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A Historical essay on the development of flexography

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Master's Thesis

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A Historical Essay on the Development of Flexography

by

Ana Maria Gómez

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A Historical Essay on the Development of Flexography

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Acknowledgments

This essay could not have been written without the help of a generation of people. These people are men like Henry Salmaggi, Wray Peal, Charles Heurich, Harry Mosher, Sam Gilbert, Jerry Shields, Joe Trungale, Joel Shulman, and Robert Zuckerman. They are men that have dedicated their lives to Flexography and who have shared their knowledge with me unselfishly.

Individuals from a younger generation, like Chris Harper, Cory Heiden and Bill Dowdell, were also a very important part of this study and can not be ignored.

Besides these two generations of flexographers, I would like to thank the people of the FTA for their support, as well as Professors David Pankow and Barry Lee for their immeasurable cooperation.

Such is flexography's past.

With exciting new developments happening all the time, its future is undoubtedly just as bright.

—FTA: Flexography, Principles and Practices, 1995

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List of Terms

Abrasion: Process of wearing away the surface of a metal by friction.

Abrasion resistance: Ability to withstand the effects of repeated rubbing and scuffing. Also called rub or scuff resistance.

Abrasion test: A test designed to determine the ability to withstand the effects of rubbing and scuffing.

Absolute humidity: Actual weight of water vapor contained in a unit weight of air. Relative humidity (RH) is the ratio of actual humidity to the maximum humidity which air can retain without precipitation at a certain at a given temperature and pressure.

Absorption: Penetration of one substance into another. In printing, the selective absorption of some of the wavelengths of white light produces colored light.

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

Accelerate: To hasten or quicken the natural progress or process of an event or a series of events. In flexographic printing, as by the addition of a faster drying solvent or by increasing the temperature or volume of hot air applied to the printed surface.

Accelerator: A substance added or method used, to hasten or quicken the natural progress or process of an event or a series of events.

Acetate: A family of solvents also known as esters; example normal propyl acetate. One of, or the family of, cellulose acetate films.

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

Acid: A compound which yields hydrogen (H) ions in solution in water; has a corrosive action in many materials, sour in taste, reddens litmus paper. Concentration stated in terms of pH values; 7 is neutral, lower number indicates acidity. The lower it is, the greater the acidity.

Across web or cross web: Direction at an angle of 90 degrees to the grain or machine direction of a web or sheet of flexible material; also transverse direction (TD); a cross grain lateral.

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

Actinic rays: Those rays of light which cause the most intense chemical change to take place in plastic films, lacquer, photographic emulsions, etc.

Activate: To put into a state of motion or increased chemical activity.

Activator: A chemistry used on exposed photographic paper of film emulsion to develop the image.

Additive color: Color reproduction by the combination of red, green, and blue light, e.g. television.

Adhere: The sticking together of two surfaces by adhesion, as ink to stock.

Adhesion: The state in which two surfaces are held together by interfacial forces; measure to the strength with which one material sticks to another.

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

Age resistance: The resistance to deterioration by oxygen and ozone in the air, by heat and light, or by internal chemical action.

Agglomerate: A cluster of undispersed particles.

Agitation: A stirring action; violent or irregular motion.

Alcohol: A group of organic solvents used in flexographic inks. $(CH_2)_nOH$

Aliphatic hydrocarbons: Solvents obtained by fractionation of crude petroleum oil. Examples are textile spirits, VMP Naphtha, gasoline and kerosene. Frequently used as part of the solvent mixture in "co-solvent" and "polyamide" type flexo inks, in conjunction with Buna-N type plates and rollers; tend to swell natural and butyl rubber.

Alkali: Chemical agent, generally soluble in water, capable of neutralizing acids. Usually caustic; pH of 7 is neutral, up to 14 indicates degree of alkalinity; base.

Anchor coat: A coating applied to the surface of a substrate to effect or increase the adhesion of subsequent coatings.

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

Aniline printing: Early name for rubber-plate printing using fast-drying aniline-based fluid inks. Now obsolete.

Anilox roll: Mechanically- or laser-engraved steel and chrome-coated metering roll used in flexo presses to meter a controlled film of ink from the contacting elastomer-covered fountain roller to the printing plate that prints the web. Volume of ink is affected by the cell count per linear inch and dimension of the cell and cell wall of the engraving. Manufactured from copper and chromium plated steel. Also given a coating of aluminum oxide (ceramic) or copper and chrome.

Anilox system: The inking system commonly employed in flexographic presses consisting of an elastomer-covered fountain roller running in the ink pan, adjustable against a contacting engraved metering roll, the two as a unit adjustable to the printing plate roll, elastomer design roll, or plain elastomer coating roll, as the case may be. Ink is flooded into the engraved cells of the metering roll, excess doctored off by the wiping or squeezing action of the fountain roll or a doctor blade and that which remains beneath the surface of the metering roll is transferred to the printing plate.

Antioxidant: A substance which prevents or reduces the rate of oxidation due to exposure of the material due to air or oxygen.

Applicator roll: Coating roll, print roll, tint roll, lacquer or varnish roll.

Artwork: The original design, including drawings and text, produced by the artist. All elements from the design from which the black and white art and printing plates are made; also refers to all of the black and white production art.

A.S.T.M.: American Society for Testing Materials.

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

Back printing: Printing on the underside of a transparent film; also called reverse printing.

Base: Often used in referring to a full strength ink or toner. Generally refers to the major ingredient used in a clear lacquer, varnish or ink. May refer to either the solvent or binder system. A cylinder before it is engraved. Base film before addition of coating.

Binder: The adhesive component of an ink, normally supplied by the resin formulation; the ink vehicle. In paper, an adhesive component used to cement inert filler, such as clay, to the sheet or to affix short fibers firmly to paper or board stock.

Blocking: An undesired adhesion between touching layers of material such as might occur under moderate pressure and/or temperature in storage or use; to extend that damage to at least one surface is visible upon their separation.

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

Bold face: Heavy face, in contrast to light face type. Used for emphasis, captions, subheadings, etc.

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

Buna-N: A synthetic rubber made from butadiene and acrylonitrile, used in the manufacture of flexo plates and rolls. Resistant to aliphatic hydrocarbons, alcohols, Cellosolve and water. Not resistant to aromatic hydrocarbons and esters (acetate).

Caking: The collection of dried ink upon rollers and plates.

Cellophane: Transparent flexible sheeting consisting of regenerated cellulose plus plasticizers with or without functional coatings such as moisture proofing.

Cellosolve: Trade name for ethylene mono-ethyl ether which is used as a retarding solvent in flexographic inks.

Central impression cylinder press: Printing press in which the web being printed is in continuous contact with a single large-diameter impression cylinder. The color stations are moved in to the central impression cylinder for printing and are arranged around its circumference.

Chalking: A condition of a printing ink in which the pigment is not properly bound to the paper and can be easily rubbed off as powder.

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

Chroma: The strength or intensity of a color.

Chromium plate: A thin covering of chromium — usually over a copper or nickel base.

Colorant: The color portion of the ink which may be pigment or dye or a combination of the two.

Converter: Refers to that type of manufacturer who produces printed rolls, sheets, bags or pouches, etc., from printed rolls of film, foil or paper.

Co-solvent: One of two or more solvents in a mixture which together dissolve a solid.

Deflection: Derivation from a straight line under load. Fountain roll pressure against the anilox roll causes both to bend or bow slightly. Excessive bending of both or either one will result in uneven ink metering and subsequent non uniform printing.

Density: The mass of a unit volume; opacity; color strength.

Die cut: (verb) To punch out with a sharp tool.

Dimensional stability: Resistance to dimensional change resulting from ambient atmospheric or other conditions.

Doctor blade: A thin flexible blade mounted parallel to and adjustable against an anilox roll for the purpose of, controlled removal of excess ink.

Dot gain: Increase in size of a dot from the film to the printed sheet. Dot gain consists of two parts, physical dot gain and optical dot gain due to the physics of light absorption and reflection.

Dyes: Coloring materials which are soluble in an ink vehicle as opposed to pigments which are not soluble and must be dispersed.

Elongation: Longitudinal deformation resulting from stress, or from stretching.

Etch: To dissolve the non-printing areas of a metal plate by the action of an acid as in the engravings used to mold the matrix.

FFTA: Foundation of Flexographic Technical Association.

FTA: Flexographic Technical Association.

Fastness: Term used to denote the stability or resistance of stock or colorants to influences such as light, alkali, etc.

Film: Unsupported, basically organic, nonfibrous, thin, flexible material of a thickness not exceeding 0.010 inch.

Finish: The degree of gloss or flatness of a surface.

Flexo: Abbreviation for Flexography.

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

Glassine: A type of translucent paper.

Gloss: The ability of a surface to reflect light.

Halftone: Photographic image formed by a pattern of discrete dot sizes. Dots vary in area and shape but have uniform density. Creates the illusion of continuous tone when seen at a distance

Image areas: The area of the printing plate which transfers ink to the substrate. The printing area of a receiving surface.

Impression: The image transferred from the printing plate to the substrate. The adjustment required to effect the above.

Impression cylinder: Roller or cylinder which backs up or supports the web at the point of impression.

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

In-line press: A press coupled to another operation such as bagmaking, sheeting, diecutting, creasing, etc. A multicolor press in which the color stations are mounted horizontally in a line.

Kiss impression: The lightest possible impression which will transfer the film of ink from the plate to the material being printed.

Laminate: A product made by bonding together two or more layers of material or materials.

Light fastness: The property of a paper which renders it resistant to change in color. Depending upon its use, a paper or paperboard may be required to show good resistance (fastness) to change in color after exposure to destructive influences such as light, acids, alkalis, or bleaching agents.

Makeready: The preparation and correction of the printing plates before starting the printing run to ensure uniformly clean impressions of optimum quality. All preparatory operations preceding production.

Matrix: A mold made from an engraving or type form from which a rubber plate is then molded.

Mil: 1/1000 of an inch; 0.001".

Misting: A mist or fog of tiny ink droplets thrown off the press by the rollers; flying, flinging.

Moire: An undesirable geometric configuration that distorts the original image, and is created by not rotating of engling the halftone screens properly.

Mounting and proofing machine: Device for accurately positioning rubber plates to the plate cylinder and for obtaining proofs for register and impression off the press.

Nip: Line of contact between two rollers.

Off-press proof: A simulation of the printed job produced directly from digital information or photo-

graphic films.

Opaque: Impervious to light rays. An ink exhibiting light-obstructive qualities.

Overprint: The printing of one impression over another.

Photopolymer: An elastomeric polymer so made that it undergoes a physical change on exposure to light.

Picking: The lifting of any portion of a surface during the printing impression.

Pigment: Insoluble color matter used in finely divided form to impart color to inks, paints, and plastics.

Polyethylene: A synthetic resin of high molecular weight resulting from the polimerization of ethylene gas under pressure. PE

Polypropylene: A synthetic resin of high molecular weight resulting from the polimerization of propylene gas under pressure. PP

Press proofs: Proofs made on a press, using the intended substrate, to obtain approval or final corrections before the production printing run is made.

Process inks: For reproduction illustrations by halftone color separation process. The four colors are: yellow, magenta, cyan, with and without black.

Proof: A test photographic print or trial impression from a printing job taken for correction or examination.

Register: In printing, the fitting of two or more images on top of each other in exact alignment.

Repeat: The printing length of a plate cylinder, determined by one revolution of the plate cylinder gear.

Reverse printing: When color sequence is reversed for printing on transparent film 2. Printing on the underside of a transparent film, known also as reverse side printing. 3. Design in which the copy is "dropped out" and the background is printed.

Rubber: An elastomeric material that is capable of recovering from large deformations quickly and forcibly.

Scuff: The action of rubbing against with applied pressure.

Shade: A color produced by a pigment or dye having some black mixed in it, therefore darkening it. Opposite of tint.

Shelf life: The length of time that a container, or a material in a container, will remain in an acceptable condition under specified conditions of storage.

Shell cup: A device used for measuring viscosity.

Shellac: An alcohol-soluble natural resin widely used in flexo inks.

Solvent: The medium used to dissolve a substance.

Stack press: Flexo press where the printing stations are placed one above the other, each with its own impression cylinder.

Stickyback: Double-faced adhesive coated material used for mounting elastomeric printing plates to the plate cylinder.

Substrate: A foundation material on the surface of which a substance may be deposited for a purpose such as printing, coating, etc.

TAPPI: Technical Association of the Pulp and Paper Industry.

Tensile strength: The ability of a material to withstand stretching.

Tints: A means of making a given color appear lighter in value by printing in a dot or line pattern of less than 100% coverage in any given area. Colors of light value obtained by mixing white in it. Opposite of shade.

Transparent inks: Inks which do not have hiding power and permit light to pass through.

