Gravure

A printing method which utilizes engraved cylinders or, infrequently, cylinder-mounted plates as the image carriers. The image areas are etched into the surface of the cylinder as a collection of tiny cells. The cylinder rotates in an ink fountain and ink collects in the cells, the excess ink being scraped from the non-image areas by a doctor blade. The paper (or other substrate) is passed between the gravure cylinder and a rubber-coated impression roller, and ink is transferred by a combination of capillary action and the pressing of the substrate into the engraved cells of the cylinder, helped by the rubber surface of the impression roller. Most gravure printing performed today is web-fed rotogravure printing, with occasional sheetfed use. Gravure is also well-suited to the printing of packaging on a variety of non-paper substrates.

Gravure printing is a direct descendent of older intaglio printing (gravure and intaglio, commonly used synonymously, are different processes; all gravure printing is intaglio, yet all intaglio printing is not gravure—for example, copperplate printing, which is an intaglio process without being considered a gravure process), developed around the same time as Gutenberg was developing relief-based printing (the mid-fifteenth century). Intaglio, primarily an artist's medium, was essentially a wooden (and soon metal) block on which the image to be printed was etched. A thin ink was poured into these etched lines or dots, and the paper on which the design was to be printed was brought into contact with the inked image carrier in such a way as to force the paper into the cells where it could pick up the ink. A porous substrate allows capillary action to enhance this process. Around 1440 C.E., the first metal plates began to be used, commonly made from copper (hence the term *copperplate engraving'). Intaglio was used primarily for illustration matter and playing cards. Around the same time, Gutenberg's letterpress-based printing press was increasing in popularity, and the use of intaglio for text was not actively pursued, as the intaglio plates were incompatible with the relief method of printing. Still, intaglio represented a more artistic rather than commercial medium, perhaps best exemplified by the woodcuts and other engravings of German artist Albrecht Dürer in the late fifteenth and early sixteenth centuries, as well as engravings by other noted artists such as Rembrandt van Rijn and Peter-Paul Rubens.*

In the first half of the sixteenth century, the invention of chemical etching of intaglio plates was a great leap forward for the process. Rather than laboriously scrape away the metal itself, artists could now simply scrape away a soft coating (known as a resist), which would allow the penetration of an acid only in certain areas, which would then etch the copper beneath the coating chemically. Chemical etching made the intaglio process even more favored by artists, and intaglio printing proved to provide better-quality illustrations than did letterpress, so it was not uncommon for the text of a book to be printed using letterpress, and illustrated pages to be printed using intaglio, the separate pages being collated together after printing. Denis Diderot's great and controversial Encyclopédie*, published in seventeen volumes of text from 1751 to 1755, was supplemented by several additional volumes of intaglio illustrations, which served to primarily illustrate various manufacturing processes as part of Diderot's extolling of the virtues of artisans. (This would be a contributing factor in the French Revolution of 1789.) Intaglio-based printing was also widely used for the reproduction of sheet music, as well as maps, needed more than ever once the New World was found and colonized. The invention of the mezzotint (an early means of representing shades of gray in copperplate* *engraving; "mezzotint" itself literally means, in Italian, "halftone") in the 1600s further refined the use of intaglio for high-quality pictorial reproduction.*

Following the invention of lithography at the tail-end of the eighteenth century, and its further development in the nineteenth century, the search was on for a means of printing utilizing cylinders, rather than flat plates, stones, or locked-up bits of type. The one desperate need of any printing press is, as its name indicates, pressure*. It is easier and less laborious to produce suitable and uniform printing pressure in the nip of two cylinders than over the surface of a flat plate, but the question was how to accomplish it; a litho stone couldn't be bent into a cylinder, the individual letters, or even lines, of type were impractical for rotary printing, and intaglio techniques weren't able to keep the ink from spilling out of the cells. The development of stereotype platemaking eventually solved the problem for letterpress printing, and the later use of zinc and aluminum plates eventually solved it for lithography. Interestingly, the first cylinder-based printing press was a gravure press, originally developed for printing on textiles in 1680. The quality was most likely not very high, but its primary usage was in the printing of calico patterns on cheap clothing. In 1783, British textile printer Thomas Bell patented a rotary intaglio press for use in higher-quality textile printing. His patent drawings show a system very much like that still in use in gravure printing today, but for non-textile printing, the idea of a rotary press languished.*

The invention of photography in the 1820s and 1830s resulted in the search for a means of transferring a photographic image to an intaglio plate. William Henry Fox Talbot devoted himself to the search for photoengraving materials and techniques. Using gelatin-based coatings for metal plates, he was able to achieve photographic etching initially for only line art, but eventually he devised formulations that would enable the selective variation of image density, which would print at varying shades. Fox Talbot soon hit upon the halftone screen, which broke up continuous images into very small, discrete dots which could be varied in size and shade of gray. This was the breakthrough photoengravers (and printers everywhere) needed. Letterpress and lithographic platemaking were the direct beneficiaries of this process, however. The intaglio process was desired by most people for little more than fine art reproductions and illustration material.

