Chapter 3

PRINTING PROCESSES

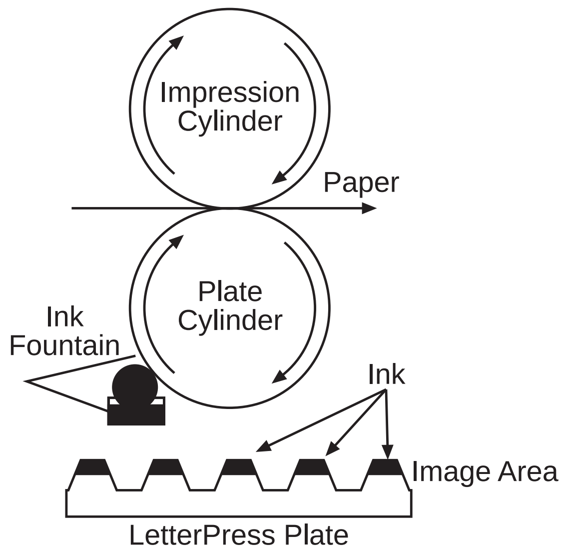
A printing process describes the method adopted by a system to transfer the image on to a substrate (material). This also means that a printing system will have a medium that carries the image in the first place before it enables the process of reproduction. Getting this printing surface prepared is dependent on the printing process. Over the years, many different ways of putting ink on paper developed and these evolved to be the printing processes. The mechanics adopted under different systems are so different that they cater to specific applications in the market. For a long time the printing industry recognized five major processes. These were :

- relief printing (letterpress, flexography)
- planographic printing (offset lithography)
- recess printing (gravure / intaglio)
- stencil printing (screen)
- digital printing (toner and inkjet)

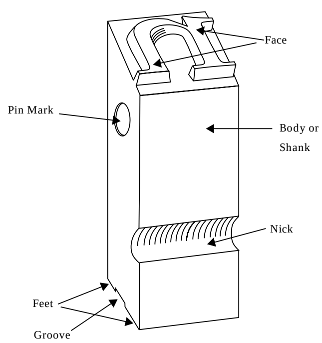
Relief printing—letterpress

As the name of the process says, the image areas are in relief and the non-image areas are in recess. On application of ink, the relief areas are coated with a film of ink and the non-image areas are not. With pressure over the substrate to bring it in contact with the image area, the image is then transferred to the substrate. If you can picture how a rubber stamp transfers ink to paper, then you understand the principle of letterpress and flexography.

Relief printing was the earliest form of printing and remained dominant for a very long time. The movable type of the hot metal era were all used with letterpress. This printing process takes its name from the manner in which the process was employed, primarily for type, and later engravings.



The plate profile is shown at the lower part of this illustration. In some cases the plate was formed as a cylinder for high-speed printing



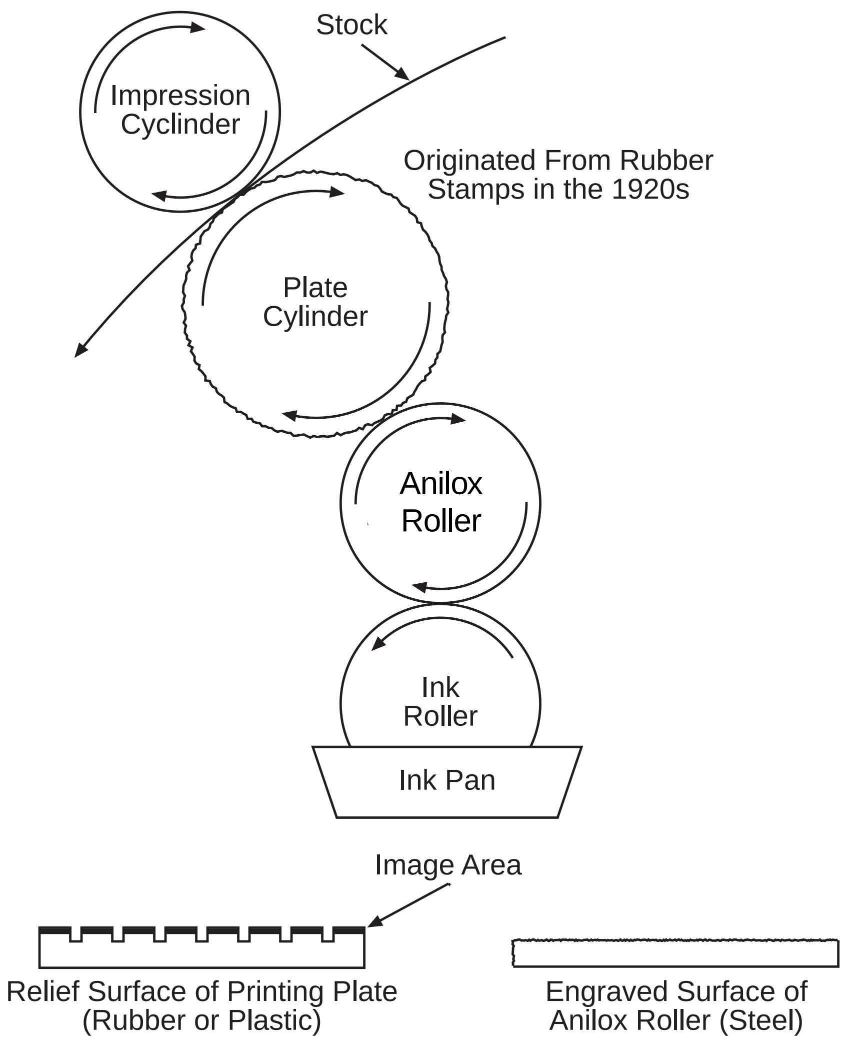
Text is made up of movable type. Types are made from an alloy of lead, antimony, and tin. A block is made of zinc or copper, in which images that are not obtainable in movable type are etched. Logos, diagrams, and illustrations are made from engraved blocks.

A letterpress printed product can be identified by the indentation that it creates in the paper. This is due to the mechanical pressure applied to the paper. In spite of this, letterpress produces images that are sharp and clean. It is a direct printing process, which means that ink is transferred directly from the printing surface to the substrate.

Letterpress is still used to some extent for embossing, imprinting, and special-purpose reproduction.

Flexography

This process adopts the same principle of relief printing and is therefore similar to letterpress. The printing surface is made of rubber instead of metal. The plate (the printing surface) is imaged from film or laser. Rubber plates were replaced by photopolymer plates during the 1970s as was the case with letterpress printing. Flexography is largely used in the packaging industry, where the substrates used are plastic, aluminum, foil, etc., for which the rubber plates are more suitable, due to their being soft. Usually flexography prints rolls of paper or foil instead of cut sheets.



The plate profile is at the lower part of this illustration and the process is shown above

Flexography features:

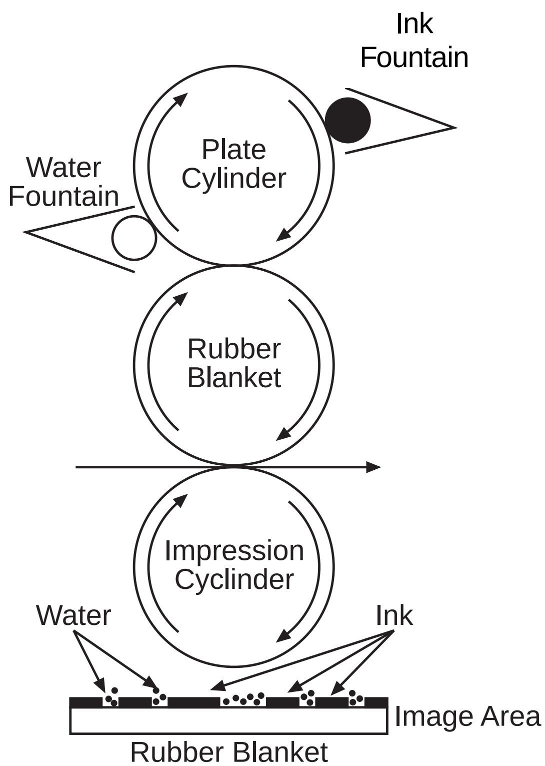
- Printing from wrong-reading raised image, flexible plate direct to substrate
- Principal applications: almost any substrate which can go through a web press – tissue, plastic film, corrugated board, metal foil, milk crates, gift wrap, folding cartons, labels, etc.
- Recognition characteristics: as a relief printing method, has recognizable, but slight, ink halo effect around letters and solid color areas
- Two categories: wide web (18 or more inches wide) and narrow web
    - Wide web flexo market: flexible packaging, newspapers, corrugated boxes
    - Narrow web market: primarily labels, high-quality process color
    - Some flexo corrugated box printing is sheetfed

The continuous, repeated imaging capability, along the length of the web substrate makes flexography very suitable for products such as wallpaper and wrapping paper.

Planographic printing—offset lithography

Lithography is the most dominant of the printing processes. It accounts for over 60% of the printing market. When people refer to printing, especially color printing, they usually think of lithography. As mentioned in our first chapter, lithography was invented by Alois Senefelder. Lithography is a chemical process and almost opposite to that of letterpress which is more of a mechanical process.

Lithography works on the principle that oil and water do not mix. A lithographic plate is treated in such a way that the image areas on the plate are sensitized and as such are oleophilic (oil-loving); and the non-image areas are treated to be ink repelling or oleophobic. During the press run, the plate is charged twice; first by a set of dampening rollers that apply a coat of dampening solution and second by a coat of the inking rollers. During this process the image areas have been charged to accept ink and repel water during the dampening. The same happens to the non-image areas that start repelling ink as they are coated with water. (Remember the basic principle on which lithography works.)



The plate profile is shown at the bottom of this illustration and the process is shown above it

Plate, blanket and impression cylinders

The lithographic process operates with three basic cylinders. They are the plate cylinder, the blanket cylinder, and the impression cylinder. All these are plain heavy metal cylinders. The plate cylinder has the printing plate wound around it. This plate is the carrier of the image that needs to be printed. In other words, it is the equivalent of the types and blocks of letterpress.

The blanket cylinder has a rubber blanket wound around it. This facilitates the transfer of the image from the plate to the blanket, and thereupon to the paper (or other substrates), when the substrate is passed between the blanket and the impression cylinder. The blanket provides the required resiliency to compensate for the unevenness of the substrate used. This is an advantage for the process, as even poorer quality stock can be used in offset printing. The impression cylinder is just a bare cylinder that acts to provide the necessary pressure to impress the image from blanket to the substrate. Pressure settings are varied between the impression cylinder and blanket cylinder when stocks of varying thickness are used.

Image transfer

The image areas accept ink and transfer them to the blanket. The orientation of the image in the plate is readable. When transferred to the blanket it becomes unreadable and in the next revolution, the image is transferred to the paper that travels between the blanket and the impression cylinder. The image is first set off from the plate to the blanket and then set off from the blanket to the paper. For this reason, lithography is also called offset printing. Since the image and the non-image areas on the plate are both in the same plane, lithography is also called a planographic process.

Types of offset presses

There are two ways in which paper can be fed to an offset printing press; either in the sheet form or in the roll form. Presses that feed paper in the cut mode are called sheet fed presses and the presses that feed paper in the roll mode are called web fed presses. Some of the presses can print on both sides of paper and they are called perfecting presses. Many of today's presses have the capability to print many colors as they have been configured with the plate, blanket and impression cylinder configurations many times over. A press that has one of this set is called a single color press, and presses that have multiple sets of the above mentioned combinations are called multicolor presses. They are usually in the two-, four-, five-, six-, eight-, and now ten-color configurations.

The plate used in lithography usually has a flat surface and is called planographic. There is no physical or mechanical separation between image and non-image areas. The plate material can be paper, plastic, or metal.

Printing unit

The printing unit is the section of the press where the print is generated and applied to the substrate. On a single color lithographic offset press, this is usually done with three cylinders called the plate, blanket, and impression or back cylinders. The plate cylinder has four primary functions:

- hold the plate in register
- come into contact with dampening system
- come into contact with inking system
- transfer inked image to the blanket

Dampening system

The purpose of the dampening system is to apply a very thin layer of water or moisture to the plate. The water is actually a special mixture of chemicals called fountain solution. The fountain solution keeps the non-image areas of the plate desensitized and printing clean. The separation between printing image area and nonprinting area is accomplished chemically by having:

- Image areas repel water and accept ink (hydrophobic)
- Non-image areas accept water and repel ink (hydrophilic)

Dampening types

- Contact or non-contact
  - Non-contact (popular on web presses)
    Brush (Harris) or spray (Smith)

- Contact dampening
  Conventional or continuous
  - Conventional has a reciprocating ductor roller.
    The rollers can be fabric covered or bareback. Fabric can be a thick cotton cloth called moelleton or a thin parchment paper sleeve

  Continuous dampening
  - Continuous is also called flooding nip
  - Direct plate-feed
  - Indirect inker-feed (integrated, Dahlgren)
  - Some combination of both (bridge)

Perfecting

Printing on both sides of a sheet of paper in a single pass through the press is called perfecting. In office imaging, laser printing, or photocopying, this is called duplexing. Sheetfed presses usually perfect sequentially. Webfed presses perfect simultaneously. In order to perfect on a sheetfed press, the sheet of paper must be flopped or tumbled end-for-end inside the press. The tail or back edge becomes a new gripper or front edge. Any size sheet error essentially becomes doubled when done with a perfecting cylinder.

Inking system

The purpose of the inking system is to apply an accurately measured or metered amount of ink to the plate. Each process requires a special type of ink and method to apply it to the image carrier. Some inks are thick like a heavy paste and others are fluid. Some systems continuously bathe or immerse a roller or cylinder while others intermittently supply a limited and metered amount of ink.

If the ink is a thick paste, then it can be distributed by a series of soft rubber rollers. If the ink is a fluid, it would drip off the rollers due to gravity. Fluid inks require miniature wells or cups to transfer the ink. These wells can be part of the image carrier itself or a special type of inking roller.

The ink film thickness determines the strength or density of a color. There are two separate controls for overall or global (sweep) and localized increases or decreases in ink volume (keys). Here are some of the factors involved in ink distribution:

- Fountain roller (ball)
- Fountain blade
- Ink keys
- Ductor roller
- Ink train
- Oscillating or vibrator rollers
- Form rollers

Ink distribution by printing process:

Offset lithography	paste ink & rollers
Gravure	fluid ink & doctor blade to remove excess ink on top surface
Flexography	fluid ink & anilox roller to apply ink to rubber relief plate
Screen	paste ink & rubber squeeze blade to force ink through porous mesh
Letterpress	past ink and rollers
Digital	liquid or dry toner powder

Image transfer

Each printing process has a method to transfer the ink from the image carrier to the substrate. Some do this directly while others have no contact at all with the substrate. Direct image transfer systems require a wrong-reading image carrier so the image on the substance is correct or right-reading.

Offset lithography	indirect, "offset," right reading
Gravure	direct, wrong reading
Flexography	direct, wrong reading
Screen	direct, wrong reading, because screen is two-sided and translucent
Letterpress	direct, wrong reading
Digital	direct, offset, or non-impact

What does offset mean?

Offset is the method of transferring an image from the plate to the substrate through an intermediate rubber blanket. When lithography was first invented, it was not an offset process, but a direct process. If desired, all of the printing processes could be "offset." The blanket cylinder has two primary functions:

- hold the rubber blanket
- transfer ink from the plate to the substrate

Looking at the various printing results

Letterpress	Same as flexo but hard metal type may deboss backside of paper.
Offset lithography	Text and line art is sharp and crisp with excellent edge definition. Halftones have high resolution screen rulings of 133–300 lpi for halftones.
Gravure	All images, both halftones and line art are screened. Solids may look wormy, screen tints may look “snowflaky” from dot skipping.
Flexography	Outside edges of solid type have a darker halo ring or outline.
Screen	Ink film thickness is very thick and can be felt. Top surface of ink may have a rough texture because of the pattern of the screen.

Waterless offset

With this concept, the use of water is eliminated from the process. Image areas are in recess from the non-image areas. The problems that are associated with ink water balance, paper expansion due to moisture content caused by water in the dampening solution, etc. are overcome with waterless offset. This concept was developed in the late 1960s by 3M as a dryographic process, but they stopped marketing because of the poor scratch resistance and durability of the plates. Plates were developed by Toray Industries of Japan in 1973. Toray made positive working plates that were more durable, had better scratch resistance, allowed longer print runs, and produced better quality. By 1978 they marketed positive working waterless plates, and by 1985 they were able to offer negative working plates.

Aluminum is the base material for the plate, and the plate is not anodized like conventional offset plates. A light-sensitive photopolymer coating is given to the aluminum base. Over this there is a very thin layer of silicon, approximately 2 microns. The plate is protected by a cover sheet, which is approximately 7 microns. This cover sheet need not be removed during exposure, and does not cause an appreciable dot gain, or undercutting during exposure.

Exposure and development

The waterless plates are made from either positives or negatives, depending on the plate type used. The plate is exposed to actinic UV light. During the exposure, the bond between silicon and the photopolymer is broken. The silicon loosens its hold on the photopolymer. The plate is developed by a chemical process that consists of tap water solution for lubrication and a glycol-based solution for treatment with a dye solution, which recirculates and is not discharged from the processor. These plates have the ability to hold a dot ranging from 0.5% to 99.5%.

The finished plate has the image areas in its photopolymer layer and the non-image areas in its silicon layer. The nature of silicon to repel ink, suits its role wonderfully in a waterless plate system. The image areas are in a recess and are protected by silicon walls. Since the image areas are protected by this wall, individual halftone dots have less capability to grow, thereby minimizing dot gain on plate. These plates are capable of producing very high screen frequencies, in the region of 200–300 lpi with negative working and 400–600 lpi with positive working plates.

Waterless press

Any offset press that has a dampening system on it can be used for waterless offset printing. Temperature and humidity control in the press room is critical in waterless offset between 80 to 88 degrees F. This is considered the optimum temperature range for inks and ink rollers in a waterless system. Each unit of the press has a different temperature, with black needing the hottest, yellow the coolest and cyan and magenta in between. When printing with good stock, we can expect good results. Since the non-image areas of the plate are made of silicon, they tend to get scratched when using poorer quality stock. This is due to the fibers from the paper scratching the silicon layer. The same problem can be caused by abrasive particles that may be used to dry ink (pumice powder).