Vehicles: The liquid components which holds the pigment in a printing ink.

Viscosity: Resistance to flow.

Web: The paper, foil, film, or other flexible material, that unwinds from a roll or sheet, as it moves through the machine in the process of being formed, or in the process of being converted, printed, etc.

Zahn cup: A device for measuring viscosity.

Abstract

The objective of this thesis is to describe the development of flexography in a historical essay, which will be a contribution to the history of printing technology. The starting point will be 1890, the year when the first patent for a rotary press using rubber plates was obtained, and the study will continue to the present day, including the latest developments.

Industry developments, as documented in various technical journals and other publications throughout this time span, will be the main source of information; but interviews with some of the people who have witnessed and participated in the growth of the process will also be used as supporting material. The Flexographic Technical Association, its library and members, has also been a source of invaluable information.

Chapter 1

Introduction

There are three basic commercial printing processes, namely, lithography, gravure, and letterpress, of which flexography is an offshoot. Though the history of lithography and gravure have been well documented, incredibly, the story of the development of flexography has not yet been written. The goal is to write this history, and, in this way, fill the gap that exists in the documentation of this important industrial process.

Though no books have been devoted to the history of flexography, many articles have been written about the various technological developments that have led to its current prominence. The main idea is to extract from these articles as much relevant information as possible, organize it, and supplement it with the experiences of people who worked in the early days of this industry.

The final product is a book that discusses the different technological developments of an important printing process, and how they succeeded each other in order to go from the primitive Aniline printing of the early years of the century to today's Flexography.

Chapter 2

Historical Background and Literature Review

1853	U.S. patent No. 9548 issued to J.A. Kingsley for rubber plate compounds for printing.
1890	Bibby, Baron & Sons built the first aniline press.
1905	First aniline press built by C.A. Holweg from Alsace Lorraine. He was granted British patent No. 16519 in November 1908.
1900	First corrugating machine built.
1909	Introduction of vulcanised rubber plates for printing on corrugated boards.
1911	First plastic plate developed by J.W. Alysworth.
1915	Introduction of individual wrappers such as bread bags.
1925	Patent No. 1,552,821 was given to Arthur Case for a Flexible Form Printing Machine.
1927	Earliest dyestuff inks developed by Geigy Co.
1930	Development of cellophane.
1930	Stan Avery develops pressure sensitive labels.
1931	James J. Deeney developed a pigmented white ink that gave opacity to transparent inks.
1932	Edward J. Peal builds and designs the CI press.
1937	3M introduces Scotchtape.
1940	Kidder Press Co. introduces the first aniline press with drying equipment.
1941	Introduction of the anilox roll by Interchemical Corporation.
1950s	Introduction of polyethylene as packaging material.
1951	First patent of a mounter proofer by Mosstype Corp.
1952	Adoption of the name "flexography" instead of aniline.
1954	Polypropylene was discovered
1958	DuPont introduces the first photopolymer plate.
1958	Creation of the FTA
1961	First course in flexographic printing given at RIT.
1962	Development of the reverse angle doctor blade.
1964	Elimination of the rubber roller as metering device and replaced by the reverse angle doctor blade.
1985	The *Sarasota Herald Tribune* is the first newspaper to print its daily edition flexographically.

TABLE 1 — DEVELOPMENT OF FLEXOGRAPHY TIMELINE

Literature Review

Most of the reference materials used for this thesis project are articles that have appeared in various technical journals or magazines. Besides these written documents, interviews with people from the industry and founders of the Foundation of the Flexographic Technical Association were used as valuable resources.

A book which contains a summary of the history of flexography is *Flexography, Principles and Practices* published by the FTA. This publication will also be cited from time to time to explain the mechanisms of a flexographic press, the way it is built and the way it actually prints. Two other books that were used were: *They Built an Industry,* by Bill Klein, which discusses the appearance of narrow flexo presses and *The Anilox Roll–Heart of the Flexo Press,* by Joseph Trungale, which discusses the technological developments of this crucial part of a flexo press.

Articles that have appeared in various magazines were another source for this project. Some of these magazines are *The Inland Printer, TAPPI Journal, Penrose Annual, Paper, Film and Foil Converter, The American Pressman, Paper Trade Journal, Printing Equipment Engineer, Print,* and *Flexo.*

Finally, the library and everyone at the FTA were also very helpful. The most valuable source, however, were the people from the industry who have accumulated a vast personal knowledge, as well as their own libraries on flexography, and were willing to share them with me. In addition to published references, these people have memories of the industry and its growth that could not be considered less important. These people include Charles Heurich, Mark Andrews, George Parisi, Wray Peal, Henry Salmaggi, Fred Shapiro, Sidney Shapiro, Al Bradie, Harry Mosher, Joe Trungale, Chris and Ron Harper, Jerry Shields, Sam Gilbert, Joel Shulman, Cory Heiden, Charles Weigand, and Robert Zuckerman; as well as Mark Cisternino and Bill Dowdell from the FTA.

Chapter 3

Statement of Problem and Goals

Since the latter part of the nineteenth century, various technological developments have made possible a printing process that prints from rubber plates using inks that will adhere to absorbent and non-absorbent materials. This process was originally known as aniline printing; today it is known as flexography. Incredibly, despite a century of constant developments and discoveries, the history of the process has not been properly documented for future generations to study. During all these years, many articles have been written on different aspects of flexography, but no complete history is available.

When someone writes a thesis project, he or she must have several goals in mind. If not, it will simply not get done. A thesis project is not just another degree requirement, it has to be something that enriches you and the community in some way.

When the thesis project topic was decided, there were two main goals in mind. Mainly doing something that would be useful for the industry. After founding out there was no real history of flexography written, it seemed like the perfect idea. The possibility of writing the history of a printing process that had had almost all of its major developments during the twentieth century was present, and in that way helped preserve the memory of an important industrial process. If the history of something is not written while many of its contributors and participants are still alive, the risk of losing valuable information increases dramatically. This is why interviews with the people on a list supplied by the FTA have been incredibly important.

The second goal is writing a book that will help future generations of printers to know how this process went from something once called "Bibby's folly" to flexography as we know it today.

Chapter 4

Methodology

The methodology used in this thesis project consisted of extensive research to uncover all the articles written throughout this century that mentioned any aspect of flexography. Most of the articles that have been written on flexography are available in the Wallace Library at RIT; those that are not, were available in the FTA library, or had to be obtained from different sources. In a few cases the articles known to have been written could not be tracked down.

Besides the research into published material, interviews were conducted with various people who have retired from the industry and were willing to help. Some of these interviews were held at the Flexo Forum in San Antonio, Texas during the first week in May, 1999. The remaining ones were conducted by telephone or in person.

The main purpose of these interviews was to help fill in the gaps that existed in the written material.

Basic Outline

Introduction

Part 1 Origins up to 1930

Part 2 - Development 1930–1950

Part 3 - Polyethylene and the next decade

Part 4 Recent history

Part 5 - Flexo and the Environment

Part 6 What Does the Future Hold?

Chapter 5

The History of Flexography

Introduction

The man who says it can not be done
is generally interrupted by the one already doing it.

—David Silverman

The name flexography was not adopted until 1952, when it was announced at the 14^{th} Packaging Institute Forum held on October 20-22, 1952 at the Hotel Commodore in New York City. Before that it was called aniline printing in reference to the kinds of inks typically used in the process, but, because of the possible health hazards that aniline posed in contact with food, Franklin Moss of the Mosstype Corporation started a crusade to change the name and the image of the printing process.

By 1952 flexography was commonly defined as a method of rotary letterpress printing that used rubber printing plates and fluid, rapid-drying inks. In the 1980s this definition was modified by the FTA to "a method of direct rotary printing using resilient raised-image printing plates, affxed to variable repeat plate cylinders, inked by a roll or doctor-blade-wiped engraved metal roll, carrying fluid or paste type inks to virtually any substrate."

Most printing processes can be described, in an extremely simple way, as "divided into three steps, . . . 1. application of ink at the printing station, 2. penetration of ink into the substrate, and 3. drying of the ink by evaporation."[1] This is true of all traditional printing methods, including flexography. The three basic characteristics of flexography are: 1. flexible relief plates, 2. fast-drying fluid inks, and 3. web printing, even though corrugated blanks are printed sheet fed. The combination of these three

factors makes this process unique. Another factor that makes flexography especially attractive is the variable repeat lengths possible with very little effort. Repeat lengths can be varied in intervals of ¼ inch more or less. Presses are designed so that a plate cylinder can easily be replaced by another of a different size. The materials that can be printed by means of flexography are extremely varied, ranging from thin tissue to 40-pt board, corrugated materials, as well as synthetic stocks like cellophane, polypropylene, vinyl, and laminated foils.

Endnotes to Introduction

[1] W.J. Hurrel and P.A. Gartaganis, "New Test Instrumentation for Quick-Drying Inks," *TAPPI* 52 (January 1969): 104.

Part 1

Origins up to 1930

Aniline printing was a simple form of letterpress printing in rotary form.

—Henry Salmaggi

The idea of printing with rubber plates originated in the U.S. some seventy years before its first real commercial application. The idea of a rotary press that used rubber plates may have been inspired by the one seen in figure 1 used for printing wallpaper in 1779.

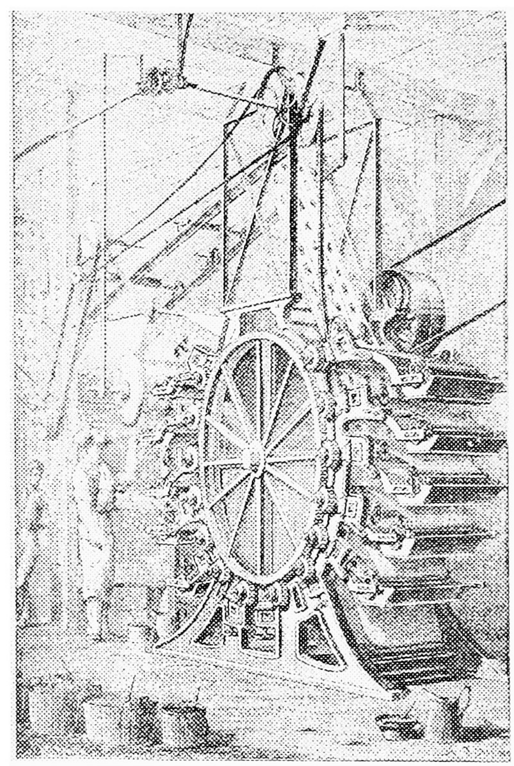


FIG. 1 — 1779 WALLPAPER PRINTING MACHINE

In 1853 J. A. Kingsley obtained U.S.patent No. 9548 for a rubber plate compound suited for printing. Even though the concept was apparently not developed further in the U.S., Douglas Tuttle assured participants at a *TAPPI* conference in 1962, he had seen a "paperboard match box printed flexographically, in Ohio, in the 1860s."[1] There is no corroborative evidence for this assertion, however.

In 1890 in England, a paper bag printing company, Bibby, Baron and Sons, developed the first rotary press that used rubber plates. This press was used with inks consisting of nothing more than dyes and sugar dissolved in water. This first attempt was referred to as "Bibby's folly" because "from a mechanical, as well as an ink standpoint, it was a monstrosity."[2]

Though improvements were made to the press, a suitable ink proved to be a considerable stumbling block. Around 1905, however, C.A. Holweg, from Alsace, Lorraine, in France, developed a press that used synthetic aniline dyestuff dissolved in alcohol to print paper used for making bags, thus giving birth to the aniline process. Since these inks dried so fast, he attached the press to a bag-forming machine, and created the first continuous operation for printed bags. In 1908, he received British patent No. 16519 for the first aniline printing press. After World War 1, Holweg started to export his printing presses to the U.S.