The problem for gravure still remained: how to produce a photographic coating for a cylinder that could be used for etching. The English engraver J.W. Swan solved the problem in the early 1860s with a carbon tissue, which was a gelatin resist coating on a light-sensitive material applied to the surface of paper. After exposure, the paper could be removed, and the exposed coating applied to another surface, such as a metal plate—or a cylinder.

Thus, all the disparate elements needed for modern gravure printing existed, and it remained for someone to put them all together. That someone was Karel Klic (in German spelled Karl Klietsch), from Bohemia (now the Czech Republic). In 1841, combining Bell's rotary intaglio textile press, Fox Talbot's halftone screen process, and Swan's carbon tissue coating, Klic developed the first gravure printing press. Still used exclusively in the printing of textiles, however, Klic made his way to England and teamed up with Samuel Fawcett, an engraver at Story Brothers and Company, a textile printing company. In the early 1890s, they developed new techniques for photoengraving, and began commercial printing of intaglio art prints, conducted with such secrecy that company employees were not allowed to venture into rooms other than those they were assigned to, lest they become exposed to all the various parts of the process. A bit paranoid, perhaps, but the company—under the name of Rembrandt Intaglio Printing Company—held a monopoly on the process for over a decade. In 1903, an employee of Klic's came to the United States and revealed Klic's process. The jig was up.

Meanwhile, in 1860, A French publisher named Auguste Godchaux developed a rotogravure press that printed on rolls (or webs) of paper, a design very similar to modern rotogravure press designs. In the early 1900s, gravure presses began turning up in the United States, and the New York Times *in 1913 was the first to print rotogravure newspaper supplements. Other newspapers began to take notice of the high-quality reproduction of photographs the new system afforded. (Today, most Sunday newspaper supplements—such as the* New York Times Magazine*,* Parade*,* USA Weekend*, and other color supplements across the country—are printed on rotogravure presses.) In the 1930s, gravure presses began to be used in the printing of packaging; a single-color gravure press in 1933 was set up to print Tootsie Roll wrappers. In 1938, multi-color gravure presses were used for the printing of Jell-O boxes. These so-called "Jell-O presses" were the largest and fastest yet designed; together, they were capable of printing up to 36,000 cartons an hour, and were in use until 1987.*

Modern advances in engraving technology have made gravure printing a high-quality printing operation. The expense of producing and imaging the gravure cylinders, however, still continues to make gravure printing an expensive process, and gravure is rarely used economically for print-runs of under 200,000 or so. An advantage of gravure printing, though, is the relative simplicity of the press, which doesn't require the intricate series of ink and dampening rollers that a lithographic press requires.

The gravure printing press has several basic elements:

***Gravure Cylinder**. A gravure press most often prints from a gravure cylinder, which comprises a steel base, which can either be a sleeve cylinder or a shaft cylinder. A sleeve cylinder requires a shaft to be attached when it is mounted on the press, or when it is mounted in the engraving mechanism. The inaccuracies inherent in the fitting of a separate shaft have brought about the development of a shaft cylinder, which comes with shafts already mounted, and they are the dominant gravure cylinder bases currently utilized. Aluminum bases have be devised to hopefully replace steel, especially in presses used in the printing of packaging, but although they are lighter they are also harder to electroplate. Newer plastic cylinder bases are being developed that are much lighter than metal bases, and contain special surface coatings (most of which are proprietary) that facilitate electroplating.*

To the cylinder base is electroplated a layer of copper, which has historically been—and continues to be—the dominant surface material for gravure cylinders—and is commonly electroplated to the base utilizing a sulfuric-acid eletrolyte. On top of the copper, after engraving, is plated a thin layer of chrome, which is applied to protect the etched copper surface from the abrasion of the doctor blade during printing. After print runs, the cylinder needs to be resurfaced. (See Electroplating.)