Offset lithography features

- Printing from right-reading planographic (flat) plate to blanket and substrate
- Basic principle: “ink and water don’t mix”
- Principal applications: publications, packaging, forms, general commercial printing, labels, books, etc.
- Recognition characteristics: sharp, clear images

Waterless offset

- Silicone surface of non-image area on a plate—recent advances in inks, plates, and presses make this a rapidly growing process
- Advantages: no fountain solution; yields cleaner, purer, more consistent color; improved color contrast; reduced dot gain; high gloss levels; reduced makeready, and running waste; faster job changeover times
- Requires special ink and plates, adapted presses
- Waterless-capable presses able to run both waterless and conventional
- Strong growth projected for high-end commercial sheetfed and heatset web offset

Sheetfed offset trends

- Press automation increases competitive advantage. Most automated features deal with makeready, nonproductive costs, and turnaround time.
    - Programmable, automatic blanket and roller washing
    - Semiautomatic and fully automatic plate changing
    - Presetting systems for fast format changes
- Improvements in feeder, sheet transfer, and delivery systems increase running speed to 10,000 to 15,000 impressions per hour.
- Digital press controls allow virtually total press supervision and control from central workstation
- De facto standard for multiple printing units on new sheetfed presses in six color units with inline coating unit. Placement of presses with seven, eight, or more units is increasing.

- Higher number of printing units accommodates more complex design and color applications.
- Increased demand for short run lengths.
- Sheetfed printing squeezed between efficient web offset operations and by digital non-impact printing processes and color copies.

Web offset trends

- Continued development of automated control systems expected for all aspects of web offset production, from makeready through drying, folding, stacking, and delivery.
- Press speeds of 2500-3000 feet per minute now possible.
- Successfully entering into competition with sheetfed at lower run lengths, and with gravure at higher run lengths.
- Waterless offset becoming more widely accepted.
- Opposing trends: regionalization of printing (in some part due to increasing postal rates) may keep run lengths, press sizes down; consolidation of printing plants may drive up need for longer runs on higher speed, wide web presses.
- Wider webs—54 and more inches wide—becoming more commonplace.
- Average run length has dropped by as much as 25% 1990–1994.
- Short run lengths (under 20,000) and extremely high run lengths (20 million) are economically feasible, depending on circumstances, with web offset and will be typical by 2000.

Direct imaging technology

Heidelberg came out with “Direct Imaging” which they called the “system solution for Computer To Press” (a different kind of CTP, essentially Computer to Plate on press). This technology takes the data stream from the computer that acts as its front end and images the plate directly on the press.The spirit of offset printing is very much alive in presses that incorporate the direct imaging technology. The plate is mounted on the press, but is quite different from conventional versions. The plate is in a continuous reel form that is wrapped externally around the plate cylinder. The image is on the surface of the cylinder. The plate has two layers, a base layer that is an ink-loving layer and a top layer, made of silicon, that is an ink-repelling layer. The laser when fired on the plate burns the silicon layer leaving the image-receptive layer intact.

Digital Front End (DFE)

The front end of the press is a computer that controls the digital data into the press. A RIP converts the PostScript data into a bitmap and fires the laser onto the plate, which is already mounted on the plate cylinder. The imaging head has 64 infrared laser diodes (16 diodes per color x 4 colors) that take the raster data and fire up the plate. The plates can be imaged in either of 1270 or 2540 dpi resolutions.

Direct imaging technology uses waterless printing. When the press is in operation, the plate is in contact with the ink rollers that apply ink onto the image areas. The image is transferred to a blanket and then onto the substrate as in offset. The QuickMaster-DI uses a common impression cylinder as its internal architecture for the press. This means that this press has only one impression cylinder, instead of one for each color (cyan, magenta, yellow or black).

The impression cylinder is in the middle and all the four blanket cylinders come in contact with this common impression cylinder. The paper travels between the blanket and the impression cylinder as in a conventional offset press.

Direct imaging

The laser technology which is built into the direct imaging press from Heidelberg forms the heart of this entire technology. Heidelberg has been a long-time known leader in the printing press arena. They have been and are a leader in the conventional offset field, but had not made a big dent in the digital work environment. However, they have had the insight to bring to our industry the strengths of conventional offset and combine it with the strengths of digital technology. In doing so, they and their partner Presstek, harnessed the combined power of these two technologies and thus was born the technology of “direct imaging.”

Register control

The satellite construction of the press ensures that the paper is gripped once preventing transfer from one unit to the other. This feature of the press minimizes the chances for misregister. Another key issue to minimizing or practically eliminating misregister from the press is in the basic technology of direct imaging itself. Since the plates are imaged on the press, there is no reason that they will ever have to be moved horizontally or laterally for register.

This is very important in the economics of running a press. A vast amount of time is spent in a press during the initial makeready of the job. Time being looked at as money these days, any saving in time has a direct impact on savings in money. Waterless as a process helps in getting brighter ink reflectance on the paper. The advantages of direct imaging are numerous.

Although the press is now available in a slightly smaller sheet size (18-3/8”x13-3/8”), which is a limiting factor, the technology is a sure success. Now a new company called 74 Karat has been started by Scitex and KBA Planeta and they have adopted the direct imaging technology in their press. A key development that has been incorporated in 74 Karat is that they have built a press that is much larger that the QuickMaster-DI 46-4. Heidelberg has launched a 74 cm press, matching Karat’s present size.

This press will have five- or six-color printing capability and images at 2540 dpi resolution. With many jobs being printed requiring more than four colors, Heidelberg’s decision to provide the special color unit will be welcomed by the industry. This press will have an automatic plate mounting mechanism, with automatic plate washup, which will save considerable time. It is called the Speedmaster 74-DI. Direct imaging is a technology that has to be watched.

Recess printing—Gravure

Gravure is another direct printing process, like letterpress with, however some major differences. The image is directly transferred from the image carrier, which is usually a cylinder, onto the substrate. Gravure is called intaglio because the image areas are in a sunken area and the non-image areas are in relief. This must sound like an exact opposite of the letterpress process. In a way, that is true.

Press construction

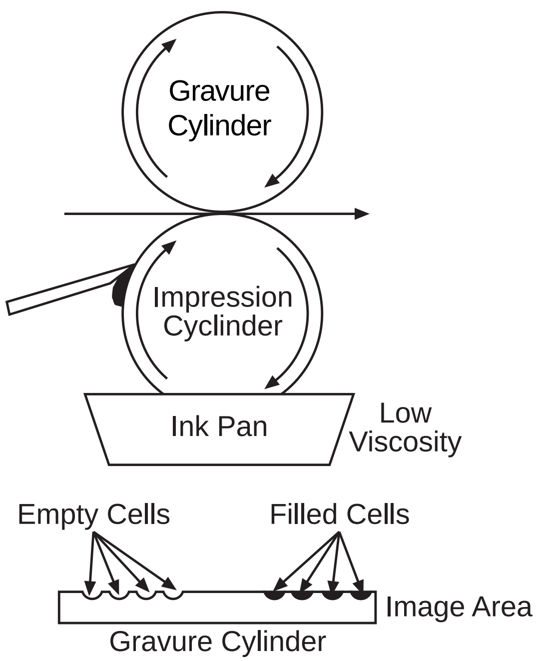
A gravure press is constructed with two cylinders per unit, a printing cylinder, which carries the image and an impression cylinder like in the offset process, that applies the required pressure to transfer the ink. Gravure cylinders are usually made of steel. This cylinder has a number of tiny cells in it, around 50,000 to a square inch. The cells are protected by walls that are in relief. The surface of the cylinder is plated with copper to hold the image. The image is transferred photographically to the electroplated copper surface. The non-image areas on the copper are chemically etched or mechanically engraved to form the cells. Each cell varies in its depth, and this enables each cell to transfer varying densities of ink to produce tones. The ink used in gravure is in a liquid form.

Doctor blade

The printing cylinder rotates in a trough of liquid ink. During this motion, the inks fill the cells of the cylinder and inks the image areas. However, the non-image areas also get inked as they are in relief. This excess ink is wiped clean by a blade called a doctor blade. The doctor blade is positioned at an angle over the cylinder so that when the cylinder rotates, the excess ink that was picked up by the non-image areas are wiped clean.

In the continuing motion of the cylinder, the paper (or the substrate) is fed in between the printing cylinder and the impression cylinder. By pressure, the ink in the cells is forced out onto the substrate. Since the printing image is made of copper, which is quite expensive, gravure is usually used for very long-run jobs which it handles well because the image is placed on the cylinder directly, and on copper, which is a strong metal. Traditionally gravure has been used by markets that have a need to produce long run and consistently good quality printing. Packaging and some long run publications therefore employ this printing process.

Most gravure presses are web-fed. Some are as large as 16 feet wide. The gravure process is used for specialty products like wall paper and vinyls. Gravure presses can print at incredible speeds like 2500 feet per minute. So one can imagine that unless the job calls for huge numbers to be reproduced, in high quality, gravure as a process cannot be chosen.



The bottom of this illustration shows the gravure plate profile. The top of the illustration shows the gravure process. Note the doctor blade removing ink from the impression cylinder.

Gravure features

- Printing from wrong-reading recessed image cylinder direct to substrate
- Three major segments: publications, packaging, and specialty product printing
- Principal applications: packaging, long-run magazines and newspaper inserts, catalogs, wallpaper, postage stamps, plastic laminates, vinyl flooring
- Recognition characteristics: serrated edge to text letters, solid color areas
- Relatively short makeready times on press; high color consistency; continuous, repeated image
- Cylinders last forever, making repeat runs very economical
- Cost of making cylinders remains high, making gravure expensive for jobs that are not repeated or not extremely long
- Trend is toward removing chemistry from cylinder-making procedure, increased use of water-based inks
- Breakthroughs anticipated in electron-beam engraving and photopolymer-coated cylinders

Stencil printing—screen printing

This is a process that is used by many artisans for short-run jobs. It is such a less expensive process that many screen printing units are operated out of garages. But that does not mean that screen printing cannot offer good quality printing. It is a pretty simple process to understand and operate.

Basically if you have seen how printing is done from a stencil, then you have probably seen the process of screen printing. The process is pretty much photographic in the image creation stage and it is mostly manual at the printing stage.

The image that needs to be printed is first captured on a photographic material, a positive usually. A silk screen is stretched tightly by hinging around a wooden frame. The process derives its name from this silk screen, which was used as the image carrier. The positive image is then transferred to the screen and developed. The image that has been transferred to the silk screen is on the porous area of the screen. The non-image areas are blocked out during the stage of image creation itself.

The screen is laid over the substrate that is to be printed and ink is poured on the frame over the screen. The ink is then wiped across the surface of the screen using a device called a squeeze. A squeeze is a wooden device that has a rubber blade. It facilitates the smooth flow of ink over the screen. Since the screen is porous in nature, the ink flows through it. Because the image areas are porous, they allow ink to flow through them. This ink is thus printed onto the substrate beneath.

Printing capability

Since the printing surface in the screen printing process is very flexible, it allows printing on three-dimensional objects too. This is something that the printing processes discussed earlier cannot offer. A substrate that is two-dimensional and flat is all that can be fed into those machines; in the case of screen printing, the printing surface itself can be wound around the substrate. So objects like cups, mugs, watches or other irregular-shaped products can be done using the screen printing process.

Although this description of screen printing may sound quite simple, in actuality there are screen printing presses that are as automated as any other printing presses. Multi-color printing presses employing screen printing process with capability to print on different substrates like polyester, metal, and pressure-sensitive materials are today a common scenario. These presses are equipped with online corona (electrostatic) treatment, and can even combine ultraviolet drying in some color units.

Screen printing features

- Printing by forcing ink through a stenciled screen mesh image directly onto substrate
- Principal applications: can print on any substrate; point-of-purchase displays, billboards, decals, fabric, electronic circuit boards, glasses, etc.
- Ink formulation, screen mesh count, and image type are major quality factors
- Recognition characteristics: heavy, durable, brilliant layer of ink

Other printing processes

The above-mentioned four printing process were considered the major printing processes for a long time. This was due to the fact that other forms of outputting ink on paper did not really have the ability to compare with the quality that these processes could produce. Moreover, the ability of other processes to produce color was very limited.

Over time other processes evolved to cater to specific market needs, and with their ability to reproduce color, they were extended to serve specific printing markets. They are all used mostly as proofing devices and without an exception they are all digital devices. One of the prime differences between the already discussed processes and the following is in the image carrier. In the traditional printing processes, the image is on a surface that produces multiple reproductions as replica to the one on the printing surface. The digital printing devices have the ability to vary the image every time they need to print. Let us take a look at some of the other technologies that could put ink on paper. For the present, we will call these *digital* printing processes:

- dot matrix (including limited color)
- electrostatic (including color)
- laser printing (including color)
- dye diffusion
- thermal printing
  - –thermal wax transfer

- inkjet
  - –bubble jet printers
- other recorders

Dot matrix

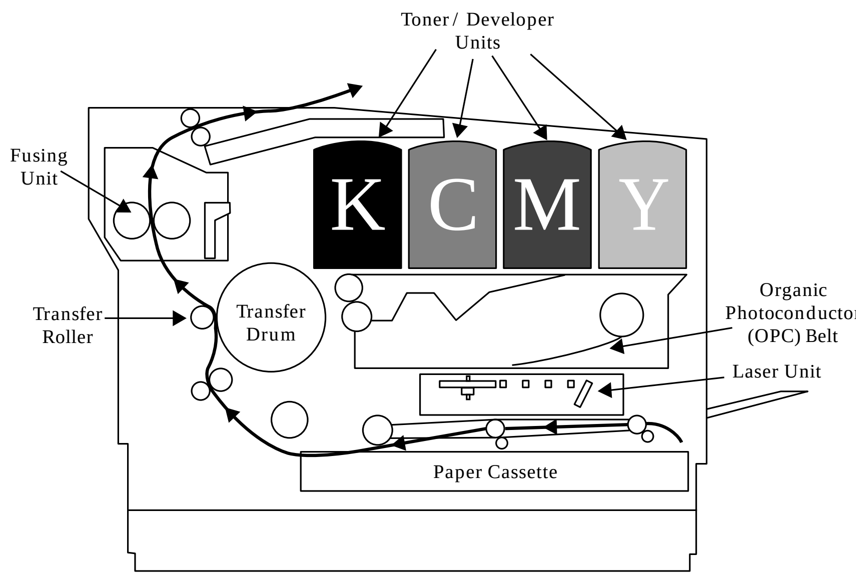
These were the early forms of outputting a document from a personal computer. Used largely in the office environment, they did (and do) a pretty good job. The printers have a series of hammers in the print head. A color ribbon, usually black, is placed in front of the head. On instruction from the computer to print, the hammer whacks the ribbon against the paper placed behind it. The ink from the ribbon is thus transferred to the paper. The character or images are constructed by a formation of small dots. The quality of the output is quite poor, and the noise that is generated by the printer is quite disturbing. Types do not look sharp and the problems are worse when printing one color over another. The quality of image transfer deteriorates with aging of the ribbon and / or the hammer.

Electrostatic

A laser beam creates a selective charge on a selenium drum when exposed to laser light. The charge takes place in the image areas. The equivalent of ink is a toner particle. This toner particle gets attracted to the charge in the drum. When the substrate is fed into the machine, the toner particles transfer from the drum onto the substrate. A lot of document copying and printing work is done this way, and is also called photocopying, because multiple copies of a document are created by the use of light. Color electrostatic printers adopt the same principle to reproduce color and, depending on the equipment, the paper may pass through the machine four times, in a single writing station, or once in a multiple-pass station. These printers can print good line work, as they have a high addressability. Some of these printers print 600 dpi.

Laser printing

This is electrophotographic imaging as in copying machines, with the printing machines driven by computers. When the document is sent for output, a laser beam charges the printing drum by applying a static charge to the photoreceptive drum. The areas that received the charge tend to attract toner particles, and the image is transferred to substrate. For permanency, the toner-based image is heated and fused with the substrate.



Laser printers can be desktop-based or higher-speed and very much like presses

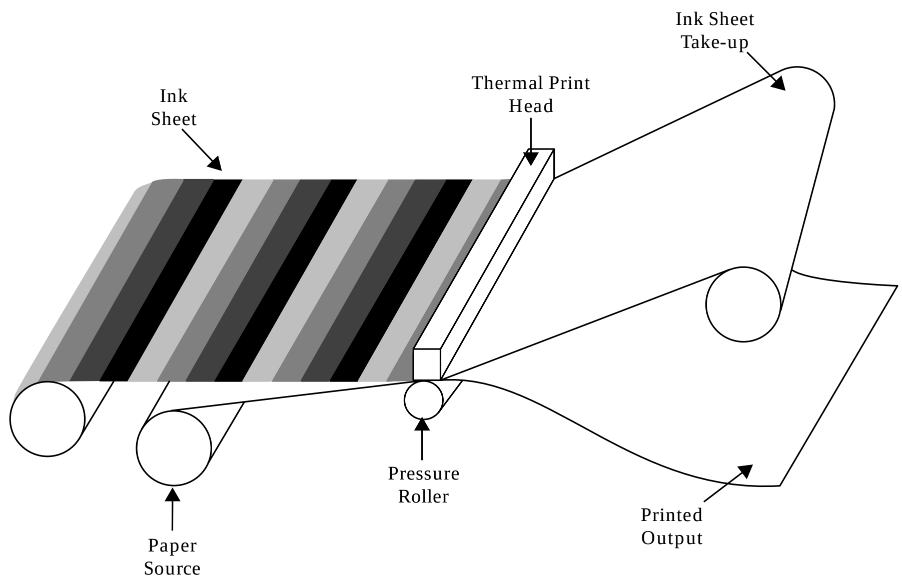
The early models of laser printers which produced good quality copies had one drawback. The speeds were not very attractive for high volume requirements. Now high-speed printers are available like the Xerox Docutech 135 and 180, as well as Docucolor 40 and 70/100 which can be used for production work. They all use the laser process principle. Though claimed to be high-speed printers, they do not compare with traditional printing process speeds. Nonetheless, they are quite popular in the short-run, and on-demand printing markets.

Thermal printing

If you have seen the way something gets printed from a fax machine, then you have pretty much understood this process. A specially made paper that is coated with a dye is used in this process. When the paper is heated it turns black. So, during the imaging process, the image areas are heated and the spots on the paper turn black, giving us the reading matter printed. This is also a popular method employed for generating labels and barcodes. Because the process involves an induced change in the state of the substrate (paper), the process is limited to printing only in single color.

Dye diffusion printers

Originally this process was created for printing on fabrics. It uses a color donor ribbon that transfers the dye to the substrate by the use of heat. The temperature is usually very high, in the region of 400 degrees C. By varying the temperature on the print heads, varying intensities of color can be printed. This can produce a feel of continuous tone printing. This process has a good potential, as the inks used in dye diffusion printing have a color gamut greater than that of photography. However the flip side to this technology is that it is expensive, slower, and requires special substrates to print on.



