylinder, act as “saddles” (hydraulic supports) and press the rotating sleeve of the impression roller against the gravure cylinder. The hydraulic fluid penetrating on the surface of the “saddles” serves both as lubrication and as cooling.

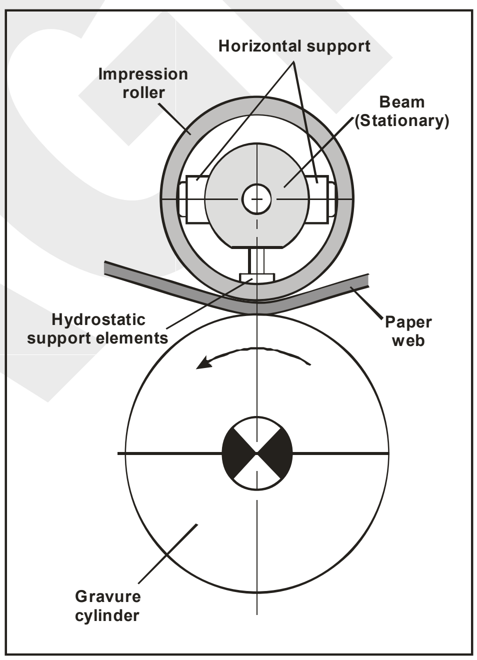
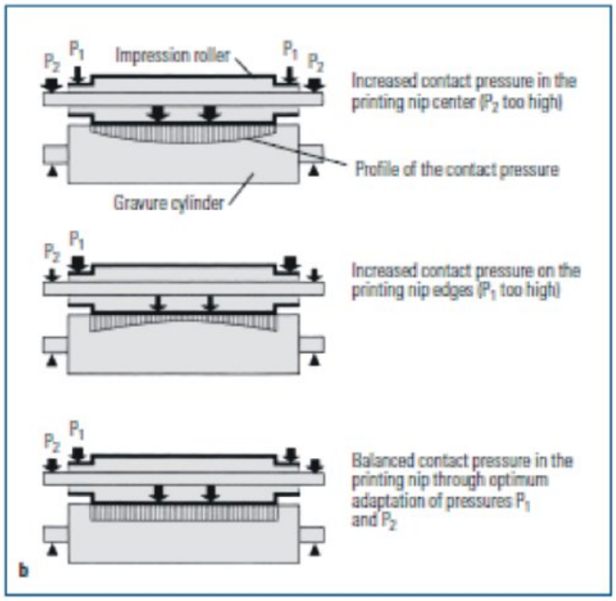


Fig. The Principle of the deflection-compensated impression roller

A number of support elements inside the roller compensate the deflection of the gravure cylinder and ensure that the contact pressure remains practically constant along the entire web width (of the paper). A hydrostatic bearing is located between the innovable support elements and the rotating sleeve (NIPCO-Voith-Sulzer).

In the further course of developments, the gravure printing press manufacturers have worked on further solutions, such as deflection-compensated impression rollers that were based on the principle of "indented bearing points." On the "K2 impression" roller (fig. 2.2-13), additional hydraulic pressure is applied to the extended shaft ends (fig. 2.2-13b) of the inner body, so that inside the roller the drawn-in bearings exert a counter-bending moment on the impression roller sleeve, which is counteracted by the normal hydraulic throw-on mechanism of the impression roller. The impression roller, therefore, deflects downward and is only brought back into even contact with the gravure cylinder by the normal throw-on mechanism.

Fig. 2.2-13
Deflection-compensated impression roller (K2, KBA).
a Gravure printing unit with K2 impression roller;
b Effect of the (hydraulic) pressures P_1 and P_2 on the contact pressure



These deflection-compensated impression rollers are also cooled from inside in order to prevent the impression roller covering from becoming too hot. This is not only done to preserve the covering, but also to prevent heat transmission into the inking unit.

The *impression roller covering* consists of a special rubber layer of high shore hardness (approx.95 Shore A) and is applied seamlessly. The impression roller is driven non-positively via the gravure cylinder when in contact with the printing material. In order to promote the *transfer of ink* from the etched gravure cylinder onto the paper wrapped around the impression roller, the impression roller or the web is *electrostatically charged* just beforehand. The ink meniscus (the top surface of a column of liquid) in the ink cells is thus raised and wets the paper more effectively. This device, which works with special voltage generators, is called ESA (Electro Static Assist). For this the impression roller must be supported by its bearings in an electrically insulated manner.

EXTRA

4.4. Impression Rollers

Use of an impression roller is the second main difference between gravure presses and other web-fed machines. The purpose of the impression roller is to push the paper against the gravure cylinder to transfer ink from the image wells. The major considerations for impression rollers are coating and hardness, pressure, and electrostatic assist.

Coating and Hardness

Most impression rollers are formed from a steel core coated with rubber or a synthetic material, such as Du Pont's Neoprene. Rubber hardness is measured by a Shore durometer. Values are given in Shore A readings. Hardness increases as Shore A numbers get larger. Different types of paper or substrates require different degrees of hardness for the impression roller. Material such as cellophane might require 60 Shore A, but kraft paper or chipboard might need 90 Shore A.

Pressure

Ink transfers to the web by pressure of the impression roller. Pressure might vary from 50 pounds per linear inch (pli) to 200 pli. More pressure does not always give better image quality, however, the amount of pressure the operator sets is determined by previous tests for the kind of paper being printed. Whatever setting is selected, it is critical that uniform pressure is applied over the entire length of the cylinder.

The area of contact between the impression roller and the cylinder is called the nib width, or flat (figure below). The amount of nib width is determined by the hardness of the impression roller and the amount of pressure. The nib width is important because it is the area of image transfer to the paper or plastic web. The nib width is adjusted to give the bestquality image on the web stock.

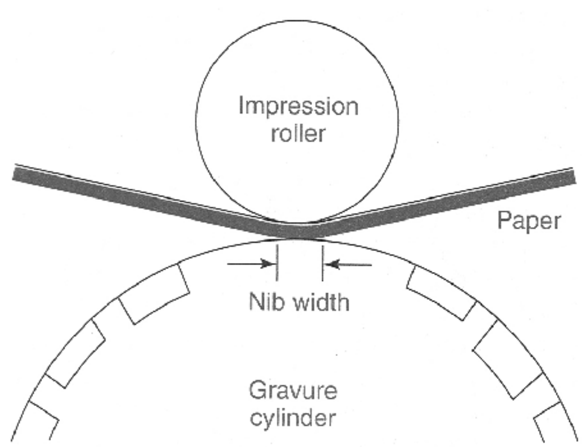


Fig. Diagram showing the nip width.

The nip width is the area of the cylinder where the paper contacts the cylinder by the pressure of the impression roller.

Electrostatic Assist

A great advantage of the gravure process is that it allows high-quality images to be printed on low-grade papers. Problems do occur when the paper surface is coarse and imperfect, however. Ink transfers by direct contact. If a defect in the paper prevents that contact, then no image will transfer. The Gravure Research Association (now part of the Gravure Association of America) designed and licensed a special device, called an electrostatic assist, to solve this problem and improve image transfer. With electrostatic assist printing, a power source is connected between the cylinder and the impression roller (figure below). A conductive covering must be added to the impression roller, but the cover causes no special problems. An electric charge is created behind the web, which forms an electrostatic field at the nib width. The charge pulls the ink around the edges of each well, which causes the ink to rise and transfer to the paper. Most presses are now equipped with electrostatic assist devices.

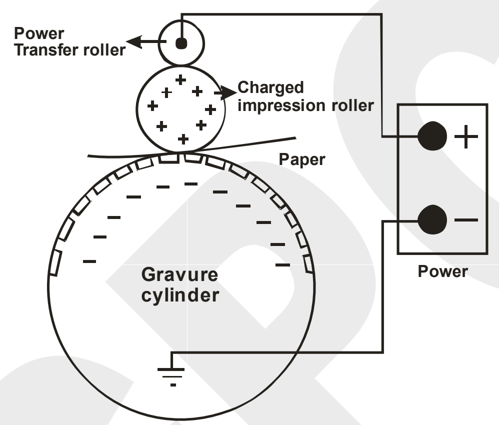


Fig. Diagram of electrostatic assist printing.

Electrostatic assist printing charges the impression roller and the gravure cylinder so that the ink lifts electrostatically from the cylinder to the paper.

4.5 - GRAVURE PRESSES

The limited number of press components and simplicity of design makes gravure easy to automate, simple to operate, and very adaptable to inline converting operations. The simplicity also ensures consistently high print quality even in extremely long print runs.

Depending on the product to be produced, presses can be 4 to 240 inches wide. Since one color is printed at a time, the number of press pits in the press depends on the printer's needs. Single-color units are used for a variety of ink, coating, and adhesive applications. Most publication presses are eight colors. Specialty products such as lottery tickets may have as many as eighteen individual units.

All gravure presses are custom built, designed to satisfy the customer's specifications based on the end product to be produced. For example a packaging press for producing labels may be 26 in. wide with seven print units; a press for producing vinyl floor covering may be 12 feet wide with six print units; both presses are identical in principle, but customized for the end product. To determine the features of a gravure press, the following factors must be determined:

- Caliper of the substrates to be printed

- Minimum and maximum web widths to be printed
- Minimum and maximum cylinder circumference (this determines page size or print repeats)
- Press speed as determined by in-line converting operations
- Tension ranges based on the physical characteristics of the substrates to be printed
- Number of print units
- Dryers sized and zoned to handle press speed, substrate, and the type of inks and coatings to be applied
- Infeed unit determined by the specific needs of the substrates to be handled
- Outfeed unit determined by the substrate and the in-line converting operations following the last print unit
- Drives, the power source determined by substrate, press speed, and tension ranges
- Controls, determined by the amount of automation desired (these include on-line video monitoring, register controls, preset job setup, production statistics, waste analysis, electrostatic assist, automated ink dispensing and viscosity control, and a long list of other on-line controls to assist in pressroom management.)

SECTIONS OF THE PRESS

SUBSTRATE SUPPLY

The substrate supply section includes the reel stand web guide, pre-treatment and infeed tension control. All web-fed gravure presses start from a reel stand that unwinds the roll of substrate to be printed. The infeed is critical for web and tension control throughout the rest of the press. High-speed presses have what is called a two-position reel stand. This allows two rolls of substrate to be mounted on the press at one time. For presses printing light weight materials, the unwind unit is equipped to splice a new roll to the end of the expiring roll. This allows continuous operation of the press when the rolls are spliced together. Presses printing heavyweight material such as sheet vinyl or thick board have a web accumulator or festoon that is described in detail later in this chapter.

GRAVURE PRINTING UNIT

At the heart of the gravure press is the printing unit. It contains the following five basic components regardless of the application:

- The engraved cylinder (image carrier)
- An ink fountain, a large pan positioned beneath the cylinder that extends the width of the printing unit

- A doctor blade assembly consisting of a doctor blade, doctor blade holder, and oscillation mechanism
- An impression system to hold the substrate against the engraved cylinder to facilitate ink transfer
- A dryer that provides heated air to dry the moving web before it enters the next printing unit

DELIVERY SECTION

The delivery section always follows the last printing unit. Publication presses are equipped with upper and lower folders to convert the full web into slit ribbons that are gathered and folded into signatures. Packaging and product presses have a wide variety of inline converting operations available depending on the product being printed. Cutters, creasers, and diecutters are just a few of the options available.

4.5.1. GRAVURE PACKAGING PRESS

Gravure Printing in the Packaging Industry

Gravure printing presses for package printing are equipped differently from those used in illustration printing. The main difference lies in the substrates and inks used, as well as in the finishing of the printed web. In *gravure package printing*,both sheet-fed and web-fed presses are utilized. Sheet-fed gravure printing presses have the advantage that shorter runs can also be produced economically, due to the more flexible and inexpensive manufacture of gravure cylinders or gravure plates. Gravure printing, and especially web-fed gravure printing, is of particular interest for the printing of packaging material as it can process:

- various formats (repeat in a circumferential direction),
- a wide range of inks with the most diverse properties, such as non-toxic, odorless, sealing effect, or metallic glaze, and is
- cost-effective with long print runs.

Gravure printing enables high-quality and consistent reproduction of the finest photographic details in even the smallest of images on thin and flexible printing material and a large number of multiple-ups on one gravure cylinder. Furthermore, this process achieves the highest, most constant and continuously reproducible print quality. Moreover, printing on both sides of the web can be carried out easily in one pass, even with an alternating number of colors. Webs printed in gravure printing can be finished immediately and long runs can almost always be printed with one set of gravure cylinders.

Today, *sheet-fed gravure printing* only plays a minor role. Sheetfed gravure presses shown in figure 2.2-34 (and fig. 1.6-8) for multicolor printing have a drying section after each printing unit. To achieve long enough drying times, long dryers are required. For presses with short distances between the printing units this has, for example, led to “tile-like” arrangements of the dryers.

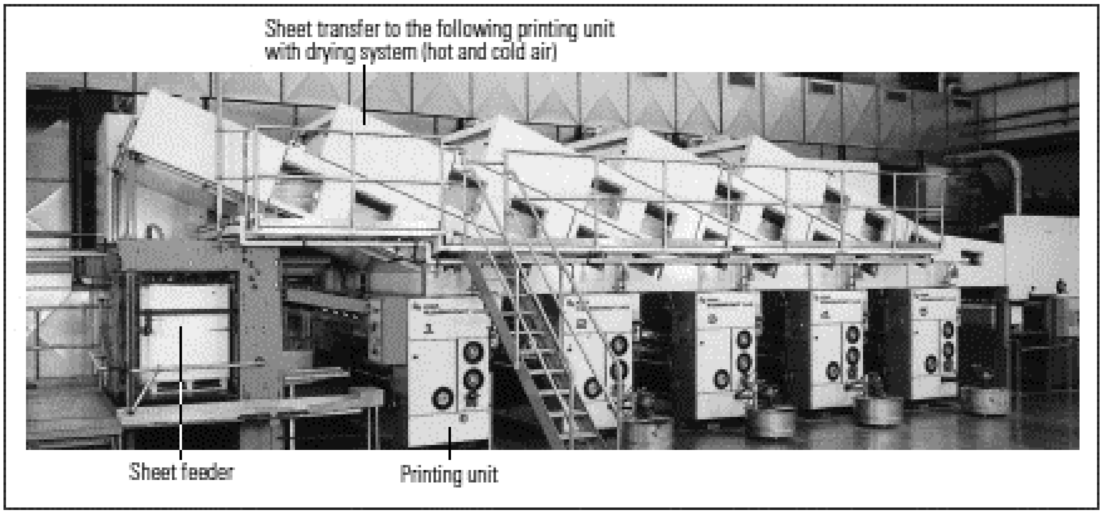


Fig. 2.2-34 Multicolor sheet-fed gravure printing press for printing of packaging material; diagram in figure 1.6-8 (Rembrandt 142, KBA)

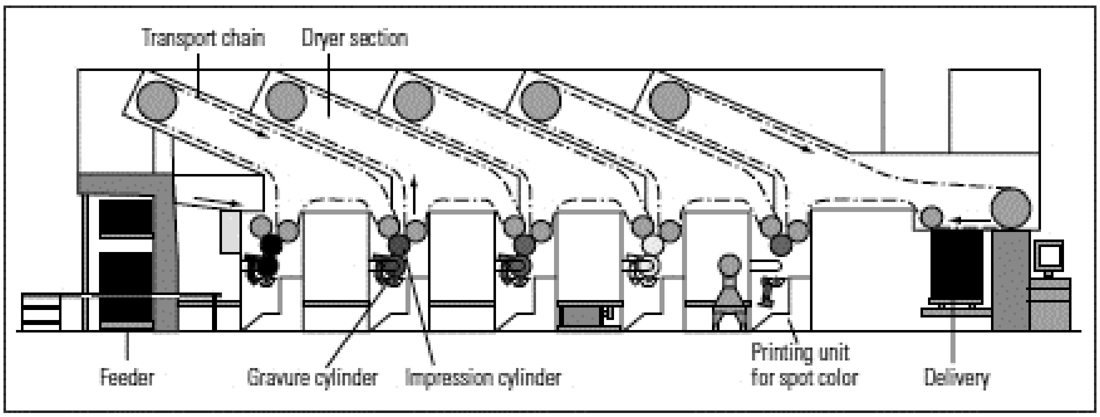


Fig. 1.6-8 Sheet-fed gravure press (REMBRANDT 142, KBA)

Rotogravure (web-fed gravure) presses are usually economically more efficient than sheet-fed gravure presses due to the generally long print runs. Therefore, we shall concentrate on the topic of web-fed gravure printing. A web-fed gravure printing press for package printing (figs. 2.2-35 and 1.6-18) consists of an unwind unit, gravure printing units arranged successively, and a *rewind unit*. The simplistic equipment, in connection with a simpler construction of the printing units, made it possible for relatively small machine manufacturing companies to produce this type of machinery. As such, a range of companies came about (especially in Italy) that offered the established manufacturers of gravure printing presses competition and even forced some of them to give up this branch of manufacture. Not until specialization into the high-quality printing of technically and particularly top-quality packaging material, such as cardboard and thin foil, could the long-standing companies assert themselves with special and sometimes patented press designs. Automatic in-line packaging production meant that in the construction of systems, gravure printing systems were almost forced into the background alongside special processing units, so that one could almost talk about a packaging machine with connected printing units.

Around the end of the 1950s, the “golden age” of gravure printing began in the packaging industry. This development was further assisted by the simultaneous *introduction of new packaging materials*, such as cellophane. This meant that many brand-name goods manufacturers were able to offer their products visually to the customer with better packaging conditions. For good quality printing of this material, the gravure printing presses of the time had to be modified. To achieve good adhesion of the newly developed inks on this non-absorbent material, it became necessary to modify the dryers of gravure printing units, and the foil surfaces had to be pretreated with base varnish. Moreover, the web substrate tension in the entire press had to be reduced, above all at the rewind unit to prevent blocking of the rewind reels.