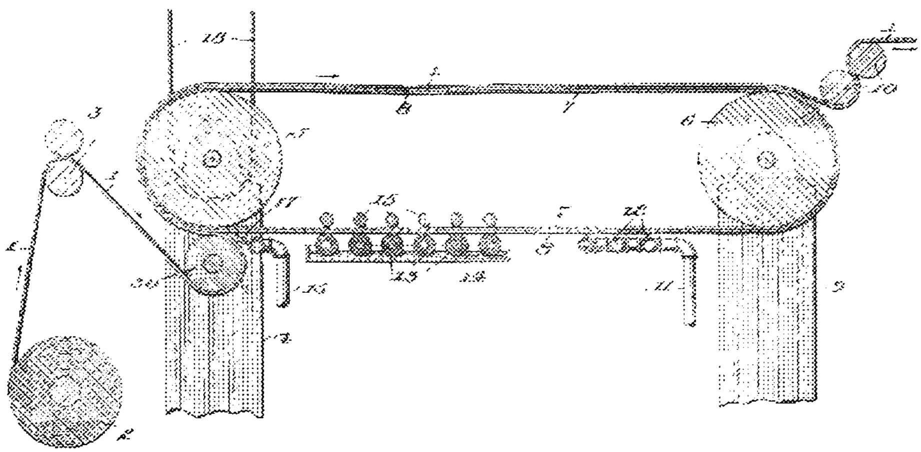


FIG. 2 — 1925 FLEXIBLE FORM PRINTING MACHINE

In September 1925, US patent No. 1,552,821 was given to Arthur Case for his invention of a "Flexible Form Printing Machine." Figure 2 shows the original diagram that appears in Case's patent. According to the text that accompanies the design, the web that is going to be printed, 1, passes through an impression roller, 30, then across rollers, 10, and out to the rewind. There is a metallic carrying belt, 7, to which a printed form, 8 is attached either with cement, glue or any other adhesive. The form is inked with "pure liquid ink or dye of any suitable composition,"[3] which is forced upward by the way of sprays, 12. The form can also be inked by rollers, 13, which pick up ink from the ink pan, 14. These inking mechanisms can be used together or separately to ensure proper inking of the form. In order to ensure clear impressions and avoid smeared copies, cleaning fluid, 17, sometimes no more than just water, is sprayed onto the form just before it comes in contact with the web.

Another early aniline press was built in 1928 by Potdevin. (figure 3) This press was used in-line with a bag tuber. The plates were mounted on canvas and held on the plate cylinder by a rod-and-reel shaft arrangement.

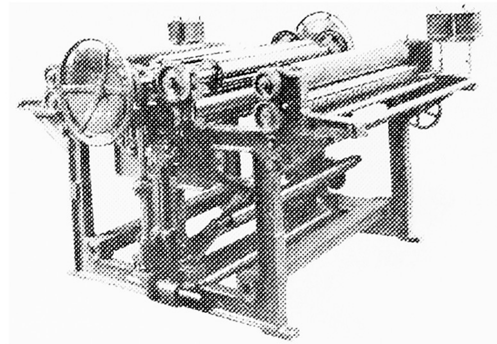


FIG. 3 — POTDEVIN PRESS BUILT IN 1928

During the first years of the century, corrugated boards were introduced as packaging material. The first machine that made corrugated cardboard is said to have been perfected around 1900 by Byron Langstan. Since corrugated material could not be printed with any available methods because of the high compression exerted by the various cylinders in a conventional press, a new method was necessary. The answer was a combination of a rubber plate, oil-based inks, and corrugated board. Even though, it could not strictly be called flexographic printing, it was the first attempt at printing with a rubber plate in one of today's leading flexo markets.

In 1909, the first plates made of vulcanized rubber for printing on this new material were created. In 1914, the Interstate Commerce Commission accepted corrugated as a packaging material with "protective capabilities similar to [those] of wood." The acceptance of these attributes was especially important when the supply of wood for crates decreased at the begining of World War 1, and the demand for corrugated increased dramatically, with a corresponding increase in the demand for corrugated printing.

The aniline presses exported to the United States were usually of two different types. The ones made by Holweg, and those by the German firm of Windmoeller & Hoelscher (figure 4), were known as stack-type presses; while those made by the British at Strachan and Henshaw were of the central impression type. What came to be known in the U.S. as the Heinrich press was actually a type of press manufactured by Windmoeller & Hoelscher, but

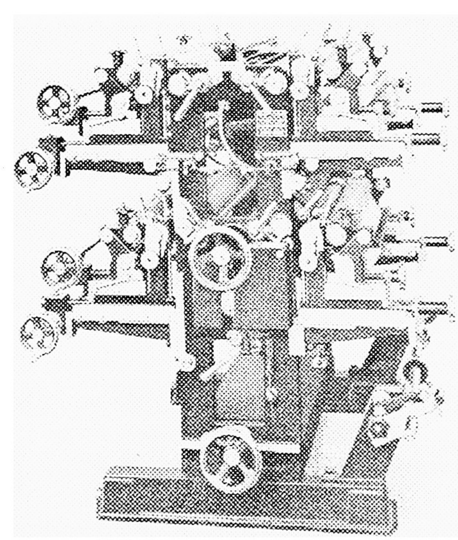


FIG. 4 — 3 COLOR W&H IN 1930

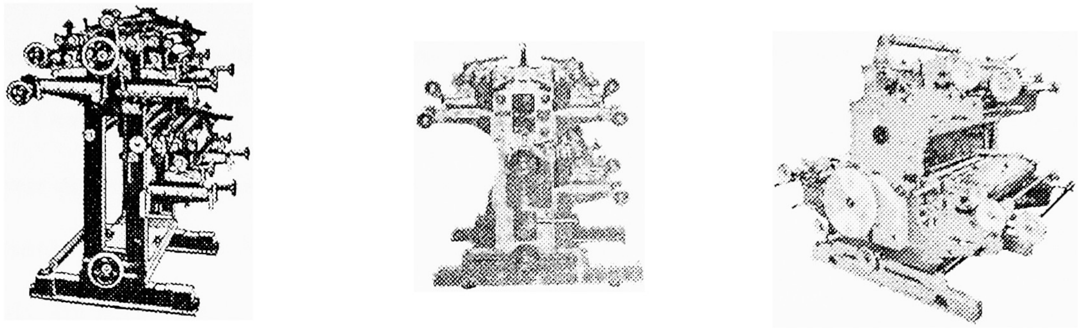


FIG. 5 — 3 GENERATIONS OF HEINRICH PRESSES (1927, 1937, 1957)

imported and sold by H. H. Heinrich. These were one-, two- or three-color presses that ranged in width from 16" to 36". (figure 5).

These presses were very simple in design. "The framework [was] . . . light in structure and hard to hold to the floor."[4] They consisted mainly of an ink pan, a fountain roller, an ink roller, a plate cylinder, and an impression cylinder. Since early aniline presses were so simple, many converters built their own machines or had them built to meet their needs; many printers also prepared their own inks and rubber plates, accounting for the poor quality of much early printing. This so-called "do-it-yourself" period lasted from 1920 to 1935.

The major problem with early presses was that working with them was extremely messy. Since there were no accurate ink metering mechanisms, ink splashed all over the floor. Rudimentary ink metering was accomplished by changing the pressure between the inking roll and the fountain roll. Both of these rolls were generally rubber, and the extra ink flowed back into the ink pan. The ink roller transferred the ink film to the plate, which then transferred it to the web in what is known as a "kiss" impression. There were no ink circulation devices built into the presses, so ink had to be stirred constantly with a wooden paddle. Typically, no splash guards were provided.

As early as 1915, the future of flexography was already being molded. Individual wrappers in the form of bread bags were being introduced into the baking business. New papers were appearing on the market everyday with waterproof, greaseproof, or alkali-proof properties. Such papers now made it possible to package difficult products like soaps and meat. Besides making packaging of different products

possible, all these materials could now be printed. Laundries were also begining to pack their products in transparent plastic, another market where flexography would one day become dominant.

During the 1920s, "one of the many problems encountered . . . was that of inadequate ink."[5] Inks were mainly coal-tar dyestuffs soluble in water that became smear proof when dissolved in alcohol with tannic and acetic acids. They were called aniline inks because the colorants used were mainly aniline oils. But these inks bled when wetted, followed the fiber of the paper, and did not print sharply. Small type printed by this process was "all but [legible.]"[6] These inks also had a short shelf life and poor light fastness.

Ink makers had a low regard for aniline printing because the quality produced was poor. They felt they were wasting their time developing quality inks for such a product. Only in 1927 did Geigy Co. begin to introduce inks that were of any real value. They were made of tri-methyl methane (basic dyestuffs) dissolved in cellosolve and chemically fixed, thereby preventing them from bleeding when they were wetted. Soon after came the dry or powdered inks developed by National Aniline, General Dyestuff Co., Calco Chemical Co., and DuPont. These inks were easier to store and formulations could be accommodated to press requirements.

The main problem caused by aniline inks was not the quality of the final product. These inks were extremely toxic due to the raw materials used to make them. Once toxicity in the inks was overcome, the bad reputation still remained and this was one of the factors that moved Mr. Franklin Moss to look for a new name for the process. Current flexo inks used for newspaper printing are even proven to be potable.

Since alcohol was the most common solvent for aniline inks, the resins used for making the inks needed to be highly acidic. Acidic resins react with the pigments in aniline inks, thereby, binding the ink to the substrate and enhancing ink properties such as strength, quality and water fastness. Shellac was the most common resin during the early years of aniline printing. The characteristics which made it suitable were: high melting point, solubility in alcohol, fast solvent release, good color properties, relatively high acid value, and most important, compatibility with aniline dyes.

Ink chemistry was advancing at a very fast pace, but ink manufacturers had to be very careful with the ingredients used to formulate the various inks. Ingredients like copper, linseed oil, brass, chromium, or salts of manganese to induced rubber to harden and perish.

Germany and England were the first countries to introduce new platemaking materials to flexography. Rigid rubber plates, for example, developed as an inexpensive alternative to metal, and were used in these countries as early as the beginning of the century. About a decade later, Bakelite Co. produced a phenolic plastic matrix to replace the clay molds originally used for rubber platemaking. The first plastic plate was developed in 1911 by J.W. Alysworth and was made from phenol-formaldehyde. By 1917, his technology was used for rubber stamps for printing war posters. The plastic matrixes developed by Bakelite Co. led to the introduction of natural rubber plates, which were also used to print on paper bags and cellophane.

In 1932 synthetic rubber was introduced for platemaking. Its main advantage was that it did not absorb oil-based inks or swell. By the end of the decade the prices for synthetic rubber were very close to those of natural rubber, also favoring the change over. Early rubber plates were hand-engraved using a set of engraver's tools or a pen knife, or molded with specialised equipment. The material on which plates were cut was known as engraver's gum. Since rotary presses were not very common, rubber plates were usually mounted on flat-bed presses, or on platen presses. Vynil was also used as plate material since its light weight reduced shipping costs.

Plates made from either rubber or engraver's gum were used for printing on a wide range of materials which could not be printed with metal plates. Some of these materials included: jute, or burlap, for making sacks, wood, glass, and celluloid. Hard materials such as tin, lead, enamelled iron for signs, and laminated wood for toys were also being printed with the new types of plates. The possibility of printing on all of these materials opened up a whole new field of advertising on useful objects like wooden spoons or coat hangers. In addition to printing on any substrate, rubber plates also reduced the costs of plates, the makeready time, and very importantly, gave better coverage with less amount of ink.

Platemaking was another major problem during this period. Plates were made from letterpress

electrotypes without taking into consideration the degree to which the plates could stretch when mounted on a cylinder. This caused circles to print as ovals and type to be distorted. Bubbles also appeared because correct moulding temperatures and pressures were not known at this time. In general, platemaking was a very inefficient process.

Even though molded rubber plates were seen at first as the perfect competition, they did not replace photoengraved plates. Rubber plates could not be used for process work because they were incapable of holding fine screens. But spot color jobs were being done at lower costs than was possible with zinc or copper plates. Rubber plates were mainly used for designs on cover pages, posters and diferent advertisement pieces.

The use of rubber plates posed many problems until they were fully developed. Swelling of the rubber caused by contact with oils was very common. Fatty oils posed no problem, but mineral oils caused almost instant swelling because the rubber absorbed most of it. Plates would also swell or expand from the heat generated by excessive friction, or from excess humidity, especially during the summer. However, depending on what the plates absorbed, they could sometimes recover their original form, if let to dry.

Cleaning rubber plates was another headache; kerosene and turpentine, common solvents at the time, could not be used. The best combination was a solution of alcohol and benzol applied with a soft rag. Unfortunately, rags left lint on the plate, which then became evident during printing. The problem with convention press rags was that they were made of short fiber material which would detach from the cloth and stick to the rubber.

Harry Mosher, a flexographic printer during the 1950s and 1960s had a very interesting story on how nylon was discovered to be the best material for cleaning flexographic plates. Sometime around 1960, a company called Rexham in North Carolina was printing hoisery bags for JC Penney. The job included a picture of nine girls from different ethnic backgrounds which was very difficult to print because it was one of the first 150-line screens to be done. Since the job was so demanding, the press crew ran out of press rags very rapidly, and the only thing available were the pantyhose that were to go

in the packages. "But it is very important that you take the girl out first!"[7] was Mosher's closing remark on this discovery. The virtue of nylon rags lay in the rags' long fibers which did not fly off.

In addition to plate and ink problems, presses were not stable enough, and there was a lack of technical knowledge. During this period the quality of flexographic printing was so poor, the process became known as "mechanical rubber stamp printing." These were the years when flexography was developing and growing. In general, it was regarded as "only an inexpensive reproduction process permitting paper converters to print absorbent stocks with fast-drying inks and complete their converting operations as the paper web came from the press."[8] This reputation would rapidly change with new developments that appeared later in the century.