The copper surface of the cylinder, prior to printing, is etched or engraved. A particular image printed in gravure is essentially a collection of many tiny cells that are etched with varying depths (darker regions of a print utilize deeper cells which can hold more ink, while lighter regions utilize shallower cells which hold less ink). This is why gravure-printed type can look fuzzy when examined under magnification. But due to this printing mechanism, gravure can print halftones extremely well. Before the development of electromechanical engraving in the 1960s, most gravure cylinder etching was performed photochemically, using carbon tissue resist coatings and ferric chloride etchants to chemically etch the image areas. Now, the artwork to be engraved is often placed before an optical scanning device, which uses photodiode to receive the image, and the image is transformed into digital data, which is then used to drive an engraving head (typically a diamond stylus), which can produce as many as 5,000 cells per second. New developments in direct computer-to-engraving-head imaging are *removing the need for a film positive from which to obtain the information to drive the engraving head.*

One particular consideration with the gravure cylinder is ensuring that it is as close to perfectly round as possible (and that the circumference of the cylinder is large enough to carry the image to be printed). The term total indicated runout is used to measure the roundness of the cylinder, and gravure cylinders are manufactured—and need to be kept—within strict tolerances. (See Gravure Cylinder and Gravure Engraving.)

***Ink Fountain**. The inking system for a gravure press is far less complex than that used for offset lithography. The gravure cylinder is partially submerged in a large pan of thin, highly fluid ink. (Ink is pumped into the pan as needed from a sump, typically located below the fountain pan.) As the cylinder rotates in the ink, its surface becomes covered with ink, and the cells fill. A thin, flexible steel doctor blade, either alone or in tandem with other pre-wiping devices, scrapes the excess ink from the surface of the cylinder before the inked cells contact the substrate. Some gravure inking fountains utilize a fountain roller, a cloth-covered roller that is partially submerged in the ink fountain and which contacts the surface of the gravure cylinder. In some configurations, ink is sprayed onto the surface of the cylinder by a nozzle. (See Inking System: Gravure.)*

***Impression Roller**. The gravure impression cylinder, or impression roller, is a hard cylinder covered with a synthetic rubber lying directly above the gravure cylinder. The purpose of the impression roller is to exert pressure on the substrate passing through the nip between the impression roller and gravure cylinder. This forces the substrate partially into the cells on the gravure cylinder, where capillary action transfers the ink to the substrate. The pressure exerted on the substrate as it passes though the nip can be adjusted. The impression roller typically has a smaller diameter than the gravure cylinder and consequently rotates at a faster rate. However, in the nip between the two cylinders, the rubber is deformed slightly by the pressure of impression roller against the gravure cylinder. Faster press speeds in recent years, however, have resulted in excessive heat buildup in smaller impression rollers. Consequently, many presses now utilize larger-diameter rollers, which also have the added advantage of reducing stress on the web, as the increased size of the nip results in the same total amount of pressure being applied but over a larger surface area. Too large an impression roller, however, can cause printing defects, as the substrate remains in the nip for a longer period of time. As with the gravure cylinder itself, the TIR of an impression roller should be carefully monitored. The excessive friction caused during web gravure printing can also result in high static charge buildup. These charges can exceed 25,000 volts and can cause such printing problems as whiskering, or health hazards such as severe electrocution. A related phenomenon, but one which is induced deliberately and which has positive effects, is known as electrostatic assist, in which the impression roller is given a static charge that attracts the droplets of ink from the gravure cells to the substrate, and helps to more completely transfer ink and reduce the occurrence and severity of such problems as snowflaking. (See Impression Roller.)*

***Substrate Control**. The feeding systems used to control the movement of the web of paper (or other material) through the press vary by press. Since gravure is used for a wide variety of different types of substrates, all of which contribute various feeding problems, web handling equipment comes in a number of different configurations. Plastics, films, and other non-paper substances are often heat-sensitive, non-absorbent, and easily stretched beyond their ability to return to their original dimensions. Paper, on the other hand, is more resistant to stretching, is less heat-sensitive, and is more absorbent. But it is also bulkier, and more often than not needs to be printed on both sides simultaneously. Consequently, web handling units* *for packaging films requires a more tension-controlled path, less heat for drying and, consequently, a faster-drying ink. Immediately after the printing unit, it is not uncommon for the web's drying path to be a vertical one; the web travels vertically up to a fixed distance, allowing it time to dry—expedited by hot-air dryers—and either out to the finishing section of the press, or back down again, depending upon how much drying time is specifically required. It has become more common for drying paths to be varied according to the job by add-on modules that provide more or less drying space. This has become increasingly necessary on higher-speed presses; modern packaging presses print at speeds of up to 1,000 feet per minute, while publication presses can print speeds exceeding 3,000 feet per minute.*