The need for ever thinner *polyethylene foil* for printed packaging led to gravure printing losing ground to flexography (central impression cylinder flexographic presses). This was aggravated by the fact that it became apparent that on most of the existing gravure printing presses no perfect printing results could be achieved without carrying out expensive modifications. This was due to the long web travel distances, the insufficiently sensitive web tension controls, the sturdy winding units, which responded too slowly for this sensitive material, and the non-adjustable drying systems of the gravure printing units. Therefore, the existing presses of that time had to be modified to conform to the new, higher demands. Higher requirements placed on the machine technology by packaging printers and at the same time a declining need for new presses resulted in a drop in the number of press manufacturers. With new investments, many of the packaging printers opted for flexography instead of gravure printing.

Nevertheless, gravure printing was able to assert itself in market sectors, such as with long print runs on paper, *light cardboard*, *transparent foil,* and *aluminium foil*, and in some cases the printing on *plastic foil* as well. Many brand-name goods manufacturers employ gravure printing for the printing of their packaging for cigarettes, candy, soup packets, coffee, cakes, pastries, butter, and cheese. Even washing detergent boxes, plastic bags, and wrapping paper are often printed on gravure presses.

Several gravure press manufacturers have developed machines on which thin, flexible polyethylene foil could be printed in good quality. For this, the existing press designs had to be overhauled and equipped with sensitive and precise web tension and measuring devices, DC-powered drawing devices, particularly smooth-running web guiding elements, completely new chill roller systems and modified non-stop unwinding and rewinding devices with DC drive engineering. Moreover, the entire drying system and the register control systems, had to be adapted and enhanced to meet the high demands. Some printing companies, for the most part in Europe, have used such presses to specialize in the printing of flexible plastics and have successfully maintained or even expanded gravure printing’s share in the healthcare product, frozen food, and high-grade plastic bag sectors.

Despite an increased need for extremely diverse and high-grade packaging materials, the pressure of costs is on the rise for printing companies. For this reason, the printing press manufacturers are concentrating on developing methods to further reduce the change-over times of the new presses, increase production speeds, simplify press operations, and increase automation. Several manufacturers of gravure packaging presses offer press configurations based on *slide-in systems*. In some presses there is also provision for the *change-over of the impression roller sleeve*. This simplifies the change-over procedures when preparing the press for a new print job and is more user-friendly.

Some presses are able to reach production speeds of up to 6.7 m/s. The print width of modern high-performance presses, normally comes to 120, 140,or 160 cm. Due to the increasing quality demands, seven or eight colors, and therefore the corresponding number of printing units, are required for more and more types of packaging. A varnishing and/or cold sealing application and possibly lamination must be carried out in-line; the installations, therefore, often consist of more than ten printing and finishing units. Today, such universal presses of modular design are almost always designed for printing packaging materials covering a broad market segment. They are equipped with *non-stop winders*.

The cost of gravure cylinders, the long and laborintensive job change-over times and the high waste rate of 3% and more (for long runs), which can arise when setting up and starting a new print job, represent a high cost factor, especially with relatively short runs. It is therefore understandable that the perspectives for gravure packaging printing are not too positive and that its projected worldwide market share for the year 2001 varies considerably. Alongside flexographic and offset printing, gravure printing's share of the packaging printing market in Europe is predicted at approximately 19% with a slight downward trend, whereby the shares in France and Italy, for example, are much higher. In the United States, a country with a fairly inactive gravure packaging printing market, a figure of around 8% with a similar downward trend is expected, while the market share for Asia is predicted to be about 50%, and for Japan even a fairly constant 85%.

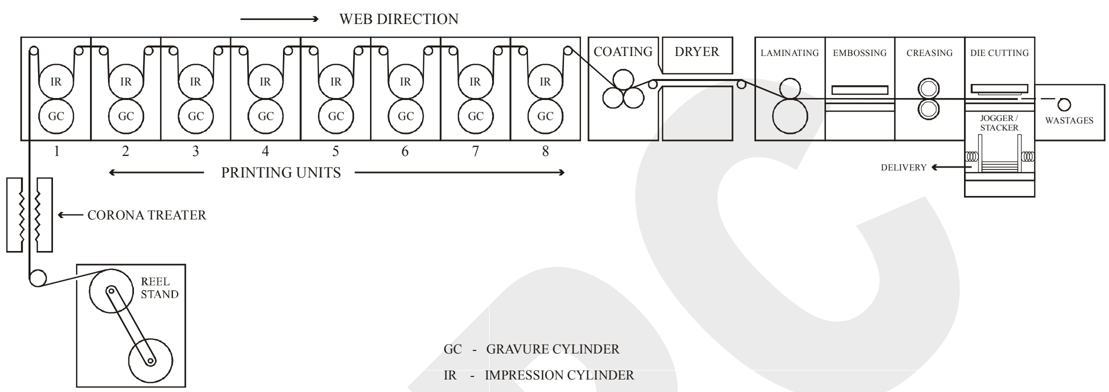
If success is achieved in significantly reducing manufacturing costs for gravure cylinders – for instance by using new plastic materials or laser systems for imaging/engraving and drastically reducing the press downtime and the waste rate – gravure printing, which is the simplest and best known printing process, could well become more widespread.

4.5.1. PRESS CONFIGURATIONS FOR PACKAGING

Gravure presses designed to produce packaging are divided into distinct groups by substrate. Lightweight substrates are used to produce, but are not limited to, flexible packaging, paper and foil labels, and wraps. Typical products produced with heavyweight substrates include folding cartons, soap cartons, and beverage contains. The ranges of weights overlap in the mid-range making it possible to print a variety of products and substrates on the same press. The single most important difference between the two different classes of press is the register and tension control systems. Packaging presses usually are combined with at least one in-line converting operation. Some common in-line operations include:

- Coating
- Creasing
- Diecutting

- Embossing
- Laminating
- Sheeting
- Slitting
- Punching/perforating
- Rewinding



Gravure Packaging Press

Gravure presses designed to print lightweight materials such as extensible films, paper, and paper/film/foil laminations usually have at least eight print units. Web widths are typically 18 to 60 inches. Flexible packaging presses also have options for reverse printing units, preconditioning systems to heat the substrate before printing, and cooling units or chill rollers to cool temperature-sensitive films and laminations. Corona treaters can also be added before printing to insure good ink and coating adhesion.

Presses designed to handle heavy substrates must have reel stands designed to handle the weight of the substrates. Presses in this group are typically built between 44 to 216 inches wide. They run at slower speeds than presses running lightweight substrates. A folding carton press with an in-line cutter/creaser will generally run at 600 to 800 feet per minute.

SPLICING

Splicing is the attachment of a new roll of substrate to the end of an expiring roll. If the press is equipped with a rewind unit for the printed web, it will also be equipped with a splicing unit. Because of the variety of substrates, there are varieties of splicing options available. There are two basic types of splices: the lap splice and the butt splice. For flexible materials of low caliper (i.e., films, foil, laminations, and papers), a lap splice is recommended.

A lap splice involves joining a new roll to the expiring roll by gluing, done at the operating speed of the press. It is often referred to as a flying splice, meaning that rolls are joined “on the fly.” Maintaining good tension and register control as the splice moves through the printing units is necessary to avoid unnecessary waste.

A butt splice involves joining two webs with tape. They are butted end to end rather than overlapping because of the thickness of the substrate. To make a butt splice while the press is running, the press is equipped with a festoon.

The festoon is a series of rolls following the unwind section of the press that gradually collapse to continue feeding substrate through the press when the unwind is momentarily stopped to execute a butt splice. When the splice is completed, the festoon rolls gradually return to their original position, ready for the next splice.

Typically applications for gravure package printing include folding cartons, flexible packaging and gravure labels and wraps. Each of these applications makes special demands of the gravure press, in addition to different requirements for in-line finishing.

Folding Carton Presses:

Folding carton press typically have from six to eight printing units and are available in either narrow (under 36 inches) or wide web (up to 55 inches) with variable cut off (repeat) in diameter ranges. Compared to the generic press, a folding carton press is designed to print board from 9 to 40 points thick, the same press can also be used to print paper as low as 60 lb. Per ream. In order to design a folding carton press, the following specifications need to be identified:

- Reel stand is sized to handle the maximum diameter and weight of the rolls of substrate to be printed. Rolls of board, depending on thickness, can reach up to 84 inches in diameter, where paper is usually packaged in up to 50 – inch O.D. rolls.
- Printing units and cut off ranges must also be determined by the range of substrate to be printed. Other printing unit specs include web width, maximum print width, printing speed, in fountain capacity, and whether one or both sides of the web will be printed.
- Dryers are specified for maximum air flow, temperature of drying air, and web length between printing nips, from printing nip to outlet roller, and length of web in the dryer.

Folding carton presses offer a variety of in-line converting operation. They include:

- Cutter / creasers for folding carton production.
- Sheeter.
- Rewinder for production of miscellaneous printed paper and board products that can be converted in an off-line cut – to – print unit. Sheeters and rewinders can both be incorporated at the end of press and used interchangeably depending on the end product.
- Rotary die cutter.
- Rotary embosser.

Pre conditioning systems installed at the unwinder exit are:

- A heated drum followed by a chill roller, is frequently used for presses designed for printing both film and paper.
- A preconditioning chamber, which blows hot air are steamed onto the web.
- A decurling device.
- A web cleaner.

Flexible Packaging Presses

Flexible packaging presses typically have eight printing units, but have been with as many as 11 units. Web widths range from under 12 inches to 63 inches, with variable repeat (cutoff) in diameter ranges. The flexible packaging press is designed to print light weight extensible films, paper and laminations (film / foil / paper combinations). In order to design a flexible packaging press, the following specifications need to be identified:

- **Reel stands.** The reel stand is designed for the range of weight of substrates to be handled. Flexible substrates tend to come in rolls of 50 inches or less in diameter, and are quite heavy when compared to similar size rolls of paper or board.
- **Printing Units and Cut offs.** Printing units and repeat length (cutoff) ranges must also be determined by the range of substrates to be printed. Other printing unit specs include web width, maximum print width, printing speed, ink fountain capacity, and whether the web will be printed on one or both sides.
- **Dryers.** Dryers are specified for maximum air flow, temperature of drying air, and web length between printing nips, from printing nip to outlet roller, and length of web in the dryer. Dryer design is critical for printing heat – sensitive substrates.

Flexible packaging presses require unwinding reel stands with very sophisticated tension control devices, both at the unwind and the infeed, to stabilize light weight extensible materials prior to entering the first printing unit.

Most flexible packaging presses are designed for roll – to – roll operation. Flexible packaging presses offer a variety on in – line converting operations. These include:

- Reverse coating.
- Laminating, either before or after printing.
- Punching / Perforating.
- Trimming.
- Slitting.

Preconditioning systems installed at the unwinder exit are:

- A heated drum, followed by a chill roller.
- A preconditioning chamber which blows hot air onto the web.
- A corona treater to ensure good ink and coating adhesion.

Most new packaging presses come equipped with trolleys or carts for complete off-press makeready, reducing downtime and change over between jobs. These carts can consist of a complete ink fountain, doctor blade and cylinder.

4.5.2. GRAVURE LABEL PRESSES

Gravure label presses typically have from six to eight printing units, web widths in the area of 36 inches on some presses to a maximum of 36 inches.

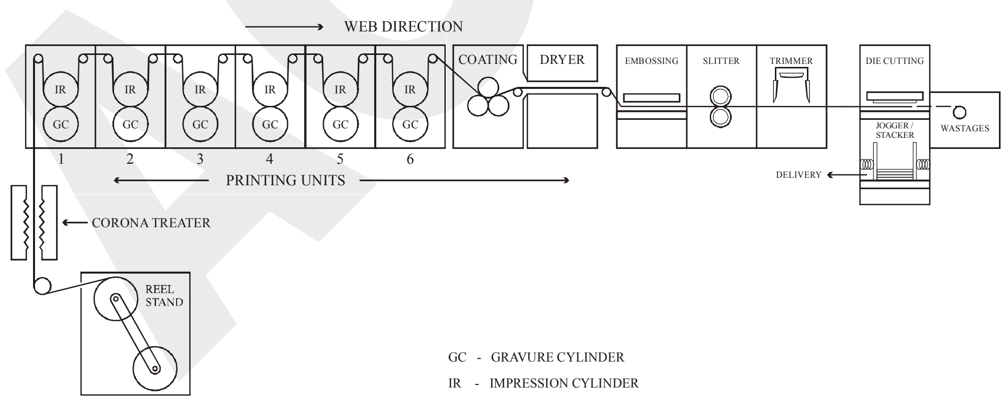
The weight and size demands of substrate rolls are less extreme than in either folding carton or flexible packaging presses. The typical label roll is 40 inches in diameter.

Dryers are similar to those on flexible packaging presses. Newer dryer units are designed to accommodate the drying of water based inks and coatings.

Label presses can be equipped with a variety of in-line converting equipment:

- Sheeter / jogger / stacker.
- Rewinder, either stand – alone or in addition to sheeter.
- Embosser.
- Slitter.
- Perforator.
- Trimmer.
- Coating unit.

Preconditioning systems are similar to those on flexible packaging presses.



Gravure Label Press

4.5.3. GRAVURE PRESSES - PUBLICATION PRESS

Examples of Gravure Printing Systems

This section describes and illustrates typical configurations of *publication gravure printing systems*. Packaging gravure printing presses are dealt with in the following section (2.2.3).

Figure 2.2-26 shows a press configuration in schematic form, where *two gravure printing presses are set up next to one another*. This illustration makes it clear how much space such installations require. The two folders, each with three deliveries, are arranged in the basement, where the reel stands are also located. Each of the 2 x 2 webs are divided into ten ribbons in the magazine turner bar superstructure and fed to the 7:7 gripper folders which are variable in format. The operator area with the control consoles and, above them, the control cabinets are located in the center between the two production lines. Two overhead cranes carry heavy press components and are used for any repair work that might become necessary.

Figure 2.2-27 again shows a press arrangement where two printing presses are set up parallel to one another. Devices for the *automatic change of the gravure cylinders* are arranged between the presses. The control consoles of each press are located outside. The two folders are at the same level as the printing units. A noise protection wall that extends up to the ceiling separates the operator room from the press.

Figure 2.2-28 shows the longitudinal cross-section of a gravure printing press that extends over *two levels*. The reel stand and folding unit are located in the basement. The (ten) printing units and the magazine turner bar superstructure are arranged one level higher.

The reel stand, printing units, and folder with superstructure can also be arranged on one level as shown in figure 2.2-29 *(first-floor arrangement).* However, when changing over to perfecting, the web needs to be underpassed in some section, which can be disadvantageous when feeding the paper (if the paper is fed manually rather than automatically).

Further configuration variations result from the arrangement of the magazine turner bar superstructure and the folder. Figure 2.2-30 shows the *coupling of two printing presses to one folder*, standing in the center.

Figure 2.2-31 shows a printing press equipped with two turner bar superstructures and folders located next to one another. This does not only improve the availability of the installation, should one folder fail to work, but it is also possible to *divide the product streams*. This is particularly important for the production of printed matters with few pages in large numbers in a fixed amount of time. Figure 2.2-31 highlights the possibility of integrating *flexographic imprinting units*. In the example shown, the flexographic imprinting unit does not have a dryer.

A *flexographic imprinting unit* with high velocity air dryer can be seen in figure 2.2-32. Flexographic imprinting units increase the diversity of gravure printing production with respect to partial runs which can, for example, be printed with varying prices and addresses (hybrid printing technology). To produce alternate imprints during production (flying plate change), the imprinting unit shown in figure 2.2-32 (also fig. 2.2-31) is equipped with two independent printing stations (two plate cylinders and two inking units, but one impression cylinder).

Tipped-in reply cards are an additional element in the conception and production of magazines. With the help of so-called *“add-a-card” devices* (fig. 2.2-33a), these postcards are automatically tipped-in at full web speed, as shown in figure 2.2-33b. The “add-a-card” machines process reply cards that are joined together in a perforated web. The accurate cycle-feed is achieved through line-hole punching. The cards are glued to the paper web with hot-melt glues.

4.5.3. PRESS CONFIGURATIONS FOR PUBLICATION

GRAVURE PUBLICATION PRESSES

Publication presses are designed for high speed printing of high quality color publications. Publication products include magazines, Sunday newspaper magazines, catalogs, newspaper inserts, and advertising printing.

The product requirements of publication gravure are:

- Versatile in-line finishing - Multiple printed sheets must be folded and assembled into complete publications on the press, or delivered as folded signatures to the bindery.
- Variable cutoffs.
- High speed production. (3000 + feet per minute)
- Color consistency throughout the pressroom.
- Adaptability to wide variety of substrates including light weight, lower-cost papers
- Lower start-up and running waste.

The majority of publication gravure presses have either 8 or 10 print units. New gravure presses tend to be in the 96 to 108 – inch web width range; most other presses ranging width from 70 to 92 inches. The same press can produce from one to six different products, with pagination of the signature from 8 to 128 pages.

Because of the width and speed of these presses, gravure publication plants use an enormous amount of paper. This requires sophisticated materials handling technology and a high degree of automation in loading paper rolls and splicing the new paper roll to the expiring roll when printing at high speed.

Construction of Publication Presses:

Modern gravure publication presses are generally equipped with only one unwinder for eight printing units. The use of wide web has led printers to run only one web per press, and larger diameter paper rolls, minimizing roll changeovers and related waste.