Thermal and dye diffusion printers have special ribbons with alternating color areas

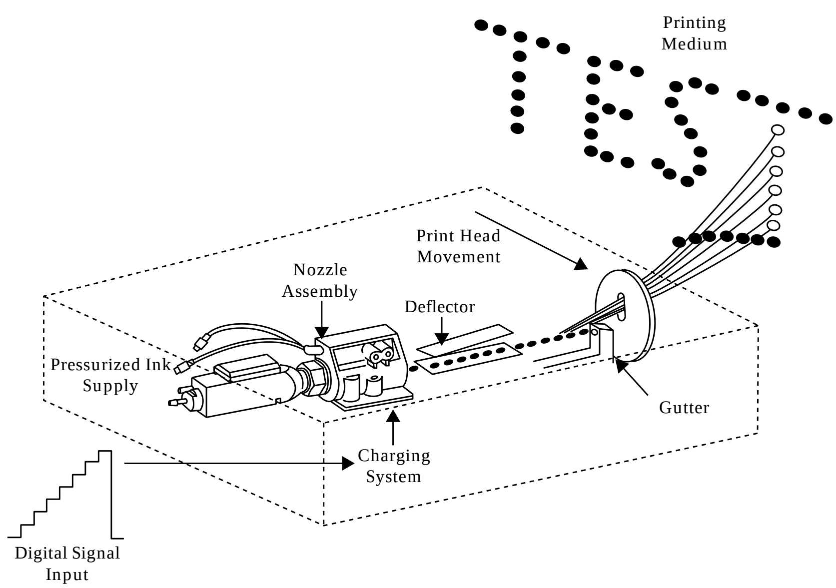
Thermal wax printing

This process is somewhat similar to that of a dye diffusion printer, using wax as the medium of “ink transfer.” A metal drum is divided into a grid that addresses a pixel to a spot on the grid. Every spot on the grid is assigned a color value. The pixels in the grid heat up and melt the wax in the ribbon, which is transferred to paper. These waxes are transparent, which makes it advantageous for these prints to be used as overhead slides for projection. Some of these types of printers have a three- or four-color ribbon to print from. They both produce color prints, but the one with four-color ribbons has more visual appeal than the tri-color ribbon printer.

Inkjet printing

This process works by spitting small droplets of ink on the surface of the paper. The amount of ink that is to be spewed on the substrate is controlled by a computer. There are three kinds of ink jet printing:

- continuous inkjet printing
- drop-on-demand inkjet printing
- phase-change inkjet printing



Continuous inkjet "spits" the ink at the substrate

Continuous inkjet printing "spits" liquid ink in a continuous fashion, and the pressure of the spurting of the ink is controlled by a vibrating device and the ink is spurted from an orifice which also determines the size of the droplet that will ultimately land on paper. All of the ink is fired from a single nozzle. This produces print which makes good line work and solid colors, which is acceptable for some low-end applications of the market. When it comes to printing fine images and multi-color printing, the drawback in the process stems from the single nozzle rather than an array or group of them. And that is what happens in continuous array ink jet. Every droplet's size is controlled by a single nozzle. Because of multiple arrays, speeds can be increased, and this gives better productivity. An array of continuous ink jet printing nozzles can also be attached to high-speed printing presses for specialized printing like barcoding or personalization.

Drop-on-demand inkjet printing

The ink is forced out of the orifices onto the substrate only where it is required. This is done by one of several methods. The inks used in this process are water-based. When heated, the water in the ink vaporizes and forms a gas bubble. This causes a droplet of ink to be pushed out of the orifice in the chamber, which will have to be replenished. The replenished ink then goes through the same process till it is pushed out. Because of this alternating method of throwing out the ink and then replenishing the chamber, the process slows. Another drop-on-demand ink jet printing method uses a piezoelectric plate. This plate carries the ink, and on an electrical current being passed, the size of the plate is deformed. The deformation of the plate reduces the volume of the ink in the plate and causes it to spill a drop. The drop of ink lands and dries on the substrate. This kind of inkjet printing is commonly used for large billboards and posters. The quality is acceptable.

Phase-change inkjet printing

The process derives its name because the ink changes its state from solid to liquid to solid before it actually lands on paper. These printers use a waxy kind of an ink in the ink chamber. This wax is heated and the ink changes to a molten state in a reservoir. When the print head receives an electrical signal, the volume of the reservoir reduces, causing the molten ink to be ejected. The reservoir is filled when there is no charge. Based on the signal received from the computer, the print head either turns on or turns off the electrical signal. Thus, the ink ejection from the reservoir is controlled. Since the ink is wax-based, it gels well with the substrate and does not penetrate the substrate. Up to 600 dpi can be addressed by this process, and it produces sharp and saturated images. As the ink settles on the surface of the substrate, its thickness can be felt; this also adds to the feel of the image printed on it. However, if handled, the print is subject to abrasion and can get damaged.

Bubble-jet printers

Bubble-jet printers are relatively low cost devices that produce color prints on plain paper. Low cost per page and low cost of the printer are the primary attraction of these printers. They are also limited in reproduction size, in that many bubble jet printers can print only up to a letter size (8.5"x11"). They can be used for applications like inhouse work, or for reports, but certainly cannot be used for contract proofs.

Slide or film recorders

Film recorders produce slides, in color and monochrome, as negatives or positives. When only one slide is needed, it can be easily produced with your camera. However, when a number of slides need to be duplicated, the need to maintain consistency and standards become critical. The basic image is created digitally in a computer and is imaged on a photographic medium for as many times as the number of copies needed. The recorders function like a camera though they do not capture light the way a camera does. Instead of aiming at the scene to be captured, the recorder aims at a Cathode Ray Tube (CRT). A light-sensitive emulsion is exposed from the beams of the CRT and this emulsion is sent for processing, the same way a conventional photographic film is processed. A recorder that has come in to cater to the high end of the market is Light Valve Technology (LVT). The film that is to be imaged is wrapped around a cylinder as in a scanner. The drum spins at a high speed, and the film is imaged by narrow beams of light through electronic light valves that modulate the amount of light that should image the film.

Ink

Every printing ink is formulated from three basic components:

- colorant (pigment or dye)
- vehicle
- additives

Pigments or dyes give inks their color and make them visible on the substrate. Without pigments, printing could occur, but it would be pointless since the image would be almost invisible. Vehicles carry the pigment through the press and onto the substrate. Without the vehicle, there is no printing, period. Additives include silicone, wetting agents, waxes, driers and other materials used to enhance performance characteristics such as drying speed, color development, slip and mar resistance. Of the three, vehicle formulation is most critical to an ink's performance on the press.

Colorants are the visible portion of the ink. They may be dyes, but more often are pigments. They may be in powder form (dry toner), in a concentrated paste dispersion known as a flush, or in a liquid dispersion. Red, blue, yellow, and black are the most frequently used colors in printing and together create purple, green, orange and other colors during the printing process. Other colors are used, but in much smaller quantities. The red, yellow, and blue colorants are almost exclusively synthetic organic pigments. The black used in printing ink is carbon black—a soot generated through burning natural gas or oil.

While not as visible as colorants, vehicles are just as important to the ink. Made up of oils (petroleum or vegetable), solvents, water, or a combination of these, they carry the colorant through the printing press and attach it to the paper or substrate. Most vehicles contain resins which serve to bind the colorant to the printing surface. The vehicle is the portion of the ink most responsible for tack, drying properties and gloss. Additives can include waxes, driers and other materials which add specific characteristics to an ink or to the dried ink film, such as slip and resistance to scuffing and chemicals.

Vehicles are complex blends of natural and synthetic solvents, oils, and resins, and are manufactured with strict attention to cycle times, heating and cooling. They can account for up to 75 % of an ink's content. Ink formulators can choose from hundreds of materials, alone or in combination, to create an infinite variety of vehicles, each with distinct properties suited to different printing applications. The vehicle is responsible for an ink's body and viscosity, or flow properties. It is also the primary factor in transfer, tack, adhesion, lay, drying and gloss. More than any other element in a formulation, the vehicle determines how well an ink does its job.

An ink's vehicle determines its rheology, or flow characteristics—whether it is liquid or paste, long bodied or short. This has a direct impact on the ink's movement from the ink fountain through the roller train, and its transfer from roller to plate, plate to blanket and blanket to substrate. The faster the press, the more critical these transfer properties become. As speeds increase, ink misting tends to increase as well. Increased shear and heat build-up on faster presses have the potential to cause an ink to break down, leading to dot gain, toning and other print quality problems.

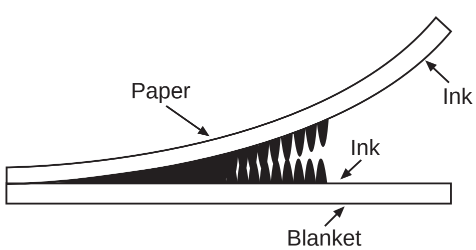
Printers desiring to use lighter weight, uncoated or recycled stocks for economic or environmental reasons complain that the softer surface of these stocks makes them prone to water absorption, dot gain and picking. Using an ink with inappropriate tack and transfer properties because of an inappropriate vehicle compounds the problem.

Ink formulations differ depending upon printing process and application. Printing presses used in the various processes require different flow characteristics or rheology for the ink to travel in an optimal fashion through the press to the substrate. Letterpress and offset lithographic inks are fairly thick or "viscous." On press, they move through a series of rollers called the ink train where the action of the rollers spreads the ink into a thin film for transfer to the blanket and / or plate and onto the substrate. Flexographic and gravure printing inks are more fluid, so that they flow easily into and out of the engraved cells on anilox rollers (flexo) and print cylinders (gravure).

All inks are made up of pigments, resin vehicles, solvents, and other additives, but the most important properties are color, color strength, body, length, tack, and drying. Color is determined by pigments, which are finely divided solids. Important characteristics of pigment include specific gravity, particle size, opacity, chemical resistance, wettability, and permanence. Body refers to the consistency and stiffness or softness of inks. Inks can range from stiff ink like that used for lithography to very liquid ink like that used in flexography. The term that is associated with this is viscosity.

Viscosity is the resistance to flow, so that a high viscosity ink would not flow. Length is associated with the ability of an ink to flow and form filaments. Ink length ranges from long to short. Long inks flow well and form long filaments and are not ideal since they tend to mist or fly. Short inks do not flow well, and tend to pile on rollers, plates, and blankets. Ideal inks are somewhere in the middle of the two types. Tack refers to the stickiness of the ink, or the force required to split ink film between two surfaces.

Tack determines whether or not the ink will pick the paper surface, trap properly, or will print sharp. If the tack is higher than the surface strength of the paper, the paper may pick, split, or tear. When putting down more than one ink on a page, the ink that has the higher tack should be put down first. Tack can be measured using either an inkometer or tackoscope. The final property is drying, but the ink must first set before it actually dries. Some newer drying systems include ultraviolet and electron beam radiation.



Tack is the relationship between ink, blanket, and paper

Ink drying

Ink drying is a very important function when considering what to use. Inks can dry by absorption, oxidation / polymerization, evaporation, solidification, and precipitation. During the process of absorption the vehicle drains into the sheet, leaving the pigment trapped by the fibers in the surface of the paper. There is really no true drying, which is why newsprint comes off on the reader's hands. When ink is dried using oxygen, it attacks the carbon atoms. This is called oxidation. The oxygen break down the double bonds of the atoms found in the drying oils, which causes the ink to dry. Sometimes the solvent is evaporated using heated rollers or dryers that cause the inks to dry, and is called evaporation. If the ink then needs to be chilled after going through a set of heat rollers the process of drying is called solidification. Finally, precipitation depends on the actual precipitation of resin from the ink vehicle by addition of moisture. This method is incompatible with the dampening solution on an offset press.

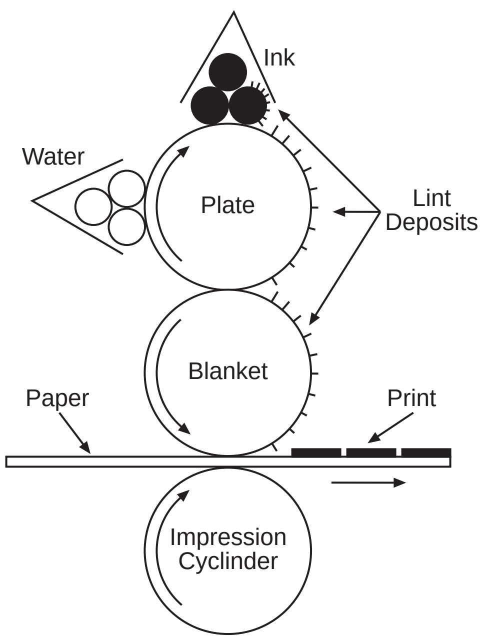
There are a wide variety of inks used for different purposes. Radiation inks have been developed to eliminate spray powder in sheet-fed presses. There are two types of radiation inks

- UV curing
- electron beam

UV curing inks dry when exposed to large doses of UV light. These inks are expensive because of the costly active ingredients. Electron beam curing inks are a good alternative to UV inks. The main cost is the high capital cost of getting the equipment to run these inks. Heatset inks are quick drying inks used mostly for web presses. The solvents in the ink disappear after a drier heats them. Once the solvents are gone, the pigments and binding resins are fixed to the paper so the ink does not spread. Another type of ink is high gloss ink. These inks contain extra varnish, which give them a glossy appearance.

There are still many problems with printing inks although they have been around for centuries. The most common problems in the pressroom include:

- hickeys
- picking
- piling
- tinting
- scumming
- ghosting



Lint deposits can transfer to the paper

Hickeys are caused by dirt. Ink cans should be closed to prevent debris from getting in the ink. Picking transfers debris from the paper back through the ink and onto the paper again. Piling happens when the ink fails to transfer from the blanket to the paper. Tinting is caused by the emulsification of ink in the dampening solution and results from poorly formulated ink. A common remedy is changing inks, though adding a binding varnish may help. Scumming occurs when the non-image area takes up ink instead of remaining clean. Ghosting (mechanical) occurs when there is uneven ink take-off from the form rollers.

The substrate used for each printing application and its end use further dictate the raw materials chosen to formulate an ink. Non-porous substrates such as plastic films and glass cannot absorb ink vehicles and require inks which dry either through evaporation or by polymerization (UV or EB). Often solvent-based, these inks are frequently formulated for additional performance characteristics. Inks used on soap wrappers, for example, must be alkali resistant; inks on liquor labels must be alcohol resistant; inks on food containers that will be heated in ovens or microwaves must resist high cooking temperatures.

Newspaper inks are formulated to dry by absorption; that is, the ink oils are absorbed into the newsprint. This process leaves the colorant sitting on the surface, and without the binding properties of resins or drying oils, it tends to rub off. For magazines, catalogs and brochures, the demand is for high quality paper, glossy printing with vivid colors that do not rub off readily. Here the printed ink is often subjected to heat to assist in drying. These properties dictate a different and more costly set of raw materials.

Many printers have made the switch from alcohol to alcohol substitutes in their fountain solutions for environmental and health reasons. If they did not communicate the change to their ink suppliers so that an adjustment in ink could be made, they may have been surprised to find a deterioration in print quality—increased scumming, tinting and toning.

Using sophisticated laboratory instruments—rheometers, viscometers, inkometers, and surface tensiometers—ink formulators can test vehicles to closely predict performance characteristics. The final test of any ink, however, will always be on the press, when the full combination of variables (ink, press speed, substrate, plate chemistry, fountain solution and even the ambient temperature and humidity of the press room) come into play. Close cooperation and continuous communication with ink suppliers will minimize potential problems and ensure that the vehicle in the ink you are using is the right one to get you where you want to go.

Inkjet ink

Inkjet printers fall into the larger class of non-impact printers. There are many techniques for printing without use of plates and pressure. These non-impact printers are used largely for computer printout and copying requirements and also include electrostatic printers, laser printers, thermal, and others. Inkjet printers are among the most important of non-impact printers. The are used to produce or reproduce variable information on a wide variety of substrates, paper, gloss, and metal, and textiles. For the last thirty years, inkjet has been predicted to be the next major printing technology.

Inkjet printers are used for many applications including mass mailings as well as home usage. Ink jet printing uses jets of ink droplets driven by digital signals to print the same or variable information directly onto paper without an imaging system. The ink is sent out of the printhead either by a pumping action, by a piezo electric crystal, or by vapor pressure. In the continuous process, electronic deflectors position the drops, while drop-on-demand places the ink only when needed. The bubble-jet printer you may own at home just drools the ink onto the paper. Once the ink is dropped onto the paper, the ink sets through absorption, spreading, and evaporative drying. Inkjet currently is the key contender for low-speed, low-cost desktop full color. The main categories of inkjet systems are listed in the following chart:

Continuous | **Intermittent** | **Drop-on-demand** | **Electrostatic**

Continuous → Liquid Inks → Dye Based or Pigment Based

Drop-on-demand → Piezoelectric or Thermal → Liquid Ink or Hot Melt

Inkjet inks are made of water-soluble dyes, polyethylene glycol, diethylene glycol, N-methyl pyrrolidone, biocide, buffering agent, polyvinyl alcohol, tri-ethanolamine, and distilled water. Since the dye must be water-soluble, this leads to poor water fastness on paper. Hewlett-Packard changed their ink formula in their HP DeskJet for a large improvement in water fastness. A problem is that of wicking, which is ink spreading away from the dots along the fibers of the paper. One way to reduce this problem is to change to hot melt/phase change inks.

Hot melt/phase-change inks are used in drop-on-demand desktop printers, but are aimed at high-quality full-color printing on a range of substrates. The phase change refers to the fact that the ink dye or pigment is contained in a binder that is solid at room temperature.

This principle requires a low viscosity ink. The inks are jetted as a hot liquid but cool almost instantly upon hitting the surface.

Inkjet technology is really not one technology, but two. The first is continuous as mentioned before. This method produces small characters at high speeds (up to 2000 characters / second). This method allows the printer to apply variable data to a job. The basic idea of this method is called oxillography. Using oxillography, ink is pressurized through a small nozzle, about the diameter of a human hair, and pulsed to form a uniform stream of regularly sized and spaced drops. These drops pass an electrode, which can induce an electrostatic charge on any droplet. Only drops that are used for character formation are charged. As the drops continue, they pass through an electrostatic field induced by two deflector plates. These plates deflect the path of the droplets by an angle proportional to the charge. By changing this degree of applied charge (changing the degree of deflection), characters can be formed on a moving substrate. Uncharged drops are deflected back and collected to be used again. There are some problems that are associated with this method of inkjetting. These problems are as follows:

- The need for sophisticated equipment for dry conditions to avoid loss of ink solvent in nozzle.
- Stationary items cannot be printed.
- The print is not solid and looks a lot like a bad dot matrix.

The second technology is drop-on-demand. This technology produces images using water-based inks for on-line printing of bags, boxes, and other items used for distribution. The drops are not deflected from one head, but from multiple heads, otherwise known as a raster. The firing of the ink is computer controlled to form the character. Drop-on-demand is slower than continuous jet, and the water-based inks require an absorbent substrate. There are limitations on this method of inkjetting

- coarse printing
- slow speeds
- only print on absorbent substrates

Rapid development is taking place in the area of continuous jet printers. These printers will be able to do quality multi-colored graphics, although at low speeds. More developments also seem to be taking place in continuous multiple inkjet systems. This system prints with 100 nozzles. In this system it is the uncharged droplets that are placed onto the paper, not the charged droplets. This should increase print accuracy, as there is no deflection between particles. Drop-on-demand developments are focusing in on smaller dot sizes in order to achieve smaller characters that in the traditional method. In order to do this, the number of heads is increased, though it prints at slower speeds. The latest technology includes the touch dry ink jet which uses 32 jets to apply thermoplastic ink, which eliminates problems associated with solvent-based inks. The medium is held in the reservoir in the form of dry pellets, which are heated just before printing.