The web roll is placed on a reel stand, which has developed over the years from simply holding one roll at a time (which required press stoppage when the roll ran out and needed to be replaced) to a two-roll stand (which required a good deal of operator skill to switch to the new roll when the first one ran out) to fully automated, two-roll unwinding systems. Most webs—either paper or packaging—tend to have three- or six-inch-diamater cores, made primarily out of cardboard, with plastic and metal cores becoming more popular, as they tend to retain their roundness more easily. (Cores that are out-of-round will result in the roll unwinding with a bump, which will cause feeding problems and perhaps web breaks.) The most common type of reel stand consists of two metal arms, one fixed, the other moveable. Attached to each is a cone which fits into the core of the roll. The roll is mounted first on the fixed arm, then the second is moved in to engage the other side and hold it firmly. The centering of the roll for travel into the press can be performed by moving the arms in or out, as may be necessary. Some reel stands also make use of an earlier configuration involving a metal bar that runs through the center of the roll. Many configurations involve two unwind stands at the end of a long central arm, the whole assembly looking rather like a see-saw. One basic problem that needs to be accounted for is, as was mentioned, the out-of-roundness of the core, which always exists to some degree. If kept within certain tolerances, it is acceptable, but the reel stand must be sufficiently sturdy to guard against any vibration caused by the non-concentric core disrupting the printing units of the press. When one roll runs out, the new one must immediately and carefully be spliced to it, the point being to avoid having to stop the press. Often, this system is automated, but it still requires careful preparation on the part of the press operator. The appropriate amount of web tension is carefully regulated by running the web around a dancing roll, a roller connected to an air cylinder that can be adjusted to apply the appropriate amount of force to the web. Newer systems carefully measure the diameter of the roll repeatedly as it is unwinding (to account of any eccentricities or out-of-roundness), either by ultrasound sensors or other means, and automatically adjust the speed of the motor driving the unwinding reel.

The final portion of the press just prior to the printing unit is known as the infeed tension unit, which is little more than two rollers, the nip of which the web passes through to reach the printing unit. This nip, regulated by a mechanism similar to a dancing roll, ensures that the web tension beyond it is consistent, regardless of what is happening to the web prior to reaching the nip. This tendency to isolate regions of web tension ensure that any anomalies are dealt with before the printing unit. (See also Web Offset Lithography: Feeding Section.)

***Sheetfed Gravure**. Most of the gravure presses in operation are web-fed presses, but occasional sheetfed gravure work is done, such as for printing proofs, fine art posters and prints, cartons, and other high-quality work for which sheetfed offset lithography is inappropriate (such as the printing of metallic inks that are incompatible with offset press chemistry). Sheetfed gravure presses consist of a pile table on which the sheets are stacked, and which are fed into the press, through the printing unit (a standard gravure cylinder-impression roller-doctor blade arrangement, with the cylinder typically inked by a fountain* *roller), transported by a series of transfer cylinders, over several drying nozzles, and finally to the delivery pile. Some configurations of sheetfed gravure presses also replace the gravure cylinder with a flat gravure plate.*

A variety of intaglio plates are used for high-quality, specialty printing such as bank notes, postage stamps, money, securities, and other such documents. These can either be sheetfed or web-fed, and are more commonly known as copperplate printing. See Copperplate Printing.

***Offset Gravure**. Some substrates (such as those with irregular surfaces) are printed by a process called offset gravure, or indirect gravure, which comprises the standard gravure printing unit, except that the image is first transferred from the gravure cylinder to a rubber-covered transfer roller which first receives the image from the gravure cylinder, then transfers it to the substrate passing between the transfer roller and the impression roller. (This is based on essentially the same principle as offset lithography.) Products printed by this method include decorated metals and woods, and other types of irregular surfaces. The resilience of the rubber image-carrying blanket makes printing on hard surfaces such as these much easier. A variety of offset gravure takes place on a flexographic press, where the Anilox roller of the flexo press is replaced by a gravure cylinder. The gravure cylinder transfers the image to a rubber blanket, which has been mounted to the flexo plate cylinder. The blanket then transfers the image to the substrate. This is known as flexo gravure, and is used to print high-quality packaging, advertising, and other materials commonly printed by traditional flexographic means, but with the increased quality of gravure printing. Gravure units are also occasionally added to regular flexographic presses, for the overprinting of various elements, such as prices, store addresses, and other design elements that need to be changed several times over the course of a print run, on products whose other elements are printed by traditional flexography.*

Gravure, like other printing processes, has specific ink requirements that produce the best results, specifically, highly fluid liquid inks with volatile solvents. (See Ink: Printing Requirements: Gravure.) Gravure presses also require paper substrates with certain characteristics to produce best results. (See Paper and Papermaking: Printing Requirements: Gravure.) Gravure is also well-suited for printing on a host of other types of substrates, such as foils, plastics, etc. When used on plastic packaging, most gravure presses require the use of fast-drying solvents.