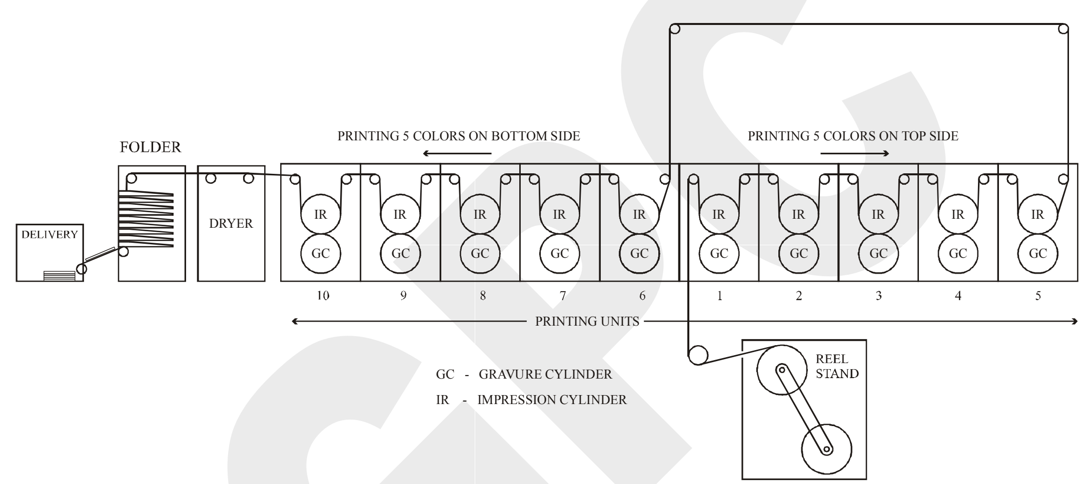
The roll of paper is transported, usually by automatic or motorized means, to the unwinder. Publication press unwinders have automatic controls for roll changeovers.

Web preconditioning units consists either of a hot air chamber or of heated drums, used to bring the paper to optimum temperature and moisture condition before printing.

Reversible printing units are equipped with two doctor blade groups, to permit printing of a web that travels from left to right as well as of a web going from right to left. The doctor blade is typically locked in a doctor blade holder, which may be integral to the press.

Publication gravure presses often add a cloth – covered pre-wipe roller to the ink fountain to improve ink application to the print cylinder. On presses with variable cylinder sizes, the depth of cylinder immersion in the ink fountain is adjustable.

For wide web presses, the impression roller is equipped with deflection compensation, which applies force not only on the journal ends of the roller, but also in intermediate positions on the roller length, to provide pressure uniformly across the web.



Gravure Publication Press

Electrostatic Assist systems facilitate transfer of ink from the cylinder engraving to the web. These systems charge the web, or the rubber, or the side of impression roller, attracting ink electrostatically to the substrate.

Wide web presses generally equipped with the rehumidifying system (stream bars) to raise the level of moisture in the paper when shrinkage occurs.

Publication gravure presses are connected to a wide variety of complex slitting, folding and finishing machines. These in-line operations include:

- Folding
- Stitching
- Auto stacking
- Inserting cards and coupons
- Gluing
- Perforating
- Flexo imprinting
- Letterpress imprinting

- Coating
- Trimming
- Rewinding

GRAVURE FOLDERS

A gravure publication press can be equipped with a variety of folders. The purpose of the folder is to take single or multiple webs from the printing units, slit them into ribbons, assemble the ribbons in aligned groups, and pass them through a cut-and-fold mechanism to produce a folded signature. Folding technology can only be described with a set of unique terms. Understanding this terminology is essential for anyone buying print, planning layouts, engraving cylinders, or operating a publication gravure press.

FOLDER TERMINOLOGY

Ribbons are formed by slitting the web as it emerges from the last print unit. These ribbons continue into folders where they are folded and recombined in various ways.

Angle bars change the orientation of the ribbon by turning it at 90° angle. Singly or in succession, angle bars are used to reorient web for reverse-direction processing, additional folding, or to superimpose a group of ribbons to obtain desired pagination.

Cylinder imposition is the way pages are laid out on the publican cylinder. The pages must match the configuration of the folder in order for every signature to have pages in the correct sequence and orientation in the finished product. A variety of cylinder layouts can be used depending on the type of folder, page size, page count, width of the press, and the final trimmed page size. A one-up imposition refers to a cylinder layout with one set of unique pages. A two-up cylinder repeats the page layout twice around the circumference of the cylinder and so on up to six- or eight-around on the newest presses.

TYPES OF FOLDERS

Variable cutoff folders are the most commonly used folders with publication gravure presses. They enable gravure printers to supply print buyers with a wide variety of product sizes.

- Upper and lower folders make up the two folder sections of a gravure press. The upper folder typically slits the web into ribbons, then uses angle bars to superimpose or gather the ribbons.
- The lower folder cuts and folds the gathered ribbons into signatures. The final size of the signature can be any desired length and width based on the dimensions of the printing cylinder.
- Former folders fold a moving web or ribbon in the grain direction of the paper (parallel to the web path). They are also referred to as long-grain folders.
- Combination folders are capable of a wide variety of folds in both the grain direction and cross-grain direction. Typically the first fold is accomplished

over a V-shaped former board and the second fold is at a right angle. Additional folds may be completed before the ribbon leaves the folder.

- Gravure lower folders are often variable in size. They are capable of producing products with different cutoffs, from different cylinder diameters, and can accommodate four-, six-, or eight-page layouts around the cylinder.
- Ribbon jaw folders assemble the ribbons then cut and fold them in the cross-grain direction. The folding action is accomplished by the jaw assembly and can be either a single or double parallel fold.
- Chopper folders have farmers and are used to produce two-on signatures or single signatures by alternating the deliveries. The fold is accomplished over the former in the grain direction.

4.6. SOLVENT BASED INKS, WATER BASED INKS, UV AND EB INKS

Gravure Inks

Gravure inks, like flexographic inks, are liquid inks; that is, they are inks with low viscosity. They are formulated with pigments, resin varnishes, plasticizers, and solvents. Many of the pigments used in lithographic inks are also used in gravure inks. The different types of gravure inks use different types of resins.

The mechanism of gravure ink drying is the same as that of flexographic inks. When the solvents are evaporated in the dryers, the solid resin remains to hold the pigments and to bind the ink to the substrate. The inks contain no driers. (Rotogravure news inks require no heat, as they dry by absorption.)

Publication gravure inks are used to print long editions on coated or uncoated paper. Here, ink cost is a factor, so relatively inexpensive resins are used for the resin-solvent varnishes. These include ester gums, zinc, magnesium or lithium rosin salts, and some hydrocarbon resins. Ester gums are chemically modified rosin, such as the pentaerythritol ester of rosin. The zinc resinates are rosins treated with zinc compounds, and the hydrocarbon resins are the same as those described for heatset web offset inks.

4.6.1. GRAVURE SOLVENT BASED INKS

With **gravure packaging inks**, other resins and solvents are used, depending on the material to be printed. There are many types of such inks, sometimes designated with letters: A, B. C, D, etc. Some of the resins employed depending on the ink type, are spirit- or alcohol-soluble nitrocellulose, chlorinated rubber, and vinyl resins.

Gravure inks are shipped in a concentrated form that decreases the tendency of the pigment to settle out. The inks are thinned or diluted at the press with a mixture of solvents suitable for use with the particular type of ink. The solvent mixture can also be varied in accordance with the desired rate of evaporation. As an example, consider a gravure packaging ink containing spirit-soluble nitrocellulose. One ink manufacturer suggests the following solvent mixtures for various evaporation rates:

Slow	Regular	Fast
1 part normal propyl acetate	2 parts ethyl acetate	1 part ethanol
1 part ethanol	2 parts ethanol 1 part toluene	4 parts ethyl acetate

Table: Recommended solvent mixtures for various rate of evaporation.

Thinners used for other types of gravure packaging inks include some of the solvents mentioned above as well as lactol spirits, naphtha, heptane, isopropyl acetate, methyl ethyl ketone (MEK), and others.

As a gravure ink is printed, the solvents evaporate from the ink remaining in the ink pan, the viscosity of the ink increases, and the ink becomes poorer in the lower-boiling solvent.

A makeup solvent mixture must be added. The idea is to use a makeup solvent mixture that will bring the percentage of each solvent in the ink back to its original concentration. Gravure inkmakers supply specifications and recommended makeup mixtures.

To keep the ink printing density constant, it is necessary to control the viscosity of the ink in the pan. Various viscometers are available. Many gravure presses are equipped with devices that control ink viscosity automatically.

Drying of Flexo and gravure inks

An advantage of water-based flexo is that and Gravure Inks recovery and disposal of the solvent is greatly simplified, but most gravure printing and flexo package printing still require inks containing organic solvents. (Many aqueous inks contain some organic solvents that must be properly disposed of.)

Organic solvents in the exhaust gas from gravure and flexographic press dryers are commonly removed by passing the gas through a chamber filled with activated carbon. The solvents are removed by adsorption onto the surface of the activated carbon particles. When the carbon becomes saturated with solvent, steam is used to strip the solvents from the carbon. While this operation is proceeding, the exhaust gas from the dryer is transferred to a second chamber, also filled with activated carbon. On cooling, the steam and solvents liquefy, separating into two layers. The recovered solvents can be either sold or used on the press as a dilution solvent.

4.6.2. GRAVURE WATER-BASED INKS

Water-based inks contain little or no volatile solvent and do not constitute an explosive hazard. However, as relative humidity increases, water evaporates more slowly. To keep the humidity from increasing in a dryer, it is necessary to increase the amount of exhaust air. Increasing the turbulence where the air impinges on the printed web is more effective than increasing the temperature when drying water-based inks and coating.

Excessive heat can cause extensible substrates to stretch and paper-based substrates to shrink, leading to register and tension control problems.

Water-based ink technology has been around since the 1960s. It is the least costly compliance option, but today's technology has many limitations. Water systems require as much as five times the amount energy that is required to dry solvent inks. Water inks have been successful in packaging and product applications where press speeds have a tendency to be slower than publication gravure press speeds. Acceptable print quality has been achieved on coated board, vinyl, aluminum foil, and lightweight papers.

4.6.3. GRAVURE UV CURING INKS

UV-curing coatings and printing inks are typically composed of a vehicle (comprising monomers, oligomers, and prepolymers), pigment, and additives, which include photoinitiator and inhibitor. The formulation is applied to a substrate and cured or polymerized rapidly by exposure to UV energy. The prepolymers contain chemical groups that react and cure with the monomer. The function of the photoinitiator is to absorb the radiation and initiate the free-radical polymerization.

UV-curing inks contain very little VOCs (Volatile Organic Compounds). Solvents found in conventional inks and coatings are replaced with low viscosity monomers and oligomers that adjust the viscosity and assist in pigment wetting to produce a workable ink vehicle. To produce a homogeneous polymerized ink film requires that the UV radiation penetrate the full thickness of the film. Except with screen printing, ink and coating films for UV or EB curing are essentially thin films. A generalized formulation for UV ink is presented in the following table.

Parts	
15-20	Pigment
25-40	Prepolymers
15-30	Monomers/oligomers
5-10	Photoinitiators
5-10	Other additives
100	

Table: General formulation for a UV ink.

Cured UV inks and coatings offer high resistance to scuffing, marring, and chemicals. They offer high opacity, gloss, and superior print definition, of especial value in printing packages. In addition, UV inks adhere well to a wide range of substrates, including polypropylene, polyethylene, polyester, and coextruded materials.

For printing on a nonabsorbent material (metal, plastic, or polyethylene-coated board), it may be necessary to add a polyester or a polyurethane acrylate to the formula to improve adhesion. The improved adhesion increases the cost of the ink and is appropriate to reduce cure speed.

With process color printing, good trapping may require tack-graded inks. It is sometimes better to fit a UV lamp between print units curing each color before the next is applied.

UV-CURING INKS FOR FLEXO AND GRAVURE

Tight emission controls of conventional flexo and gravure inks make UV-curing inks attractive. UV inks offer consistent color and viscosity during the print run because they contain no volatile solvents or water that can evaporate, causing changes in color and print characteristics. Once the job has started, press adjustments are minimal, and ink additives are not required. Even during a break in the run, the inks will not dry in the pan, anilox roller, or printing cylinder.

Polymerization

Polymerization occurs in three steps: initiation, propagation, and termination. Initiation involves generation of a reactive species. During irradiation with UV. the reactive species is formed by action of the energy on a photoinitiator to generate a free radical or a cation. In the propagation step, the reactive species reacts with another molecule, lengthening the chain and passing along the free radical. The propagation step is repeated many times. In the termination step, the free radical is “captured’ (no longer free), and the reaction is complete. All of this occurs very rapidly so that very large molecules are built in a second or so.

Applications of UV-Curing Inks and Coatings

UV-curing technology is applied in printing inks, coatings, adhesives, and laminates. UV curing inks are well established for difficult-to-dry nonabsorbent stocks such as plastic packaging and wet-on-dry printing. Instantaneous drying allows colors to be dried at press speed between printing units, thus eliminating the problems associated with wet-on-wet web or sheetfed printing.

In publication and commercial printing, UV curing is used on posters, magazine covers, book covers, and a broad range of products. In packaging, UV curing is used for printing and coating of paper, paperboard, film, and ceramics, producing folding cartons, labels, and record jackets among many products. In converting industries, it is used in many applications such as laminates, adhesives, and clear and pigmented coatings.

OTHER UV-CURING SYSTEMS

i. Free-radical-curing systems

Photoinitiators that generate free radicals under UV illumination are used with materials such as acrylic or methacrylic monomers or prepolymers.

Unsaturated, high-boiling acrylic or methacrylic monomers, oligomers, cross-inking agents, and low-molecular-weight polymers comprise the fluid, low-viscosity, light-curing coating system used in UV-curing inks and coatings initiated with free radicals.

Free-radical polymerization and cross-inking processes are inhibited by oxygen, which reacts with free radicals and interferes with both the initiation and propagation steps of the polymerization reaction. Coating surfaces are appropriate to remain tacky or "oxygen-inhibited." A blanket of nitrogen gas is used to remove air and prevent this inhibition. Good design of the equipment keeps nitrogen consumption to a minimum. Tacky surfaces can be overcome by a post cure or bake cycle.

The inhibition of cure is also overcome by incorporating amines into the formulation. For UV-curing inks, a high concentration of free radicals at the surface overwhelms the negative effects of oxygen.

The degree of cure, which is not easily measured, is affected by the following:

- Concentration of the photoinitiator
- Type of photoinitiator
- Radiation wavelength and intensity
- Film thickness
- Effect of oxygen
- Additives to the ink or coating
- Nature of the substrate and back scattering or transmission of UV light

ii. Cationic-curing systems

Most pigments absorb UV radiation, so that only very thin films or clear coatings can be cured by UV-free-radical chemistry. Under UV radiation, cationic initiators form cations, reactive acidic materials that react with cycloaliphatic epoxy compounds and vinyl ethers in the ink formulation to form a cross-inked network. Cationic initiators are not effective with acrylic or methacrylic systems.

Cationic-curing systems differ from free-radical systems in their components, chemistry, and properties, providing the possibility of a more complete cure of thick films. Cationic-curing inks and coatings are more expensive, but they offer many advantages over free-radical chemistry. The irradiated photoinitiators are more stable than the free radicals generate~ in other systems, and curing continues after the UV radiation of the printed or coated product stops. This largely overcomes the problems of undercuring sometimes experienced with free-radical systems.

Cationic-curing formulations exhibit lower shrinkage, which helps provide better adhesion on many difficult substrates. Cationic-cured films are more flexible than free-radical-cured films. Cationic systems are not air-inhibited, the photoinitiators do not initiate photodegradation reactions, and their stability permits migration of the activated initiator through a pigmented film, so that thicker films can be cured. Commercial adoption of cationic systems has been slow, partly because of higher costs and slower cure rates.

Cationic varnishes are used for overcoating plastic and metal containers such as toothpaste tubes and aerosol cans. Their ability to cure throughout thick ink films, combined with outstanding adhesion and low odor makes them attractive for printing heavy films on difficult substrates. These excellent properties have stimulated the development of UV curing flexographic inks for flexible packaging.

The free-radical and cationic systems are complementary systems, not rivals for the same market.

4.6.4. EB-CURING INKS AND COATINGS

Inks for electron-beam curing generally consist of pigments or dyes dispersed in high-boiling acrylic monomers or prepolymers used as reactive thinners to reduce the viscosity (table below). Other than the absence of photoinitiator, the chemistry of EB-curing inks and coatings is similar to that of UV free-radical-curing systems. Although a fully formulated EB-curing system is not merely a UV system without photoinitiator, the same principles apply and most of the same raw materials are used.

Parts	
38	Epoxy acrylate prepolymer
55	Resin Prepolymer
6	Wax and additives
1	Silicone slip additive
100	

Table: formulation for an EB-curing coating.

ELECTRON BEAM SYSTEMS

EB curing uses high energy streams of electrons rather than electromagnetic radiation to cure inks and coatings. Electrons accelerated by a high-voltage positive field have a short wavelength with energy sufficient to create free radicals when the electrons collide with monomers such as acrylates and methacrylates. Curing is instantaneous even in thick films, and no postcuring is required.

The 5-10% of UV formulation that comprises the initiator package is replaced by prepolymer or monomer. This offers several advantages. The EB energy easily penetrates thick films, and through-cure is no problem.

Replacing the photoinitiator with monomer or prepolymer enhances the mechanical properties of the cured film and reduces the presence of extractable materials. Eliminating the expensive photoinitiator reduces the cost of the ink and reduces risk of odor or contamination with toxic materials. Eliminating the possibility of odor and taint from the photo initiator is especially important with food packaging.

It should be possible, at a sufficiently high voltage, to generate electrons with enough energy to penetrate a sheet and cure ink or coating on both sides at once, but suitable equipment is apparently unavailable.

Equipment for Applying and Curing EB Inks and Coatings

Electron beams are generated by applying an accelerating voltage to a cathode. They have an energy of 120-300 KeV. Two types of EB accelerators are used in printing and converting plants. In the scanner type, electrons, generated from a point cathode in a high vacuum, are spread out into a curtain by a beam splitter. In the linear cathode generator, electrons are emitted from a suspended wire cathode. The electrons are not focused but are emitted over the total length of the wire.

The electrons leave the beam housing through a very thin metal foil. When these electron beams strike suitable monomers, they initiate polymerization. It must be performed in the absence of oxygen by using a vacuum or a nitrogen atmosphere.

The disadvantages of EB curing are the high cost of the installation, the need to operate in an inert atmosphere to minimize the inhibiting effects of oxygen, and the need to shield the equipment to protect operators from X rays generated when electron beams strike metal.

These problems are reduced with the latest designs that incorporate developing technology.

EXTRA

GRAVURE INKS

Ink is the critical link that ties the mechanical parts of the printing process together. Gravure inks are fluid, fast drying, and functional for virtually any application that can be produced on a gravure press.