System	Colors reproduced	Resolution/DPI	Application
Continuous	26,000–16.7 million	150–300	Pre-film color proofing
		Photo realistic	
		Transparencies	
Drop-on-Demand	26,000–16.7 million	160-400	Short run color printing
Electrostatic	4,000–16.7 million	300-100	Short run printing
		Color overheads	
		Office copy work	
		Durable signature	

Inkjet has many benefits as well as problems. Benefits include low price for equipment, high print quality, use of plain paper, and low-cost consumables. Problems include that of having water-based inks which are too volatile and dry in the nozzle and dry slowly. In the future we can look forward to high resolution at a low cost, reliability, fast drying black ink, speed, and possible continuous tone color.

Inkjet printers transfer color to a page by squirting ink onto the paper. The different methods of applying the ink are known as liquid and solid inkjet. Both of these methods apply ink only where it is needed; this results in a variable cost per page. Liquid inkjet uses liquid ink that drys on the paper through evaporation. Liquid inkjet consists of two techniques known as pulsed inkjet and thermal inkjet. Pulsed inkjet uses hydraulic pressure to control the ink sent to the print heads and then to the paper. Thermal inkjet uses a heating element normally located in the ink nozzle that causes the ink to form bubbles. Once the bubbles become large enough, they are forced from the nozzle onto the paper. The problems with this technology are non-uniform spot shape and color density that is lost when ink is absorbed into the paper. Another shortcoming is that the ink remains water soluble and will smear if exposed to moisture.

Solid inkjet uses ink that is solid and must be melted before it is sprayed onto the paper. This ink solidifies quickly when exposed to room temperature and results in a better dot than liquid inkjet. The ink is dropped on the page using a print head which contains nozzles of each color. The ink hardens as soon as it makes contact with the paper. Once the page has been completely covered, a cold roller applies pressure to flatten the ink and strengthen its bond to the paper.

Inkjet has has two major subcategories: drop-on-demand [DOD] and continuous, further defined by the size of the finished product. Drop-on-demand ink jet heads have an array of tiny jets (240, 300, 600 per inch, depending on resolution) that each emit a single droplet of ink at an extremely high rate. Pressure difference caused by reducing the volume of ink in a reservoir causes this phenomenon. There can be multiple heads for printing process colors; however print speed is relatively slow (under ten ppm) because of the difficulty controlling each droplet and amount of time needed for the ink to dry.

A variation in the drop-on-demand technology is bubble-jet, where the ink is actually boiled and the resulting drop fired at the substrate. Still another variation is solid inkjet. Ink is contained in solid sticks which melt when heated. The resulting liquid is fired in the same way as the water based ink products, but instead of absorbing into the substrate, the ink resolidifies on contact. The printed piece is often three dimensional. This process works on almost any substrate. With continuous ink jet, ink is fed as a continuous stream. The stream is separated into droplets which are then electrostatically charged and deflected by magnetic fields to control the placement on the substrate. Unused ink is recycled.

Toner

Electrostatic, electrophotographic, and xerographic printers all use electrical charges transferred to a nonconducting surface that either attract or repel the toner. There are several types of electrostatic processes: direct electrostatic, color xerography, and ElectroInk.

The imaging material is a thermoplastic material (containing lampblack) that is used to create an image. The first toners were used in 1938 when Chester Carlson and Otto Kornei performed their experiments with electrophotography using a powder to transform printed images to a paper sheet. These experiments were conducted from 1944 until 1948. In 1950, Xerox released the product of these experiments, the first xerographic reproduction equipment. Since the introduction of the equipment, toner has become one of the most widely used reproduction vehicles.

There are three major groups of toners:

- dual component
- mono component
- liquid

Dual-component is the most common type of toner used today. It is made up of two distinctive parts—toner and carrier beads. There are three major ways of developing dual component toners, the most common of these being cascade development. It is based on triboelectrification, which is the process of exciting toner particles by causing an electrical charge (static) through the use of friction. The triboelectrification process causes excited particles to cling to read carriers. Toner is 3–30 µm in size, depending on the desired resolution of the printed image. The higher the resolution is, the smaller the toner particles needed. Dual-component toner is used in over 90% of the current xerographic copiers and digital printers. Printers such as Xeikon and the Xerox Docutech use dual-component toners for the development of their images.

Color xerography uses a pre-charged drum or belt that conducts a charge only when exposed to light. The scanning laser is used to discharge this belt or drum which creates an invisible image. Toner containing small iron particles is magnetically attracted to the appropriate areas of the image and repelled from others. This image is then transferred to a roller which collects all four colors. The image is then electrostatically transferred to plain paper where it is fused by heat and pressure.

The monocomponent toners differ from dual-component toners in that they do not require the use of carrier beads for development. There are several ways to charge monocomponent toners, induction, contacting, corona charging, ion beam, and traveling electric fields. The easiest and most commonly used of these is induction charging. Through induction charging, a conducting particle sitting on a negative surface becomes negatively charged. Because the opposite charges repel each other, the negatively charged particle is repelled by the negative plate and drawn to the positive plate. Through this process, particles lose their negative charges and become positively charged. Once toner particles become charged, they can be transferred to the substrate. Most low-end printers use one of these monocomponent toner-charging methods.

Direct electrostatic printers apply a charge directly to specially coated paper. Liquid toner particles are then swept across the paper and stick to the charged regions. Repelled toner is removed from the page before the next color pass. After all colors have been placed, the toner is then fused. This technology can be easily modified for large format printing. Liquid toner provides the advantage of finer toner particles that can be used to achieve high resolution output.

Liquid toners are comprised of toner and solvent. It is the use of solvent instead of developer that causes them to be liquid. Liquid toner solvents are nonconductive and primarily made up of thermoplastic resin particles, which are suspended in a saturated hydrocarbon. In many respects liquid development is related to or considered with powder-cloud development. In both cases, freely moving charged toner moves under the action of an electrostatic field.

Indigo ElectroInk is a variation of xerography that uses liquid toner. The liquid toner is charged electrostatically and brought into contact with the photoconductor where it is either attracted or repelled. The colors are imaged to an offset blanket from which the composite color image is then transferred to the paper media. This liquid toner offers the advantage of delivering very small dots that can produce very high resolutions. The Indigo E-Print 1000 is based upon this technology.

Thermal transfer devices include thermal wax transfer and dye sublimation. Thermal transfer technologies use a three- (CMY) or four- (CMYK) color ink-coated ribbon and special paper which are moved together across a thermal head. Wherever the thermal head applies heat, the ink fuses to the paper. This technology requires 3 to 4 passes across the thermal head depending on the use of a 3 or 4 color ribbon of ink. The result of this process is single-bit dots of the primary colors. The QMS ColorScript 230 is an example of a thermal wax printer.

Dye sublimation uses a similar technology, except that the inks used change to a gaseous state. This requires the thermal head to deliver a much higher temperature but results in finer control and smaller dots which can deliver multi-bit color. This results in continuous tone color. The gas that carries the color and tone entirely covers the dot being imaged. If less ink is carried, the dot changes in tone. In contrast, thermal wax would cover only half the dot area and the rest of the cell would remain white. Fresh consumables (a ribbon in most cases) used for each image result in a constant cost per page, regardless of the number of colors used.

For several decades, ink manufacturers have sought new raw materials which address economic and environmental considerations. For example, vegetable-derived oils such as soy and linseed oils have been used in place of petroleum-based oils in some formulations, water is replacing volatile solvents in others, and pigments are selected to eliminate heavy metals from inks, particularly those used for food or toy packaging. The adaptation of technology to individual process or product needs can be complex. The successful implementation of electronic printing technology requires an appreciation of a wide range of scientific disciplines. The interaction of ink or toner with the print mechanism and substrate needs careful consideration. The prediction of final print quality and its control will need evaluation. With all of the variables in printing press, substrate, and end-use requirements, inkmakers face an exciting challenge.

Will inkjet printing ink and toner compete commercially with offset lithography ink? There is an appeal here because it eliminates rollers, dampeners, and plates; it requires no film. On the negative side, however, are the costs of the equipment, the limited resolution of the currently popular ink jet printers, and limitations in inks. The graphic industry anticipates continued improvement in inkjet equipment in the areas of ink technology and costs.

Digital printing is becoming very popular since the introduction of the Indigo and Xeikon presses in 1993. These digital devices use toner, which is similar in principle to that used in a copy machine. But how does the fine powder stay on the page? Chester F. Carlson created the photocopier methodology. He found that in order to get copies of something it either needed to be rewritten or photographed, and knew there had to be a better way. He first looked at photoconductivity for the answer, and realized that if the image of an original were projected onto a photoconductive surface, current would only flow in the area the light hit. In October of 1937, his first patent was created for what he called electophotography. Chester hired Otto Kornei to help him out. Otto took a zinc plate and covered it with a coating of freshly prepared sulfur and wrote the words “10-22-38 Astoria” on to a slide in India ink. The sulfur was given a charge and the slide was placed on top of the sulfur and under a bright light. The slide was removed and the surface was covered with lycopodium powder. The powder was blown off and there was an almost exact image of “10-22-38 Astoria.”

In order to preserve the image, Carlson took wax paper and heated it over the remaining powder. The wax was cooled and was peeled away, creating the first photocopy. This method created a blurry image though and Carlson wanted better dry ink. A fine iron powder was substituted and mixed in with ammonium chloride salt and a plastic material. The ammonium was to clean the image and the plastic was designed to melt when heated and fuse the iron to the paper. This was the first toner and in order to produce different colors, different tones were used.

Toners are pigmented bits of plastic about ten micrometers in size. The manufacturing of toner is a multistep process consisting of mixing pigments and internal additives with the base toner polymer, which breaks the pigmented polymer into particles of the desired size. The most important step is blending the pigments and other internal additives with the polymer binder at the right temperature so that it flows, but has a high viscosity. If the temperature is too high the pigment will not disperse as well.

The name electophotography is classified under patent class 355, subclass 200. It is defined as a device wherein the electrical conductivity, the electric charge, the magnetic condition, or the electrical emissivity of a light-responsive medium is selectively altered directly by light reflected from or transmitted through an original, whereby a visible or latent image is formed on the medium and persists after exposure. In simpler terms, a photoconductor acts as an insulator, retaining a charge of electricity. Areas of the surface contacted by light lose their charge. The remaining areas with charge attract oppositely charged particles of toner that is transferred to the paper. For most printers using this method, the drum is re-imaged for each sheet, unlike in lithography where the same image is produced multiple times.

There are various types of toners and development systems available on the market. Dry toner printers use a form of magnetic brush system to carry toner/developer from the supply to the development zone. These utilize non-magnetic toners carried on a magnetic iron which provides charge by rubbing contact or magnetic toners which contain a proportion of magnetic oxide. Dry powder toners are made up of the following components:

Constituent	**Function**
Magnetic Oxide	Colorant, provides magnetic counterforce transport; readability
Pigment	Color black, hi-light, filler
Polymer Binder	Fusing, toner stability
Charge Control Agents	Charge stability
Surface Additives	Lubrication/cleaning, toner flow

With these toners there are significant temperatures necessary in xerography. The first is the temperature at which the image is fixed to the paper. Anywhere above this temperature the toner is very fluid and splits apart. Once it splits, it then is left on the fuser roll and attaches itself to the next page. Toner also has some problems that differ from those of inks. Particle size also has a lot to do with the quality that you can get from a machine using a dry toner. Particle size usually ranges from 10–20 mm in diameter. Particle size any larger than this will usually produce jagged lines and dots. Toners which produce smaller dots take longer to make, and cost more.

Another type of toner is liquid toner. These toners are charged, colored particles in a nonconductive liquid. Liquid toner particles are much smaller than those of dry toners, and are capable of smaller particle sizes ranging from 3 mm to submicrometer sizes. Liquid toners are used in copiers, color proofing printers, electronic printers, and electrostatic printer-plotters. Liquid toners are made up of dispersants, resins, charge control agents, and pigments. The dispersants must be non-conductive in order to not discharge the latent image as well as interact with any other materials used in the process. The resin is used as a vehicle for the pigment or dyes to provide stability, and aids fixing of the final image.

The charge control agents are added to the toners to impart charge on the toner particles. Metal soaps are a common material used as a control agent. Finally, the pigment controls the color of the toner. Important factors of the pigment include particle size, dispersibility, and insolubility in the toner dispersant.

Liquid toners could be combustible, rather than flammable because of their high flash point. If evaporation does not occur and comes in contact with flesh, slight irritation may occur. Devices that use liquid toners are well-ventilated, or re-cycle any hydrocarbons through an internal system.

A major imaging problem is that charge voltage decay between the time of charging the photoconductor, exposing, and toning can affect image density and tone reproduction, as the amount of toner transferred is dependent on the exact voltage of the charge on the image at the instant the toner is transferred. The second deals with the toner chemistry. Because the chemistry is not understood, variations in batches of the same toner occur. In liquid toners the isopar that is used to disperse the toner is a volatile organic compound, which may require venting and is subject to Environmental Protection Agency regulations.

The process and the product dictate what type of inks you can use. A conventional lithographic press, an inkjet system, or a digital printing press are not only used for different applications, the inks used are all different. This will affect the quality and the other printing attributes. In almost every electronic printer, the consumable (the ink) is specific to the device.

Digital presses

Variable data

Digital presses have one unique capability that conventional printing processes cannot deliver. In a digital printing device, every copy that is printed is imaged that many number of times. Which also means that the printing surface is imaged once for every copy that is printed. This is in contrast to the conventional printing process where the printing surface is imaged once, and multiple copies are generated from that printing surface. It is this feature in a digital press that slows down its production. But the uniqueness of this feature opens up a new opportunity, which is exploiting the necessity to image every time for a copy. Since every copy needs to be imaged on the printing surface, every copy can also be varied on the printing surface. Which opens up a whole new world of printing capability—variable data printing.

Imagine all that one could do with variable data. Specially targeted messages can be printed for a select audience, instead of printing static data that may not be completely targeted to a particular audience. You can now have your brochure specially printed for you. The press will print your name, address, and even have contents in the copy that have been personalized to suit your tastes. Variable data includes images. The key to producing efficient variable data is handling powerful databases. There are off-the-shelf programs like Print Shop Mail, and Darwin (Scitex) and extensions to QuarkXPress like Datamerge that promise to exploit the potential of variable data. We have to keep in mind that though the potential of variable data is humongous, we are at an evolving stage of this great possibility. Digital presses provide this capability, which conventional printing processes can never do.

Digital printing features

- Digital printing is a rapidly growing segment of printing.
- Principal applications: short-run, on-demand printing.
- A digital printer can be defined as one that inputs a digital data stream and outputs printed pages.

- The broad categories of digital printers include electrostatic, inkjet, and thermal. But we can also say that any printing process that takes digital files and outputs spots is also digital.
- Interdependency with digital presses will likely create major changes in the operation of the printing industry and increase the volume of digital printing.
- Xerox DocuTech, Xerox Docucolor, Indigo E-Print, Xeikon DCP, Scitex, Agfa, Chromapress, and Canon CLC-1000 are among current major electronic systems.
- Digital masters made directly on press, printed with waterless offset lithographic process, characterize short-run direct imaging printing presses.
- Cost of digital presses and consumables impact competition between digital printing and offset lithography. Run length, turnaround time, and bindery needs / solutions are major cost factors in this competition.

On-demand printing involves short notice and quick turnaround. In the printing industry, print-on-demand can be defined as “short notice, quick turnaround of short, cost-competitive print runs,” which all results in lower inventory costs, lower risk of obsolescence, lower production costs, and reduced distribution costs.

Most traditional printing does not satisfy this criteria and does not result in these advantages. The disadvantage of traditional long-run printing is that the reproduced information becomes obsolete, which requires the disposal and re-manufacture of new material. In the United States, approximately 31% of all traditional printing is thrown away because it is outdated. This number includes 11% of all publications, 41% of all promotional literature, and 35% of all other material. Although print-on-demand is a more sophisticated phrase for the printing industry, there is no specific technology that is used to perform such a job. On-demand printing (also known as demand printing) can be produced with a traditional press because the customer does not care so long as the quality is acceptable, and it is done quickly and economically.

Digital printing is any printing completed via digital files. A digital press may be capable of printing short runs economically, but digital printing on printing presses is well-suited for slightly longer runs.

When comparing on-demand printing and digital printing, demand printing is economical, fast, and oriented to short runs. On the opposite end, digital printing is printing from digital files, but is not restricted to short runs. Demand printing can be done with digital files or conventional film or plates; however, digital printing is done only with digital files.

Variable printing

Variable information can be printed by digital presses, which are presses that print digital data. On different pages you could have different names and addresses. This cannot be accomplished by traditional printing. With traditional printing, the prepress work is performed, the plates are made, and they are run on the press. The end result is thousands of pages that are identical. The information is static. The capacity to print variable information, which results in variable printing, is the key factor of customized printing. To accomplish customized printing today, conventional pages or static pages are run through high-speed inkjet devices for variable information. Many digital presses offer this ability. Unlike inkjet devices, digital presses are not limited to six or twelve lines of copy, but some can customize the entire page.

The basics of customized printing is the combination of variable information with output devices that do not require intermediate films or plates. They are true digital printing systems in that all or part of the image area can be changed from impression to impression. Short run can best be defined as one that is less than 5,000 impressions. Almost 56% of commercial, book, and office printing, including duplicating and copying, falls in the category of run lengths from 500 to 5,000 impressions. Presently, only 2.8% of this printing is done in four or more colors. By the year 2000, the amount of four-color printing in this run-length market will increase to approximately 11.5%.

Traditional printing presses usually operate in the long-run category; however, this trend seems to be changing. In order to stay competitive in this growing industry, printers are attempting to compete with moderate or even short-run categories. While most traditional presses will have difficulty meeting the needs of the short-run category, this is where a new market is developing. It is projected that the short-run wars will take place in the 100- to 3,000-copy range. The on-demand process consists of the client supplying electronic files or camera-ready materials and specifying how many copies of the publication will be needed. The printer produces the publication directly from the disk or camera-ready artwork and delivers it within a specified timeframe.

Currently there are three specific on-demand strategies in our industry: on-demand printing, distributed demand printing, and on-demand publishing. “On-demand” means that the data is stored and printed in electronic form. It does not necessarily have to be an electronic file, but usually it is a digital file which provides the effectiveness of the short run. The second strategy, distributed demand printing, requires that the electronic files be transmitted to other locations, printed, and distributed locally.