Flexography

A form of printing that uses flexible rubber relief plates and highly volatile, fast-drying inks to print on a variety of substrates, commonly used in package printing.

Flexography has its origins in the development of natural and synthetic rubbers. Natural rubber is obtained by the treatment of latex, a milky exudation of various trees and plants, primarily native to the tropics. It was used by many pre-Columbian civilizations in Central and South America (such as the Mayas). Samples of rubber were sent back to Europe by missionaries and explorers in the sixteenth century, and in the late eighteenth century, British chemist Joseph Priestley (famous primarily as the discoverer of oxygen) found that latex rubber, when heated, would erase pencil marks. From this "rubbing" ability, he coined the term "rubber."

In 1839, Charles Goodyear accidentally discovered a means of strengthening natural rubber, a process he called "vulcanization." In the mid- to late-1800s, various rubber products and patents began appearing.

In the late 1800s, letterpress (printing from raised type, typically bits of metal) was the dominant form of printing, with the alternate processes of lithography and gravure still in their formative years. It was found that letterpress type could be set into plaster and that unvulcanized liquid rubber could be poured into the mold and, after heating and cooling, could make a workable rubber stamp. Soon, it was found that the rubber stamp concept could be applied to the manufacture of printing plates, which could be useful for printing on surfaces that did not yield good results with conventional letterpress processes, in particular corrugated paperboard.

The invention in the 1930s of synthetic rubbers made the properties of the rubber stamps and plates much more reliable than they were with unreliable natural rubber. Advances in rubber platemaking were pioneered by the Mosstype Corporation, which developed effective processes for both aniline printing (as flexography was known until the 1950s) and for letterpress printing. In the 1940s, Mosstype developed effective off-press plate-mounting systems, which minimized downtime and made aniline printing more efficient. In 1938, two men at the International Printing Ink Corporation devised a way of accurately and effectively metering the film of ink transferred to the rubber plate. Their system was inspired by the etching of gravure cylinders, which transfers ink from cells to the substrate. They developed an ink roller, engraved with a controlled size and number of cells, and plated with copper and chrome that effectively metered the ink film transferred to the aniline printing plate. They called their roller an anilox roller, and it is still the basis of modern flexographic presses.

In the first decades of the twentieth century, as was mentioned, flexography was known as "aniline printing," taking its name from the type of dyestuff used in the inks. In the 1930s, the aniline dyes were declared toxic by the FDA. Although aniline printers were by then using different types of inks, the name remained. In the late '40s, it grew apparent to industry leaders that the name "aniline printing" had to go, as the name had bad connotations, since the process was widely used for printing food packaging. In 1951, the Mosstype Corporation, in its company newsletter, held a contest to rename the process. Alternate names were solicited, and a final choice would be voted on. Two hundred suggestions came in from printers around the country, and a special committee formed by the Packaging Institute pared the list down to three: permatone process, rotopake process, and flexographic process. On October 21, 1952, it was announced that the overwhelming choice was "flexographic process," or "flexography."

Like other printing processes, there are a wide variety of press configurations. In its most basic form, however, the flexographic press comprises the following parts:

'Ink Fountain'. Flexo ink, typically a thin, volatile liquid ink, is stored in an ink pan, where a rubber-covered fountain roller rotates. The fountain roller picks up a thick film of ink and transfers it to a metering roller, typically known in flexography as an *anilox roller*. The anilox roller is a chrome- or ceramic-covered roller whose surface contains small, engraved pits or cells (typically from 80:1,000 cells per inch).

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

Some alternate configurations include a chambered or enclosed system, in which the anilox roller sits in the ink fountain itself (removing the need for a fountain roller), the ink metering performed by a doctor blade (a strong strip of steel, plastic, or other material) that is placed between the fountain and the nip between the anilox roller and the plate cylinder. The angle and pressure of the doctor blade ensure a controlled and uniform ink metering. Another fountain roller-less configuration pumps ink from an ink tank to the surface of the anilox roller (which sits above an ink pan, the latter acting as a catch basin). A doctor blade is also used in this configuration to meter the ink film. Another more elaborate system, called an enclosed inking system, features two doctor blades—one at the bottom of the anilox roller, the other at the top, the ink reservoir located between them. Ink is pumped onto the surface of the anilox roller, where the top doctor blade is responsible for metering. This system is typically used on high-speed presses, and is popular due to the fact that, since the inking system is not exposed to the air, ink viscosity can be tightly controlled.