Gravure ink is made of colorant dispersed in a vehicle capable of forming a very thin continuous film. After printing, the ink dries by evaporation leaving a dry printed film. Gravure inks can be custom-formulated for different substrates and end uses.

COMPOSITION OF GRAVURE INKS

Ink compositions include colorants and vehicles. Vehicles are composed of binders, modifiers, and solvents.

COLORANT

The component that imparts color to ink by absorbing selected wavelengths of light is a pigment or a dye. Pigments are fine solid particles that are insoluble in the liquid portion of the ink. They are selected for properties such as color, lightfastness, and chemical resistance. Dyes are soluble in the liquid portion of the ink and can be either synthetic or natural in origin. Most dyes are very transparent and have limited resistance properties. Fluorescent inks are made from dyes.

VEHICLES

Vehicles are made up of binders, modifiers, and solvents. **Binders** act as the glue that keeps the colorant and other ingredients evenly dispersed in the liquid ink and adhere it to the substrate. The main component of the binder is the resin, a special class of polymers that may be either natural or synthetic. The resin is dissolved in a solvent along with other components of the vehicle. After printing, the solvent evaporates in a process of drying and the resin solidifies The remaining solid layer of resin, colorant, and other ingredients is called the ink film. Common resins include nitrocellulose, maleics, phenolics, vinyl co-polymers, modified rosin esters, and acrylics

Modifiers are added during ink manufacturing to improve such properties as holdout, gloss, and scuff resistance. Modifiers, also referred to as additives, perform a very important function and can determine the success or failure of gravure ink. Modifiers added during the formulation process include neutral pigments, waxes, plasticizers, viscosity modifiers, and slip agents.

Solvent serves two purposes: to dissolve the resin and to adjust viscosity. Solvent is classified as either active, diluent, cosolvent, or incompatible, based on its ability to dissolve the resin in a specific ink. A solvent for one resin system may be incompatible in another. Active solvent is a true solvent for the ink resins. A diluent thins ink without acting on the resin. Cosolvents are mixtures of solvents that are more active mixed together than they are separately. Incompatible solvents will not mix with the ink formula and can cause the ink system to degrade. For example, an incompatible solvent added in a very small amount can cause resin to kick out of the ink. Technically this is the flocculation or precipitation of the solid part of an ink.

GRAVURE INKS MANUFACTURING

The majority of gravure printers purchase inks manufactured to suit their needs. Some printers purchase what they call bases and blend their own finished ink. A base is a highly pigmented dispersion that is made and stored separately from a finished ink. Blending is the process of custom-mixing the pigment dispersion with the vehicle, solvent, and modifiers to form a stable ink ready for printing or shipping. Either way, the physical properties and performance characteristics must be built into the ink from the very beginning of the process.

The goal of the ink manufacturer is to minimize the press-side adjustments needed during a pressrun. Gravure inks are manufactured strong so they can be thinned and extended to compensate for the following:

- Cylinder wear
- Variations in the substrate
- Variations from press to press
- Variations in doctor blade settings
- Variations in press speeds
- Changes in drying rates caused by atmospheric conditioning

Dispersion

Dispersion is a complicated process consisting of three overlapping steps: wetting, grinding, and stabilization. The dispersion is created by uniformly distributing the pigment particles in a vehicle.

During wetting, the air on the surface of the pigment particles is displaced by the vehicle components. The grinding step breaks aggregates or agglomerates of pigment into smaller particles. Grinding is accomplished using a heavy-duty machine called a mill. A variety of mills are used for pigment grinding.

Stabilization of a dispersion is necessary to prevent the pigment particles from re-agglomerating or flocculating. Flocculation can cause a loss of color, lower gloss, poor rub resistance, and increased settling in storage.

PROPERTIES OF GRAVURE INKS AND EXTENDERS

In addition to viscosity, gravure inks have several properties that influence the flow of the ink. Fluids that have the same viscosity, no matter how fast they are flowing or how vigorously they are agitated, are called Newtonian fluids. Water and motor oil are good examples of Newtonian fluids.

Fluids that change in viscosity when agitated are called non-Newtonian fluids. Most gravure inks fall into this category. The presence of pigments and other solids causes the ink to have a higher viscosity when at rest than when in motion. Different types of pumps can be used on the ink delivery system on a gravure press to reduce the mechanical effects on the fluid ink.

The tendency of ink viscosity to drop when the ink is agitated and then immediately return to a state of higher viscosity within seconds after agitation is stopped is called thixotropy. This is a common property of water-based inks and some solvent-based publication inks. Understanding the behavior of these fluids is necessary for the printer to efficiently maintain optimum printing viscosity.

COLOR

Strength or intensity of color is an important characteristic of gravure ink. There are three types of instruments commonly used to measure color—calorimeters, densitometers, and spectrophotometers. Understanding the difference between these instruments is important for proper communication between the printer, print buyer, and ink manufacturer.

The calorimeter or filter spectrophotometer views a sample through three wide-band color filters. These filters mimic the human eye’s sensitivity to red, green, and blue light. This is a handy pressroom tool, especially for checking line or solid colors. It is used in packaging and product gravure more often than in publication gravure.

Densitometers are very useful for determining the amount of ink on a substrate. They do not match the human eye’s sensitivity to color, and they are not able to detect differences in color. Densitometers are used primarily for process-color printing.

Spectrophotometers measure the relative energy levels, or intensities, of all the visible wavelengths reflected or transmitted from a sample. The measurements can be used to produce a three-dimensional graph of an individual color. The spectrophotometer is capable of translating color differences into a set of coordinates representing positions in a color space system such as CIE Lab.

The appearance of color is influenced by the viewing conditions which include the light source, the surroundings, and the viewer. Noon sunlight from a slightly overcast sky has a flat distribution curve (i.e., the light is neutral white with no predominant hue). By comparison, incandescent light has a predominant red and yellow hue, and fluorescent light is predominantly blue. The viewing field of the surround influences the viewer. Because the light source and viewing conditions exert a strong influence on color perception, color comparisons should be made under standardized conditions, with a neutral gray surround and a 5000 K light source set at an overhead angle to eliminate shadows.

Color measurement instruments have many practical applications. They can be used to compare incoming materials to standards, and cylinder proofs to production proofs. Color measurement instruments can also be mounted on the press to monitor color during the printing process.

GRAVURE INKS CLASSIFICATION

The Gravure Association of America (GAA) has developed an ink classification system over the years to assist the printer in determining the proper solvent to use for mixing. In publication gravure, the letter designations are rarely used today. In an attempt to set standards for communication, the Gravure Publication Ink Committee set up basic classifications in which the inks are classified by end use. Group I inks are designed for tabloids, supplements, magazines, and inserts printed on uncoated groundwood papers. Group VI / SWOP inks are formulated primarily for coated paper. SWOP is the "Specifications for Web Offset Printing." The GAA ink classification system is still used for packaging and product inks.

- A-type inks use aliphatic hydrocarbons as solvent. These are usually used for publication printing and can be referred to as Group VII inks.
- B-type inks are also publication inks and usually require at least 50% of the solvent to be an aromatic hydrocarbon. These inks are also referred to as Group VI.
- C-type inks include various formulations, most of which contain nitrocellulose. These formulations require solvents of the ester or ketone class such as ethyl acetate, isopropyl acetate, or normal propyl acetate, acetone, or methyl ethyl ketone (MEK). These solvents can be mixed with alcohol because alcohol is a latent solvent for nitrocellulose; when mixed with an equal amount of an acetate solvent, alcohol works as well as a pure ester. C-type inks are the most common solvent-based inks used in packaging gravure.

There are eleven categories in the GAA ink classifications. In addition, there are special inks and coatings that are not classified. Many special coatings have been developed to enhance end use performance. Some of these products include catalytic coatings, barrier coatings, ultraviolet cured coatings (UV), and heat transfer inks for textile decorating. The Food and Drug Administration (FDA) and the United States Department of Agriculture (USDA) set regulations that affect the choice of pigments and vehicles that can be used to formulate inks for specific applications. Gravure printers and print buyers need to be aware of any regulations that might affect a particular application.

SPECIAL PRODUCTS BY GRAVURE

As mentioned earlier, the gravure printing process has the ability to handle many unique products. Listed below are just a few of these applications.

- Heat-seal coatings resemble a clear transparent topcoat. During a subsequent converting operation such as bag making, the heat seal will remelt and fuse with itself or some other surface of the package.
- Cold-seal adhesives have the ability to adhere to themselves, making a seal without using heat. This is especially useful for ice cream and other frozen products.
- Laminating adhesives can be applied either in line on a gravure press or on a laminating machine. The laminating adhesive provides a bond between two substrates and contributes barrier properties to the structure.
- Electrically conductive coatings are usually pigmented with conductive carbon black. One use for this coating is as a background for spark discharge graph papers and message forms.

GRAVURE INK TESTS AND MEASUREMENTS

WET INK TESTS

The most important test to perform before using ink on press is a test for color, shade, and strength. This is easily accomplished with a drawdown. Drawdowns from the ink to be used should be compared to an existing standard. To insure the tests produce predictable and reliable results, consistent procedures, equipment, and viewing conditions should always be used. Ink drawdowns can be made using a smooth-edged blade, wire-wound rod, glass rod, or a laboratory proof press. Other wet ink tests include:

- Ink viscosity should be measured after the ink has been thoroughly mixed and is at pressroom temperature.
- Test pH for the acidity or alkalinity of the ink. Water-based inks in particular should be tested for proper pH levels. A pH meter is the most reliable method of testing.
- Ink abrasiveness can be tested on a variety of abrasion testers. Abrasive ink can cause excessive cylinder and doctor blade wear
- Weight per gallon should be checked on each new batch of ink when it is received. The reading should be taken at a standard temperature, since ink is subject to volume expansion when heated.
- Solids content is related to weight per gallon. Solids are what is left after the ink is completely dry. Solids content is very important in determining coat weight and engraving specifications.

TESTS FOR GRAVURE PRINTED SUBSTRATE

Printed products must meet customer specifications for both appearance and performance. Physical tests are conducted to insure product performance. Visual tests are used to evaluate the printed product for print defects and correct color match.

AGPC

Physical tests include:

- Rub or abrasion is common to all gravure-printed products. The Sutherland rub tester is widely used to test for rub resistance and the Tabor tester is commonly used for abrasion testing.
- Blocking is a condition wherein the printed surface adheres to itself and another surface. It is a function of temperature, relative humidity, pressure, time, and the surface characteristics of the contact material. Many blocking tests have been developed to predict a printed product's tendency to block.
- Slip refers to coefficient of friction (COF). COF is an extremely important property for publications and packaging converting. There is a variety of testing equipment available, but results are difficult to correlate. Standard test methods should be established between the printer and customer to insure consistent product performance.
- Ink adhesion is usually tested with a 6-in. strip of Scotch #600 or 610 adhesive tape. It is pressed firmly against the ink film, with a short tab free for grasping. The tape is quickly pulled or lifted at approximately 45°. The amount of ink transferred to the tape is evaluated. Variations to this test have been established to meet specific end-use requirements.

Other visual tests include:

- Register
- Skipping or missing dots
- Mottle
- Drag-out
- Haze
- Setoff
- Picking
- Pinholing
- Railroading or tracks
- Screening
- Scumming
- Snowflaking
- Volcano
- Whiskering and feathering

Complete descriptions of print defects and test methods are available from the Gravure Association of America.

ROTOGRAVURE INKS

With the exception of intaglio or steel die printing, which requires a much stiffer ink and is used for printing stationery, currency, and postage stamps, most gravure printing is done by rotogravure, which is a fast, high-volume method of printing. Rotogravure presses often have a wide web and are used to print long-run magazines and catalogs, labels and wrappers, beverage carriers, wallpaper, gift wrap, textiles, linoleum, and many other products. Sheetfed gravure is used only for a few artworks and products requiring rigid control of color such as cosmetic boxes.

Solvent-based gravure inks (with solvent recovery) will continue to dominate publication gravure printing as long as environmental regulations permit the widespread use of toluene. Should toluene become unacceptable, water-based inks can be used. Water-based inks dry more slowly, they interact with paper, and they are more expensive. (The toluene is recovered, reducing its cost and environmental impact.)

CHARACTERISTICS OF ROTOGRAVURE INKS

Gravure inks contain volatile or low-boiling solvents that are of easily dried by evaporation. Although the construction of the rotogravure press limits the exposure of ink to air, highly volatile gravure inks do evaporate on the press, and this changes their viscosity. The printer therefore must control ink composition (and printability and color) by checking the viscosity of the ink periodically. Modern presses are equipped with automatic viscosity controls.

Rotogravure presses do not have rubber rollers or plates, and the inks can be made with strong solvents that help them adhere well to plastic. The solvents can be so strong that the ink actually etches the plastic.

Gravure inks must be nonabrasive and free from grit. Abrasive particles wear doctor blades and cylinders. A nicked or badly worn doctor blade will cause streaks, requiring the printer to stop the press and change blades, a very expensive proposition on a large, high-speed press. If the cylinder is damaged, the press may be down for a long time while the cylinder is being repaired or replaced.

Gravure inks are less heavily pigmented than lithographic, flexographic, or letterpress inks because the gravure cylinder delivers an ink film that is thicker than the one delivered by lithographic, flexographic, or letterpress plates. This thicker ink film delivered in shadow areas contributes to the gloss that is characteristic of “gravure quality”.

Gravure inks are not shipped at the low viscosities used on press because the pigments tend to settle out. Instead, gravure inks are usually sold in concentrated form to be diluted, or “let down,” at press side, using recovered solvent.

Because the gravure cell transfers a large volume of ink with a low pigment concentration, gravure is an excellent method for printing gold (bronze) and silver (aluminum) inks. Gravure golds are brilliant and nontarnishing. These metallic pigments are difficult to print by lithography, which requires inks with high pigment loadings.

Since gravure inks for package printing and publication printing differ in composition and have different end-use requirements, they are often considered in two groups. Plastic film makes an excellent packaging substrate for rotogravure because it is smooth, glossy, and nonabsorbent. With transparent plastic film, the image is usually printed on the reverse side so that the film gives the package a high gloss and protects the printed ink film.

SOLVENCY

In general, a given solvent will dissolve a particular class of binders or vehicles, but its behavior is influenced by the other materials in the ink. Viscosity is related to solvency: strong solvents give low-viscosity solutions. For example, the viscosity of an 8% solution of nitrocellulose in ethyl acetate is lower than the viscosity of an 8% solution of nitrocellulose in normal-butyl acetate. Ethyl acetate is a much better solvent for nitrocellulose than is normal-butyl acetate.

CLASSIFICATION OF GRAVURE INKS

Gravure inks are commonly classified according to their application and composition. Type A and B inks are used for publication printing, and types C through X for packaging. Any of these inks may be formulated with wax or synthetic resin to achieve scuff resistance or with other additives to achieve special properties.

FORMULATIONS OF GRAVURE INKS

Representative gravure ink formulations are presented in the following table.

General inks		Publication inks (Catalogs)	
Parts		**Parts**	
20	**Pigment and toner**	**8**	**Phthalo blue**
28	**ResinMonomers/oligomers**	**15**	**Chlorinated rubber**
47	**Solvent**	**10**	**Phenolic modified resin**
5	**Wax, plasticizer, and additives**	**5**	**Plasticizer**
		1	**PE wax**
		51	**Toluene**
100		**10**	**Ethyl acetate**
		100	

Table: Typical formulations of rotogravure inks as shipped by the manufacturer.

Pakaging inks		Water-Based Publication inks	
Parts		**Parts**	
33	**Titanium dioxide**	**15**	**Phthalo blue**
22	**Nitrocellulose varnish (in ethanol/toliol/ester)**	**47**	**Acrylic resin**
		30	**Water**
37	**Rosin ester varnish**	**2**	**Alkali**
3	**Plasticizer**	**1**	**Antifoam**
5	**Wax compound**	**2**	**PE wax**
100		**3**	**Isopropanol**
		100	

Table: Typical formulations of rotogravure inks as shipped by the manufacturer.

WATER-BASED GRAVURE INKS

Water-based inks are widely used in package-gravure printing, and almost all gift-wrap is printed with water-based inks. Water is inexpensive, and it causes minimal environmental problems. It sometimes causes problems with paper, however. Some packaging gravure still uses solvent-based inks that provide desired functional properties and better adhesion. Printing with solvent-based inks requires solvent recovery or incineration.

GRAVURE INKS FOR VARIOUS SUBSTRATES

As with other types of printing, the printer must consult the ink manufacturer for help in selecting the best ink.

- Newspaper supplements are usually printed with type A inks, which are based on aliphatic hydrocarbons.
- Supercalendered or coated publication papers are usually printed with type B inks, which contain aromatic hydrocarbons, usually toluene (toluol).
- For glassine and vegetable parchment papers, a good film former is needed for good flexibility and adhesion, and type E (alcohol) inks work very well; the lack of residual odor is an additional advantage if the paper is used for a food or candy wrap.
- For printing poly(vinyl chloride), type V inks are preferred; the strong solvents (ketones plus toluene) permit use of resins that provide good adhesion.
- For poly(vinylidene chloride) (sometimes called PVDC) and for “K film” (cellophane coated with PVDC), type D inks are often used. The solvent is typically a cosolvent comprising an alcohol plus an aliphatic hydrocarbon).
- Type C gravure inks use a ketone or ester solvent. Aluminum foil is printed with type C or D inks, but to ensure good adhesion, the printer must buy a foil that has been degreased. The foil may be primed with nitrocellulose, shellac, or a vinyl resin.

In addition to publication and packaging inks, gravure is sometimes used with heat-transfer inks for textiles. Heat transfer inks contain a sublimable dye. The dye is printed on paper using gravure, lithography, flexography, or screen printing. When the printed paper is heated and pressed against a textile, the dye sublimes (evaporates) and migrates into the textile fibers, decorating the textile.