Endnotes to Part 1

[1] Douglas E. Tuttle, "Flexography at the Threshold of the Corrugated Container Industry," *TAPPI* 45 (January 1962): 154A.

[2] *Flexography, Principles and Practices* (Ronkonkoma, N.Y.:Flexographic Technical Association and Foundation of Flexographic Technical Association, 1980), 2.

[3] Ibid, 2.

[4] Arthur Case, "Flexible-form printing machine," patent No. 1,552,821, United States Patent Office (September 8, 1925).

[5] *Flexography, Principles and Practices* (Ronkonkoma, N.Y.:Flexographic Technical Association and Foundation of Flexographic Technical Association, 1980), 3.

[6] Ibid, 4.

[7] Harry Mosher, interview by the author, FTA Forum 99, San Antonio, TX, 4 May 1999.

[8] D. E. Tuttle and Stewart Hoagland, "Aniline – Adolescent of the Graphic Arts," *Print* 7 (November 1952): 1.

Part 2

Development 1930–1950

Flexography was a four-season business.
What worked in summer was no good in winter. The miracle was that so much acceptable work was produced at all.

—Bill Klein

The 1930s was a very important period for flexographic printing. Cellophane was introduced by DuPont and would become the first non-absorbent substrate to be printed by the aniline technique. The invention of cellophane brought growth, but at the same time the industry still faced big problems. The main problems were caused by the inks. Up to this point, flexographic inks were mainly a combination of aniline dyes, shellac, and alcohol, and were transparent. In order to print on cellophane, or on any transparent material, inks are best if opaque. This was also true for printing on colored backgrounds or even on kraft paper. The background color completely destroyed the tonal values of transparent inks.

Finally, in 1931, James Deeney developed a pigmented white aniline ink made of titanium dioxide that could be used as a base coat, and as an additive to give inks opacity. Opacity was the characteristic that the industry was looking for, but because the new aniline inks were not glossy, printed pieces appeared to be of poor quality. At the same time, the standard of living in the U.S. had risen and consumers demanded well-designed, disposable packaging.

After the problem with opacity of the inks was hurdled, the problem of overprinting had to be attacked. In order to get good results by overprinting inks, each layer needs drying time between printing stations. Since the stations in a flexographic press were very close together, sometimes only ten to twelve inches apart, heaters could not conveniently be inserted in these spaces. When heaters were, in

fact, squeezed into a press they had to be manually removed every time the press was stopped. They were also so close to the inking system that the ink dried and caked directly on the rollers. The only solution to this problem was a new press design that allowed more space between each printing unit. However, such changes had to wait until the Depression was over. The "do-it-yourself" stage was still at its peak, and, even though quality had been improved, it still "left much to be desired."[1] according to the Flexographic Technical Association.

Shortly after the appearance of titanium dioxide white ink, pigmented yellow and orange inks appeared on the market. In 1934, metallic inks were also introduced. In 1938, water based inks were developed for printing on paper and paperboard. The early alcohol aniline inks were considered solvent base inks. These new inks were a dispersion of color pigments in a water-protein system, and depended on absorption for drying. However, up to 1955, the inks commonly used in flexographic printing were alcohol or solvent based.

The end of the Depression brought with it new developments, in packaging material. Moisture-proof cellophane and acetate film were now used for making bags, and were added to the existing version of cellophane, glassine, and foil as substrates printed by flexography. Examples of cellophane-printed packaging can be seen in figure 6.

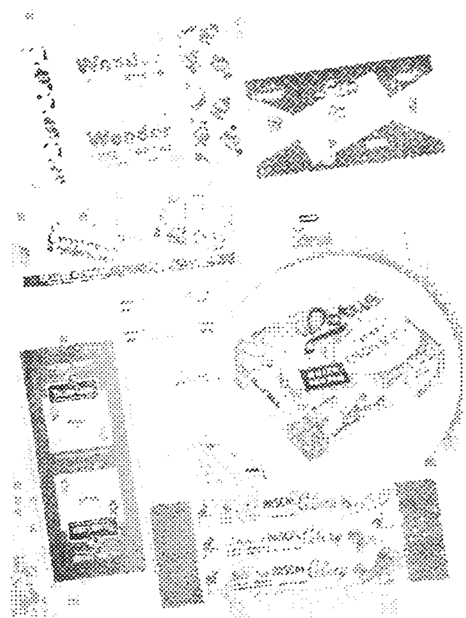


FIG. 6 — PRINTED CELLOPHANE SAMPLES

During the Depression years, one invention gave birth to a whole new industry. This invention came to be know as the pressure-sensitive label. Stan Avery developed the first self-adhesive paper sheets around 1920 while working for The Adhere Paper Company. His assignment was to develop a machine that would apply a coating of adhesive on a roll of paper, and then cover it with a removable backing. The sheets were then cut to size and these were used as "labels" for sticking funeral signs to car windows. By 1935, he was producing "one-sided thumb tacks" that were being used as price

markers and can be considered the first real application of a pressure-sensitive label. Later on, promotional labels were introduced, and before long, name and serial plates, inspection or information labels, and cosmetic identification labels were being produced with Avery's system. In 1940 the idea of a roll label dispenser box was introduced into the market. This new invention gave way to better release liners and synthetic adhesives.

By the end of the 1940s, self-adhesive tape was already being printed, but it required a transparent cover to serve as backing. In 1937, the 3M Company developed the first self-wound tape made of acetate fabric. During the same period, Mark Andrews, Sr., a flexographic printer who started his career in the 1930s, introduced the first tape printers. He described the next step as follows: "we fixed up a perforating device and . . . we could perforate the Scotch Tape . . . it had a nice workup, and the printing was centered properly between the cuts so it had the reasonable appearance of a label."[2] He founded the Mark Andy Company and his first presses were capable of printing very narrow webs, incuding tape that was two to four inches in width. The first presses would not only print, but would also die-cut the pressure-sensitive rolls. The dies would use enough pressure to cut only the top portion of the web, leaving the backing untouched. The advantage of this press was its simplicity and low cost. However, its disadvantage was that it could only produce very simple one- or two- color jobs. These first Mark Andy presses began the "narrow web" segment of the flexographic industry. By the end of the 1950s, the widest Mark Andy was four inches wide and printed a maximum of three colors.

Mark Andrews had a very peculiar method of selling his presses. He carried one around in the back of his car, willing to sell it to whoever wanted to give flexo printing a try, he also sold them without a down payment or a specific repayment schedule. This unconventional method not only boosted his sales, but encouraged many people to set up their own businesses. Mark Donner, founder of Rick Mark Company in Seattle started his company in this way. After the war, without work, he sent Mark Andrews a letter asking for information on his presses. A couple of weeks later a truck pulled up with a press and a note that read "turn it on, you'll see how it operates. Pay me when you can."[3] There was also an invoice for $600 which Donner paid off in one year.

Paul Styers of Emblem Tape remembers some of the problems with early Mark Andy presses. "You had to watch these presses like a hawk. [They] were equipped with old clutches that ran on the friction of a belt or leather strap with a spring. And you could tighten that thing up and get more tension on your rewind, or let it go and, in any case, you would change your registration. . . . It was like trying to play a ukulele that was out of tune."[4]

In 1937, there were four flexographic press manufacturers in the U.S.: Potdevin Machine Co. of New Jersey; Klingrose; Hudson Sharp Machine Co. of Wisconsin; and Kidder Press Co. of Massachusets. These four companies manufactured stack presses, that is, the type used by 95 percent of the printing companies in the U.S. up to 1940. Before real four-color printing could be done using the aniline system, a very simple press design modification was necessary. Earlier presses printed a maximum of two colors using a central impression cylinder. (figure 7) The first four-color aniline presses just duplicated this system and had two impression cylinders with four inking systems.

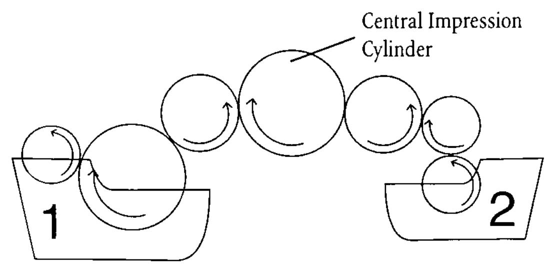


FIG. 7 — TWO COLOR CENTRAL IMPRESSION CYLINDER PRESS

In 1938 Kidder Press introduced the first press designed to print on film, a design used to this day, where by the web travel is overhead. This press was known as the *Celloprinter.* Up to this time, the substrate that was going to be printed had to go underneath the floor to get to the plate cylinder (figure 8); the new design had the web going above. (figures 9 and 10) By the beginning of the war, some

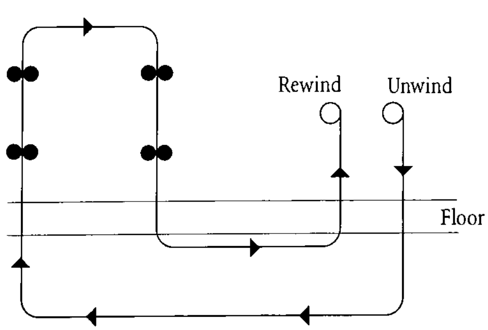


FIG. 8 — STACK PRESS BEFORE 1938

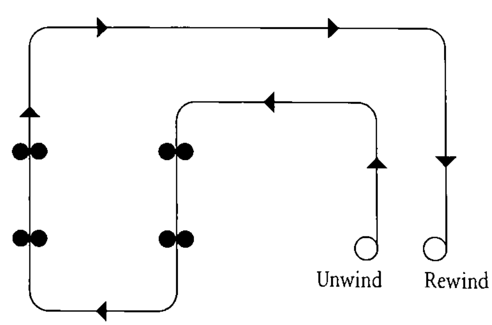


FIG. 9 — CELLOPRINTER

fourteen or fifteen of these presses had been sold in the U.S. After the war, and over the next three years another sixty or so were sold according to Wray Peal. "By the completion of 1948, aniline printing, the predecessor of flexography, seemed to be well on its way as the process of the future."[5]

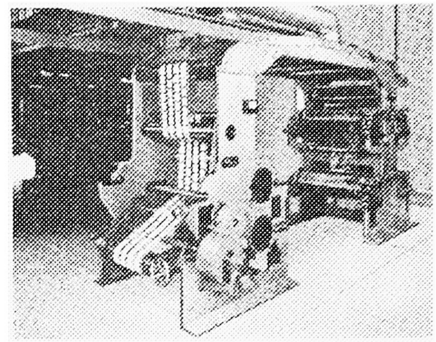


FIG. 10 — PICTURE OF A KIDDER CELLOPRINTER

However, all the presses were not being produced at home; some of the demand was still being supplied by European manufacturers like Windmoeller & Hoelscher, Holweg, and Strachan and Henshaw, all manufacturers of central impression presses. When World War II broke out in 1939, imports of presses from Europe were suspended, and, during the next decade, new press manufacturers appeared in the U.S.

FIG. 11 — 1940 POSTER

The war years brought harsh times to every business. Even though the printing of advertisements or direct mail experienced a clear decline during the war years, stationery and business forms were being printed in greater amounts than ever before. Rubber plates appeared just in time to help these craftsmen produce lower cost pieces even as metal plates were in short supply. Rubber plates were especially valuable when printing solid colors. Some of their advantages included a low initial cost, short preparation, greatly reduced makeready time, and especially important during hard times, long plate life. Figures 11 and 12 show examples of posters printed in 1940 and 1942. In figure 11 only *WHY* and the question mark are printed from rubber plates. Figure 12 is entirely printed from rubber plates.

FIG. 12 — 1942 POSTER

One perfect example of the advantages of using rubber plates occurred in the mid-west in 1941. A small bakery that sold doughnuts in collapsible-type boxes had the price — 10 cents — printed on the package, but saw the need to increase the price to 12 cents. The bakery could not afford to throw away the boxes and reprint them, so a printer proposed an ingenious solution. The printer took the cartons, cut circles out of rubber and overprinted the previous prices. Using the same material, he cut out plates with the new price in reverse figures, and in 48 hours began delivering the "new" packages to the customer.

At this point, printing in register was a big challenge. In order to obtain good register, the plates had to be cut with great accuracy. Since most plates were being hand-cut, the cutter had to be an expert in order to make them register. Several steps were necessary in order to achieve this. First, a drawing was made on tracing paper with a pencil. Then it was wrapped around the roller with the drawing against the rubber. When the back of the drawing was "ironed," the image was transferred to the rubber. Next, the non-image portions were cut away from the roller, and it was then ready to be mounted on press. These were the steps required for a one-color job. When the job required two, three, or more colors, the same original was used to transfer the image to every roller in order to assure registration.