'Printing Unit'. The inked anilox roller is adjacent to the plate cylinder, a steel drum on which the rubber flexographic plate is mounted (usually by means of an adhesive backing, rather than the plate clamps used in offset lithography). The raised impression on the flexo plate picks up the ink and transfers it to the substrate passing between the plate cylinder and the smooth, steel impression cylinder. The plate cylinder can either be integral (the cylinder body, end-caps, and shafts are all one piece), demountable (the shafts are removeable), sleeve (the cylinder face is slid onto a bored cylinder using high-pressure air), and magnetic (the cylinder is magnetized, allowing metal-backed plates to be mounted magnetically, rather than by means of adhesive). (See Plate Cylinder: Flexography.)

In some applications (typically those in which ink strike-through is a problem, and is likely to cause ink buildup on the impression cylinder), the impression cylinder is replaced with an impression bar, a G:H-inch-diameter steel rod clamped into the proper position behind the web. The bar does not rotate, and as a result the moving web wipes off any ink likely to accumulate on it.

'Plates'. There are three types of image carriers in flexography, two of which can be categorized as plates:

Rubber Plates. A negative of the image to be printed is placed on top of a metal alloy coated with a light-sensitive acid resist. When exposed to light, the resist hardens in the exposed image areas, and remains soft and soluble in the unexposed, non-image areas. The unhardened resist is washed away after exposure, and an etchant is applied to the surface, which engraves those areas not protected by the hardened resist. The result is a metallic relief plate. A mold—or matrix—is then made of the relief plate. After cooling the mold, a rubber sheet is pressed into the matrix which, after cooling, will be a rubber relief plate. Various finishing operations optimize the plate for flexographic printing.

Photopolymer Plates. Manufactured either from sheet photopolymer or liquid photopolymer materials, a photographic negative is placed on top of the photopolymeric material and exposed to ultraviolet light, which hardens the photopolymer in those areas through which it passes (the image areas), leaving the unexposed regions unhardened. After exposure, washout procedures remove the unhardened photopolymer from the non-image areas, leaving the image areas in relief.

Plates are mounted on the plate cylinder either by an adhesive backing or by other means, such as plate clamps. See Plate: Flexography.

A third type of image carrier is called a design roll, which consists of a layer of vulcanized rubber applied as an unbroken "jacket" on the surface of the plate cylinder itself. The imaging of the plate is commonly performed using high-energy lasers, which atomize the non-image portions of the rubber surface, leaving the image areas in relief. Design rolls, due to their seamlessness, are useful for printing continuous background patterns such as those found in packaging, wrapping, and other forms of decorative printing applications. They are also capable of higher print runs than conventional plates, with which they are occasionally used in tandem. (See Design Roll.)

'Substrate Control'. There are two main portions of the substrate control system on a flexographic press (or, indeed, on many other web-fed presses).

Infeed Section. The feeding systems used to control the movement of the web to the press vary. Flexography is used to print a wide variety of substrates, primarily those used for packaging, so each feeding and tension-control system needs to be tailored to the specific requirements of the substrate in question. Typically, the web is placed on a reel stand, which can either be a single-position unwind (one roll is mounted at a time, the primary advantage of which is its ability to accomodate a wide variety of roll widths and diameters) or a flying-splice unwind (a second roll is mounted above the first one, which is then spliced—with varying amounts of automation, depending on the device—onto the end of the expiring roll). Single-position unwinds are useful when roll changes do not need to be made very often. Flying-splice unwinds, however, do not allow the wide variety of roll sizes that single-position units do. Flying-splice stands used for packaging can accomodate up to 24-inch diameter rolls, while stands for paper or other heavy substrates can accomodate up to 72-inch diameter rolls. One basic problem that needs to be accounted for is the out-of-roundness of the core, which always exists to some degree. If kept within certain tolerances, it is acceptable, but the unwind stand must be sufficiently sturdy to guard against any vibration caused by the non-concentric core disrupting the printing units of the press.