TESTING GRAVURE INKS

The development and application of a significant testing procedure is not a simple task. However, a simple drawdown with a broad scraper or knife will give a fair amount of information about an ink. The drawdown can conveniently be done with a wire-wound rod-a Meyer bar (figure below). The sample ink can be drawn down next to a standard, and the inks compared for drying speed, shade, color strength, finish, and penetration. A more sophisticated instrument is the GRI printability tester, which is a bench-size proof press. It has been used in product development and research laboratories to study gravure ink/paper interactions. An anilox hand proofer conveniently produces a print for visual or instrumental evaluation.

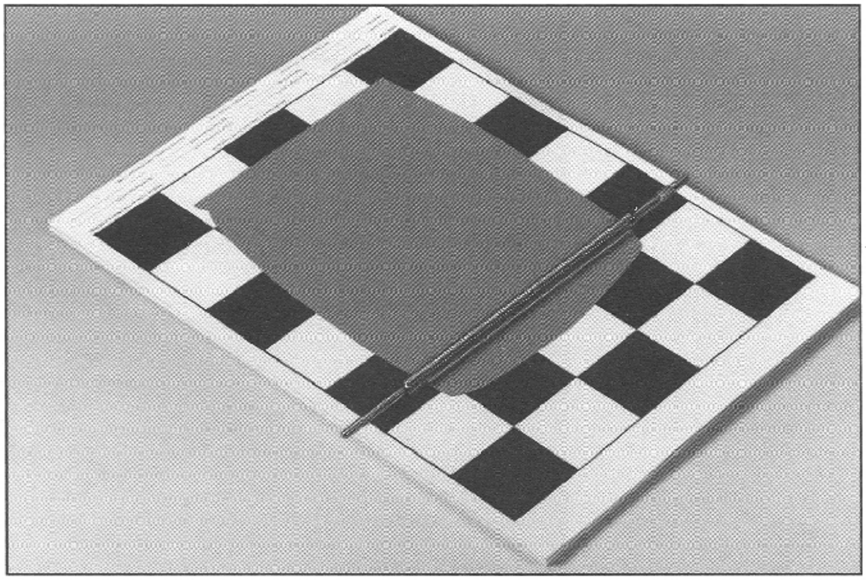


Fig. Draw down test.

When ordering ink, the printer may wish to specify uniformity of strength and shade, shipping viscosity, density or specific gravity (weight per gallon), and dilution viscosity. Viscosity, of course, is monitored not only upon receipt and after dilution but also throughout the printing process.

PROBLEMS WITH GRAVURE INKS

Printing problems associated with gravure inks are discussed in the following section on troubleshooting. Two common problems are illustrated in figures below.

Fig. Gravure print problems - Snowflaking or missing dots.

Fig. Gravure print problem - Whiskers (magnified about 15-20x).

Snowflaking is caused by failure of the paper to touch the ink in the gravure cell during printing. The picture illustrates the importance of a very smooth paper. Snowflaking is reduced by the use of electrostatic assist (electroassist).

Whiskers are caused by static electricity and are reduced by eliminating static. The electroassist, so helpful in controlling snowflaking, aggravates whiskers.

UNIT: IV – GRAVURE PRINTING

PART - A - 1 Mark Questions

1. Name the various layers of imaged copper cylinder.

i. Base steel core layer
ii. Nickel layer
iii. Base copper layer
iv. Engraving copper layer
v. Chromium layer

2. What are the different methods of copper plating the cylinder?

i. The thin copper layer method (approximately 80 mm of copper)
ii. The Ballard skin method (removable copper skin of 80 to 100 mm)
iii. The heavy copper plating method (approximately 320 mm of copper)

3. How do gravure inks dry?

Gravure inks dry by evaporation of solvents. Gravure inks are low viscous inks. This low viscosity is achieved by using a high proportion of solvent. To dry the printed ink, the solvent must be evaporated by using high velocity air drying after leaving the printing nip.

4. What are doctor blade streaks?

One of the most common print defects unique to gravure printing is the doctor blade streak. This streaks occur because a foreign particle (dirt) will get lodged under the doctor blade, causing a streak. Proper doctor blade oscillation can minimize this problem and reduce cylinder wear.

5. What are solvents?

Solvents serves two purposes – to dissolve the resin and to adjust viscosity of ink. Solvents are liquids that dissolve a solid. In an ink, the evaporation of solvent leave the solids behind as an ink film on the substrate.

6. What do you mean by solvent based inks?

Gravure printing uses solvent based inks which are shipped in a concentrated form. These inks are thinned or diluted with a mixture of solvents suitable for use with particular type of ink. Gravure inks dry by evaporation of solvents.

7. State the different types of doctor blades used for gravure.

Types of Doctor Blades based on designs:

- Conventional doctor blades
- MDC / Ringier doctor blades
- Counter face doctor blades
- Rounded doctor blades

8. State the doctor blade-wiping angle recommended for gravure printing.

Manufacturers recommend a contact angle of between 55^{o} to 65^{o} angle for optimum wiping performance.

9. State the functions of doctor blade.

The function of the doctor blade is to wipe ink from the surface of the Gravure copper cylinder, leaving ink only in the recessed gravure cells.

10. What are the different types of gravure impression roller?

- Three-roller system using engraved cylinder, impression roll, and a backup roller.
- Two-roll system using engraved cylinder and a crowned impression roller.
- Two-roll system consisting of the engraved cylinder and an internally – supported impression roll.

11. State the functions of gravure impression roller.

The functions of the impression roll are to force contact between the web and the engraved cylinder, to create the necessary web tension between printing units, and to propel the web through the press. The impression roll brings the substrate in contact with the engraved cylinder resulting in proper ink transfer. It is a friction driven rubber covered metal cylinder. It helps to propel the web through the press and set the web tension pattern between press units.

PART - C: 3/6 Marks Questions

1. What is integral shaft and mandrel shaft?

There are two basic cylinder designs (figure below).

- **Mandrel**
- **Integral shaft**

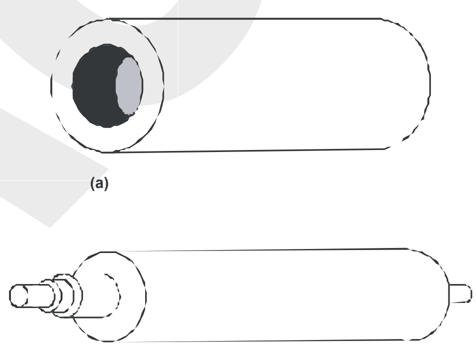


Fig. Two forms of gravure cylinders.

There are two basic forms of cylinder construction: mandrel (a) and integral shaft (b)

A **mandrel cylinder** (sometimes called a sleeve or cone cylinder) is designed with a removable shaft. Most holes are tapered so that the shaft can be pressed into place and then removed easily.

In the **integral shaft design**, the shaft is mounted permanently on the cylinder. The cylinder is formed first, and then the shaft is either pressed or shrunk into place. The shaft is attached permanently by welding and remains in place for the life of the cylinder.

Integral shaft cylinders are more expensive than mandrel cylinders but are generally considered to produce high-quality images. This is because they produce greater support across the length of the cylinder during press runs than hollow mandrel cylinders.

2. What is ballard skin copper plating?

The Ballard shell process is a special technique used by some publication printers that allows easy removal of a copper layer after the cylinder has been printed. The cylinder is prepared in the usual manner, including copper plating, except that it is cut twelve thousandths to fifteen-thousandths (0.00012 TO 0.00015) of an inch undersize in diameter. The undersized cylinder is coated with a special nickel separator solution and is returned to the copper plating bath. A second layer of copper is then plated onto the cylinder over the first layer. The cylinder is then cut or ground to the desired size, given an image etch, and printed.

The difference between most gravure cylinders and Ballard shell cylinders is seen when the cylinder has been printed and is ready to receive another image. The second copper layer can be simply ripped off the ballard shell cylinder base. A knife is used to cut through the copper to the nickel separator layer, which allows the shell to be lifted away. The cylinder can then be cleaned, a new nickel separator solution can be applied, and another shell can be plated to receive the image.

3. State the functions of drying system in gravure printing.

Dryers are necessary for high – speed gravure printing because the web cannot run straight through multiple printing stations without making contact with other rollers. The ink must be dry enough not to stick to any roll it contacts with the printed side of the web. Heat sources of gravure dryers include steam, gas, electric, thermic oil, gas/oil combination, and waste heat from incinerator. Gravure dryers are designed based on the substrate, ink and coating, specified by the printer. Each dryer has an exhaust duct containing a damper to control the amount of air exhausted and consequently the amount of fresh air is drawn into the dryer.

4. What is electrostatic assist?

A great advantage of the gravure process is that it allows high-quality images to be printed on low-grade papers. Problems do occur when the paper surface is coarse and imperfect, however. Ink transfers by direct contact. If a defect in the paper prevents that contact, then no image will transfer. The Gravure Research Association (now part of the Gravure Association of America) designed and licensed a special device, called an electrostatic assist, to solve this problem and improve image transfer. With electrostatic assist printing, a power source is connected between the cylinder and the impression roller (figure below). A conductive covering must be added to the impression roller, but the cover causes no special problems. An electric charge is created behind the web, which forms an electrostatic field at the nib width. The charge pulls the ink around the edges of each well, which causes the ink to rise and transfer to the paper. Most presses are now equipped with electrostatic assist devices.

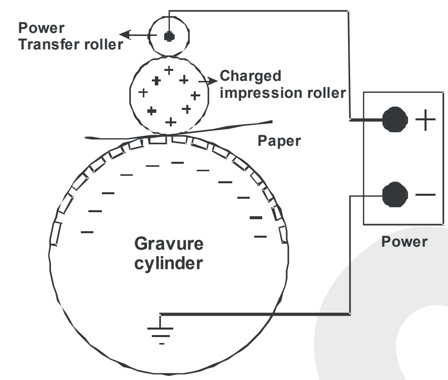


Fig. Diagram of electrostatic assist printing.
Electrostatic assist printing charges the impression roller and the gravure cylinder so that the ink lifts electrostatically from the cylinder to the paper.

5. What is a solvent recovery system?

Solvent recovery system removes solvent fumes from- the dryer exhaust air and collects the solvent for reuse. Solvent recovery systems are excellent for multiple press operations where the solvents be selected for easy recovery and reuse. Publication gravure liters use solvent recovery systems almost exclusively. The recovered solvent costs only a fraction of the cost of new solvent and helps to offset the cost of the solvent recovery equipment.

Solvent recovery for packaging and product gravure operations more difficult because of the variety of solvents used in the ink and coating formulations. Recovered solvent requires further treatment before it can be reused. This often increases the cost above the cost of new solvent. Solvent recovery is very rarely cost effective for packaging and product printers running multiple solvents.

6. What are the factors that determine selection of solvents for gravure inks.

Solvents are particularly important in gravure – they ensure the low viscosity of the ink and they also change the pigment concentration / optical ink density. The following factors are important for selecting solvents:

- Boiling point
- Evaporation number
- Flash point
- Explosion limit
- Odour
- Work safety and
- Ecological compatibility.

Completely different solvents have to be used for Publication gravure and Gravure package printing. This is mainly because of the very varied requirements of individual packaging.

7. State the advantages of water based gravure inks.

- Water based inks are designed to be reduced with water and the press clean up is done with water. Most water inks are emulsions rather than solutions as in the alcohol type ink.
- Water based inks are almost always used on absorbent surfaces such as paper. Water is the usual solvent.
- The main advantage of water – based inks is that they do not present a fire hazard since solvents other than water are not necessarily needed. Water is very convenient for use and economically it is also cheaper.
- Water based inks have been successful in packaging and product applications where press speeds have a tendency to be slower than publication gravure press speeds. Acceptable print quality has been achieved on coated board, vinyl, aluminium foil, and light weight boards.

GLOSSARY

Balance

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

Carbon Absorber

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

Chalking

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

Combination Folder

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

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.

Doctor Blade

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

Dynamic Balance

The state when rotating masses are in equilibrium.

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.

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.

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.

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.

Face Printing

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

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.

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).

Incineration

The destruction of solid, liquid or gaseous wastes by controlled burning at high temperatures.

Mandrel

A shaft upon which cylinders, or other devices, are mounted or affixed.

Photoengraving

A metal plate prepared photochemically, from which the matrix or rubber mold is reproduced.

Pigment

An insoluble coloring material dispersed in a liquid vehicle to impart color to inks, paints and plastics. *See also dyes.*

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.

Score

To make an impression or a partial cut in a material to facilitate its bending, creasing, folding or tearing.

Slitter

A machine to cut roll stock in the long direction. Three types are widely used: razor blade slitter, shear slitter and score cutter.

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.

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.

Water-based Ink

An alternative to solvent-based inks, these contain a vehicle whose binder is water-soluable or water dispersible.

Web Guide

The device which keeps the web traveling in a straight or true path through the press.

PART - C: 12 Marks Questions

1. Describe the process sequence for the preparation of copper cylinder.
2. Explain the various methods of copper plating the gravure cylinder.
3. Explain the gravure drying systems with diagrams.
4. Describe the working principles and functioning of gravure solvent recovery system.
5. Explain the structure and mechanisms of gravure doctor blade.
6. Explain the structure and mechanisms of gravure impression roller.
7. Describe the construction of a gravure packaging press with diagrams.
8. Explain the main sections of a gravure label press with diagrams.
9. Describe the construction of a gravure publication press with necessary sketches.
10. Explain the characteristics of solvent-based inks and water-based inks used for gravure printing.
11. Write notes on a) Ultraviolet inks b) Electron beam inks used for gravure printing.
12. Write short notes on (a) Label press (b) Solvent based ink (c) Drying chambers.

UNIT - V – SCREEN PRINTING

5.1. MESH, SQUEEGEE SELECTION

5.1.1. MESH (WOVEN SCREEN PRINTING FABRIC)

The woven screen printing fabric serves two primary functions: the fabric supports the stencil system, and the fabric's mesh permits ink to flow through the image area. The mesh plays a dominant role in metering the amount of ink that will flow onto the substrate.

The earliest fabrics used for screen printing included silk, hence the former name for the process: silk screen printing. Today, monofilament polyester is the most common screen fabric, followed by multifilament polyester, nylon, wire mesh, and silk, in that order.

Nylon, for example, is often used for container printing where the fabric must conform to unusual surfaces during printing and then it return to its original shape afterwards. Metalized polyester and stainless steel are commonly used when maximum stability is required and static is a by-product of the print action. The mesh may be grounded to relieve erratic print edges where the ink follows a conductive path onto the substrate.

MATERIALS USED FOR SCREEN PRINTING FABRICS

The two basic categories of fabrics commonly used in screen printing are multifilament and monofilament.

MULTIFILAMENT FABRICS

Multifilament Fabric is made up of many fine strands twisted together to form a single thread. The multifilament threads are woven together to form the screen mesh. Multifilament fabric is gauged by the double-X system. Used for many years for measuring silk bolt cloth, but not based on any real measurement, the double X is preceded by a number denoting mesh count. The higher the number the finer the mesh and the smaller the mesh openings. Multifilament fabrics commonly range from 6XX to 25XX. Most multifilament fabrics used for screen printing applications are either silk or polyester.

i. Silk

Silk, the original mesh fabric used in screen printing, is the strongest of all natural fibers. Each silk filament varies in width, causing irregular mesh apertures that can distort the printed image. Since silk is a multifilament mesh, it cannot be woven as fine as monofilaments. Therefore silk is only suitable for work where accurate registration and fine details are not required. Because silk has irregularities and a rough surface structure, ink particles tend to become lodged between the twisted strands, making silk difficult to clean. For these and other reasons, long-time users of silk have turned to multifilament polyester.

ii. Polyester

Multifilament Polyester is less expensive than domestic and imported silk. It has more uniform mesh apertures and doesn't expand as much as silk during printing. As opposed to silk, polyester is not affected by strong chemicals used in cleaning or reclaiming the screen. The disadvantage of multifilament polyester is that the fibers tend to flatten considerably more than monofilament fibers at thread intersections. This results in a closing of mesh apertures that shows up in printing as saw-toothed image edges.

Because of their construction, multifilament fabrics are thicker and have a rougher surface structure than monofilament. They adhere well to knife-cut stencils and are best suited for printing where heavy ink deposits are required. Multifilament fabrics are usually used to print textiles, large posters, and textured or contoured surfaces.