When rubber plates were used on flat presses they posed no problem at all. When they were wrapped around a cylinder, however, distortions were inevitable. Generally rubber plates were made up of two or three layers of fabric covered with a rubber film. The image would be cut out of the top layer (figure 13) The presence of the underlying fabric made it difficult to wrap the plate around a cylinder because it had a tendency to return to its original flat position. Plates were either cemented onto a metal cylinder or tacked onto a wooden one.

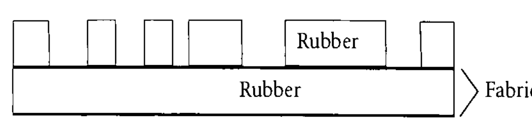


FIG. 13 — ORIGINAL PLATE STRUCTURE

Most of these annoyances did not occur when using molded plates, but these came with their own set of problems. Molded plates were initially made from a clay mold which was then filled with strips of rubber and vulcanised to make the plate. These molds cracked very easily and often left feath-

ered edges on type and images. With this method, it was very complicated, almost impossible really, to control plate thickness and make two identical plates. As soon as bakelite and other plastics were introduced on the market, however, they rapidly replaced clay for making molds. The feather effect on type was eliminated, and breakage occurred less often. In addition to bakelite and other plastics, the introduction of the hydraulic vulcaniser made it possible to control plate thickness.

Even though World War II dominated the first half of the next decade, developments occured in several important areas of flexographic printing.

As already noted, flexographic presses before 1940 did not include a drying system between printing stations, though not for lack of trying. Different devices were designed and adapted to the presses by nearly every printing company. These adaptations to the presses caused a lot of problems, sometimes even fires in the case of a web break. After several years of experimentation, Kidder Press Co. introduced in 1940 the first aniline press with a drying system included. The press included hot air circulating dryers between each printing station for between-color drying, and a hot air circulating oven in the overhead pass. It even included an exhaust system to remove the evaporated ink solvents. Even though these improvements were primitive compared to presses today, they permitted the use of more highly pigmented inks and speeds up to twice as fast as formerly possible.

With time, other drying methods appeared. For example, inks could also be dried by a gas flame placed after the printing units but before the rewind. This gas flame was also used to fuse the ink to the wax coating when used on cellophane. Another method used electric hot bars between units. Hot rollers and strip heaters were also used to help in drying the ink. These different methods could be used independently or combined, depending on the press, printer, or problem. Figure 14 shows a press with all the different drying systems combined.

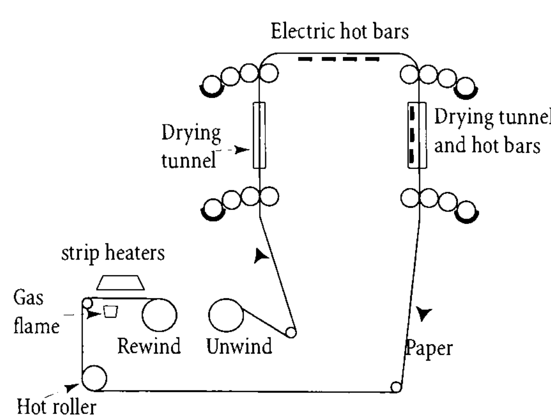


FIG. 14 — VARIOUS DRYING SYSTEMS

In 1941, possibly the most important develop-

ment in the flexographic printing industry was introduced. The graphic arts division of Interchemical Corporation introduced Douglas Tuttle's mechanically engraved metering roll. This roll, called an anilox, was an adaptation of the gravure coating cylinder. Tuttle's metering roll got its name from a line of inks being marketed by Interchemical Corporation at that time with names ending in "ox"; Anilox was simply the tradename for their aniline inks. Interchemical Corporation's policymakers decided that the new technology should be made freely available to the entire industry. They applied for a patent in 1939. Once the application was filed and no one else could claim it, the company chose not to complete the final steps. However, in 1971, Charles Heurich patented a doctor blade device as a means for metering the amount of ink that the anilox roll transfered to the plate. Figure 15 shows the cell pattern on the anilox roll as seen on Heurich's patent No. 3,613,578.

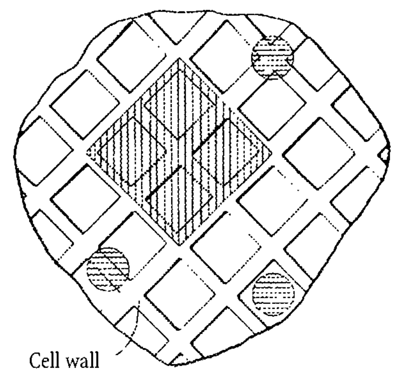


FIG. 15 — ANILOX ROLL CELL PATTERN

The main difference between the roll designed by Tuttle and the one used by the gravure industry was that Tuttle's was made of steel instead of copper because of its greater durability. The material with which the anilox roll is coated is of vital interest to the flexographic industry, and there is a constant search for more durable and longer lasting materials such as ceramic.

The anilox roll served to control the ink film thickness being deposited on the plate. Typically ink film thickness was controlled by a combination of pressure between the ink application roller and fountain roller, ink viscosity, and press speed (figure 16). This caused serious problems when colors other than black had to be reproduced on repeating jobs; the squeeze pressures and ink film thickness were impossible to duplicate

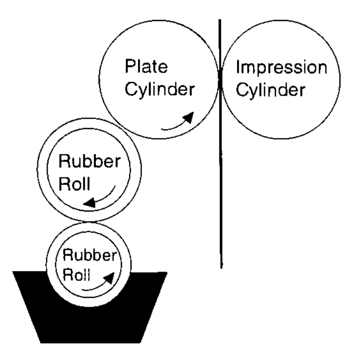


FIG. 16 — PRESS DESIGN BEFORE THE ANILOX ROLL

from run to run. The introduction of the anilox roll gave birth to a newly designed press. (figure 17)

Anilox rolls were chromium plated steel rolls that were mechanically engraved with cells that would pick up the ink from the fountain roller. The excess ink was wiped either by a doctor blade, or eliminated by pressure from the metering roller. The ink film thickness that reaches the plate is controlled by the number of cells on an anilox roll and their depth.

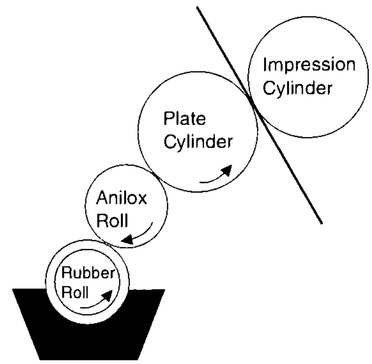


FIG. 17 — PRESS DESIGN WITH AN ANILOX ROLL

Trials over the years concerning rubber roll/anilox roll ratios took place. Eventually it was determined by Kidder Press Co. that ratios must be held to no more than 4-6:1. As the ratio increased, the level of fresh ink needed to rewet that remaining on the anilox's surface, allowed the ink's consistency to approach that of "mud"— much too heavy to allow clean printing. Therefore, because operators wanted to make adjustments, the development of the Reverse Angle Doctor Blade took an important step forward.

The mass production of anilox rolls to satisfy the growing demand was the next problem the industry had to face. The company Paper Machinery & Research, PM&R, later Pamarco Incorporated, was created in 1944 in order to give printers alternatives other than the few anilox roll producers available up to then. At the beginning of the 1950s the main problems in anilox roll production came from the absence of standards among the existing engravers as to cell shape, count, conformation and depth. This lack of standards was reflected in incongruences in carrying capacity and release characteristics from one roll to the other. PM&R then set out to create standards which could be accepted and adopted by the industry; some are still in use today.

Since the first anilox rolls were introduced, the surface coating on them has changed a great deal. They have progressed from machined steel; to mechanically engraved, copper-flashed, chrome-plated; to as-sprayed ceramic; to mechanically engraved, ceramic over-sprayed; to mechanically engraved, finer

ceramic over-sprayed; to ceramic coated, laser engraved. The most recent anilox rolls have a variety of different cell construction angles with screens up to 1800 cells per inch.

Another important detail that had been unaddressed up to this point was the viscosity of the ink. Because there were no real viscosity measuring systems, it was the press operator's experience that determined correct viscosity. This was done by dipping a paint stick in a bucket of ink and estimating the speed of its flow off the stick after ir was removed. Besides experience on press, operators also needed to determine how to adjust the viscosity of the ink. Up to this point, it was the press operator's ability that determined the outcome at the end of the press. Even though operating a press was considered an art, poor color matching and bad quality were fairly common. According to Joseph Trungale, "aniline printing was in danger of declining to a non-growth printing method unless a better means of distributing the ink was developed."[6]

The Mosstype Corporation had been supplying aniline printing plates to the industry since 1927. Over the years they had developed formulas for figuring the stretch factor of rubber plates, the use of stickyback for plate mounting, and the use of phenolic moulding resins for rubber plates. Mosstype was also very interested in controlling plate size and rollers to facilitate makeready. In the 1940s they launched the "Mounter-Proofer," a machine that provided a way of setting up and making ready the cylinders **off the press**. The mounter-proofer was patented in January 1951 with patent No. 2,539,965 to Franklin Moss. (figures 18 and 19) The original design was later modified to ease registration control. In the first model, the plate was mounted on the back cylinder, while the 1970s model mounted the plate on the front cylinder. This machine was one of the first attempts at control-

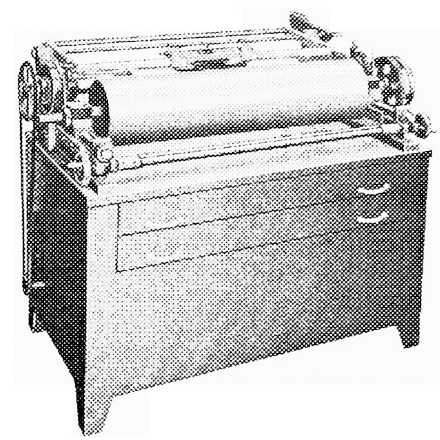


FIG. 18 – 1947 MOUNTER PROOFER

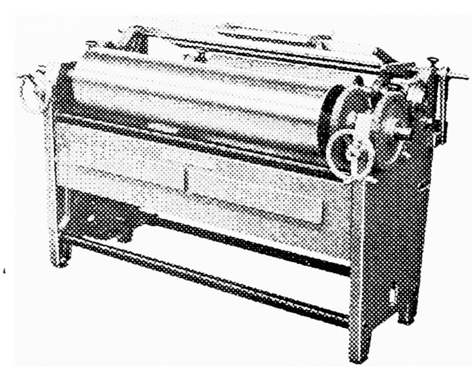


FIG. 19 – 1970 MOUNTER PROOFER

ling register **before** going to press. If plates were not correctly made, they would never register, a problem that could be foreseen by the Mounter-Proofer and corrected before going to press. This improvement was also responsible for the first off-press registration proofs. This advance alone reduced press downtime and increased productivity greatly.

By the end of the war, methods for keeping the ink rolls in continuous movement, even when the press was stopped, were developed, as well as a system called "automatic press cylinder 'throw-off'." This is defined as: "the automatic moving away of the plate cylinder from the impression cylinder and the [inking system from the plate cylinder.]"[7] The main advantage of this development was that the plate would not be left in contact with the impression cylinder in case the press was stopped. This reduced waste, and even the case of a web break caused by weakening of the material at the point of contact. The end of the war also brought a rapid growth in the industries using aniline-printed products, mainly the food and packaging industries. The number of substrates available to these industries also increased after the war. The aniline process could print on anything from newsprint to vinyl.

By the 1950s, flexography was being used to print many different kinds of packaging besides grocery bags. These included counter rolls, wrappers, gummed and pressure-sensitive tapes, tubes, egg cartons, PE and various plastic films, laundry boxes, ink bottle caps, and corrugated paper, among others. Figure 20 shows two candy bars packaged in flexo-printed wrappers. Some revolutionary products printed by this process included the trademark on a waffle-back Axminster carpet, and an oval shaped toothbrush case. Some experiments were also being done for printing newspapers.

FIG. 20 — SAMPLES FROM 1952

During these years narrow web presses were designed to supply a growing market for pressure-sensitive labels. At the same time extremely large presses were also being designed in order to satisfy the need for printed corrugated boxes. "In the mid '50s a flexographic printer meant to us [the corrugated printing industry] a 12-inch wide attachment was located on the 1-to-1 shafts of our folder-gluer."[8] By

the end of the decade an order for a 78-inch flexo press attached to a folder-gluer was placed with Koppers Co., which delivered in January 1960 the widest flexo press built until then.