The unwinding stand is one of the several "tension zones" on a web-fed press. The unwinding tension is important for proper register, and to prevent web breaks. Enough tension needs to be created to properly feed the substrate into the printing unit, yet too much tension can cause slippage elsewhere in the press. There are a wide variety of mechanisms that control web tension such as braking systems or a dancing roll, a roller connected to an air cylinder that can be adjusted to apply the appropriate amount of force to the web. A dancing roll is especially useful in that it can compensate for the decreasing diameter of the roll as it unwinds into the press, the diameter change altering the tension on the web.

The final portion of the press just prior to the printing unit is known as the infeed unit, which consists of two steel rollers and one rubber roller, the point being to brake the web and create a "tension barrier" between the unwind section and the printing section. This barrier ensures that the web tension beyond it is consistent, regardless of what is happening to the web prior to reaching it. This tendency to isolate regions of web tension ensures that any anomalies are dealt with before the printing unit. (See also Web Offset Lithography: Feeding Section.)

Outfeed Section. After the printing unit comes the outfeed unit, also known as the cooling drum unit, which acts to pull the web through the printing unit, create another tension zone separate from the printing unit, and guide the web to the rewind unit. This section commonly uses chill rolls, which are rollers cooled with water, brine, or some other substance that removes heat (generated by friction and/or from the drying portion of the printing unit) from the web prior to rewinding. The printed web is rewound on one of two types of rewinders, a surface rewinder which uses a moving roller to wind the roll by frictional contact with the outside surface, or a center rewinder, which winds the roll by means of a shaft inserted through the core. (See Web Offset Lithography: Rewind Equipment.)

'Inks and Substrates'. Flexographic presses typically use liquid inks that possess low viscosity and dry primarily by evaporation of the vehicle. Flexographic presses use either water inks (occasionally on non-absorbent substrates such as polyolefins and laminated surfaces and, in the past, on various types of paperboard) or solvent inks (for use on surfaces such as cellophane). Water-based flexographic inks, however, have a longer drying time on less absorbent substrates and a dry with a low degree of gloss. Water-based inks are undergoing further research and development due to the desire to decrease the dependence on solvent-based flexographic inks, which contribute to air pollution. Currently, however, water-based inks do not perform very well when printed on non-absorbent substrates. Ultraviolet curing inks are also extensively used in flexographic printing. (See also Ink: Printing Requirements: Flexography.)

Paper and Paperboard. Flexographic printing is done on kraft board, in particular corrugated board. White, bleached, and clay-coated linerboard are also often printed, the latter providing the best degrees of ink holdout and ink receptivity. Other types of paper- and paperboard-based flexo products include envelopes, folding cartons, milk cartons, coated paper-based gift wrapping, groundwood-based mass market paperback books, multi-layer bags used to package pet foods, fertilizer, and gardening supplies, wax paper- and glassine paper-based food packaging, and vegetable parchment used to line meat packaging. As with most other printing processes, the paper's moisture content can affect printability and runnability, in particular the drying characteristics of the ink. A moisture content greater than 5:7% can cause difficulties with flexo ink drying.

Non-Paper Substrates. Polyethylene is the most commonly printed film substrate used, encompassing end uses from adhesive tape to "boil-in-bag" TV dinners. The typical film manufacturer will produce over 1,000 different products. Some films need to be "treated," which involves reorienting the surface electrons, a process that improves ink adhesion and trapping. However, overtreating can cause ink setoff and blocking.

Polyester films tend to be stronger and have more desirable characteristics for flexographic printing and are increasing in popularity. Originally used in photography, microfilm, audio- and videotape, and leisure suits, polyesters are finding more and more applications in flexo-printed packaging. Its high degree of chemical stability, which makes it desirable as a packaging material, also makes it difficult to print on, however. Chemical treatment of the surface of polyester films can help alleviate this problem. One particular problem with polyester films (and indeed many types of plastics) is their reduction in tensile strength at high temperatures, such as those generated by friction during printing. This can make these materials more susceptible to expansion and/or shrinkage, causing registration and aesthetic problems.

In an average year, 350 million pounds of polypropylene film is used for flexible packaging, 22% of which is for snack food wrappers alone. (This variety of polypropylene is called "oriented polypropylene".) Although it is widely used, its bare surface characteristics do not facilitate wetting by inks; frequently, it needs to be "activated" either by a corona, high-voltage discharge, or by exposure to a flame. (The latter treatment is not performed often.) Polypropylene films also lose much of their resistance to stretching beyond 140ºF, temperatures commonly encountered in printing and converting equipment.

A variety of vinyl film used as a common flexo substrate is polyvinyl chloride, about 240 million pounds of it being used for packaging each year. Other types of vinyl film are specifically produced for particular applications. Vinyl films are widely used for their chemical and water resistance. Unlike many other types of plastic films, treatment of the surface to improve ink adhesion is rarely necessary.