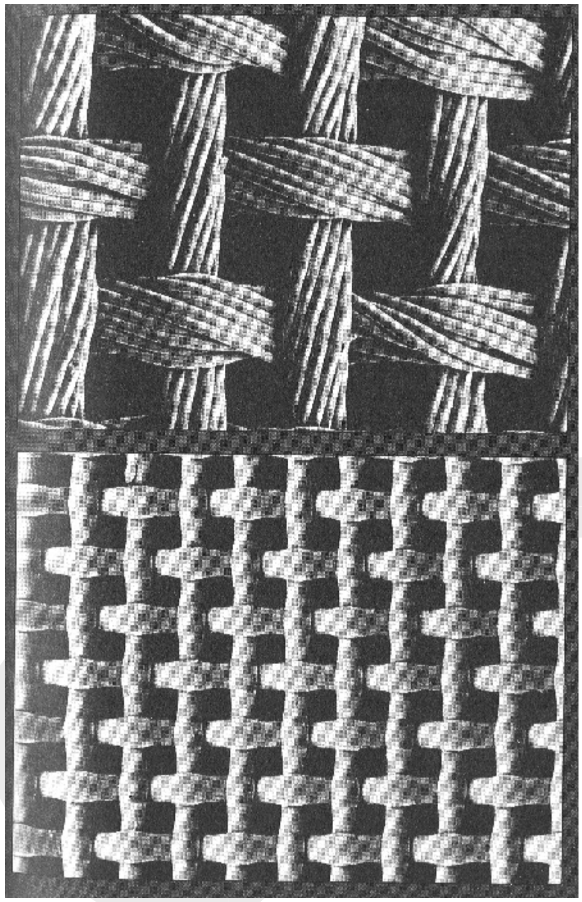


Fig. Multifilament mesh (top) and monofilament mesh (bottom)

MONOFILAMENT FABRICS

Monofilament fabrics are constructed of single strands of synthetic fiber woven together to form a porous mesh material. Monofilament fabrics have a smooth surface structure that produces uniform mesh apertures. These fabrics include polyester, nylon, wire mesh, and metalized polyester. Monofilament fibers can be woven finer than multifilament's and still retain adequate open areas for easy ink passage. Unlike multifilament fibers, monofilament fibers are measured by actual mesh count per inch or centimeter. Therefore a #200 nylon mesh would contain 200 threads in one linear inch (tpi). Monofilament fibers are available in a wide variety of mesh counts ranging from approximately 38 to 420 threads per inch. Multifilament fibers, on the other hand, can be woven only to 25XX or 30XX, which roughly corresponds to 200 tpi.

iii. Nylon

Nylon, which is available only as a monofilament, has similar construction characteristics to monofilament polyester with the exception of stability. Nylon is a very elastic fiber, making it a favorite for printing irregularly shaped or contoured surfaces. However, elasticity is an undesirable characteristic wherever critic registration is a necessity. Nylon is also affected by temperature and humidity, making multicolor registration very difficult at times.

iv. Wire Mesh

Wire mesh, commonly called wire cloth, is commonly used with abrasive inks, such as those used to print on ceramics, or wherever extreme sharpness, close tolerance, and thick ink film deposits are required, as in printed circuit boards. Wire mesh is extremely stable and is available in very fine mesh counts up to approximately 635 tpi. Reclaiming these screens, the process of stripping the stencil from a screen so it can be reused, is comparatively easier than with nylon or polyester, and they can be reused many times. Wire mesh, however has a total lack of memory, i.e., it will not spring back if dented or grooved, as will nylon, polyester, or silk.

v. Metallized Mesh

Metallized mesh is a relatively new fabric developed for screen printing. It is composed of a monofilament synthetic fiber, either polyester or nylon, coated by an extremely thin layer of metal. In combining these elements, metalized polyester or nylon mesh has the advantages of both wire and monofilament synthetics. It will not dent or deform like wire nor does it repel indirect stencils without pretreatment as does polyester or nylon. The metal coating makes cleaning the screen easier than that of synthetic fibers. Metalized mesh has excellent dimensional stability and can be used for very long runs where close tolerances and exact register are a necessity.

SELECTING A MESH (SCREEN PRINTING FABRIC)

Selecting a screen fabric is one of the most important decisions a screen printer must make. The type of material along with mesh count, substrate absorptivity and shape, nature of ink, type of stencil, squeegee composition and blade angle, the design characteristics, and the thickness of the printed ink deposit required are all factors considered prior to actual printing.

The following are general rules of thumb that can be used in deciding which screen fabric will best suit the printer's needs.

- Monofilaments are more abrasion resistant, available in finer mesh counts, and offer easier cleaning and ink passage than multifilaments. The screen surface must be mechanically and chemically pretreated to allow indirect stencils to adhere.
- Multifilaments have a thicker and rougher surface than monofilaments and offer excellent adherence for knife-cut stencils along with heavy deposits of ink.

- The open area of a mesh is the area between threads; it allows the passage of ink. The larger the percentage of open mesh area, the greater the amount of ink deposited during printing.
- Each mesh opening should be at least three times larger than the average grain size in the pigment of the ink otherwise a screen will clog during printing.
- Mesh count varies according to thread diameter the smaller the thread diameter, the finer the mesh.
- Thread diameter is one factor that determines the thickness of the printed ink film—the thinner the thread, the thinner the printed ink deposit; conversely, the thicker the thread, the thicker the ink deposit.
- The finer the detail in the design, the finer the mesh needed to reproduce it. For halftone and full-color printing, a mesh least three times finer than the screen ruling of the halftone is needed.

5.1.2. SQUEEGEE SELECTION

THE SQUEEGEE

The squeegee is a rubber or plastic blade, attached to a handle, use to force ink through the open areas of the stencil and mesh to the substrate. The functions of the squeegee are to control the spread of ink across the screen during printing to bring the ink-filled screen into contact with the substrate and-to a certain extent-to determine the thickness of the printed ink film.

Ink is applied to one end of the screen. The squeegee blade should be slightly larger than the image area to ensure even ink coverage. The Width of the blade is a function of the image size. As much distance as possible between the blade and edges of the frame is recommended, but the squeegee needs to exceed the width of the image area by a inch or two on each side of the image width. The squeegee controls the spread of ink because it is used to draw the ink across the screen, causing it to penetrate the open area of the image carrier. This can be done either manually or by machine, depending upon the type of work, length or run, or availability of equipment.

The second function of the squeegee is to bring the ink-filled screen into contact with the substrate during off-contact printing. Screen printing can be done either on-contact or off-contact with the substrate.

During **off-contact printing**, the screen is lowered to a point slightly above the substrate. The squeegee is drawn across the screen with downward pressure. Because of the elasticity of the screen, the pressure of the squeegee forces the stencil into contact with the substrate. As the squeegee passes, the stencil immediately separates or snaps off from the wet print. Off-contact printing generally produces sharper prints by eliminating image spread and smudging. The use of a vacuum base will prevent a flat, lightweight substrate from sticking to the underside of the screen when it is raised. In manual printing, off-contact can be established by taping cardboard shims to the underside corners of the frame.

Automated Screen printing presses employ adjustable devices that control the amount of off-contact.

On-contact printing is done with the underside of the screen in full contact with the substrate. On-contact is used when heavy ink deposits are required. However, since image sharpness will decrease considerably, it is used only on substrates for which image sharpness is of little importance, e.g., textiles such as terry cloth or towels.

SQUEEGEEE SELECTION

I. Shapes of Squeegee blades

Squeegee blades are available in a variety of shapes. Different shaped blades are used to print on different substrates. The simplest and most common profile used in screen printing is a square 90° angle. The general shapes and uses for each blade angle are found in the following table.

Shapes of Squeegee Blades		
A. Square edge	-	For printing on flat objects
B. Square edge with rounded corners	-	For extra-heavy deposits. For printing light color on dark backgrounds or printing with fluoresent inks.
C. Single-sided bevel edge	-	For use mostly by glass or nameplate printers.
D. Double-sided bevel edge	-	For direct printing on uneven surfaces; bottles.
E. rounded edge	-	For printing heavy deposits of ink on containers and ceramics.
F. Double bevel edge	-	For printing textile designs.
G. Diamond edge	-	For container printing and applications

II. Squeegee Hardness

Squeegee blades are rated according to hardness, which is measured in values of durometer. Generally, soft, low-durometer, dull squeegees deposit more ink; while hard, high-durometer, sharp squeegees deposit less ink.

Hardness Categories of Squeegee Blades	
i. Extra	45 - 50 durometer
ii. Soft	50 - 60 durometer
iii. Medium	60 - 70 durometer
iv. Hard	70 - 90 durometer

III. Squeegee Materials

Squeegee blades are more commonly composed of synthetic materials rather than rubber, especially for printing runs over 200. Although rubber blades are easy to use, they tend to lose their shape and edge quickly. The introduction of plastic compounds, such as polyvinyl and polyurethane, has solved this problem. Synthetics tend to keep the desired edge throughout long print runs and will resist inks, solvents, and abrasion better than rubber.

Squeegee composition has evolved through the l990s. Notable Variations on the material used has resulted from manufacturers offering dual and triple durometer squeegees, fiberglass backing support, and the Combi™ which offers a more consistent printing edge. Dual durometer squeegees evolved as a reaction to the use of a metal backing blade. The backing blade was added to the squeegee holder assembly to provide rigidity support for the squeegee to reduce flexing during the print stroke. One layer of the squeegee has the specified durometer for printing while the second has a higher durometer. Triple-durometer squeegees sandwich the higher durometer with two layers providing two printing edges: the blade is turned when the first side wears, offering more production time between sharpening.

The squeegee must be flexible, because there will be a measurable amount of bending in the squeegee as the force of the printing cycle occurs. Squeegees may be placed in the press at a predetermined angle. Nevertheless during the printing stroke both downward pressure and forward motion exert stress to the squeegee. If the material does not have sufficient resilience, the transferred ink may become distorted during printing. On the other hand the squeegee must be stable so a consistent printing edge will be presented stroke after stroke.

Squeegee profiles and durometer must be selected with respect to the material and image to be printed. A squeegee that is too soft or hard can distort the image or cause poor ink transfer. The following table provides guidelines to follow during squeegee selection.

Guidelines for Squeegee selection				
Soft	-	Textitles, garments,irregular shapes	-	low resolution, large ink deposit
Medium deposit	-	most products	-	good resolution, varied ink
Hard	-	flat surfaces	-	high-resolution graphics

FLOOD BAR

During the printing sequence the flood bar cycles to replenish ink in the mesh image areas. The flooding action of the cycle ensures that a continuous supply of ink is in place for the print stroke. Flooding also helps to prevent ink drying in the image areas when using conventional solvent inks. Flood bars are typically made of metal. Care should be taken to avoid nicking the flood bar, which can result in uneven ink flow and damage to the mesh.

OPERATION OF SQUEEGEE AND FLOOD BAR

The squeegee and flood bar are generally fitted in a holder and then clamped in the press (except in the case of manual printers who have a multitude of handle shapes to choose from). Presses will have a clamping system that fits the supplied squeegee holder or can be fitted to holders supplied by other manufacturers. Other considerations include adjustments for squeegee and flood bar angle This ability can assist in improving ink transfer on inks with different viscosities or different squeegee blade profiles. The holders should have control screws for adjusting pressure the best case is to have a pneumatic system to maintain consistent pressure during the print and flood strokes. During print setup the squeegee and flood bar pressures can be increased at staged intervals to optimize the best impression and flooding of ink.

The contribution of the squeegee and flood bar to the print is often overlooked or underestimated. Optimizing print performance is simple: use three control points—speed, angle, and pre sure. Whether the press is manual or automated these monitoring points must be addressed for properly controlled printing. speed directly linked to the ink's thixotropic properties. The ink is formulated to move and shear when energy is applied by the squeegee. Careful observation and measurement will help identify the speed best suited for a particular operation. The angle of attack is critical in transferring the ink from the mesh to the substrate. Practice has shown that 70-75° is best for most applications. The flexing action of the squeegee will place the printing edge at approximately 45° with the edge at 90° to the substrate. A steeper angle may cause the ink to snowplow, resulting in poor ink transfer. A shallower angle will push the ink through the mesh, causing distortion in the image. Pressure must be controlled to provide sufficient transfer of the ink. To determine best pressure, begin with too little pressure and increase in incremental adjustments. When optimum printing is achieved, reduce pressure until the print breaks and then add pressure until the print is optimal. The best pressure may be determined by examining microline targets, tint patches, slur or resolution targets on both sides of the substrate (flat), or similar targets on containers. When targets cannot be placed on garments or similar products, pressure must be adjusted on setups and the targets blocked out for production. The targets should be checked at regular intervals to establish printing consistency.

5.2.1 SCREEN PRETREATMENT

After the fabric has been stretched and mounted to the frame, it must be properly prepared to receive the stencil. Generally synthetics tend to repel indirect stencils because of their smooth filament structure. For such stencils, the fabric must be lightly roughened to insure excellent adhesion. A fine abrasive powder is gently rubbed into the stencil side of a wet screen, then thoroughly rinsed.

Degreasing is the next step in screen preparation. Degreasing removes any grease or oil residue left in the screen from reclaiming chemicals. In the case of new screens, degreasing removes grit and hand perspiration deposited during the stretching procedure. Degreasing should be done to all screens, new and reclaimed, immediately prior to stencil application. This will ensure tight stencil adhesion and prevent stencil breakdown.

5.2.2. SCREEN STRETCHING / TENSIONING

BASIC STEPS IN SCREEN STRETCHING / TENSIONING

i. Inspect frame for any damage (nicks, old adhesive, etc.)

ii. Select and inspect specified fabric. The fabric should be properly sized to fit stretchning equipment and frame. Follow manufacturer's recommendations.

iii. Be sure the fabric is square to the frame.

iv. Lock or secure the fabric to the frame or clamping system. Loosen corners to avoid stress if possible.

v. Begin tensioning the fabric incrementally; do not exceed manufacture's maximum tension specifications immediately. Experiment with rapid tensioning as well. Keep in mind the objective: a finished screen with the fabric at the recommended tension.

vi. Measure the tension of the stretched screen and record the final tension level prior to placing the screen in inventory.

Fabric color is an important characteristic to consider, particularly as the color affects stencil exposure. Threads can be dyed to promote better stencil exposure factors; e.g., reducing light undercutting. Fabric colors available are typically red, yellow, and gold-orange. The fabric color filters incident light from emerging out of a thread and exposing the stencil in an image area, hardening the emulsion, and preventing printing ink from passing through to the substrate.

STRETCHING THE SCREEN PRINTING FABRIC

Stretching and attaching the mesh material to a wooden or metal frame is a major factor in preparing the image carrier. Overstretching or understretching the fabric directly influences the quality of the printed image. Smudging, poor registration, and premature stencil wear can all be attributed to incorrect screen tension.

Manual Stretching

In many small shops, screen material is **stretched by hand.** A device that resembles rubber-tipped pliers is used to stretch the fabric over a wooden frame. Tacks, staples, or the groove-and-cord method are commonly used to attach the fabric to the frame. Hand-stretching is very time-consuming and usually will not produce uniform stretching or the high tensions needed for synthetic fabrics on large frames.

Uniform stretching assures even screen tension, which is required for accurate printing production. This, plus the need for timesaving procedures, has led most large shops to use mechanized stretching devices.

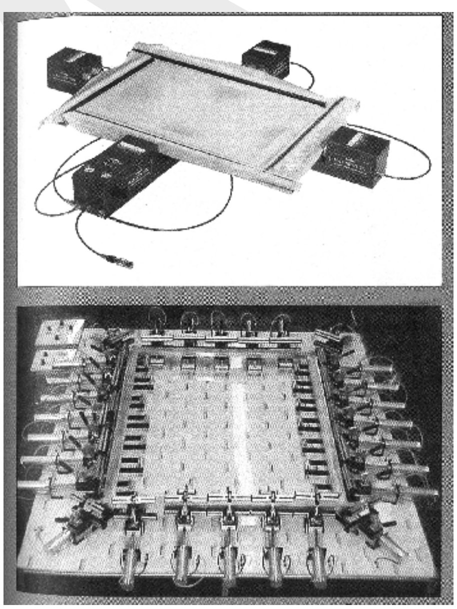


Fig. Screens can be stretched manually

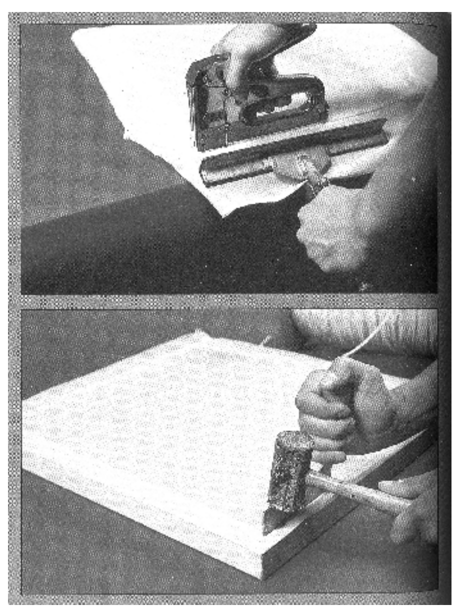


Fig. Screens can be stretched mechanically

Machine Stretching

Most machines used for stretching are either mechanically or pneumatically controlled. In either system, the procedure is basically the same. The screen fabric is cut slightly larger than the frame to allow a series of grippers or stretcher bars to suspend it above and outside the frame edges. The mesh is stretched to a specific tension percentage which is dependent upon the type of fabric and mesh count.

A **tension meter** is a precision instrument used to measure the surface tension of the stretched screen fabric. Obtaining a specific tension level affects print sharpness, register, printing ink density, and stencil life. The tension meter consists of an indicator dial and a spring-loaded measuring bar supported by metal beams. When a tension meter is placed on the screen fabric, the tension meter's measuring bar pushes into the fabric. As the screen tension increases, so does the pressure on the measuring bar, and the tension is indicated on the dial. The tension variation within a screen should not vary by more than ±0.5 newton/centimeter (N/cm) for high-quality printing and ±1.0 N/cm for an average-quality job. The allowable variation between screens is just slightly higher: ±1.0 N/cm for exact register, and ±1.5 N/cm for average register.

Using a tension meter with a mechanized stretching device can make it possible to obtain the correct tension for screen printing and to duplicate tension accurately from screen to screen.

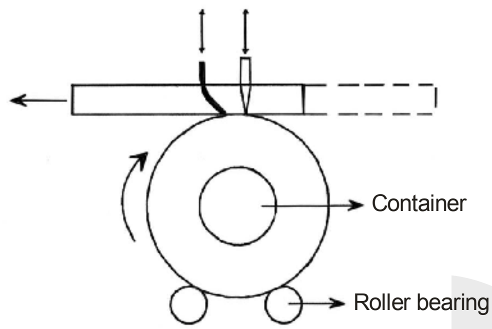
In addition to separate machines and devices used to stretch the fabric off the frame, some frames have a built-in **mechanical stretching system.** Basically, these devices are composed of a hollow aluminum frame with adjustable gripper bars housed inside that hold the mesh securely. A series of tension bolts, which are accessible from the outside frame edge, are tightened, causing the gripper bars to pull the mesh in a straight outward direction.

Fig. A Tension meter is used to ensure proper screen tension

5.3. SCREEN PRINTING MACHINES

5.3.1. CONTAINER PRINTING MACHINES

These machines are designed on the cylinder-bed principle. The curved surface of the printing cylinder is replaced by the curved surface of the container, which is supported by two roller bearings. The printing action is exactly the same as on the cylinder press; the screen reciprocates over the rotating container while the stationary squeegee forces the ink through the screen. The machines are usually an integral part of the container making and filling process, though some pre-printed containers are still made. These machines are made in a range of sizes to print the smallest perfume or large oil drums.