These publications can then be stored, printed, and shipped locally as needed. The third and final strategy is on-demand publishing (also known as demand publishing), in which the data is stored in paginated form and transmitted for immediate printout. This is done by large-volume magazines. Portable Document Formats, such as Adobe Acrobat, are being used to distribute the print-ready document files.

Electronic printing allows variable data printing. Traditional printing does not. Let us now compare the major features of the three traditional printing processes as we move into a discussion of packaging:

	FLEXOGRAPHY	GRAVURE	OFFSET LITHOGRAPHY
Substrates	Wide variety, can print on most packaging materials	Wide variety, can print on most packaging materials	Limited, not easily adapted to films or laminated packaging materials including polyethylene, paper, foils, and laminates
Impression Pressure	Light “kiss” impression pressure	Heavy pressure in printing nip	Relatively high pressure in printing nip
Plate life/ Run length	Avg. plate life between 1-2 million impressions	Avg. cylinder life between 3-4 million	Avg. plate life between short and long run available up to 300,000
Press Size	Many web widths available; widths range from 6” to 90” (wider for corrugated)	Many web widths available; widths range from 2” to 110” (wider for vinyl flooring)	Standard format size; sheetfed up to 60” web-fed 11”-60”
Cut-off Repeat length	Variable repeat	Variable repeat	Standard format / fixed cut-off
Speed	Product dependent: toilet tissue–3,000 fpm;	Product dependent: publication–3,000 fpm vinyl flooring–50 fpm	Product dependent: sheet-fed 12,000 imp / hr 2500 fpm pressure-sensitive labels-150–300 fpm
Ink	Fast-drying fluid ink solvent, water, and UV curable dry trapping	Fast-drying fluid ink solvent, water dry trapping	Heat-set and non heat-set paste ink wet trapping
Digital imaging	Laser engraving and laser exposable available	Heavily utilized	Yes, on press and off press

Packaging

Packaging graphics are the last and possibly the most important advertising many products receive. Flexographic printing technology is used on a wide variety of materials for a great variety of packaging applications. Arguably, it is the flexographic process's "flexibility" that is its greatest advantage. Soft compressible printing plates, fast-drying fluid inks, and a simple, efficient ink delivery system give the flexographic printer the ability to reproduce high quality graphics on many different surfaces.

During the last decade, the dollar volume of products produced by the use of the flexographic printing process has been growing at a rate of approximately eight percent a year, a rate unparalleled by any other printing technology. Some of this growth is due to the increased need for packaging and packaging graphics. However, another source of new business for flexography is products that have traditionally been printed by the other major printing processes—gravure and offset lithography. Print buyers are beginning to recognize flexography as an economical, high-quality alternative to gravure and lithographic printing.

Packaging buyers have begun to hold the flexographic printer to the same high quality standards as lithography and roto-gravure. This means that the flexographic printers will have to consistently deliver high quality graphics. Specifically, tone reproduction is expected to be the same resolution in flexography as that printed by lithography and gravure. Historically, the flexographic printing process has been used for low-cost/low-quality packaging graphics. In fact, the stigma of being a "cheap" printing process has caused some packaging buyers to ignore flexography when selecting a process for higher quality graphics. Even within the industry a culture shift from low-cost/low-quality to low-cost/high-quality has been slow to come about.

Adding to the problems flexographers find when competing with other printing processes is the fact that there are no established standards for flexographic printing. Some standards that may be helpful include trapping, dot gain, and specific values for process color inks. The fact that the flexographic industry is without these standards complicates communication between buyers, suppliers, and printers, and makes quality consistency very difficult.

The recent move to "desktop" design has also introduced new problems for flexographic printers. With the use of the computer it has become relatively simple for the novice to create attractive new package designs. Unfortunately, many of the novice designers are ignorant of the limitations of the printing technology that will be used to mass-produce their designs. Also, many designs that appear attractive on a computer monitor are impossible to reproduce on a flexographic printing press due to press registration problems and ink limitations.

When a designer who has experience creating a package design to be printed by offset lithography or gravure applies the same design principles for a flexographically printed graphic, they may be creating problems for the flexo printer. Without the benefit of research into production methods and equipment, an otherwise simple design for gravure or offset would pose many printing problems for flexo.

Traditional printing processes

The three most commonly used printing processes are lithography, flexography, and gravure. Each of these processes has its own inherent advantages and disadvantages. To better understand the primary differences in each process, one needs to compare three key areas: the ink, the ink delivery system and the image carrier.

The most commonly used printing process (based on the number of printing presses currently in production) is lithography, sometimes called offset lithography. Lithography is used heavily in the publication industry for printing magazines, catalogs, and many daily newspapers as well as a number of other applications like annual reports, advertising, and art reproduction. Lithography is also often used for packaging such as folding cartons, labels, and bags.

Offset lithography is classified as a "planographic" process. That means the printing plate or image carrier used for lithographic printing holds both the image and non-image on one flat surface or plane. The image areas of a lithographic plate are chemically treated to be attractive to the lithographic paste ink, while a fountain solution or ink-repellent chemical protects non-image areas from inking.

In a lithographic printing press, a paste ink is applied to the image areas on the plate, the image is then transferred to a blanket (hence the term offset), and then to the substrate. Lithography has been a favored process because it can reproduce soft tonal values on coated substrates. Another highly prized feature of lithography is its ability to print 300-line screen images with excellent fidelity.

Gravure packaging

Gravure, sometimes known as roto-gravure, is the second most commonly used process in Europe and the Far East, and the third most commonly used process in the US. The gravure process prints perhaps the widest variety of products of all processes. Gravure is heavily used in the magazine printing industries and also prints many of the inserts in the Sunday newspaper. Vinyl flooring and woodgrain desktops and paneling are also printed by gravure. An offset gravure process is used to print the M on M&M candy and the printing on many medicine capsules. Gravure is used for many of the same packaging applications as those of flexography. Gravure is used for:

- Publications
- Products
- Packaging

The gravure printing process is classified as an "intaglio" process. An intaglio printing process recesses the image below the level of the non-image areas. A gravure image is etched or engraved into a copper plate or copper-plated cylinder. All gravure images are etched in a cell format on the gravure cylinder. By varying the size and depth of each cell, the gravure press can vary tones. Often, after the copper is etched or engraved, the plate or cylinder is plated with chrome to add durability and run-length to the gravure cylinder.

In a gravure press, a fast-drying fluid ink fills the recessed cells, a thin metal strip called a doctor blade clears the non-image area of ink, and then the image is transferred directly to the substrate under heavy impression pressure from a rubber-covered impression roll.

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

The flexographic printing process is classified as a relief process. A relief printing process is characterized by the image areas being raised above the surrounding non-image areas. Letterpress is also a relief printing process, the primary differences between letterpress and flexographic printing technologies are:

1. Plate hardness—the letterpress plate is hard and non-compressible; the flexographic plate is soft and compressible.
2. Ink—the letterpress ink is a paste consistency; the flexographic ink is a fluid, about the same consistency as paint.

In a flexographic press, an ink metering roll called an anilox is brought into light contact with the raised image areas of the flexographic plate by an adjustment controlled by the flexographic press operator. The flexographic press operator then moves the plate into light contact with the substrate to cause image transfer.

Flexographic packaging

Flexographic printing units in use today are simple in design and easy to understand. The following components makeup a flexographic printing unit:

- fountain roll
- anilox roll
- doctor blade
- dual doctor ink chamber
- plate cylinder
- impression roll

There are three types of flexographic printing units being used today: two roll, two roll with doctor blade, and dual-doctor chambered systems. The two roll units are usually found on older flexo presses, and on narrow web presses. Narrow web presses doing process color work will probably be equipped with two roll units and doctor blade, and more modern wide-web presses are equipped with the dual-doctored chambered system. Each of these printing units may preform acceptably; however, a doctor blade system should be used when doing screens and process color flexographic printing.

To understand each of these printing units, it is important to first understand the “heart” of the unit, the anilox roll. The surface of every anilox roll has been engraved with a tiny cell pattern, cells so small they can only be seen under magnification. The size and number of these cells determines how much ink will be delivered to the image areas of the flexographic plate, and then to the substrate. An anilox roll is either copper engraved and then chrome plated, or ceramic coated steel with a laser engraved cell surface.

On a two-roll flexographic printing unit, the rubber-covered fountain roll rotates in a bath of fluid flexo ink. As the fountain roll rotates, it drags a supply of ink from the ink pan and delivers it to the cells of the anilox roll. The relatively soft, rubber-covered fountain roll is held in tight contact (nipped) with the anilox roll. As the anilox rotates past the nip point, excess ink is “wiped” from the non-cell area by the fountain roll. Once past the nip point, each cell is filled with ink, and a measured, repeatable amount of ink is available to the printing plate. On the press, the flexographic press operator moves the “metered” anilox roll into light “kiss contact” with the image areas of the flexo plate, and then moves the plate cylinder into light “kiss contact” with the substrate to achieve ink transfer. The steel impression roll supports the substrate during ink transfer.

When a doctor blade is used with a two-roll unit, the nip between fountain and anilox roll is opened to allow the ink to flood the anilox and fill the cells. The doctor blade, a thin metal or polyethylene blade, then comes into contact with the anilox to sheer excess ink from the non-cell areas. When the flexographic press is equipped with chambered doctor blade inking units, the fountain roll and inking pan can be eliminated, and ink is delivered directly to the anilox through an enclosed chamber.

Anilox cells

The best flexographic printers select anilox rolls for their press after carefully evaluating the type of printing they intend to do, and the type of substrate they will be printing on. Often the flexographic printer will perform test runs to determine the ideal type of anilox roll in an effort to maximize graphic elements related to screen ruling, solids and spot color, type, and substrate.

These are the important characteristics of an anilox roll:

- Cells Per Inch (CPI)—The number of cells in a linear inch. CPI counts will range from 140 CPI to 1200 CPI. A general rule of thumb is as the cell count increases, the ink delivered to the plate decreases. To achieve adequate ink densities, a flexographer printing linework on absorbent corrugated linerboard would be using anilox rolls at the low end of cell count (160, 180, 200). If the corrugated printer was required to print halftones at 55 or 65 linescreen, the anilox roll would have to be replaced with a roll of higher cell-per-inch count (280, 300, 360). Another important concept is that as line screen resolution increases, cell per inch count should also increase. For instance, a process color graphic on a polyethylene frozen food bag may be printed at 133 lpi. For best results, and in order to avoid “flooding” the halftone dots with ink, the cell count of the anilox roll that inks the 133 lpi printing plate should be at least 550 or 600 cells per inch.
- Cell Volume—Cell count and cell volume are related. As a general rule, as CPI increases, cell volume decreases. Anilox cell volume is described by a theoretical or measured volume, and reported as Billion Cubic Microns (BCM) per square inch of cells. Typical BCM ratings for printing applications range from a low of 1.8 to a high of 14.

Using our example of the flexographer printing linework on absorbent corrugated linerboard, the low cell count anilox being used may have a cell volume of 10.0 BCM, and the process color on polyethylene at 133 lpi, and a 600 linescreen plate may be inking with an anilox cell volume of 2.8 BCM.

- Cell Angle—Anilox cells are engraved in a linear pattern, and at various angles. Typical anilox cell angles are 30°, 45°, and 60°. It is important to understand that the screen angle of the printing plate and the cell angle of the anilox roll can combine to cause an objectionable moiré pattern, even if only one-color halftones are being printed. Many anilox roll suppliers produce a random cell (no-angle) anilox that may be used for limited applications.

While an anilox cell angle may be selected to help avoid moiré, the problem of moiré is usually avoided by angling the separation screens. Research and experience has shown that the 60° angle allows for more complete ink transfer, and is becoming the preferred cell angle for flexographic printers. There is currently no other single component of the flexographic process that will have as significant an effect on flexographic print quality as the type of anilox roll being used.

Plate cylinders and repeat length

All flexographic presses, with the exception of corrugated and newspaper presses, have a variable repeat length capability. This variable repeat length is possible because the plate cylinder on a flexographic printing unit is removable and interchangeable with plate cylinders of different diameters. The flexographic package printer can minimize substrate waste by having an adequate inventory of plate cylinders of various diameters, and choosing the cylinder size that best fits the print dimensions. Most lithographic presses are limited to a fixed repeat length (often called a "fixed cutoff"). The plate cylinder used for most lithographic presses cannot be changed to conform to various package sizes. In this case each package layout and design must fit into the "fixed" dimensions dictated by the press and plate size of the specific lithographic press.

Flexographic plates can be mounted around the entire circumference of the plate cylinder, and images can be arranged to print a "continuous repeat," void of any seam area where the plate ends butt. Continuous repeats can also be accomplished by using laser-engraved design rolls. Flexographic presses can be built in several basic configurations: Stack Press, In-line, Common Impression Cylinder (CIC), and Corrugated.

Stack Press	One to eight color units Web can be printed on both sides with some stack presses Traps should be no less than 1/32" for thin films Often in line with other converting operations, including polyethylene extrusion, lamination, rotary and flatbed die cutting, and sideseal bag converting.
In-Line	Up to twelve color units Often used for printing thick substrates, like corrugated, paperboard Can print two sides (with the aid of a turn-bar) Often in line with other converting operations Not recommended for printing thin packaging film materials
CIC	Four to eight color units limited to one-sided printing Ideal press for hairline register at high speeds on thin, stretchable films Longer make-ready times required because of the inaccessibility of the printing units
Corrugated	Usually no more than four colors All corrugated presses are sheet fed Widths up to 120" Less accurate register capabilities Limited to one-sided printing

Multicolor capabilities

Flexographic presses commonly come with multicolor capabilities. Recently the flexographic industry has experienced an increase in installations of six and eight color presses. In some limited applications, as many as twelve colors can be applied in one pass through a flexographic press. From a creative design perspective the possibilities for eye-catching color are greatly enhanced by a printing process offering so many color capabilities. Combinations of four color process and spot colors, multiple spot colors alone, or high fidelity process color printing allow the designer a great deal of creative latitude when designing a graphic to be printed by flexo.

It is important to note that for transparent film substrates, the chances are good that one of the color stations will be required to apply a white backup or "choke" plate. Without the white backup, colors would appear flat and transparent. The white plate is a characteristic unique to processes utilizing clear or colored substrates.

Another important color characteristic of flexographic inks is that they are usually made from opaque or semi-opaque pigments. The color sequence usually adhered to for flexographic printing is lightest to darkest colors in the press units. Overprinting two or more spot colors will most likely result in the creation of an objectionable "mystery" third color in the overprint areas.

Reverse-side printing

An exception to the rule of lightest-to-darkest color sequence occurs when a spot color or line art job calls for "reverse-side printing." Reverse-side printing means the job is reversed laterally and printed on a clear substrate like polyethylene, polypropylene, or polystyrene. After printing, the graphics will be displayed from the "reverse" or substrate side, rather than the side of the substrate where ink has been applied. This technique is often used for non-food packaging, or for applications where another film will be laminated to the printed film.

Flexographic plates

There are a many types of flexographic printing plates, with the primary differences being the material from which the plate is made and the plate thickness. The type of plate material to be used to print a flexo job is decided by the flexographer after consideration of the graphic elements they are asked to reproduce. Although few flexo printers print from both rubber and photopolymer plates, many have two or three types of rubber or photopolymer materials for platemaking.

Another important characteristic of all types of plates is durometer (a measure of the hardness or softness of a plate). Printing plates (rubber or photopolymer compound) are soft and are of concern to graphic designers. Dot gain is affected by the durometer of the plate being used. Plates of higher durometer (harder), will print with less dot gain than softer plates. However, lower durometer plates transfer solid images more smoothly and completely than high durometer plates. The plate thickness is dictated by the flexo printer's type of press and plate cylinder inventory. Generally speaking, wide-web printers print from thicker plates than do narrow-web printers.

Molded rubber plates

The molded rubber plate has been used for flexographic printing since the 1930s. However, the introduction of the photopolymer plate in the 1970s marked the beginning of a period of steady decline in the use of the rubber plate.

From a design perspective, the important characteristics of molded rubber plates include:

- Molded rubber plates shrink shortly after they are removed from the molding press; consequently, plate films should be adjusted to compensate for shrinkage. The amount of shrinkage depends on the type of rubber being molded, but is typically 1.5%–2.0% along the grain of the rubber and .5%-1% across the grain of the rubber. To ensure accuracy, the exact shrink factors should be communicated between production artists and plate makers.
- Resolving capability of a rubber plate is limited to the 120-line screen.
- Molded rubber plates may be more difficult to register in the plate mounting step than photopolymer plates.

- Prints from molded rubber plates can only appear to be continuous repeat if images are nested in the job layout design, to hide the plate seam.
- It is difficult to mold accurate rubber plates larger than 24"x 36", consequently designs larger than 24"x36" must be done by piecing together multiple plates for each color.

Laser-ablated plates and design rolls

A design roll is a rubber-covered roll that has been imaged by laser ablation. The design roll is seamless, and can carry images around the entire circumference. The laser ablation imaging process is direct-to-plate. This process can also improve register capabilities. The specified trap between colors can be accurately achieved, bleed can be handled, registration marks can be provided as part of the design and eyespots or other devices can be placed precisely.

Laser-ablated design rolls are often used for long-run jobs that require continuous printing, and can be run in combination with other flexographic plates. Direct-to-plate laser ablation can also be used for imaging plates rather than an entire roll. However a laser-ablated plate must be mounted on a plate cylinder and will not be seamless. Laser-ablated plates are often used for short-run jobs and for spot coating on flexo or offset presses.

From a design perspective, the important characteristics of laser-ablated plates and design rolls include:

- Resolution is limited to a 100-line screen for tone reproduction, but can be a 200 to 300 line screen for tints.
- Laser-ablated image carriers do not require film output.
- Laser-ablated design rolls can be a truly continuous repeat design; laser-ablated plates require nested images to give the appearance of continuous repeat.
- Plates or design rolls imaged on a circumference do not require distortion.
- Laser ablation can be performed on both rubber and sheet polymer materials.

Photopolymer plates

Today, the photopolymer plate is the most frequently used plate for flexographic printing. There are two general categories of photopolymer plates available, sheet and liquid. The main difference between the two is the physical state of the raw material from the supplier. Sheet photopolymer is supplied in a solid state, while the liquid plate is supplied as a liquid which has about the same consistency as honey. The liquid solidifies when exposed to ultraviolet light. From a design perspective, the important characteristics of photopolymer plates include:

- Photopolymer plates have guaranteed resolving capabilities of a 150-line screen. Some high-end flexo printers have actually printed from plates with a 200-line screen.
- Prints from photopolymer plates can only appear to be continuous repeat if images are nested in the job layout and design to hide the plate seam.
- Most of the newest plate positioning and register devices rely on a ”one piece” flexographic photopolymer plate.
- Some service bureaus and flexographic plate makers presently have the capability of filmless, direct digital imaging for conventional (non-laser-ablated) sheet photopolymers.