The first samples that came out of the press were a complete success; 15,000 blanks per hour were being printed and the ink was drying at incredibly fast rates. But after the novelty wore off, problems began to appear; the ink started to dry on the rollers once the press was stopped, the rubber ink metering roll developed a flat when left overnight in contact with the anilox roll, and the print cylinder was impossible to reach because of the frames that surrounded it. All this meant excessive set-up and clean-up times. However, despite all the difficulties, corrugated could be flexo printed, and the results were clean sharp impressions at high speed with almost instantaneous drying, but at costs that could not be maintained.

Over the next several years multiple experiments were done in various plants throughout the country in order to accomplish the project of printing corrugated boards using flexo presses in a commercially feasible way. Finally, sometime around 1962 the first commercial flexo presses for printing on corrugated were built and attached either to a folder-gluer or to a printer-slotter. (figure 21)

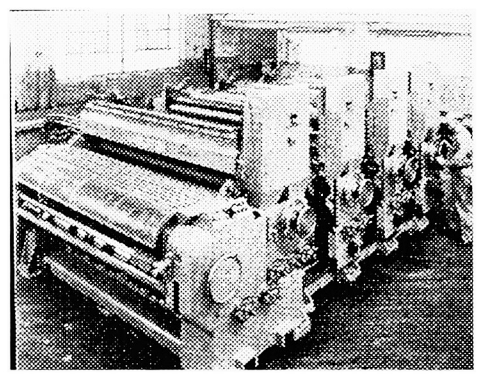


FIG. 21 — PRINTER SLOTTER

Besides printing directly on corrugated boards, two plants, one in Wisconsin and one in Germany, were attempting to preprint corrugated liner. Prior to 1980, conditions were very complicated because it was not possible to fit an automatic electric eye onto the corrugator knife, because of its weight. The problem of registering the corrugator with the print was addressed in various manners. One was fitting a manual differential drive that needed someone turning a handle when it started slipping out of register. According to Peter Chadwick, "as long as you were not printing accurately edge to edge (or even worse, a square to within half an inch of the edge) of the box, this was more or less satisfactory."[9] The second method was the use of a direct drive knife which gave the oportunity of fitting an electric eye onto it.

The first direct drive knives appeared around 1976, and the electric eyes two years later. The major advantage of direct drive knives was the possibility of changing from one box size to the next in a way that was not possible before. This enabled short runs of different size boxes; reducing stockholding costs for corrugators, and almost eliminating changeover times. "It was the equivalent of making a flexographic printing machine where you could change the print roller within one print length and without stopping the press! . . . By 1984, a corrugator without a direct drive knife was a real liability!"[10]

In order to get the maximum out of a corrugator, liner preprinters had to be 88 inches wide in the U.S. and 98 inches in Europe, with print lengths at least 80 inches. Rubber roller doctoring did not give good color uniformity, especially when printing boxes with all color background. Chambered doctor blades were the answer. And central impression cylinders were essential for holding registration. By 1988, Cobden Chadwick Ltd in England was building presses with 116 inch diameter drums, 98 inch print width, 96 inch print length, and six colors on the impression cylinder.

Another problem in this industry is the short print runs, and the laborious process of carrying print rollers that weigh a ton each in and out of the press and into printing position. Since 1980, Cobden Chadwick was using stepping motors with push-buttons to move the rollers into place. Around 1990 Cobden Chadwick lost their dominance of the market when Fischer und Krecke, a German company, built a satisfactory robotic changeover system for print rollers. Today a good liner preprinter would have six to eight color stations, 96 inch print lengths, around 100 inch diameter drum, robotic changeover, automatic print setting, downstream register varnishing unit and flying splice.

Up to around 1960 flexographic printing has developed at an incredible rate. Presses were being built in sizes that ranged from one-inch widths for cellophane tape up to eight or nine feet for preprinted liner for corrugating. Now that printing was being done on nearly every substrate, the next problem that needed addressing was high quality halftone printing. The best that any flexo printer had accomplished so far was a line screen of 85 lines per inch.

Endnotes to Part 2

[1] *Flexography, Principles and Practices* (U.S.:FTA and FFTA,1980), 4.

[2] Bill Klein, *They Built an Industry* (Lima, Ohio: Fairway Press, 1994), 21.

[3] Ibid.

[4] Ibid, 40.

[5] Wray Peal, "The Early Days of Flexo," *FLEXO* 18 (December 1993): 119.

[6] Joseph Trungale, *The Anilox Roll – Heart of the Flexo Press* (Plainview, NY: Jelmar Publishing Company, 1997), 4.

[7] *Flexography, Principles and Practices* (U.S.:FTA and FFTA,1980), 6.

[8] Henry E. Kulwicki, "Flexographic Printing Equipment for Corrugated," *TAPPI* 45 (January 1962): 158A.

[9] Peter Chadwick, letter to Robert Zuckerman (August 12, 1999).

[10] Ibid.

Part 3

Polyethylene and the next decade

"Phenomenal" is a good word to describe the growth of flexography or flexographic printing in the last ten years.

—*Inland Printer/American Lithographer 1963*

Between 1950 and 1960 many new packaging films were developed. These new materials were to compete with cellophane which had been the "champion film of the packaging trade for twenty years."[1] The first real competitor for cellophane was polyethylene (PE) which had better physical characteristics, including improved flexibility and extensibility. These characteristics were responsible for the introduction of PE into various markets where uses for other films were restricted.

However, PE was not perfect. The material stretched and wrinkled easily under pressure and heat. To overcome these problems, the industry had to refine its presses and make new adjustments. Some of these adjustments included better control of the web tension in the unwind and rewind, edge guiding equipment, automatic splicers, and closely controlled drying systems. In addition to the adjustments made to the industry standards, stack-type presses, a new style of press with a common impression cylinder (CI) was introduced. CI presses are said to have been introduced by Edward J. Peal in 1932, but were not considered viable before PE was introduced as a printing substrate. Edward J. Peal worked for Kidder Press most of his life, and is said to have designed as many flexographic presses as anyone in the United States.

Presses can be divided into three different categories depending on the material being printed. Common impression cylinder presses are used to obtain tighter registration on materials that are more elastic and stretch easily, like PE. (figure 22) Horizontally aligned presses, called "in-line" or "straight-

line" are used for stocks such as chipboard. They are used when the web should not be bent. (figure 23) A vertical layout, or "stack-type" is used for printing flexible materials that are dimensionally stable like paper or cellophane. (figure 24)

When printers started printing on different film materials such as vinyl, cellulose acetate, and polyethylene, the use of plastic plates became very popular. Their key advantage was the ability to resist inks and solvents, but they did not offer fine screen halftones. In 1953 the commercial rubber plate was limited to 85-line screens. However, developments in this area came rapidly, and by 1959, screens were already up to 110 lines per inch. Screen ruling kept increasing with time and effort until it stabilized at around 120 lines per inch, a resolution at which printers could get good grey balance and correct halftones.

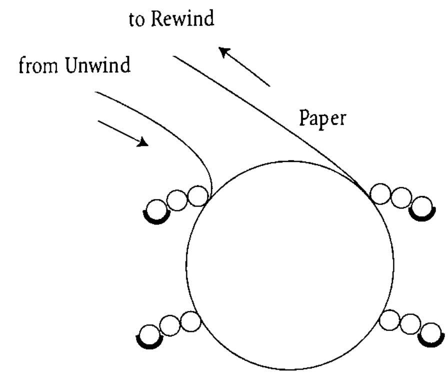


FIG. 22 — COMMON IMPRESSION CYLINDER PRESS

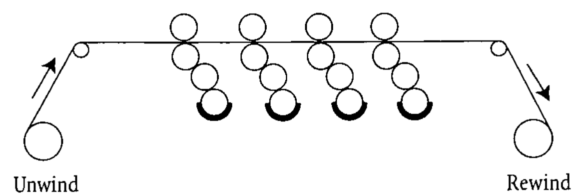


FIG. 23 — INLINE PRESS

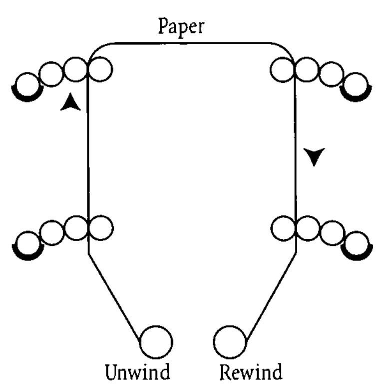


FIG. 24 — STACK TYPE PRESS

Up to this point, a common resin called shellac had been used as the primary binder, or vehicle, in flexographic inks. However, since shellac was produced by an insect in India, the industry was dependent on nature for its obtainment. The invention of cellophane had been responsible for the wide spread use of shellac; now the introduction of polyethylene was going to be responsible for the development of the first synthetic resin. This new synthetic material was a polyamide resin, the most common one being rosin. In 1955, polyamide resin flexographic inks were introduced. They produced superior gloss, better scuff resistance, faster drying times,

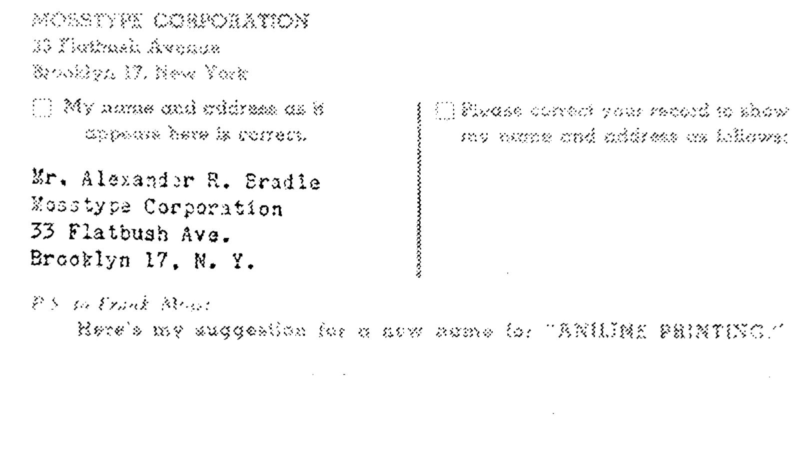
better water and heat resistance, and better adhesion to various types of flexible films. However, these inks had problems; they solidified in cold weather, needing the development of a new solvent which required public acceptance. Figure 25 shows an actual advertisement for the flexographic ink division of Sun Chemical, which produced higher gloss and stronger colors on various materials, as well as resistance to refrigeration. This sample appeared in *Flexography* in 1957.

FIG. 25 — ADVERTISEMENT THAT APPEARED IN FLEXOGRAPHY MAGAZINE

New inks were also developed for corrugated printing, a market in which flexography demonstrated it could be used to print with better legibility, less deflection, and lower production costs due to less material waste. These new inks were based on acrylics, a synthetic resin. They were faster in drying times, harder, and showed less variations in viscosity compared to those based on shellac, which varied from batch to batch. During the early 1970s major changes in ink technology were based on the discovery and use of new solvents such as urethanes, acrylates, polyamides and polyesters.

Up to 1952, printers relied mainly on the solvent's evaporation rate for fast-drying of the inks. Even though external heaters were sometimes needed, web speeds ranged from 100 – 1000 feet a minute. Later, speeds of up to 1,600 feet were achieved but not maintained because the inline folding equipment, at the end of the press, could not keep up with these speeds. Roll to roll presses were reaching 2,300 feet per minute on bag stock at a US converter's operation, on a regular basis, by 1965. At this point press operators began to realize that there was "no known limit to the possible web speeds of the Aniline process."[2]

During the late 1940s most convertors were printing packaging used by the food industry. The name aniline printing caused a problem because aniline means "a coal tar derivative with its connotation of harmful or toxic substances."[3] Because of this negative association, many food manufacturers refused aniline printing for their product packaging. In order to sell their products, the aniline printing industry started to advertise their process with terms such as "Lustro printing" or "Transglo printing." In March 1951, Franklin Moss, president of the Mosstype Corporation, decided to write in the *Mosstyper*, — a publication produced by his company, — to suggest new names for the process. He enclosed a reply card with every copy so readers could express their opinions. (figure 26) He also took his project to other publications and eventually more than 200 names were proposed. Eventually, the long list was narrowed down to three names: flexography, rotopake and permatone. A ballot was published in various magazines, including the *Mosstyper*, so that readers could choose a name from the three finalists. Figure 27 shows a copy of the voting ballot that appeared in the Mosstyper. On October 22, 1952, at the 14th Packaging Institute Forum in New York City, flexography was announced as the new name. The term flexography and the adjective flexographic were adopted very quickly and gained worldwide acceptance.