Other films used as flexographic substrates include polystyrene, cellophane, metal-coated films, synthetic papers, latex papers, and a variety of other surfaces. As in any printing process, the compatibility of substrate with ink constituents is crucial; some substrates, such as polystyrene, can be easily damaged by some solvents used in flexo inks.

'Press Configurations'. There are three basic press configurations used in flexography (with many different variations, depending on the manufacturer). A stack press is used for multi-color printing, and each color station is, as its name indicates, stacked vertically, some configurations using two parallel stacks of printing units, sending the moving web in a U-shaped path. Stack presses include two to eight separate color stations (the most common stack presses possessing six stations), each with its own inking rollers, plate cylinder, and impression cylinder. The advantage of a stack press is the ease of reversing the web, allowing both sides of the substrate to be printed in essentially one pass. The accessibility and independence of each color station also make such a press easily adjustable to each specific application. The increased web tension produced on a stack press, however, sometimes precludes its use for very thin or highly extensible substrates, as stretching can cause misregister.

A second type of flexo press is a central impression press, which uses a large-diameter common impression cylinder to carry the web around to each color station. The advantage of such a press is the ease of maintaining proper registration. The use of larger impression cylinders (up to 83 inches in diameter) has, in the past, led to an increase in press speed, but as drying methods have improved there is no longer a strict correlation between larger impression cylinders and increased speed. Central impression presses are not overly useful for faciliating reverse printing, however.

An in-line press is a third type of multi-color press; separate color stations are mounted in a horizontal line from front to back. They can handle a wider variety of web widths than can stack presses, but as with stack presses it can be difficult to maintain accurate register on some substrates. The in-line press can also make use of turning bars to "flip" the web over, allowing easy reverse printing.

'Sheetfed Flexography'. Flexographic presses are rarely sheetfed, although most, if not all, corrugated board is printed in sheets rather than as continuous webs. The rigidity of the substrate enables it to be kept horizontal throughout its trip through the press. The sheets are essentially pushed into a set of feeder rollers which send them through the impression nip(s) and finally to the outfeed stack. Printing can be accomplished either by printing on the top of the sheet or on the bottom.

'Hybrid Flexographic Presses'. There are several varieties of "hybrid" printing processes that combine aspects of flexography with other methods.

Flexo Gravure. Flexo Gravure is a form of offset gravure. Offset gravure printing essentially replaces the flat offset plate with a longer-lasting gravure cylinder, transferring the image to a rubber blanket which, in turn, transfers the image to the substrate. In flexo gravure, offset gravure is performed on a flexographic press, with the gravure cylinder replacing the anilox roller. A rubber blanket (such as that used in offset lithography) is mounted on the flexo plate cylinder. The ink is transferred to the engraved cells of the gravure cylinder (which, unlike conventional gravure, need to be engraved so that the image is right-reading); the image is then offset onto the rubber blanket (where the image becomes wrong-reading), and is finally transferred onto the substrate. Flexo and offset gravure are utilized when the desire for the high-quality gravure image carrier and long life of the gravure cylinder are needed for substrates that are not easily printed by traditional gravure. The flexible rubber blanket ensures high-fidelity image transfer on a wide variety of surfaces.

Offset Flexo. Offset flexo is a hybrid of flexography and offset lithography in which the anilox roller transfers the ink to a flexo plate (which needs to have its image in positive-reading form) which then offsets the image to an offset blanket cylinder mounted between the plate and the impression cylinder. Cylindrical plastic containers need to be printed in this manner. In some presses, all the color stations are positioned around a single blanket cylinder, and a multi-colored image is registered on the blanket, a single multi-color image being transferred to the substrate in essentially one pass.

The main advantage of flexographic printing, as was mentioned earlier, is its ability to print on many different types of substrates. There are far too many flexo substrates used to provide a comprehensive list here; flexo presses print everything from breath-mint wrappers to plastic packages that hold king-size mattresses. In the past, different types of polymers (i.e., plastics) mixed together tended to yield poor substrates with low print characteristics, but new advances in chemistry and manufacturing are producing new blends of plastics—known as "plastic alloys"—which can impart different qualities to the final product, such as increased strength, chemical resistance, resistance to the penetration of oxygen or other gases, etc. As the substrates change, so must the ink; cooperative efforts between ink manufacturers and the manufacturers of substrates ensure that for each new substrate that can be printed a compatible ink will enable printers to utilize it effectively, efficiently, and economically.