Platemounting systems

Offset lithography has long been able to take advantage of pin register for quick accurate color-to-color registration. The first commercial device for mounting and proofing rubber printing plates was probably developed in the 1940s by Franklin Moss, founder of the Mosstype Corporation. Until the recent adaptation of pin register and micro-dot register systems to flexographic plate mounting, color-to-color register was entirely dependent upon the skill level of the plate mounter. Many platemounters became highly skilled, while others were less accurate in plate positioning and registration, resulting in poor registration on the press.

The concepts of pin register and micro-dot register were developed to make accurate plate mounting fast and easy for everyone, even the beginner. Pin register requires a systems approach. That is to say that each prepress station, right up to the critical plate making and mounting stage has to adopt pin register or micro-dot line-up techniques. Pin positions or micro-dot targets must be accurately transferred through each step of prepress.

Mounting tapes

Mounting tape is the two-sided adhesive used for affixing flexo plates onto the plate cylinders. Mounting tapes also come in a variety of types and thicknesses. Two general types of mounting tapes are "hard" tapes and compressible tapes. A compressible tape is actually a thin layer of foam coated on both sides with an adhesive. The thin foam layer acts as a shock absorber to minimize over-impression on the flexographic plate. By contrast, hard tapes offer no shock absorbing characteristic and are only used to adhere the plate to the cylinder.

Research of various mounting tapes has shown surprising findings. For instance, one test of five different mounting tapes found solid ink density variations from 1.34 to 1.66 by simply changing mounting tape. Dot gain is greater with harder tapes than with softer tapes; usually, the less dot gain the better. Soft cushion tapes, however, do not provide for a uniform ink transfer in solid printing areas, often causing pinholes.

Cylinder preparation

Each cylinder should be checked for condition and accuracy before a plate is mounted on it. Cleaning, checking for defects, and checking for accuracy before mounting the plate will often save material waste, press time, and extra work.

- Cleaning—Plate cylinder surfaces should be thoroughly cleaned to provide the best possible surface for plate mounting. Improperly cleaned cylinders can cause inaccurate plate pressures by trapping ink or other foreign matter between cylinder surface and mounting tape. A cylinder surface with oil, grease or any other residue on it will not allow proper adhesion of the mounting tape and will eventually lead to plate lift. When cleaning a cylinder, it should be noted that many water-based inks require some type of detergent to rewet dried ink for cleaning purposes. Often these detergents leave an invisible residue or film on the surface of the cylinder that inhibits adhesion of tape to metal. Final cleaning of the cylinder surface should be done with a solvent that will leave no residue.

- Gears—Gears should be kept clean and well lubricated. Make a practice of noticing the condition of each with each job change. If they are removable, make sure they are tight when replaced.
- Total Indicated Runout (TIR)—Good pressroom practices includes the use of a dial indicator to check cylinder circumferences and bearing accuracies. Runout of each plate cylinder is important. Recommended tolerances for runout have been +/–0.001” for line work and +/-0.0005” for halftones; however, with today’s more demanding quality requirements a good practice is to always work at halftone tolerances.

Substrate and substrate influence on flexographic printing

Substrate is a generic term for the packaging materials printed by flexography and other printing processes. These materials aren’t necessarily chosen for their printing characteristics, but because they’re functional. Thanks to flexography’s versatility, there is almost no material that has not or cannot be printed by it. It has been said that if any material can be put in a roll, it can be printed by flexography. The quality of a printed product is affected more by the substrate than the type of process that applies the graphics. Packaging industries utilize a wide variety of substrates to satisfy the demands of a wide assortment of packaged products. Substrates can be classified into three general categories:

Paper/paperboard
- kraft linerboard (corrugated)
- clay coated kraft (corrugated)
- solid bleached sulfate (SBS) (folding carton)
- recycled paperboard (folding carton)
- coated paper (labels, gift wrap)
- uncoated freesheet paper (paperback books)

Polymer films
- polyethylene (PE) (dry cleaner, bakery, and textile bags)
- polypropylene (PP) (snack packages, candy wrappers, cookie packaging labels)
- polyvinyl chloride (vinyl films) (labels, wall coverings)

Multilayer / laminations
- metallized papers (gift wraps)
- metallized film (snack food bags)
- polyethylene coated SBS (milk cartons)

The important characteristics of substrates as they relate to the packaging printing process are:

Color

A printing ink is significantly influenced by the color of the substrate on which it is applied. The flexographic process is often used to print corrugated containers with unbleached brown kraft linerboard exteriors. Color matching on these types of material surfaces is difficult to achieve.

Paper / paperboard—White, brown kraft, and a variety of colored papers.

Polymer films—Can be clear, white, combinations of white and clear, or colored.

Multilayered / Laminations—The color characteristics are decided by the topmost layer with reflective qualities. Foils and metallized papers or films are silver, or tinted to a colored finish.

Whiteness/brightness

The whiteness or brightness of a paper is the paper's light reflective qualities. Even on bleached or coated papers there are differences in the whiteness or brightness of a sheet. Paper containing a high percentage of recycled fiber may appear to be more off-white than paper made from 100% virgin fiber.

- Paper / paperboard—Whiteness and brightness increases with bleached and coated papers. Optical brighteners may also be added to paper to increase brightness.
- Polymer films—White films can vary in opacity, which will affect brightness. Clear films require a printed opaque white ink under color images. Colored films are not be included in this measurement.
- Multilayer / laminations—Decided by the topmost layer of film or paper with reflective qualities. Foil and metallized printing surfaces require a printed white ink under color images.

Opacity

All substrates have a measurable opacity rating. Opacity is the ability of a substrate to prevent light transmission. The more opaque a substrate, the less light will pass through. A color printed on paper or film with a low opacity rating will be influenced by what lies beneath the substrate.

- Paper / paperboard—Thin lightweight papers have lower opacity and will be more prone to ink show-through.
- Polymer films — On clear substrates, opacity depends on the opacity of the printed white ink layer. The opacity of white or colored films depends on the film manufacturing process; films may be made white or colored by adding the appropriate colored resin to clear resin during the extrusion process. Darker films may tend to be more opaque than lighter films, but all films can be manufactured with high opacity.
- Multilayered / laminations—Usually high opacity is achieved by the multiple layers of opaque or semi-opaque substrates.

Smoothness

Smoother substrates allow for the printing of higher line screens. Rough, irregular surfaces such as newsprint and corrugated liner board require coarse screen rulings. Defects in smoothness can be described as either macro or micro. Macro refers to irregularities that can be seen with the naked eye; micro refers to a very small area with defects not readily seen with the naked eye.

Because the flexographic ink is fluid and generally not regarded as tacky, fiber pick (a problem common to lithographic printing) is not an issue.

- Paper / paperboard—Newsprint, corrugated linerboard, and paperboard are relatively rough. Calendered and coated papers are the smoothest.
- Polymer films—Polymer films are the smoothest printing surfaces, consequently roughness is not a problem; however, ink adhesion sometimes is a problem.
- Multilayered / laminations—The smoothness is dependent on the substrate used as a printing surface.

Absorption

On substrates with little or no absorption characteristics, the ink will dry at the surface providing more saturated color and less dot gain for halftone printing. Papers with low absorption rates are referred to as having high "hold-out." This means the paper holds or prevents the ink from being absorbed into the sheet.

- Paper / paperboard—Corrugated, newsprint, and paperboard are very absorbent. Calendered and coated papers are less absorbent and exhibit high ink hold-out.
- Polymer films—Polymer films are non-absorbent and exhibit the highest ink hold-out.
- Multilayered / laminations—Absorption characteristics are dependent on the substrate used as a printing surface.

Gloss

Coated papers and films have gloss characteristics that influence the gloss of the inks that are applied to them. High gloss finishes are very shiny, and tend to be reflective. Matte or low-gloss finishes can be applied to all substrates by matte coatings, and uncoated and uncalendered papers have low gloss.

- Paper / paperboard—Calendered and coated papers are high-gloss while corrugated linerboard, uncalendered newsprint, and paperboard have low-gloss qualities. Gloss can be increased after printing by applying an overprint varnish or lamination.

- Polymer films—Films are higher gloss than the highest gloss papers. Films can also be produced with a matte finish.
- Multilayered / laminations—The gloss of the printing surface is dependent on the substrate used as a printing surface; gloss can be increased after printing by applying an overprint varnish or lamination.

Caliper

Caliper is the thickness of a substrate. Caliper is usually measured with a micrometer. Thin sheets of paper may have a caliper as small as 0.002”, and thicker sheets may have a caliper of 0.010”. Paper with caliper readings greater than 0.010” are often referred to as paperboard. The caliper of paperboard may be as much as 0.030”. Polymer films are by definition thin. Dry cleaner bags are 0.00065”. The thickest calipers used for flexible packaging are 0.005” to 0.006”.

Thin films require printing conditions with very accurate tension controls. Paperboard caliper should be uniform and free from low spots that will lead to print skips (voids) on the flexo press. For all substrates, caliper uniformity is critical.

- Paper / paperboard—Thinner papers are more consistent in caliper, paperboard may have inconsistencies in caliper.
- Polymer films—Thin films are susceptible to stretch during printing. Caliper inconsistency will cause misregistration, and print wrinkle problems.
- Multilayered / laminations—Caliper increases as layers are added. Extremely thin layers may be laminated together to attain required barrier and printing surface properties.

Flexographic design considerations

Trapping

Trapping is the overlap of color to avoid misregistration during printing. Misregistration is caused by substrate handling and tension problems on the press, irregular or inconsistent plate elongation from one color to the next, inaccuracies in the plate mounting, and limited register capabilities. A preliminary test run and analysis of the press will determine the registration tolerances. Typically, a designer will build traps into the file if the job is a simple one, otherwise trapping will be handled by using an option in a drawing or trapping software program like Trapwise or DKA Island Trapper, or handled entirely by the prepress service bureau. The best trapping applications allow for partial traps—where only the areas of an image that require trapping are affected, while leaving all other areas at their original dimensions.

Traps serve the same purpose in packaging as in commercial printing. There are two primary differences: 1) in packaging there are generally more colors, and 2) with flexographic printing, larger traps are required to compensate for misregister. Guidelines when designing for flexography would include avoiding tight registration requirements, creating sufficient trap for anticipated misregistration, designing with the dominant color printing over the lighter color, and avoiding trapping of gradations. Trapping may cause a dark line where the colors overlap.

A label printed on a narrow-web press should be trapped at a minimum of 0.005”—some require as much as 1/32", or 0.031" compared to average traps of 0.002"–0.005" for lithography. A typical trap area for a job on wide-web polyethylene might be 1 point (1/72", or 0.014"). However, if an objectionable dark trap line is created by the 1 point overlap, the designer may plan for a trap of .5 points. Trapping for linerboard or corrugated may require 1/64" to 1/8".

Typography

The soft flexographic printing plate, irregular substrate surfaces, and the fluid flexo ink can have a profound negative impact on text-sized type printed by flexography. The line strokes of smaller point sizes of type often increases during the printing process because of the compressibility of the printing plate and the fluid nature of the flexo printing ink. Negative or reverse type often tends to become pinched or fills in. In extremely adverse situations (poor press equipment or rough irregular substrates), lettershapes may begin to appear rounded and lose their shape.

It is the problem of impression pressure on the printing plate in the printing nip that causes most of the deformation of type. Smaller point sizes of type are most adversely affected and require attention.

For wide-web polyethylene printing, typical minimum type sizes are:

- Positive type—six point for sans-serif fonts and eight point for fonts with serifs.
- Reverse type—nine point minimum (it may be a good idea to spread 9 point reverse minimum type). For narrow-web printing, some fonts may be printed as positives as small as three point type, while others may lose shape at six or eight points. Use bolder fonts instead of light-weight versions.

When designing a job to be printed on corrugated, it is best to choose a medium weight typeface, and to avoid serifs for any type that is smaller than 18 point. A good rule of thumb is to avoid type that is made up of stroke widths less than 1/32" for positive type and 3/64" for reverse type. All type should be set at normal letterspacing.

To help compensate for the "weight gain" of flexographic type, it may be possible to use the trapping technique of spreads and chokes. Chokes are used on positive type, spreads are used on negative type. Some programs, such as Freehand and Illustrator, allow the designer to adjust the thickness of the type. This type effect can be achieved by selecting the text, converting to a "path" and then specifying a value for the"width" for the outer and/or inner "stroke" of the type. In some cases, these programs allow the designer to simply select the type and choose a desired effect such as "heavy" to thicken the selected type to print bolder.

In prepress design, some compensation can be done by choosing either a lighter face or a bolder face. For example, if bold positive type is desired, use a medium weight face. If a medium negative type is desired, specify bold face on the desktop. However, should this technique of selecting style attributes be used, make sure the printer font selected is installed on the output device to be used in the production process.

Letterspacing must be considered when designing for flexo. In offset, letters can be squeezed together to form a denser appearance on the page. The same spacing printed in flexo may cause the letterforms to merge together to become unacceptable. However, when printing fine-serif type with major letterspacing, the serifs may begin to lose their shape. Ideal letterspacing occurs when letters are close enough together to lend support to each other while under the pressure of the printing nip, yet not so close that they begin to join together under that same pressure.

Whenever possible, sans-serif fonts are preferred for flexo printing, however, the larger the point size being printed the better the chances that the font will reproduce as desired.

Unofficial industry standards and recommendations for type:

- Six point minimum for positive type, nine point minimum for reverse or knock out on wide web.
- Four point for positive, six for reverse on narrow web.
- When using small size type, avoid fonts with fine serifs or delicate strokes.
- Kerning may cause squeezing across cylinder. Avoid tight line spacing.
- Letterspacing and / or line spacing may increase slightly in the curve dimension due to plate elongation during the plate-mounting phase.
- All positive text should be printed in a single color if possible.
- Avoid placing fine type on the same color plate with line work and solid printing areas.
- Specify type thoroughly and accurately to the service bureau or flexographic prepress department.
- Avoid reversing type out of two or more colors unless a dominant color outline is used.

Plate distortion and elongation

From a prepress and design perspective, one of the most important characteristics to understand about flexography is the phenomenon of plate elongation. As a flexographic plate is mounted on a plate cylinder, a natural elongation occurs in the curve around the cylinder direction. Consequently, if the printed design is meant to be a circle, the image must be compensated by distorting (shrinking) the image in the around-the-cylinder or curve dimension, and the image on the resulting plate films may appear to be oval. After proper distortion factors have been applied and the plate has been mounted and printed, the oval will elongate to form a circle. The same distortion requirements hold true for all images. This is a general formula used for calculating plate elongation:

$$\frac{\text{factor based on plate thickness}}{\text{cylinder repeat length}} = \text{stretch per inch}$$

Sample calculation used for rubber plate distortion;

- T =Plate thickness with mounting tape; π carried to 4 decimal places = 3.1416;
- R.L. = Repeat Length of the plate cylinder

Plate Thickness	=	0.107"	Repeat length = 18.8"
Mounting Tape Thickness	=	0.020"	
TOTAL		0.127"	

$$\frac{\pi \times 2T}{\text{R.L.}} = \frac{3.1416 \times 2(0.127)}{18.8''} = 0.0424''$$

This means that for every linear inch of plate used in the around-the-cylinder or curve direction, the images will increase at the rate of 0.042"/inch. To apply the calculation to a design measuring 12 inches in the curve dimension:

12" x 0.042" =0.509"

This means that plate films should output to measure 11.490" in the curve dimension, or 95.7% in the curve dimension, and 100% in the other dimension (ignoring any plate shrink as discussed in the Flexographic Plates section). Software written specifically for flexography can compute plate distortion factors and apply them to each color separation.

This formula shows that as the plate thickness increases the stretch factor increases, and as the cylinder repeat length decreases, the stretch per inch increases. The flexographic industry is currently using a variety of plate thickness in combination with a variety of mounting tape thicknesses. The type and thickness of the plate being used is dictated by the type of press being used and the type of work being printed on the press. Some typical plate thicknesses for some of the larger flexographic printing markets are:

Combined board corrugated	0.250", or 0.107"
Wide-web flexible packaging, preprint, and folding carton	0.107", or 0.067"
Narrow-web label	0.067", or 0.045"
Newspapers	0.024"

These are only examples of plate thicknesses currently being used. Recently there has been a trend toward thinner plate technology for flexographic printing.

There exist today many software packages with the capability of shrinking or distorting an image in one dimension. To be sure that the design will be the correct size and shape, the design has to be output to film after plate thickness has been determined and the proper distortion factor applied. The plate distortion step should be performed as close to the film output or plate setting stage as possible, and can be performed by the raster image processor (RIP) operator using distortion software. The actual distortion process need not be of concern to the designer.

Halftones and screening

The flexographic printing process historically has been recognized for its ability to apply spot color and line art graphics to a wide variety of substrates, especially those used for packaging. However, it is the recently improved capability of high-quality, economical four-color process printing that has given the flexographic process an edge over other processes for packaging graphic applications in full color.

Dot gain

All printing processes are subject to the natural and unavoidable occurrence called "dot gain." Dot gain can be described as an increase in the diameter of halftone dots from the film to plate and a further increase in size from plate to print. For example, when the image setter outputs a 50% screen film dot, the flexographic platemaking exposure step may cause that 50% film dot to "grow" to become a 51% dot area on the plate. This is a small and relatively insignificant gain in comparison to plate-to-print gain, where a 50% film dot may eventually print on a flexographic press as a 65% or greater print dot.

Halftone dots can be generated in a number of shapes including the square dot, the elliptical dot, octagonal dots, and symmetrical and asymmetrical round dots. Square dots begin to join at 50% (arranged in a checkerboard pattern), and the connected areas continue to increase as the dot area increases. Dot gain occurs at the perimeter of the halftone dot; as individual dots join, the perimeter area increases, causing a large density jump at the dot area where the contact first occurs.

Dot shapes. Without question, a round dot screen is the ideal for the flexographic process. There are however different versions of round dot screening software. Individual film dots on the best round dot screens for flexography do not begin to touch until they reach the 70-75% region. Most design software can provide for a round dot; however, dot shape should be determined as close to the platemaking step as possible, either at the film imagesetter or the platesetter. Consequently, the same type of dot should be available on the RIP and imagesetter, or platesetter.

The fluid ink and compressible plate used for flexographic printing tend to increase dot gain, making dot gain compensation an especially important step for high quality tone reproduction. Each different substrate printed by flexography will also influence dot gain characteristics.

It is important to understand that dot gain compensation is different for each printing process, for many different substrate surfaces, and often for different printing presses within the same process. Fortunately, dot gain is predictable and compensated for by a color separator, or adjusted for compensation in Photoshop, or in RIP-based calibration packages like Agfa Calibrator.