Container printing machines

5.3.2 THE FLATBED HINGED FRAME PRESS

Flatbed presses are primarily used for printing on flat substrates of various composition, size, and thickness. For example, flatbed presses can print on a wide range of substrate thicknesses, from very thin plastic and textiles to 1-inch. (25mm) board. Flatbed presses can be divided into three categories: hand-operated, semiautomatic, and fully automatic.

Hand-operated screen printing tables are still used in many commercial shops. The frame is placed in clamp-type hinges, which allow the operator to lift the screen between print strokes to remove and replace the substrate. Improvements to hand table operation have increased speed and quality. Vacuum tables or beds which keep the substrate stationary during printing, improve print quality and multicolor registration. Counterweights and larger handles are attached to the squeegee to increase printing speed and to maintain a constant angle between the screen and squeegee.

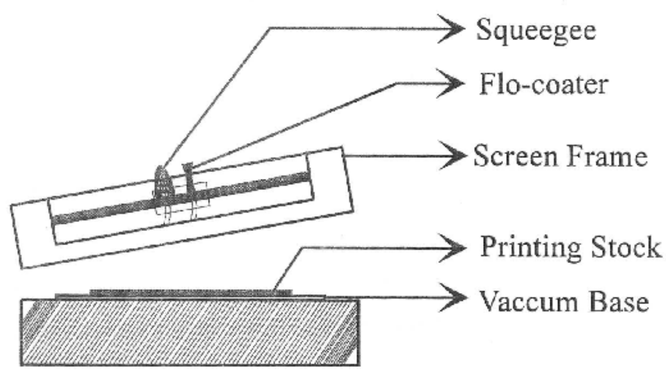
Hand tables are often found alongside highly developed automated presses. They can be used for test runs of packages that will eventually be mass-produced either with automatic screen printing presses or an entirely different printing process.

Semiautomatic flatbed presses work on the same principle as hand tables except the hand operation of the squeegee and frame lift are mechanized. Vacuum beds are used to keep substrates in position during the printing operation. Feeding and delivery of the substrate can vary according to the manufacturer’s design or the printer’s needs. Some semiautomatic presses employ manual feed and delivery while others have manual feed but automatic delivery. Semiautomatic flatbed presses print the same substrates as the hand table; however, production and print quality improve because of the consistency maintained by mechanical squeegee stroke pressure and constant blade angle.

5.3.2 - AUTOMATIC FLATBED HINGED FRAME SCREEN PRESSES

The automatic flatbed hinged frame screen press is capable of printing on both flexible and rigid substrates—as thin as paper or as thick as 0.75-in. (18-mm) masonite.

During the printing cycle of an automatic flatbed press, the flat or sheet-like substrate is automatically fed and registered on a stationary vacuum flatbed. The screen is held in a carriage, which brings it into printing position above the sheet. Image transfer takes place as the mechanically controlled squeegee moves across the screen. After the impression is made, the carriage moves away from the bed and the squeegee returns to its starting position, coating the screen with a layer of ink called the flood coat. This is accomplished by a metal blade attached to the back of the squeegee that comes into screen contact after the impression stroke. The flood coat returns ink to the starting position but does not force ink through the image areas. This insures a proper ink supply to every part of the screen. Most automatic presses use the flood coating method. After the printed substrate is mechanically removed, the press repeats the printing cycle.



FLAT-BED HINGED FRAME

Flatbed press sizes vary enormously. Although the common press sizes range from 8.5x11 in. (215x279 mm) to 60x90 in. (1.5x2.3 m), presses especially for circuit printing are smaller than 8.5x11inches., and one standard flatbed press measures 78x156 inches (2x3.9 m). Speeds range from over 2,000 impressions per hour (iph) on smaller presses to over 1,000 iph on larger presses.

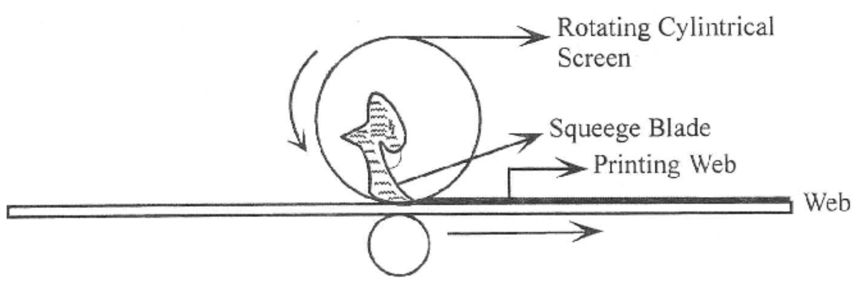
There are many variations of the flatbed principle, some of which are used in printing T-shirts, textiles, wallpaper, and electronic circuits. Flatbed web presses, for example, are used to produce labels and decals at relatively high speeds (150 ft./min.). Whether the press has manual feed and delivery or automated devices in any combination, the basic flatbed principle exists for all variations.

5.3.3. THE ROTARY SCREEN PRESS

Compared to the flatbed and cylinder designs, the rotary screen press is a relatively new screen printing system, with the first rotary screen printing machine introduced in Holland in 1963. A fine-wire cylindrical screen containing a squeegee-like blade inside rotates over a continuous roll of paper. The rotary screen mesh is coated with a photosensitive emulsion and exposed in contact with a positive. It is then processed similarly to most photostencil materials. The squeegee, which remains stationary, forces ink through the rotating Screen as the web travels underneath. Ink is continuously pumped inside to maintain high printing speeds. The web, which varies from lightweight giftwraps and textiles to thin paperboard and wall covering vinyl's, is capable of traveling through several printing stations at speeds of 200 ft./min. (61 m/min.). Each station has its own screen unit that may be printing one of several colors or a clear final coating. At the end of the printing cycle, the web is transferred to slitting and sheeting units. The slitter first splits the web vertically, and then the sheeter cuts the split web horizontally into sheets.

This machines are specially used for high volume production of printed textiles and floor and wall coverings. The functional principles are entirely different from conventional screen printing. Here the screen is in the form of seamless perforated cylinder, made of light metal foil. The squeegee is hollow and run inside the perforated cylinder. Through the hollow squeegee, ink is pumped to the screen.

As the screen (cylinder) rotates the ink is passed on the web (stock). The screens are made in various grades according to the ink thickness required on the stock. In this method stencil are formed by direct photoemulsion method, but it requires specialized coating and exposing technique.



Rotary Screen

5.3.4. CAROUSEL MACHINES

Based upon the hinged frame principle, these machines were originally designed for multi-color printing on to T-shirts and sports wear. They consist of multiple printing bases or 'garment platens' which can be rotated on a central pivot – hence the name 'carousel'. Above each platen is a printing head (also rotational) consisting of a hinged frame carriage, squeegee and flo-coater; the latter being mechanically driven on the more sophisticated machines.

The printing cycle begins with a garment being slid over the platen. The first screen is then positioned over the platen for printing. After the first color has been printed the second screen is brought into register with the platen. The process is continued until all the colors have been printed. The garment is then removed from the platen for drying; usually by infrared radiation.

The carousel principle has been adapted for printing onto a wide range of substrates. The garment platens are replaced by small vacuum bases, and intermittent UV curing heads are positioned between each printing station.

The machines are available in a variety of configurations, the standard being 6 or 8 stations, having 4-6 printing heads. The standard formats are 406 x 355 mm (16 x 14") and 558 x 457 mm (22" x 18"). Maximum speeds of 4800 iph or 700 printed pieces per hour have been claimed by some manufacturers.

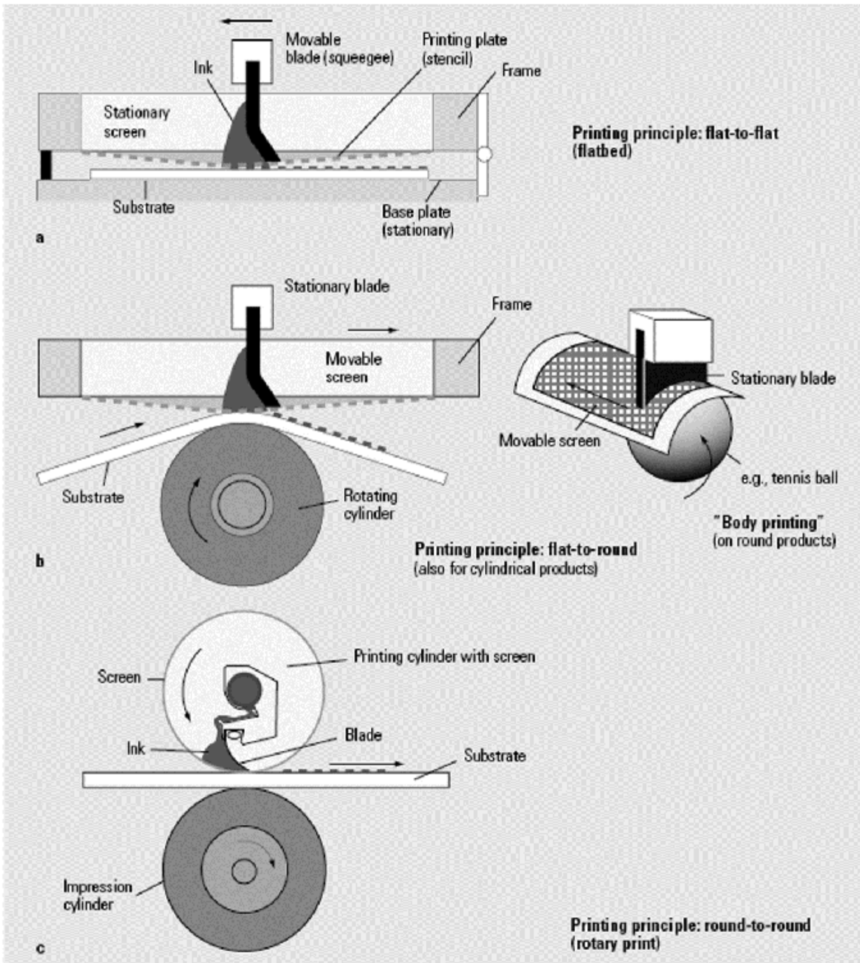


Fig. 1.3-24 Screen printing technologies.
a Flatbed;
b Flat-to-round/"body printing";
c Rotary printing

5.4. SCREEN PRINTING INKS - TYPES, PROPERTIES

SCREEN PRINTING INKS

Inks and Substrates. As was mentioned several times above, screen printing is suitable for printing on an almost infinite variety of substrates. The most important consideration is ensuring that the ink used is suitable with the surface, both in terms of chemical compatibility and the facilitation of proper drying. Screen printing commonly requires paste inks that are thick and able to print sharply through the screen. They must also perform well under the action of a squeegee. The solvents used should also not be overly volatile, as excessively early evaporation would cause the remaining ink components to clog the screen.

Screen inks typically utilize a drying-oil vehicle, although ultraviolet-curing inks and other forms of fast-drying inks are making strong inroads in screen printing. Often, in the decoration of fabrics, glassware, and ceramics, heat transfer printing is utilized, which involves screen printing the design onto a decal (in one of a variety of ways; see Decal), then transferring the design (which is composed of sublimable dyes) to the desired end substrate by means of exposing the decal to increased heat and pressure. (See Heat Transfer Printing).

COMPONENTS OF INKS AND INK SYSTEMS

The principle components of a printing ink are pigments or dyes (colorants), vehicles, and additives. An ink can be opaque or trans parent, depending on the ink's components.

COLORANTS

All printing inks consist of a colorant, almost always a pigment but occasionally a dye. Dyes are soluble in a solvent or vehicle, while pigments are insoluble.

Pigments are finely ground solid materials that impart colors to inks. The nature and amount of pigment that an ink contains, as well as the type of vehicle, contribute to the ink's body and working properties.

Pigments can be organic or inorganic. Organic pigments tend to produce transparent inks, which are used for process-color printing, while inorganic pigments tend to produce opaque inks.

The term organic means "derived from living organisms." Organic pigments are made from petroleum products: blacks by burning gas or oil, other colors be reacting organic chemicals derived from petroleum. The most common black pigment, furnace black, is made by burning atomized mineral oil in brick-lined furnaces with a carefully controlled supply of air. The products of combustion are cooled, and the pigment is collected with electronic precipitators or in bag filters.

Inorganic pigments are formed by precipitation—that is, by mixing chemicals that react to form the insoluble pigment, which then precipitates, or settles out. The most common white inorganic pigment is titanium dioxide. Inks made from titanium oxide are very opaque and have excellent colorfastness

VEHICLES

The vehicle carries the pigment and adheres it to the substrate. In addition, it gives an ink its consistency. The vehicle is composed mostly of a varnish, which is a solvent plus resin and/or drying oil, along with waxes, driers, and other additives. The vehicle carries the pigment, controls the flow of the ink or varnish on the press, and, after drying, binds the pigment to the substrate. Vehicles also control the film properties of dried ink, such as gloss and rub resistance. The resins are formulated to optimize the ink's ability to adhere to a substrate.

The solvent serves to maintain the vehicle's flow until curing. The solvent is carefully selected for its compatibility with the vehicle and the substrate. Different ink systems use specific solvents to enable the ink to function properly.

The solvent in the ink can flash off during curing. The solvent products are termed volatile organic compounds (VOCs) and are regulated by government agencies. Most ink systems producing VOCs contain petroleum-derived solvents. Consult the Material Safety Data Sheets (MSDS) for the content of the ink system. Note handling and disposal instructions as well.

ADDITIVES

Most ink systems offer greater versatility through additives, which change an ink's out-of-the-can personality. Toners will provide greater color strength while mixing, and halftone bases reduce color strength. Thinners will change viscosity, and adhesion promoters improve adhesion. The printer must consult with the ink supplier concerning the use of additives. Improper use typically results in poor ink performance.

5.4.1 - TYPES OF SCREEN PRINTING INKS (FOR SPECIFIC APPLICATIONS)

i. INKS FOR DECALCOMANIAS

Pressure-sensitive decals or waterslide decal transfers are usually printed by screen because the process delivers thick, opaque films with enough flexibility to withstand the movement of the carrier paper while they are being transferred. These inks usually require good light resistance. UV inks have been used to successfully screen-print pressure-sensitive decals.

ii. INKS FOR CIRCUIT BOARDS

When a thick film is required on a printed circuit, the screen printing process is often the best way to print it. The ink must adhere to clean copper and resist the chemicals used in etching the copper to produce the circuit. If it is necessary that the ink be removed with a solvent or alkali after etching, the ink must be sensitive to solvent or alkali.

iii. POSTER INKS

Posters are printed with poster inks on a variety of board and paper stocks Nonoxidizing resins and oxidative drying inks are used the most. Overprinting with a gloss varnish extends the life of the print.

iv. ENAMEL INKS FOR METALS

Enamel inks formulated from oil-based alkyds modified with melamine or urea formaldehyde, cellulose lacquer, epoxies, and other synthetic resins yield attractive signs for outdoor use.

The metal surface must be thoroughly degreased; aluminum is often anodized or given a nitrocellulose wash for the ink to adhere well. Baking enamels yields a product that is tough and has good resistance to aging, light, and weather.

Even more permanent are vitreous-enameled aluminum and steel products. Vitreous enamels are glasslike material or frit ground together with oxide colorants, clay, and water. After degreasing and surface treatment of the aluminum, it may be screen-printed with enamel based on borosilicates and immediately fired (without drying) at very high temperatures.

v. INKS FOR PLASTICS

Pigments for plastic printing must not migrate or bleed into the plastic. The solvent must be able to etch the plastic enough to improve adhesion without causing crazing (stress cracking of the plastic surface). Thermoplastic adhesives or binders are helpful if the plastic is to be vacuum-formed after printing.

The awkward shapes of polyethylene bottles are readily screen printed, and the thick ink deposits provide glossy and bright colors.

Screen Printing Inks for Special Applications

Poster inks	–	**Used for general graphics printing.**
Plastisol inks	–	**Primarily used in garment printing (t-shirts). May include additives which puff when ink is cured.**
Textile inks	–	**Also used in garment printing and on large textile presses.**
Decal inks	–	**Suited for labeling and long lasting/weatherability properties.**
Pastes	–	**Found in industrial electronics printing.**
Ceramic inks	–	**Inks may be printed on decals then transffered to product for firing. Ceramic inks are permanent.**
Epoxy inks	–	**A two-part ink cures by oxidation with the hardner. Excellent durability.**
Vinyl inks	–	**Formulated to work with vinyl. Surface tension issues and off-gassing of the vinyl are primary concerns.**
Speciality inks	–	**Inks may be specially formulated to print with a particular material such as polycarbonates, polyethylene, or other types of plastics.**

AGPC

vi. INKS FOR GLASS

Inks for glass are either enamels or frits that are fired at high temperatures, or epoxy or other plastics that are baked at lower temperatures. Oil-based and synthetic resin-solvent-based inks are used to print items like dials, mirrors, and glass signs. UV inks are used to decorate mirrors.

Special inks may be used for windshield applications in the automotive and aviation industries. Glass containers may have graphics applied where the ink provides a graphic design. The ink may also act as a resist for etching the image with acid.

vii. PLASTISOLS AND EMULSIONS FOR TEXTILES AND GARMENTS

Plastisols and emulsions are the two kinds of inks commonly used to print textiles and garments. Inks based on an acrylic emulsion are suitable for all types of fabric and are printed directly onto it. They will dry at room temperature, but to achieve resistance to laundering, they must be cured 2 or 3 min. at 320°F (160°C). A plastisol is a (dry) vinyl resin dispersed in a plasticizer; there is no solvent. The plastisol is pigmented and printed on the fabric. When heated above 300°F (149°C), the plasticizer “fuses with” the resin and a film is formed. Since the plastisol penetrates the fabric, the film formed on heating incorporates the fabric, producing an excellent bond. Plastisols can also be printed onto release paper, partially cured, transferred to the fabric, and then cured completely.

Plastisol inks must be durable in order to withstand washing and drying of the garment. The cured ink film must remain flexible and adhered to the garment through repeated washings.

QUALITY CONTROL OF SCREEN PRINTING INKS

Because of the exceptionally broad variety of products produced by the screen printing process, a complete discussion of quality control is impractical. As with all inks, color match, color strength, and fineness of grind are important. Adhesion to the substrate, and compatibility with screen, squeegee, and stencil material should be checked. Suitability for the proposed end use is always important.