MOSSTYPE CORPORATION
33 Flatbush Avenue
Brooklyn 17, New York

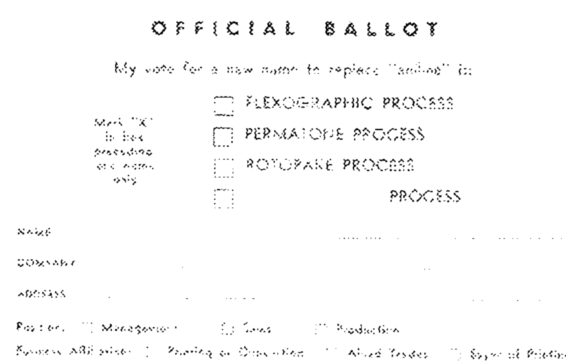
☐ My name and address as it appears here is correct.

☐ Please correct your record to show my name and address as follows:

Mr. Alexander R. Bradle
Mosstype Corporation
33 Flatbush Ave.
Brooklyn 17, N. Y.

P.S. to Frank Moss:
Here's my suggestion for a new name for "ANILINE PRINTING."

FIG. 26 — COPY OF THE CARD THAT APPEARED IN THE MOSSTYPER LOOKING FOR A NEW NAME FOR ANILINE PRINTING


OFFICIAL BALLOT

My vote for a new name to replace "aniline" is:

Mark "X" in box preceding one name only

☐ FLEXOGRAPHIC PROCESS
☐ PERMATONE PROCESS
☐ ROTOPAKE PROCESS
☐ PROCESS

NAME
COMPANY
ADDRESS

FIG. 27 — VOTING BALLOT

In 1956, after the name flexography was adopted, Robert P. Long and John A. Nicholson began to publish the first magazine about the industry. The first flexographic forum was held in 1957, sponsored by the Packaging Institute's Flexographic Committee. Due to the success of this Forum, the Flexographic Technical Association (FTA) was born in 1958. Doug Tuttle and Robert Zuckerman were appointed to choose an executive secretary; they selected Julian Ross as the first employee of the FTA. The association was charged with making "all existent knowledge available as well as to encourage and promote new technology."[4] The first technological forum was held in New York in February 1959, and the first edition of the book *Flexography–Principles and Practices* was published in 1962. As Mark Andrews Jr. described it, the FTA was "a wonderful and successful experiment in the promotion of an entire industry."[5]

In the fall of 1961, the FTA and Rochester Institute of Technology (RIT), joined together to produce the first college-based course in flexographic printing. Thus, RIT became "the first major printing school to offer a course of study in flexography."[6] The course, which had to be taken by all first-year students, included both theory and practice, and students had the opportunity to work on flexo presses donated to the Institute by Heinrich Equipment Corporation. At this time, flexographic coursework was considered part of the letterpress department. The creation of this program was a major contribution to the industry. As Julian Ross, executive secretary of the FTA, explained at this time: "If [the] FTA does not help these schools make such instruction available, nobody will. . . [C]onverters will have to make do with untrained help."[7]

Around the same time that RIT was starting to teach flexo printing, narrow web press design for label printing was changing. These presses, as explained earlier, used rotary dies to cut the labels. Until 1958 dies were typically made of soft metal, making them very vulnerable to wear. A new generation of dies was made of hardened steel, which eliminated the dulling problems. Later on, around 1968, dies began to be chrome plated. This new development "increased [their] life by a thousand percent."[8]

Narrow web printing was a growing market and the number of competitors grew every day. In 1952 there were a dozen or so printers, in 1955 there were around 100, in 1965, 250, and by 1970 the num-

ber had reached 1,000. One of the reasons for this unexpected growth is explained by Mark Wert who worked with Soabar: "All products in one way or another have to be identified . . . so you do it with a label or you do it some other way."[9] The label-printing industry had become so important, that in 1962 the Tag and Label Manufacturers Institute (TLMI) was created as an outgrowth of the Tag Manufacturer's Institute (TMI).

During the 1960s, Mark Andrews Jr. started to work with his father. At the same time, Mark Andy was starting to feel the effect of competition coming from Webtron. Since Mark Andrews Jr. had been trained as an engineer, he put his knowledge to work and one of his major contributions to the company was to customize the presses it was producing. Since then, the Mark Andy Company only produced 7-, 10-, and 16- inch wide presses. Up to this point, every press produced by Mark Andy Company was tailored to the needs of each costumer and in addition, had innovations which Mark Andrews Sr. would think of in the process of building it. The result of competition coming from Webtron, as well as Mark Andrews Jr.'s contributions, was better flexographic printing equipment.

By the end of the sixties, the first four-color narrow web presses were on the market ready for process-color printing. But it was not until 1972, when DuPont introduced Flexographic photopolymer plates, that process-color labels were possible.

In January 1958, at the Great Lakes Newspaper Mechanical Conference, DuPont introduced the first photopolymer printing plates. These new plates were composed of a layer of photopolymer and a metal support. The photosensitive plastic hardens when it is exposed to ultraviolet light, but roomlight does not affect it. In order to create plates for printing, a high contrast photographic negative is placed emulsion-side down in contact with the plate. Then it is exposed to UV light and the unexposed areas, that is areas which were not hardened by the light, are washed out with an alkaline solution. The entire process can be completed in fifteen minutes or less. In 1958, the plates were still being tested in laboratories, but would soon be sold under the Dycril name. Some offset business form presses were even equiped to use the Dycril plates in the late 1950s.

In 1964, the design of flexographic presses would change forever. The rubber roll that helped

meter the ink film that was deposited on the anilox roll was eliminated and replaced by a doctor blade.

By the early 1960s, the industry was already producing six-color presses and adding a doctor blade was easy to do in stations 1,2,and 3, the down side of the press. Problems arose when blades had to be added to the other three stations (the upside), because they had to be inserted in an awkward position underneath. The chambered reverse angle doctor blade (RADB) was developed to solve this problem, and the first RADB systems were seen around 1968. Figure 28 shows a press design patented by Charles Heurich in 1971, featuring both a doctor blade and a rubber metering roll. This new design helped eliminate the problem of rimmed inks. This was caused when the pressure applied between the rubber roller and the anilox rolls, produced an ink film that was denser at the edges than in its center.

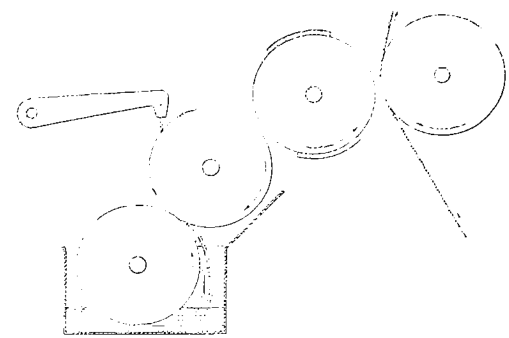


FIG. 28 — FLEXOGRAPHIC PRESS INCORPORATING A DOCTOR BLADE

At the beginning doctor blades were manufactured from blue steel and they ran against a chrome plated anilox roll. Later, steel doctor blades were changed to ones made of stainless steel when water-based inks were introduced, and then to the plastic ones we see today. In the mid-70s, ceramic-coated anilox rolls were already available, but they had no cell patterns or engravings on them, these were called "as sprayed" coatings. Charles Heurich and his team at Pamarco began a series of experiments and developed a steel roll engraved with a cell pattern of 65–75 cells per inch, which was then coated with ceramic. When the same roll was produced and tried in a RADB system, it wore out the blade in less than ten minutes and even cut the operator. After many enquiries on how to make the blade last longer, someone suggested plastic. Once a reliable source of supply was found, plastic doctor blades were shown to be effective and the hazard was eliminated.

Up to the 1960s, flexography was considered essentially a letterpress process characterized by extremely fast-drying, low viscosity inks that relied on solvent evaporation for their effect. The original flexographic, or aniline inks were "a solution of shellac in denatured alcohol to which [was] added alco-

hol-soluble basic dyes for coloring."[10] By the 1960s, however, three different types of inks existed: alcohol-soluble, water-soluble, or co-solvent.

Water-based inks were very attractive because they freed the industry from a dependance on organic solvents, were nonflammable, and had very little odor to them. In addition to the original characteristics expected from flexographic inks, new inks had to satisfy the following needs: flexibility, gloss, adhesion to foil and PE, resistance to heat smear in sealing equipment, scuff resistance, and resistance to extreme cold and dampness. In order to produce good inks, an ink manufacturer had to take into consideration the following elements when selecting the pigments that were going to be used: desired hue, degree of required transparency or opacity, resistance to bleeding in the presence of moisture, and permanence.

Co-solvent inks use a combination of alcohol solvent and aliphatic diluent. The development of these new inks caused some problems for plate and press manufacturers. Rubber press rollers and plates would swell and distort when they came into contact with the new ingredients. This led to the use of synthetic rollers with such inks, but it meant changing rollers for specific uses and printers were reluctant to do this., because downtime between jobs was costly. Eventually, presses were mounted with synthetic rolls for every job. The appearance of co-solvent inks also meant an increase in ink inventory which was not well received.

In any case, all of these developments in ink manufacture and formulation were only effective if the stock was appropriate and press-operating techniques were properly applied. The management of viscosity and drying speed was critical. When drying speed is too fast, ink will dry on the rollers and printing plates, and affect distribution. All of this assumes that testing will be done to ensure that the correct ink for each substrate is used.

The majority of inks used by printers rely on evaporation for drying. This creates the problem of solvents evaporating in the ink pan and affecting the vehicle/solvent ratio. In order to compensate for this evaporation, different corrective actions must be taken. The pressman can be charged with adding solvent to the ink tank every now and then, but generally he has other more important things to

worry about. Besides, too much additional solvent will weaken the color. Other solutions include additions to the press, such as automatic dripping features that constantly add small quantities of solvent to the ink tank, or a pumping system that constantly circulates the ink supply from a reservoir to the press. The first pumping systems were introduced on the market in 1958 by Graymills Corporation. (figure 29) Solvent evaporation can also be greatly reduced by covering the ink pans and controlling the temperature around them. Also, a press room should be free of open doors and windows near a printing section, preventing excessive air circulation around the printing station and ink pumps.

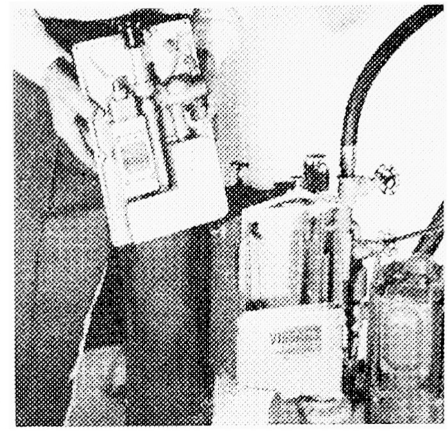


FIG. 29 – GRAYMILLS PUMP IN 1958

Endnotes to Part 3

[1] *Flexography, Principles and Practices* (U.S.: FTA and FFTA,1980), 6–7.

[2] D. E. Tuttle and Stewart Hoagland, "Aniline – Adolescent of the Graphic Arts," *Print* 7 (November 1952): 2.

[3] *Flexography, Principles and Practices* (U.S.: FTA and FFTA,1980), 1.

[4] Robert Zuckerman, "Early History of the FTA,"*Flexo* 18 (December 1993): 71.

[5] Mark Andrews Jr., "Happy Birthday, FTA," *Flexo* 18 (December 1993): 16.

[6] "Teamwork of FTA and Rochester Tech. Institute Initiates 'First' Course in Flexography," *Paper, Film and Foil Converter* (February 1961), 1.

[7] Ibid.

[8] Bill Klein, *They Built an Industry* (Lima, Ohio: Fairway Press, 1994), 127.

[9] Ibid, 98.

[10] John S. Autenrieth, "Resins for Flexographic Inks," *TAPPI Proceedings* 46 (January 1963), 139A.

Part 4

Recent history

Profitability will only be possible if you have predictability of the process and product.

—Ed Kozel

In the last two or three decades, many of the developments in flexographic printing have been centered on polymer chemistry. Important discoveries include new members of the olefin family like polypropylene (PP), which is used as a substrate replacement for cellophane, or new photopolymers that are used for better plates.

Polypropylene was discovered in 1954 in Italy and has the unique property of being manufactured with specific structural orientation. This means that it can be made to tear in one direction but be tear-proof in the other. In order to be receptive to printing, it has to be coated with a special material, and since it is generally heat-sealed, a heat-seal coating has to be applied as well. The idea of coating a substrate with different materials to change its properties gave birth to another family of materials that can be printed by flexography. These are multi-layer substrates, the number of which seem to grow daily.

A good example of coated or layered materials is pressure-sensitive labels. Stan Avery is regarded as the father of the pressure-sensitive label since he produced the first ones in 1930 for Doral Deena Cosmetics. Even though his process was not then commercially feasible, he never gave up. At first, he produced window displays in stores, funeral signs for cars, or price tags in gift shops. Late in his life, in 1974, he introduced the pressure-sensitive postage stamp, which is familiar to everyone today. However, the technology for cancelling the stamp was not then available and the project was shelved for nearly twenty years.