One of the most important considerations for a successful four-color tone reproduction is an understanding of the ink hue and dot gain differences that exist for the flexographic printer. When high-quality tone reproduction is important, the best results are obtained by first performing a preliminary press test run called a "fingerprint."

A fingerprint of the press will provide important information to the color separator or the desktop designer. By printing a target of this type under controlled conditions, color separation films can be adjusted to compensate for flexographic dot gain and ink hue.

Highlights

Another important consideration when color separating for the flexographic process is the placement of the minimum highlight dot. Most photopolymer flexographic plates are capable of holding a two percent highlight dot. Since the highlight areas of a flexographic print show the most dot-gain, it is extremely important that the minimum highlight dot capabilities be discussed with the printer before separations are made.

Vignettes

Flexographic highlight dot gain makes it difficult (if not impossible) to print a fade-away to white paper without a harsh break at the highlight edge. When designing for flexo, it is best to fade off the end of the design, or border the highlight end of the vignette.

A vignette or blend

Screen ruling and substrate

The selection of the proper screen ruling is critical to four-color process flexography. Screen ruling capabilities are most often dictated by the type of substrate being printed. The corrugated industry, for example, prints halftones screened at 45, 55, 65, or 85 lines-per-inch. Flexographic newspaper printers print halftones screened between 65 and 100 lines per inch. Flexible packaging on film-based substrates is commonly done at 120 to 150 lines per inch, and high-quality label printers have the capability of printing 200 line screen images.

Anilox cell count and separation screen ruling should be correlated to achieve the best flexographic print. A general rule of thumb is that the separation screen ruling should be no more than 25% of the anilox that will be used to apply ink to the plate. The ideal from an ink-application-to-the-plate perspective is to have a minimum of four anilox cells on top of each halftone dot.

Screen angles

Cells are engraved on an anilox roll at one of three possible angles 30°, 45°, or 60°. To avoid anilox moiré, film or plate screen angles should be at least 7.5° away from the anilox cell angle. Cyan, magenta, yellow, and black screen angles should also be set at angles at least 15° apart from each other.

Stochastic screening

Stochastic or Frequency Modulated (FM) screening for flexography may offer some advantages over conventional half-tone screening. FM screening eliminates the possibility of moiré, and also allows the flexographer to print high-fidelity color. High-fidelity color is a technique used to extend the printed color gamut by printing a total of six or sometimes seven process colors. The multicolor capabilities of flexo and the random dot pattern of a stochastic screen to avoid moiré make high-fidelity color an excellent design option.

The dot size used for FM screening is extremely small and comparable in size to the highlight dot of conventional screening. The flexo highlight dot is subject to excessive dot gain. Consequently, FM screening for flexography should not be attempted unless the printer and color separator have performed press fingerprints to determine the ideal dot size to be used, and accurate dot gain compensation curves.

A final point about films made for flexographic plate making: The polymer plate material is very soft and will easily trap air between the film and the plate during the plate exposure. Consequently, when making films for sheet photopolymer plates, a special “matte emulsion” film must be used to avoid out-of-contact areas during plate exposure.

Step & repeat

The concept of printing the same image multiple times across the width of a web and around the entire repeat length of a cylinder is known as “step and repeat.” Package printing industries apply this concept in combination with variable repeat length and variable web width capabilities. The ideal is to maximize substrate usage and productivity by fitting as many repeated images on the flexographic plate as possible.

Often, a technique called nesting will be required. By placing duplicate package layouts or label graphics strategically between other layouts or graphics, the job can be designed for maximum productivity and minimum material waste. The best method of nesting images is to cut and paste original graphics. This step in the flexographic prepress process is done in the production art stage. Most standard layout programs do not have the capability of step and repeat. Step and repeat can be performed on some illustration programs and by specialized software that will create templates to allow the production artist the ability to impose multiple images for film output, while working within the confines of web width limitations and plate cylinder repeat length.

In the past, multiple sets of flexographic plates were made from one set of films, and imposition was performed in the plate mounting stage. Today, photopolymer plates and pin register or micro-dot plate register systems require one-piece plates, and one-piece plates should be made from one-piece films. The need for large one-piece films for wide web flexographic printing applications has brought about the need for large format imagesetters and film processors.

The flexographic printing process is sometimes prone to a quality problem known as “plate bounce.” This problem is especially prevalent when lead edges of the printing plate run parallel to the printing nip, and can be avoided by a layout technique called staggering the plate. Not all designs will allow this technique, but when possible, staggering the plates may provide for higher press speeds. Another technique used for minimizing plate bounce is the use of “bearer bars” in the non-image areas. Bearer bars provide continuous contact between the plate surface, the anilox, and the impression roll.

Die-cutting & converting

When designing graphics for a die-cut label or die-cut folding carton, an artist must take care to place all graphical elements in the correct positions. A die-cut folding carton is an excellent example to illustrate the fact that the first requirement for design is that it conform to the shape of the package.

Packaging engineers often use computer aided design (CAD) systems to design folding cartons, corrugated containers, or rigid paper boxes. CAD files can be exported to illustration programs to provide the designer a two-dimensional layout of the job.

The designer should remember that eventually the design will be converted to a package, and each package forming process has special considerations that may be adversely affected by the design of the package. Some important considerations when designing for a job to be a die-cut box or converted to a bag include:

- Bar coding—Bar coding can be created on the desktop or provided through another outside source. In either case, bar codes should run parallel with the web direction, and should be cut back to compensate for flexo gain characteristics.

- Bleeds—For die-cut jobs it is important to have a copy of the die being used. This will allow the designer the opportunity to see where packages fold and join, and where bleeds will be required. The amount of bleed required depends on the press being used. Bleeds can be created with standard illustration programs.
- Cut areas—Because flexographic printers do in-line flatbed or rotary die-cutting, the die must be held in register with the colors being printed on the package. Important graphic elements should not be placed too close to cut areas.
- Glue areas / seal areas—To assure sealing when forming a folding carton, glue areas should be free of ink and varnish. Polyethelyne bags are often heat sealed. All areas in or near a heat seal should be free of ink. Heat sealing is also done on some folding cartons; for example, milk cartons are laminated with polyethylene and will be heat sealed at the seams. The design should be void of ink in the heat-sealing areas.
- Score lines—Die-cut folding cartons usually fold at score lines. The designer should consider a score line a critical registration area.
- Varnish areas—Many folding cartons or labels require the application of an over-print varnish. In some cases, variable information like freshness dating or product coding will be added during packaging. Often these areas must be free of varnish. This application requires a special "spot varnish" plate.
- Windows—Die-cut windows should be clearly indicated. A window used for folding carton or label work presents problems in the die-cutting operation. Before designing a window, check with the printer or package convertor to make sure that windowing is within their capabilities.

Prepress output

After a design has undergone the required production art trapping, distortion, and imposition steps, it is ready for film output or, in some cases, it is ready to go directly to digital flexo platemaking. Imagesetters used for the flexographic process have some unique requirements.

- Accuracy—The nature of the flexographic process includes a number of areas that might lead to print misregister. When precise register is required, the imagesetter being used should be the more accurate drum imagesetter, rather than its predecessor, the flatbed capstan imagesetter. However, capstan devices are suitable for single-color jobs with less demanding register requirements and are especially useful for unusually long jobs. Capstan devices can output film up to 80", while drum scanner lengths are limited to the circumference of the imaging drum.
- Size—The imagesetter should be large enough to handle the largest films required for platemaking.
- Film—The imagesetter must be capable of handling 0.007" matte emulsion film.
- Calibration—It is imperative that the imagesetter be properly calibrated. Film dot percentages below 10% should not vary by more than 1% from the required dot area. Film dot area over 10% should not vary by more than 3% from the required dot area.
- Uniformity—Light screen tints should be a uniform dot percentage, with no variation in size between individual dots.
- Shape—The imagesetter and RIP screening information should be capable of outputting a “hard” round dot.
- Resolution—Resolution should be adequate for the screen ruling to be output (1200–3600 dpi).
- Processor—Because flexographic plates require a relatively lengthy exposure, the film density becomes an important factor. Imagesetter exposure levels and film processing chemistry should be adjusted to provide D-Max areas of 4.0 and D-Min of 0.04 or less.

Proofing

“Proofing” for a flexographic job is not always a clearly defined activity. Historically, a flexographic proof had been a plate proof made on a mounter-proofer during the plate mounting procedure. This practice continues today in many wide-web flexo applications. The mounter-proofer proof is not appropriate for color matching. Instead, this proof is used internally to verify plate register, plate quality, and plate content. This type of proof is not used for customer approval.

A "contract proof" is a facsimile of the job a printer agrees to reproduce; the customer and printer sign a contract for printed material based on a contract proof. The typical "contract" proofing system used for offset lithography is not suited for flexographic package proofing. Basically there are three general problems associated with offset proofing when applied to flexography.

- Substrate—Most proofing systems proof to a limited number of substrates. Flexographic package printing is done on a wide variety of substrates, and colors proofed on any substrate other than the one to be printed will show color variation when compared to the live press run.
- Spot Color Matching—Film-based or digital proofing systems are based on CMYK toner applications. Many of the packaging graphics are line art and spot color, not screen tints of CMYK.
- Halftone Dot Gain Compensation—When a proof of a process color graphic is required, most film-based proofing systems are not calibrated for flexography. Proofing systems like Imation Matchprint and DuPont Chromalin were designed for offset lithography. These systems were designed to replicate dot gain as it would typically occur in offset lithography. To use these proofing systems, the flexographer has to output two sets of films: one set compensated for flexographic dot gain (cutback dot percentages) and sent to platemaking, and one set with increased dot percentages to replicate on-press dot gain, used for proofing.

Most flexographic printers use cutouts and "dummy" mock-up packages for proofing purposes. Digital proofs can be made from an inkjet or dye sublimation printer and used as a facsimile for the mock-up. When critical spot color matching is required, the flexographic printer will often provide the client with a catalog of colors applied to the substrate to be used. These colors may be variations of conventional color matching systems like Pantone, or Focoltone, they may be colors formulated by the printer, or they may be colors requested by the buyer. In any case, spot color matching should be visually evaluated and numerically verified by color measurement instruments.

Halftone film-based systems can be used for process color flexographic proofs; however, the current systems will continue to require that two sets of films be produced—one for plates, and one for proofing. Digital proofing systems (both halftone and continuous tone), when used within a color management environment, can be manipulated to output contract proofs for flexographic printing. When used in a color management environment, digital proofing can eliminate the need for an extra set of films for proofing purposes.

Packaging conclusions

The flexographic printing process has evolved from letterpress to become the most adaptable process currently used for packaging graphics applications. Because the process is unique, there are many unusual design features that should be considered during the prepress stages of a flexographic printing job.

Add to the unique flexographic design features the design features that are unique to packaging requirements and those that are unique to various substrates and design can quickly become a nightmare. In order to create successful designs for a flexographically printed job it is useful for the design and prepress personnel to have a basic understanding of the process, and its unique design considerations.

The design and prepress personnel may also find it useful to understand those features of a flexographic printing system that offer a wider latitude of design considerations, like that of multicolor capability. The most important areas of flexographic design are as follows:

Trapping. Generally speaking, traps need to be larger for flexographic printing than traps for the other printing processes. The type of press being used for printing and the substrate being printed also should be considered when deciding what trap measurements are appropriate. The best register (and so the least amount of trap requirements) can be achieved on a common impression cylinder flexographic press. Traps for prints to be done on an in-line or stack press should be larger than those intended for a CIC press. Thin films of polyethylene are the most difficult substrates to print without stretch, consequently these films may require larger areas of trap than designs to be printed on more stable films such as polypropylene.

Typography. The flexographic plate may cause type to distort somewhat during the printing process. A natural and unavoidable stretch occurs in the web or machine direction when the flexographic plate is mounted. This plate stretch may cause an increase in line spacing to blocks of text composed in that direction, or an increase in letterspacing when text is composed to run parallel with the web direction. Abnormally high pressure in the printing nip can cause a significant increase in the weight of type selected by the designer. Reverse type may be “pinched” by the excess pressure. Wider webs and rougher substrates like paperboard are especially prone to excess pressure being applied in the printing nip.

Plate elongation. Unlike any other printing plate, the flexographic plate will elongate or “stretch“ during the plate mounting process. The elongation for each design must be compensated for in the prepress stage. General axioms to apply are:

- The thicker the plate, the more the stretch.
- The smaller the cylinder to be used for platemounting, the more the stretch.

Halftones. The flexographic plate has its own dot gain characteristics; each substrate will also contribute to differences in dot gain and tone reproduction. Highlights are also a challenging area of print for the flexographic process. Special care should be taken when generating film separations for flexographic printing. The best results for halftone printing can be achieved by first performing a “fingerprint” test run of the flexographic press in question. This test will provide the color separator with the information necessary to apply the correct gamma for the printing conditions. The rougher the substrate, the greater the dot gain. The durometer of the plate being used and the type of mounting tape also have a significant influence on dot gain.

Screen angles. The cells of the flexographic anilox roll are engraved in either a 30°, 45°, or 60° angle; these cell angles make a one-color moiré possible. Common practice when screening for a flexo job is to re-angle screens by either adding or subtracting 7.5° from standard offset screen angles.

Many unique packaging considerations are important to design and prepress for flexographic printing. The following techniques are often used for packaging design and prepress.

Step and repeat. Many smaller packages or labels are often printed multiple times on wider webs. When step and repeats are necessary, images may be turned 90° or 180° to allow for the best fit and least amount of waste.

Stochastic screening. Stochastic screening may be used when printing high-fidelity color or when printing multiple screen tints. Halftones for corrugated are best suited to stochastic screening techniques.

Die-cutting and converting. Package printing usually is only one step in a package conversion process. When designing graphics for packaging, special requirements must be considered. For polyethylene and other substrates that will be heat-sealed, it is important to keep heat-seal areas free of ink. A folding carton to be die-cut should have all image elements located such that when the box is formed they will appear on the correct panel. It is also important to keep glue areas free from coating or ink that may interfere with bonding.

Paper issues in reproduction

Runnability

Runnability is the ability of a paper to run through a press efficiently with no loss of productivity or increase in downtime. Runnability affects the profitability of a job and is a major concern to the printer. There is a difference between purchase price and user cost. A paper can have the greatest print quality characteristics but if it can't be run through the press, it is of little value. This is because of the large area of surface contact with the rubber blanket and stiff, tacky, paste inks.

Lithographic paper requirements. Conventional lithography uses a dampening or fountain solution to wet the plate's non-image areas so they stay ink-free or clean. Therefore, the paper must resist weakening of its surface strength due to repeated exposure to moisture from each successive unit.

Water resistance. Excess water or poor water resistance can cause the coating of the paper to soften, weaken and leach out onto the blanket. This causes piling and milking. Calcium carbonate (limestone) is a common coating and filler ingredient. Being an alkaline, it will increase the pH of the fountain solution and cause other print problems.

Offset litho paper requirements. Lithography, especially sheet-fed, uses thick, paste inks that are very tacky. Therefore, the paper must have good bond strength to resist rupturing of its coating or fibers from the surface. Of all the printing processes, lithography deposits the thinnest film of ink—about one (1) micron thick when dry. A micron is 10^{-9}m or .00004 inch. Therefore, any loose surface dirt or contamination such as fizz, lint, or slitting and cutting dust will show as an aesthetic print defect.

Gravure paper requirement. Image areas are engraved below the surface of the cylinder so paper must be very flat and smooth to make good contact with the well opening to transfer (pull out) ink. Gravure inks are very fluid and have little tack to pick up coating and fibers.

Paper should have sizing so fluids inks don't feather. Comparing coated and uncoated stocks:

Coated paper	**Uncoated**
Has a mineral coating	Has no coating
More expensive	Less expensive
Smoother surface	Rougher surface
Higher gloss	Less gloss
More holdout	More absorbent
Better image quality	Poorer image quality
Stronger surface	Weaker surface

Basis weight

Basis weight is a measurement of weight of some unit of area. It is the weight (in pounds) of a ream (500 sheets) in the basic size for that paper grade. It is important because paper is solid by weight, not linear distance or surface area by volume. Basis weight tolerances are +/- 5%. The US system of basis weight is very confusing because of the difference basic sizes for each grade category:

Basic paper sizes

Bond, ledger, writing	17"x22"
Cover	20"x26"
Bristol	22.5"x 28.5"
Index	25.5"x 30.5"
Newsprint, tag	24"x 36"
Coated, text, book, offset	25"x 38"

The metric system uses grammage, which is grams per square meter (g/m^2). For a 25"x38" basic size, the conversion factor to go from basis weight to grammage is to multiply by 1.48. Multiply by 0.675 for g/m^2 into lbs. A 100 lb book paper is equivalent to a 148 g/m^2 and a 50 lb is 74 g/m^2.

Substance weight usually applies only to writing grades of paper (bond, duplicator). It is the same as basis weight. "M" weight is the weight for 1,000 sheets, not 500. M weight is twice the basis weight.

The thickness of cover grades is measured in thousanth of an inch. Ten (10) point is .010". Thickness is often called caliper and it is measured in points or mills which is a thousandths of an inch (.001"). Bulk for book papers is expressed in the number of pages per inch (ppi) for a given basis weight. 50 lb book paper can vary from 310 to 800 ppi, .003" to .0013" respectively.

Paper grain direction

The grain direction, or alignment of paper fibers, affects the feeding and transporting of paper through the press. You want to handle paper on sheetfed presses at very fast production speeds of 15,000 impressions per hour (iph). The wrong grain direction can cause a loss in productivity.

- If 25"x38", then the grain is long
- Fold a sheet in both directions
  - Cleanest fold is with the grain
- Tear a sheet in both directions
  - Cleanest tear is with the grain
- Cut two strips in different directions
  - Most rigid or stiffer strip is with the grain
- Moisten only one side of a sheet of paper
  - The paper will immediately curl and roll with the grain

The grain should run parallel to the printing cylinders or along the longest dimension which is called grain “long.”

Why grain long?

The sheet must follow a relatively tight “S” curve as it wraps around the impression cylinder on its way to the transfer cylinder. If the sheet is grain long, it is more pliable and will gently follow and conform to the “S” curve. If grain short, the sheet is stiff and rigid and will slap against the cylinder. The wet ink surface will then mark and scratch. If the paper absorbs moisture it will expand mostly in the cross-grain direction. This makes the sheet of paper longer front-to-back. The packing beneath both the plate and blanket can be adjusted to compensate for the size change so images will now register and fit properly.

Finishing & bindery

Substrate and printing issues affect bindery and finishing. When folding you want to fold parallel with the grain to prevent cracking, especially on black solid colors. Perfect bound (hot melt) books should have grain direction parallel with the spine or back bone. Sheetfed presses require flat paper to prevent feeding, register, and printing problems. Paper should lie flat and have no curls, buckles, waves, or puckers. Flatness is very related to moisture content and relative humidity (RH). Mechanical curling on roll or reel set is greatest near the innermost core or reel where paper is wound very tightly around a small diameter. Tail-end hook is caused by forces of tacky ink splitting when the sheet is peeled off the rubber blanket at a sharp angle. It is especially noticeable on heavy coverage near the tail end of the sheet.