This is often determined with tests for light resistance, product resistance, weathering resistance, laundering, and the like. Some quality control tests appropriate for screen printing inks are listed in the following table.

Appropriate Quality Control Tests for Screen Printing Inks

Wet ink film tests	Dried ink film tests
Color	Color
Viscosity	Opacity/Hiding Power
Masstone	Rub Resistance
Length	Scuff Resistance
Fineness of Grind	Glass
Density/Specific Gravity	Adhesion
Tinctorial Strength	Flash Point
Tack	Drying Rate
	Flexibility
	Lightfastness

5.4.2. PROPERTIES OF SCREEN INKS

The Nature of Screen Inks

Screen printing applies the thickest film of any common printing process, making it excellent for fluorescent and fade resistant inks. The thick film applied by a screen is often one of its advantages, but screen printing can also apply a thin film—one as thin as or thinner than the film applied by rotogravure.

Screen inks differ from other printing inks in one important way. To transfer well from roll to roll, printing inks must be “long,” i.e., they must show some tendency to form a string when pulled away from a wet surface. Screen inks do not transfer from one roll to another. Therefore, they are “short” and “buttery.” Short inks pass through the openings of the screen without leaving fuzzy edges. If the inks were long, they would form strings when the screen was lifted from the wet print; these strings would ruin the print.

Most screen inks contain volatile solvents, which represent up to 70% of the formulation. These solvents often include ethers of propylene glycol and dipropylene glycol blended with mineral spirits (aliphatic hydrocarbons) to give the right volatility or evaporation rate. These mixtures are called cosolvents. Other solvents include cyclohexanone, isophorone, ethylene glycol monobutyl ether, high-boiling aromatic solvents, and water.

Like other sheetfed inks, oil-based screen inks that dry by oxidative polymerization are normally alkyds based on linseed or another drying oil. Ethyl cellulose, acrylics, vinyls, vinyl dispersions or plastisols, epoxy, nitrocellulose, and urethane resins are also used in making screen inks. Catalytic-curing inks are often employed for printing bottles or circuit boards.

Most screen inks dry by evaporation: high-velocity, hot-air dryers, wicket dryers, simple drying racks, flame dryers, and even microwave dryers are used.

Ultraviolet (UV) drying systems solve one of the screen printer's greatest problems, slow ink drying. Continuing development of UV-curing technology has led to the manufacture of a broad range of UV-curable inks for a variety of applications. UV inks are used regularly to print plastic bottles, containers, point-of-purchase displays, pressure sensitive decals, printed circuits for the electronics industry, and membrane touch switches for electrical appliances and instruments.

Representative screen ink formulations are shown in table below:

For Polyethylene Bottles		Fluorescent Poster Ink	
Parts		**Parts**	
6	**Toluidine red**	**46**	**Fluorescent pigment**
10	**Titanium dioxide**	**4**	**Ethyl hydroxyethyl cellulose (EHEC)**
82	**Long-oil epoxy**	**17**	**Rosin ester**
2	**Two-way drier**	**29**	**VM&P naphtha**
—	**Antifoam**	**4**	**Butoxy ethanol**
100		**100**	

Table: Typical formulations of Screen inks.

SELECTION OF SCREEN INKS

Resin-based inks provide many advantages and are now - widely used. They are relatively inexpensive, provide good coverage and high color strength, and give short inks when they are highly pigmented. Extenders such as clay and calcium carbonate are commonly included to provide proper rheology without giving excessive color strength. They also reduce the cost of the ink. Because the ink film is so thick, high color strength is ordinarily unnecessary. Extenders reduce the tendency of the ink to bubble and form pinholes during drying.

For printing on glass bottles, the "ink" may be a dyed or pigmented plastic that cures on drying, or it may consist of a pigment (an oxide colorant) added to a glass frit that fuses with the glass on annealing. These glass frits or vitreous enamels can also be applied to aluminum or other substrates.

Transparent pigments, used alone, tend to highlight any imperfections in the mesh or squeegee by accentuating any variation in thickness. If transparent pigments like phthalocyanine blue or diarylide yellow are used, an opaque pigment such as titanium dioxide is also added.

5.5. SCREEN PRINTING APPLICATIONS

PRIMARY MARKET SEGMENTS

Screen printing may be easily classified by the wide range of market segments that it serves, including the following:

- Garments and textiles: T-shirts, coats, sheets, towels, and fabrics
- Home products: wall coverings, linoleum, simulated wood grains.
- Product marking: appliances, dashboards, in-line applications
- Large-format printing: billboards, displays, fleet marking
- Electronic printing: circuit boards, membrane switches, display coatings
- Coating market: UV applications
- Fine art printing: collectable prints, fine art reproductions
- Poster printing: low-volume displays

These market segments point once again to the diverse applications for graphic communication and manufacturing that screen printing affords.

Applications

Screen Printing on Flat Surfaces

Posters and Graphics Printing in Short Print Runs Large-format posters in particular can be produced relatively conveniently in fairly small print runs. The quite thick ink film produces coloring that is very brilliant and resistant even with halftone color impressions.

Traffic Routing Systems and Signs. Large printing surfaces for high resistance inks are found with traffic signs and routing systems. The requirements they impose are best met using screen printing.

Vehicle Fittings and Instrument Dials. With vehicle fittings a narrow tolerance range of the translucency of the impression is required in addition to its precision. For example, it must be possible for control lights to light up in precisely defined colors.

Printed Circuit Boards for Electronics. Due to its simplicity and flexibility, screen printing is an important process during the development of printed circuit boards for electronic circuits. Accurate printing onto copper-laminated hard paper or glass-fiber reinforced epoxy board with etching allowance, solder resist, or assembly designations in the necessary coating thickness is only possible in large quantities with screen printing.Restrictions are, however, imposed on the latter as a result of the extreme miniaturization of components and printed circuit boards.

Photovoltaic. Special conductive pastes are used to print on photoresistors and solar cells, which serve as the contact points for current transfer. In doing so, particular importance is placed on high coating thickness in areas that are, at the same time, extremely small and covered with printed conductors, in order to optimize the efficiency of the energy production with the solar cells as fully as possible.

Compact Discs (CD). Screen printing is one of the major processes for printing on CDs. Pad printing and more recently even offset printing are also used.

Textiles. The depth of the ink absorption in textiles calls for a large volume of ink to be supplied and screen printing is the preferable process for applying it. Clothing, canvas shopping bags, webs of material, and so on, can be printed in both flatbed and rotary screen printing.

Transfer Images. Screen printing is frequently used to produce transfer images for ceramic decoration.These images are put together from ceramic pigments for firing. The pigment’s grain size necessitates the use of a screen mesh that is not too fine. After detachment the images are removed from the base material and placed on the preburned bodies by hand. A recognizable feature of these ceramic products is the thick layer of ink. The images can be placed above or below the glazing.

Decorative Products, Labels, Wallpapers. Seamless decorations such as textile webs, wallpaper, and other decorative products, as well as labels often require rotary printing combined with reel material. Special machines are designed for this. Rotary screen printing with sheet material is used primarily for higher print runs (examples are given in sec. 2.4.3).

Surface Finishing. *Transparent varnish* can also be applied using screen printing technology (for spot varnishing, in particular) *to finish* the printed product.

Screen Printing on Curved Surfaces

Almost anybody that has an even, convex and concave (to a limited extent) not too structured surface can be printed using screen printing.There are virtually no restrictions with regard to the material of the body to be printed on.

Ceramics can be printed directly with screen printing. Ceramic pigment inks can be used for subsequent baking or just a low durability varnish applied to the glazed product.

It is not always possible to print directly onto plastic components. Surface treatment, for example involving flame treatment, corona charging, or the application of primer is often necessary to ensure that the ink adheres.

Bottles. Glass bottles with a baked finish or pretreated plastic bottles for the food and domestic products sector are printed using the screen printing process.

Toys. Toys, such as balls, and so forth, can be printed in full in several operational steps.

Glasses. The screen printing process is often used for drinking glass decoration, with thick coatings of all inks and also gold being applied.

Advertising Media. The type of advertising medium that can be decorated or provided with some other overprinting by the screen printing process ranges from cigarette lighters or ballpoint pens to pocket knives and pocket calculators.

PRODUCTS PRINTED BY SCREEN

Decalcomanias. Pressure-sensitive decals or waterslide decal transfers are usually printed by screen because the process delivers thick, opaque films with enough flexibility to with stand the movement of the carrier paper while they are being transferred. These inks usually require good light resistance UV inks have been used to successfully screen-print pressure sensitive decals.

Circuit boards. When a thick film is required on a printed circuit, screen process is often the best way to print it. The ink must adhere to clean copper and resist the chemicals used in etching the copper to produce the circuit. If it is necessary that the ink be removed with a solvent or alkali after etching, the ink must be sensitive to solvent or alkali.

Posters. Posters are printed with poster inks on a variety board and paper stocks; they may be clay-coated, patent-coated, or liner. Clay-coated board is well suited for photographic halftone printing. Nonoxidizing resins and oxidative drying inks are used the most. Overprinting with a gloss varnish extends the life of the print.

Metals. Enamel inks formulated from oil-based alkyds modified with melamine or urea formaldehyde, cellulose lacquer, epoxies, and other synthetic resins yield attractive signs for outdoor use.

The metal surface must be thoroughly degreased; aluminum is often anodized or given a nitrocellulose wash to improve ink adhesion. Baking enamel inks yields a product that is tough and has good resistance to aging, light, and weather.

Even more permanent are vitreous-enameled aluminum and steel products. ***Vitreous enamels*** are glasslike material or frit ground together with oxide colorants, clay, and water. After degreasing and surface treatment of the aluminum, it may be screen-printed with enamel based on borosilicates and immediately fired (without drying) at very high temperatures.

Plastics. Thermoplastic adhesives or binders for inks are helpful if the plastic is to be vacuum-formed after printing. Pigments for plastic printing must not migrate or bleed into the plastic. The solvent must be able to etch the plastic enough to improve adhesion without causing crazing (stress cracking of the plastic surface).

The awkward shapes of plastic bottles are readily screenprinted, and the thick ink deposits provide bright, glossy colors.

Glass. Inks for glass are either enamels or frits that are fired at high temperatures, or epoxy or other plastics that are baked at lower temperatures. Oil-based and synthetic resinsolvent-based inks are used to print items like dials, mirrors, and glass signs. W inks are used to decorate mirrors.

Textiles. Plastisols and emulsions are the two kinds of inks commonly used to print textiles. Inks based on an acrylic emulsion are suitable for all types of fabric and are printed directly onto it. They will dry at room temperature, but to achieve resistance to laundering, they must be cured 2 or 3 min. at 320°F (160°C). A plastisol is a (dry) vinyl resin dispersed in a plasticizer; there is no solvent. The plastisol is pigmented and printed on the fabric. When heated above 300°F (150°C), the plasticizer “fuses with” the resin and a film is formed. Since the plastisol penetrates the fabric, the film formed on heating incorporates the fabric, producing an excellent bond. Plastisols can also be printed onto release paper, partially cured, transferred to the fabric, and then cured completely.

Membrane touch switches. These switches, seen at checkout counters at fast-food restaurants and supermarkets, on electronic games, on appliances, medical equipment, and many other electronic devices, provide a major market for screen printing. They are made of three layers of synthetic film the circuit layer, a spacer, and a graphic overlay.

The circuit is usually applied to a polyester (PET) film by screen printing with conductive inks, which are typically blends of nonconductive, organic binders and conductive particles, usually silver or graphite. The ink is cured at temperatures around 300°F (160°C) to achieve the desired conductivity. Polyester is preferred because of its chemical resistance and its ability to withstand the high curing temperature. Polyester shows good resistance to flex fatigue, cracking, and deformation, and conductive inks work well on polyester.

The space layer (or spacer) holds the circuit layer and overlay sheets in register and keeps them apart except when the switch is depressed. The film has pressure-sensitive adhesive on both sides and is diecut at the locations of each switch. To assure that this layer expands and contracts at the same rate as the other layers, it is typically made of PET film.

The graphic overlay is usually made of PET, but polycarbonate is sometimes used. It must withstand the flexing for the designed life of the device, and PET is reported to withstand 100 million switchings. This layer is decorated with screen inks, often on the back side (or second surface), which protects the print from scratching and abrasion. This structure is visually summarized in figure 6-1.

<u>Trouble- shooting</u>

For the ink manufacturer to help solve ink problems, the printer should be ready to supply the following information:

- Screen material (e.g., monofilament, nylon)
- Mesh size (e.g., 160)
- Stencil material (e.g., blackout materials, diazo-sensitized photo screens)
- Squeegee composition (e.g., polyurethane)
- Squeegee hardness and durometer (e.g., hard 66-75 Shore A).

UNIT: V – SCREEN PRINTING

PART - A - 1 Mark Questions

1. Name the device used to measure the squeegee hardness.

Durometer.

2. What is a mesh? / What is the function of screen mesh?

In screen-printing, the fabric's mesh permits the ink to flow through the image area. The mesh plays a dominant role in metering the amount of ink that will flow onto the substrate.

3. What is a squeegee? / State the functions of aqueege.

Squeegee is a rubber or plastic blade attached to a handle, used to force screen printing ink through the open areas of the stencil and mesh to the substrate.

4. State the various parts of an automatic cylinder screen press.

A screen carriage, a squeegee, an impression cylinder.

5. What is the composition of screen printing inks? / State the main ingredients of screen printing inks.

Screen-printing ink consists of pigments or dyes (colorants), vehicles, and additives.

6. Name some of the products printed by screen-printing process.

Posters and displays, greeting cards, name plates, printed circuits, glass bottles, T-shirts, Textiles, plastic bottles, etc.,.

7. What is the main limitation of Screen Printing?

Halftone printing is limited to coarse screens. Conventional inks requires some time for drying and requires space consuming racks to allow the printing inks to dry.

8. Name any two applications of screen printing.

Garments and textiles : T-Shirts, Fabrics, Towels, Coats

Large format printing : Bill boards, Displays, Fleet marking.

9. Mention any three kinds of screen printing inks.

Plastic Inks, Glass Inks, Poster Inks, etc.

10. Mention any three applications of screen printing on curved surfaces.

Bottles, Toys, Glasses.

11. State the different meshes used for screen printing.

- Silk
- Polyester
- Nylon
- Wire mesh (or wire cloth)
- Metalised polyester.

12. What are the various types of screen-printing machines available?

i. Flatbed screen–printing presses
   a) Hand operated flatbed press
   b) Semi–automatic flatbed press
   c) Fully automatic flatbed press
ii. Flatbed vertical lift screen printing presses
iii. Cylinder bed screen printing presses
iv. Container screen printing machines
v. Rotary screen printing presses
vi. Carousal screen printing presses

13. What are the applications of rotary screen-printing machines?

These machines are specially used for high volume production. These presses are used to print on textile webs, floor coverings, wallpaper, decorative products, labels, stickers, office stationery printing, canvas shopping bags, etc.,.

GLOSSARY

Durometer

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

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.

3/6 Marks Questions

1. What are different screen squeegees available?

A. Squeegee blades (based on materials)

i) Rubber squeegee blade
ii) Squeegee blade made from synthetic materials
iii) Polyurethane squeegee blade
iv) Polyvinyl squeegee blade

B. Squeegee blades (based on hardness)

i) Extra soft blade (45- 50 durometer)
ii) Soft blade (50 – 60 durometer)
iii) Medium blade (60-70 durometer)
iv) Hard blade (70-90 durometer)

C. Squeegee blades (based on shapes)

i) Square edge blade
ii) Square edge with rounded corners blade
iii) Single sided bevel edge blade
iv) Double sided bevel edge blade
v) Rounded edge blade
vi) Diamond edge blade

2. How screen pretreatment is done?

After the fabric has been stretched and mounted to the frame, it must be properly prepared to receive the stencil. Generally synthetics tend to repel indirect stencils because of their smooth filament structure. For such stencils, the fabric must be lightly roughened to insure excellent adhesion. A fine abrasive powder is gently rubbed into the stencil side of a wet screen, then thoroughly rinsed.

Degreasing is the next step in screen preparation. Degreasing removes any grease or oil residue left in the screen from reclaiming chemicals. In the case of new screens, degreasing removes grit and hand perspiration deposited during the stretching procedure. Degreasing should be done to all screens, new and reclaimed, immediately prior to stencil application. This will ensure tight stencil adhesion and prevent stencil breakdown.

3. State the various types of screen printing inks available.

- Lacquer inks
- Gloss enamel inks
- Epoxy inks
- Vinyl inks
- Fluorescent inks
- Phosphorescent inks
- Textile inks
- Plastisol inks
- Catalytic inks
- Enamel inks
- Special inks for automotive and aviation industry.

4. Write about the properties of screen printing inks.

- Screen printing applies the thickest film of any common printing process, making it excellent for fluorescent and fade resistant inks.
- Screen inks do not transfer from one roll to another. Therefore, they are "short" and "buttery." Short inks pass through the openings of the screen without leaving fuzzy edges.
- Most screen inks contain volatile solvents, which represent up to 70% of the formulation.

- Like other sheetfed inks, oil-based screen inks that dry by oxidative polymerization are normally alkyds based on linseed or another drying oil.
- Catalytic-curing inks are often employed for printing bottles or circuit boards.
- Most screen inks dry by evaporation: high-velocity, hot-air dryers, wicket dryers, simple drying racks, flame dryers, and even microwave dryers are used.

PART - B - 12 Marks Questions

1. Explain the various meshes used for screen printing.
2. Describe the different types of squeegees used for screen-printing. How will you select the squeegees?
3. Describe the different methods of screen tensioning (or stretching).
4. Explain the working principles of automatic flatbed screen-printing machine.
5. Describe the working principles of rotary screen printing press.
6. Explain (a) Container screen-printing machine (b) Carousel printing machine.
7. Describe the different screen printing inks used for various applications.
8. Explain the various applications of screen-printing process.
9. Write notes on (i) Screen Tensioning (ii) Rotary Screen Printing (iii) Screen Mesh.