At the wet end (headbox) of the papermaking machine, paper is almost 99.5% water. At the dry roll end, paper is only about 5% water. The amount of water contained in a sheet of paper is called its moisture content relative humidity (aka RH); the amount of water or moisture in the air at a given temperature is called the relative humidity or RH. Cold winter months are usually dry. Warm summer months are usually wet or damp. Many printers have little or no control of the environmental conditions that affect paper.

Dimensional stability

Paper is hydroscopic which means it breaths and acclimates with the surrounding environment. The exposed outer edges of a pile or load can either absorb or release moisture while the inside of the pile, which is protected, remains unchanged. This causes the paper to swell and expand or shrink and contract in size.

Wavy edges on paper is caused by an increase in RH of the atmosphere in the pressroom. Wavy edged paper causes mis-registration on press or poor fit between colors. It usually occurs at the back corners and gets progressively worse, thus fans out. Severe cases cause wrinkles starting at the lower center and progressing diagonally to the outer back corners.

Conditioning and trimming paper

Paper must first be brought into temperature equilibrium before it is opened up and exposed to the humidity of the environment. Conditioning depends on the volume or amount of paper and the relative difference in temperature between the paper and air. Six cubic feet of paper takes 72 hours (3 days) to condition at 50 degrees difference.

Sheets should be both square and accurate to size. Front-to-back dimension is critical on sheetfed perfecting presses. Many printers trim stock for accurate size.

Cleanliness

Paper should not have any loose surface contamination such as dust, lint or dirt. If it does, the result will be voids in print areas called hickeys, fisheyes, or donuts. Many times this is caused by a dull rotary slitter or flat blade knife. It shows up as contamination on the blanket at the outer edges of the sheet only. Hickeys come from three different sources:

- paper
- ink
- dirt

Strength

Strength is primarily determined by how well the inner fibers are bonded or closely intermingled together, more so than thickness. Web- or roll-fed presses that are under high tension need a lot of tensile strength so web breaks do not occur. Weak surface strength tends to pick and cause hickeys, or delaminate and split apart. Stretch (elasticity) is the amount of distortion paper undergoes under tensile strain or tension. It is important in web or roll printing because paper is under a constant pulling stress. Stretch is generally greater in the cross direction (CD) than in the machine direction (MD).

Print quality

Print quality is defined by those factors and characteristics that influence the appearance of the printed image on the paper. Some print quality problems are unjustly blamed on the paper when some other factors, such as ink, blanket, or press, are really the cause.

Whiteness

Whiteness is the ratio of red, green and blue reflectance. Likewise, it's also the amount of cyan, magenta and yellow density. It is important in full four-color process printing that the paper be as white as possible so it can reflect all the colors in the spectrum. Printing is a subtractive process. White can be many different colors. White can be very neutral and balanced or it can have a predominant cast or hue.

If the paper is "cold" it is toward the blue side (CIE + b*).

If the paper is "warm," it is toward the red side (CIE + a*).

Brightness

Whiteness is the ratio of RGB reflectance. Brightness is how much blue light only is being reflected. Adding blue to a yellow paper makes it whiter (neutral) but less bright. The TAPPI (Technical Association for Paper and Pulp) specification calls for measuring brightness (% Ref.) at 427 nm. If the brightness is over 87%, the paper can be classified as a number one (#1) sheet. Titanium Dioxide (TiO2) is a popular additive that makes paper whiter, brighter and more opaque. Calcium carbonate (limestone) is a more practical and less expensive alternative for paper filler and coatings. Paper mills sometimes add fluorescent brightening agents (FBA) to paper to make them look whiter than they really are. For a fluorescent material to fluoresce, the light source much contain some ultra-violet (UV) energy. Natural daylight is UV rich. Fluorescent agents are also used in specialty inks.

Opacity

If the paper is not opaqued but translucent, the image from one side can be seen on the other. This is called show-through and can be very distracting to the reader. As the paper caliper or weight increase, whether from fiber or filler, opacity increases because more light can be absorbed. Calendering reduces opacity because air spaces, which act as light traps, are collapsed. Strike-through is when the ink physically penetrates through a sheet of paper, not the light.

Smoothness

The smoothness or roughness of paper greatly affects printability. This is less so for offset lithography because the pliable rubber blankets can easily transfer ink into the low valleys. Surface texture can be measured, quantified, and profiled with instruments. Gloss is the amount of specular or mirror reflection a surface has. The flatter or smoother a surface is, the more gloss or shine it will have. Calendering increases smoothness and gloss because the rough surfaces are polished flat. More calendering of coated papers changes the paper's finish from matte, to dull, then gloss, to finally ultra-gloss. Paper gloss is measured at a 75 degree angle of geometry. Heatset web inks have poor ink gloss.

Formation

Formation is the term used to describe a paper's fibrous structure, uniformity, and distribution. Formation is judged by transmitted back lighting, such as a light table. Uneven clumping of paper fibers is called "wild" and will cause mottled printing because of the difference in ink absorption due to paper fiber concentration or density. Back tap mottle is a sporadic problem where the paper is blamed. It usually occurs in purples or blues. Pulling a single impression of just cyan or magenta shows no mottle, but together, it's mottled. The still-wet ink is non-uniformly back trapping onto subsequent blankets.

Two sidedness. Printers want paper to be as similar as possible for both sides of the sheet. This is because of sheetwise, work & turn, and work & flop impositions and layouts. Colors on facing pages (reader spreads) must match at the cross-over. Fourdriner-made paper is two sided because of the effects of the felt and wire side on water drainage.

Absorbency & holdout. Paper, by its very nature, has an affinity for inks, especially the liquid inks used in flexography and gravure. There must be a delicate balance or compromise between the paper's ability to absorb ink and its holdout. Too much of one and not enough of the other will cause several different print quality problems to result.

Too absorbent. If the paper absorbs too much ink then the solid images will appear weak and flat with little gloss. Halftones and screen tints will have excessive dot growth or dot gain and look dark, dirty, plugged up and filled in. Uncoated papers and newsprint may act like a blotter.

Holdout. Holdout is the ability of a paper to allow a fresh, wet ink film to sit on the top surface of the paper and not be quickly absorbed into the paper. If so, the ink will dry with a higher density (darker), and more gloss (shine). The more fluid the inks or more absorbent the paper, the less holdout there is.

Ink mileage

Paper holdout determines the mileage or ink consumption rate. It is very similar to an automobile's gasoline mileage. The more holdout, the better the ink mileage. One pound of black ink should cover 360,000 square inches of area on coated paper, but covers only 150,000 on newsprint.

Set-off

Set-off occurs when the fresh, wet ink film on the top surface of a bottom sheet makes physical contact with the bottom side of the next top sheet and the ink transfers. The image will always be wrong reading. Set-off occurs when there is too much holdout, an ink film that is too thick, an ink that dries too slowly, or cold paper.

Blocking

Blocking is a severe case of set-off. Blocking occurs when the wet inks dry in contact with each other and effectively have been glued together. Because the sheets stick together they cannot be easily separated without damaging the image areas. Usually, these sheets must be thrown away.

Spray powder

A printer can prevent set-off and blocking by using a fine white powder that is sprayed onto the top surface of the sheet. This anti-set-off spray powder prevents the sheets from making any physical contact.

It allows air and oxygen to flow between the sheets so they can dry faster. The powder is usually a corn starch. If too much spray powder is used, it dries in the ink and makes it very rough, almost like sandpaper. This can cause abrasion when two pieces run up against each other. It also detacts from the gloss of the inks. Excess powder can also cause problems on the second pass through the press.

Racking or traying

Sheet-fed printers try to avoid set-off, blocking and excessive spray powder by running small lifts in their press delivery. This is called racking or traying. Paper is very heavy and small piles or lifts keep the weight and pressure to a minimum. These piles are separated and supported by metal angle braces and plywood boards.

Chalking

If any ink takes too long to dry, the thinner viscosity vehicles, oils, solvents and other ingredients that bind or adhere the ink to the surface drain into the paper. The result is a dry ink that is mostly just pigment powder and can easily be rubbed or scratched off. This is called chalking.

Blistering

Heatset web offset presses dry the inks by passing the web through a hot, open flame gas oven. Blistering occurs on coated paper when there is heavy ink coverage that seals the sheet closed. Any moisture trapped inside the sheet suddenly vaporizes, turning into steam and rupturing the paper surface. Blistering is likely to occur when:

- the paper is coated
- there is a lot of heavy ink coverage on both sides of the paper or substrate
- there is too much moisture in the paper
- the dryer oven temperature is too hot
- the web speed is too slow

When you get right down to it, paper seems simple but it is rather complicated.

The digital movement

The age of electronics and computers has changed the way printed products are created and produced. Since the early 1980s, printing and publishing technology has been evolving new methods for production digital imaging. Before going further, let's define what exactly a digital image is. The term digital literally means "composed of numbers," so a digital image is an image that is composed of numbers. Every file, whether it be an image, a sound, or a text file, is nothing more than a string of binary digits. By modern convention the binary digit 0 is used to represent an image element, the binary digit 1 is used to represent a non-image element. Binary digits are called bits. A byte is a binary numbers represented by eight bits, it can have 256 possible values ranging from 1 to 255.

Digital images

Scanner

Images can be digitized by a scanner. A scanner captures an image and converts it into a computer file of binary values (0s and 1s) that correspond to the brightness of the image at various points, pixels. The ability of the scanner to "see" variations in brightness depends on how much information is stored in a pixel, an amount called pixel depth. The deeper the pixel, the more information it can store.

Digital image type	*Pixel size*	*Tones/colors*
Binary image	1 bit	2
Grayscale image	1 byte	256
RGB color image	3 bytes	16,777,216
CMYK color image	4 bytes	4,294,967,296

Digital photography

Digital photography is another way to digitize images. Digital cameras and cameras backs are used to photograph subjects using charged couple devices (CCD) that record the coupled images as electronic voltages. These analog voltages are converted to digital signals that can be fed directly into color correction software that produces images without the need for films or scanners.

Digital type

All output devices today are raster-based. This means that they create type and images as patterns of spots or dots on paper, film, plate, and other substrate. In 1985 Adobe introduced PostScript as a language for driving raster-based output devices, and for producing typefaces as vector-based outlines. Almost all digital fonts now fall into 2 main categories:

- PostScript or Type 1 fonts are scalable outline fonts which are defined using PostScript's bézier curves and work best with Raster Image Processors (RIP) because they do not need to be converted to be RIPped and output.
- TrueType fonts are also scalable outline fonts but they are based on quadratic curves. Created by Apple, these fonts must either be converted to Type 1 before being RIPped or a TrueType Rasterizer must be used to create the bitmap for the output device.

When data is stored in a file, it is usually structured in a manner that is tailored to specific types of information. It is also structured in a manner that allows recovery of the data with a reasonable degree of efficiency. There are various document structures that feed into the digital printing process.

Text data

In order to maintain effective and consistent results in the exchange of textual data across multiple platforms, an encoding scheme must be used to represent alphanumeric characters as a set of binary digits. ASCII eventually become the standard and is now used in most personal computers.

The ASCII (American Standard Code for Information Interchange) describes a coded character set which is primarily intended for the interchange of information. The character set is applicable to all Latin alphabets; eight bits are commonly used to represent each character in ASCII code.

Graphical data

Bitmaps

A bitmap is described as a rectangular array of pixels, which are used to form an image. In a bitmap, the pixel depth specifies the number of colors the pixel can show; 24 bits or 3 bytes (RGB) is often used as a practical maximum for the number of colors that should be required in any bitmap image. Once an input device such as a scanner or a digital camera has captured a bitmap image, it can then be manipulated using different types of software tools. These tools range from simple paint packages that offer a limited range of editing capabilities, to sophisticated photo-editing packages that offer a suite of complex editing and special effect tools. Common bitmap file types are TGA, BMP, PCX and TIFF (Tagged Image File Format).

Vectors

In computer graphics, vector data usually refers to a means of representing graphic entities such as lines, polygons or curves, by numerically specifying key points to control their generation. There are many common vector file types. Example: Auto CAD DXF, Auto CAD DWG and Wavefront OBJ.

Metafiles

Metafiles usually contain both bitmap and vector data. Metafiles are widely used to transport bitmap or vector data between hardware platforms. Some examples of the common metafile types are RTF, WGM, Macintosh PICT, and EPS (Encapsulated PostScript).

PostScript

The revolutionary product developed by Adobe Systems was a computer language called PostScript and a process that could interpret PostScript page descriptions and generate a data stream to drive a digital printing device such as a laser printer or film writer. The PostScript page description language has become the heart of desktop publishing and electronic prepress. It standardized the language that each application program outputs by developing RIPs for many different printers and output devices.

The RIP, or raster image processor, is really the PostScript programming language compiler. It interprets the file and executes its commands, which are to draw objects on a page. The end result of RIPping is a bitmap for the entire page that tells the output engine where to place dots. Digital imaging makes all direct-to outputs possible by replacing photography when used to image films, replacing films when imaging plates, and imaging plateless systems directly.

Digital printing is divided into three main categories of technologies:

- direct-to-plate off-press
- direct-to-plate on-press
- direct-to-print

DIRECT-TO-PLATE

There are two categories of direct-to-plate technology, direct-to-plate off-press and direct-to-plate on-press.

Direct-to-plate off-press

Direct-to-plate systems are the logical answer for longer run sheetfed and web offset printing, at least for now. That's why we are most likely to find commercial and publication printers, who use special cylinder-to-press approaches, print runs in the millions. Offset printing has been a bit behind because the CTP equipment hadn't been available. Direct-to-plate or computer-to-plate (CTP) means that electronic information from a file is sent in PostScript form to an off-press platemaking device. There plates are written, exposed, and processed so they are ready to hang on an offset printing press. The platesetter exposes the plate using a precisely guided and focused laser beam to deliver the data. CTP can save time and money, and can yield improvements in quality and consistency.

Direct-to-plate on-press

Direct-to-plate on-press, called direct imaging presses, is a system that uses plates that have already been "hung" or put in place on the plate cylinders on a press. Once hung, these plates are then imaged with the digital information for the print job. Before the plates can be imaged, the digital information has to be prepared. The electronic files, generated on the desktop computer and delivered in their native applications, first go to the printer's desktop workstation. There the operator performs a flight check, final imposition, and conversion to PostScript. Next, the PostScript files are digitally separated and bitmaps are generated via the RIP to a server and subsequently transferred to plates on press. Each plate is mounted on each press unit and imaged simultaneously. In direct imaging press, the prepress steps of film output and off-press plate are eliminated.

The technology used to image digital information from the press computer directly to each plate is called laser dot imaging. It was developed by Presstek. Laser dot imaging was first brought to the market on the GTO-DI from Heidelberg.

DIGITAL PRINTING

Once the plate is made, however, the image reproduction process is a purely analog affair. Ink is transported from reservoir to plate, and then from plate to substrate by mechanical means. Modern printing process may incorporate a number of digital subsystems to monitor and control color register, paper tension, paper density, and other important variables. However, the image information that the press transfers to the substrate does not have to exist in a digital form. Analog printing presses often employ computers to help them do their job more efficiently, but they do not need computers to tell them what to print. We do not consider modern lithography or gravure processes digital, even though the images they reproduce almost certainly were in digital form at some point earlier in the process.

Direct to print

Direct-to-print or digital printing is the production of printed materials directly from digital information residing in an electronic file in a computer. Put another way, it's the output of digital information from an electronic file onto a substrate of some kind. Until now, most direct digital printing devices, with the exception of imagesetters, produced continuous tone output. Imagesetters use lasers to expose graphic arts film, special paper, or plate materials with digital information. When the film is reproduced, the halftone dot structure is in place and the project is ready to be assembled into a film flat, which is then subsequently imaged to make a printing plate. If plate materials are imaged, the job is ready to go to press. Images printed by one of the traditional printing processes must have a halftone dot structure to be reproduced. Digital printing has this capability, so it's finally become printing to commercial printers as well; they can have their dots and digital too.

Traditional printing does not allow us to print variable information. With traditional printing, the prepress work is performed, the plates are made, and they are run on the press. The end result is thousands of pages that look exactly the same. This information is not variable; it is static. In contrast, many of the digital presses (presses that print from digital data) can print variable information. On different pages we can have different names and addresses. The ability to print variable information which results in variable printing is the critical component of customized printing.

For years, printers have been reporting that press runs are becoming shorter each year. A commercial printer's average order fell from 20,000 press sheets in the early 1980s to 5,000–10,000 press sheets today. No one talks about the customers who forgo ordering a printed product because they really need about 1,000 copies or less. Shorter printing runs evidently do not mean that people are buying less print—the printing industry is putting more ink on paper every year; people seem instead to want to buy more of less—they want more short runs than long runs.

On-demand printing

On-demand is a term that means different things to different people. In a general sense, the concept of on-demand is basically one of short notice and quick turnaround. In the printing industry, it is also associated with shorter and more economical printing runs. When all of this is combined, the definition becomes "short notice, quick turnaround of short, economical print runs." When all criteria are met, it results in lower inventory costs, lower risk of obsolescence, lower production costs, and reduced distribution costs.

Distribute and print

By combining digital printing with telecommunications, one can greatly reduce the delivery timetable of printed product. Most printing plants today use a print-and-deliver approach; the job gets printed, loaded on trucks or put in the mail, and delivered to the customer or their audiences. With digital printing and telecommunications, the customer or an electronic service bureau can design the pages, assign them to forms, and send the images electronically to many local printers for production. This new approach reverses the process of deliver-and-print, and gets the message into the hands of audiences quicker.

Fast turnaround

A few years ago, turnaround time at a commercial printer was 14 to 21 days, today it is about 10 days. For many projects, even that time does not work. When we add that reality to the decreasing size of the print orders, we can see why digital full-color printing is the right process at the right time. Digital printing is very fast—as a rule of thumb, two-sided full color print runs of 500 11"x17" sheets will take less than a half hour to go through these machines. And when the printing is completed, the product is ready for finishing. What must be factored is the time to flight and prepare the file for printing.

Personalization

One way a company can distinguish itself from the competition is to add perceived value to its product or performance. It can do that with improvements, innovations, and pricing options. Direct the message to the target audience as individuals (personalize it) and you also add value. Marketers, especially cataloguers, would like to use their databases in more sophisticated ways. Specially versioned catalogs, based on a consumer's previous purchases, credit history, and demographic information, are supposed to be the waves of the future. Short run, personalized digital printing becomes a tool to test these pieces before a full-fledged roll out. Shorter-run specialty catalogs, those with final print runs of 5,000 to 10,000 copies, can even be printed digitally in five or ten different editions of 1,000 each, with fewer pages of well-chosen merchandise.