Most markets for flexographic printing have had parallel developments. During the 1960s the printing of corrugated boards experienced a huge surge in sales, mainly attributable to the fact that flexo printing stations were attached either to the printer-slotter or the folder-gluer. In the late 1960s these two machines were combined and the printer-slotter-folder-gluer was born. The first machines of this type included one or two printing stations, but they eventually grew to include up to six color stations for printing on corrugated boards.

By the mid 1960s rubber plates were being molded from matrices. These matrices were generally made of thermosetting, phenolic resin-impregnated sheets. The first step in producing a rubber plate was the selection of a suitable original. Originals could be type forms, electrotypes, Dycril originals, zinc or magnesium photoengravings, or hard rubber masters. The matrix material was pressed against the original in a heated molding press, then separated from it, and left to cool off, after which, the mold or matrix was cured. Once the matrix was ready, it could be placed over a layer of rubber and vulcanised in order to obtain a relief printing plate. This was a very long and tedious process and as a solution, plates made from photopolymers were developed. These plates had a new structure as shown in figure 30.

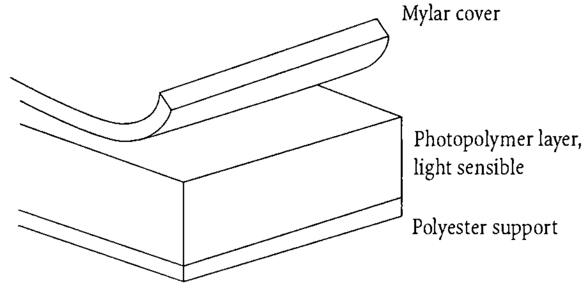


FIG. 30 — PHOTOPOLYMER PLATE STRUCTURE

In the late 1970s, early 1980s, anilox rolls were still being chrome-plated and cells were engraved only at a 45° angle. The only variable that engravers and printers concerened themselves with was the shape of the cells; these could be reverse-pyramid or quad-cells. At this time, cell counts did not exceed a maximum of 550 cells per linear inch. Today cell patterns can be etched at 30°, 40°, 60°, or even in a random pattern, with cell counts reaching of up to 1,800 cells per inch, depending on the kind of work being printed. Etching angles could be varied due to the introduction of lasers for engraving. Mechanical engraving can only be done in 45° angles. When choosing the angle of the cells for the anilox roll, in

color printing it is important to ensure that the screen angle on the plates does not interfere in such a way as to create undesirable patterns in the printed piece.

Today, and for the last twenty years, reverse angle doctor blades have been the preferred method of metering ink. Using doctor blades instead of the two roll system makes it possible to use more highly viscous inks for denser colors. They also permit printers to obtain the same color, independent of press speed, thanks to their constant wiping action. Today, doctor blades are not only made of steel –stainless, white, or blue– they are also made of plastic. Plastic blades are presharpened to give the best metering. This presharpening, or preshaping, is called "pre-honing." (figure 31)

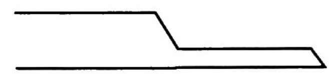


FIG. 31 — PREHONED BLADE

The control of solvent evaporation in the ink pan, a special concern in the industry, gave birth to the enclosed-chamber doctor blade. This new system includes a covered ink pan, a reverse-angle doctor blade, and a proximity blade. Ink is constantly supplied by a pumping system. The proximity blade is used to enclose the ink chamber, thereby protecting the ink from coming in contact with air and moisture, as well as paper dust or particles. (figure 32) In this case, both blades are made of plastic. Some of the advantages of the enclosed ink chamber are maintenance of color and reduction of change over times, both of interest to the newspaper, flexible packaging, and corrugated printers. Figure 33 shows the design of a modern flexographic press.

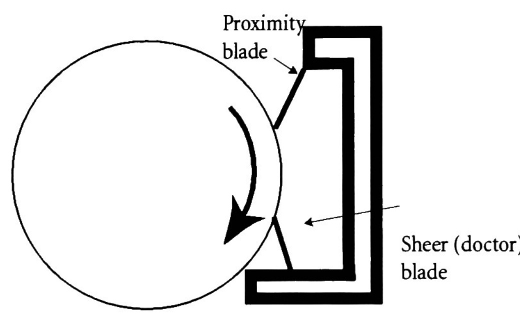


FIG. 32 — ENCLOSED INK CHAMBER

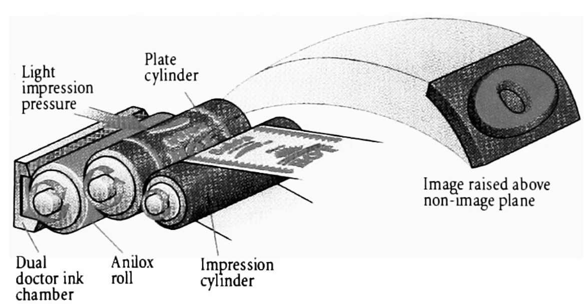


FIG. 33 — MODERN FLEXOGRAPHIC PRESS
COURTESY OF AGFA EDUCATIONAL PUBLISHING

Before the 1970s, the main problem in engraving cylinders, — not only anilox rolls, but also gravure plate cylinders — was eliminating the seam. The solution came with laser engraving, and the first models were introduced to the industry in the mid 1970s. Lasers were first used in the Navy but eventually commercial uses were found for them as well. The laser engravers of 1975 used a rubber roller that was first coated with zinc and then with a photosensitive emulsion. A full-sized film was then fitted on the roller, exposed, developed, and the zinc chemically etched from the areas to be engraved. The roller would then rotate in front of a continuous laser beam that would reflect off the zinc and burn away the rubber in the etched areas. The process was long and complex, and relied on the ability of the operator to join the film in such a way as to create a seamless roller.

The first machine that read "art work" and turned the laser beam on and off was introduced in 1977. This new technique eliminated the need for zinc coating, and the subsequent chemical etching, but it still needed a full-size image. One year later, ZED Instruments of England introduced a system that could engrave a seamless roller from unjoined work and produce multi-level engravings. This was done by scanning the artwork, then electronically processing it to control the join; only then was the laser beam turned on. A few years later, designs could be scanned and saved on magnetic tapes for future use, making remakes without the original possible, as well as step-and-repeat techniques. Eventually, it was possible to send work directly from a Scitex or Hell computer to the engraver without the use of film or bromides. Today lasers are used to produce high-quality, ceramic-coated anilox rollers, as well as laser-engraved rubber plates, and photopolymer imaged plates.

Once anilox rollers could be engraved, the problem of cleaning them had to be attacked. Ceramic, by nature, is harder to clean than steel or chrome. Ceramic is a rougher surface and ink gets into even the smallest crevices. Additionally, water-based inks adhere to the roll and are even more difficult to remove from the ceramic. Even though more modern systems exist, most printers are still using the "scrub it in the sink" method. Conventional off-press cleaning methods include ultrasonic cleaners or soda blasting, in addition to brushes. Other techniques utilize chemical cleaners. But, the latest technology in anilox roll cleaning consists of "releasing a steady stream of polyethylene media to impact the

surface of the rollers and remove the ink."[1] This media is nonabrasive to the roller and completely recyclable.

Research on photopolymer plate technology is constantly being undertaken. Today plates are one fourth thinner than they were 25 years ago when the Cyrel plates were introduced by DuPont. New plates are being developed for all areas, even the fast-growing, flexo-printed newspaper industry. Thanks to the introduction of liquid photopolymer plates in 1985, the *Sarasota Herald Tribune* was the first newspaper to print its daily edition using flexographic printing. Multi-layer rubber plates, which absorb shock and reduce haloed images, have also been introduced. And the new technology in Cyrel plates does not require drying time and equipment, they are thermal. This reduces plate making time which in the long run becomes shorter make ready times and greater efficiency. Stickyback plate technology has also experienced changes during the years, mainly in the development of stronger adhesives that prevent plates from falling off the cylinder.

Endnotes to Part 4

[1] Bob Temple, "Plastic-media cleaning of anilox rolls," *Converting Magazine* (January 1998).

Part 5

Flexo and the Environment

If all the environmental concerns and regulations in place today had existed at the outset of the development of the process we call flexography, the printing process would not have been developed.

—*Fred Shapiro*

The flexographic printing industry has had to overcome many environmental hurdles. These include reducing and eventually eliminating solvent content in inks, implementing such safety regulations as guards on gears, reducing gas emission in the press room, reducing fire hazards, and even housecleaning and storage regulations.

The first safety concerns were for the workers' health. Bill Dodge who worked for Fasson describes the fumes that came out of the presses as intoxicating, and describes the effect of those fumes as: "You got a pretty good high working at Fasson. Some guys would hear a radio playing. . . .They got all banged up like these kids do today sniffing glue."[1]

At the beginning of the 1960s, the primary safety issue concerned a fire caused by the solvents in the ink. Chuck Reed recalls that Fasson was visited by the Plainsville fire truck almost daily. The gasses let off by evaporation of these solvents was not then a major concern. Press rooms were supposed to smell and, says Reed, "odors were an accepted part of working in a press room."[2] At this point, printers only had a general idea of what went in the inks; most of the information concerning solvents and ingredients was not given by the ink manufacturers because it was classified as proprietary. No one knew the damage they were causing to the air, ground, and water. The lack of concern for the environment at this time can be seen indirectly in the content of just about every activity promoted by the FTA; the

emphasis was on quality and productivity in order to compete with lithography or gravure printing.

The introduction of PE as a material for producing bread bags led to the development of new polyamide inks. The first hints of potential problems with traditional inks and their solvents were seen when Continental Bakeries imposed a gas chromatograph test to detect any hydrocarbons that might be responsible for the illnesses suffered by people consuming bread that came in the new PE bags. The effects on the industry of this demand from Continental Bakeries was seen at the 1968 FTA Forum when Sun Chemical announced of hydrocarbon-free flexo inks made of alcohol-soluble polyamide resins. These new inks eliminated the aliphatic hydrocarbons such as VM&P naptha and lactol spirits contained in the old inks, and also reduced the amounts of toluene and xylene.

In the early 1970s the first air emission control regulations started to appear. But they were targeted to large firms with emissions over 100 tons per year. Most of the print shops at this time did not get even close to those levels, hence they did not worry. However, everyone, big or small, had to apply for Air Permits. Accurate information was still very limited concerning the nature and amount of emissions given off by the operations. "Even the professional engineers who prepared the permits used rules-of-thumb, mostly based on their experience with solvents exhausted by spray painting booths."[3] Up to now, formulations were still proprietary and concerns were focused more on the quality of the end product. The Clean Air Act of 1980 changed some of these practices when it mandated a 35 per cent cutback in air emissions coming from printing plants.

The oil embargo of 1971 put a premium on all products derived from petroleum including solvents. This seemed like the perfect opportunity to develop water-based flexo-printing inks. Unfortunately the process was not as simple as it appeared to be. Most printers complained that water-based inks did not produce the same gloss, were very difficult to adhere and caused clean-up problems on anilox rolls. Some companies made water-based inks work, but were beset by mechanical problems that had to be resolved by the machinery industry. These problems included drying systems, anilox roll-cleaning techniques, and changes in the ink train in order to transfer controlled layers of ink with a minimal amount of solvent. Even though water-based inks have been available for years, flexographic print-

ers were not willing to accept the technology and make the necessary mechanical changes until the environmental pressure was obvious.

Slowly, the solvent content in inks has been reduced but not completely eliminated. UV-cured inks may be the answer, but, substrates will also have to be developed that more fully take advantage of their virtues. Solvents were not the only environmental hazard the government was targeting. There was also a growing concern over certain pigments in different inks. The result was that leaded pigments, widely used in yellows and oranges, as well as barium, contained in yellow-shade reds, were soon prohibited.

By the 1980s, the regulation of hazardous waste and effluent discharges, had become very strict. "Where and how we put our solvent waste became as great a concern as where the vapors were going."[4] Printers had to learn to collect, label, and properly dispose of their waste material. These issues led to practices such as recycling with a distillation unit, and reusing inks and solvents. At the same time, water discharges became an everyday issue, especially since printers were expected to return water that was cleaner than what had originally came into their plants. At first no one could understand the reason for this policy. But instead of wrestling with the problem of removing hazardous chemicals from the water and environment, the industry decided to eliminate those chemicals completely.

The introduction of Material Safety Data Sheets (MSDS) to American industry was another big milestone for flexography. Now printers would know what ingredients went into their inks. They found out why certain inks behaved the way they did, and what effect each solvent had on the final product. Information that had been classified as proprietary until then, was now made public.

As the years have passed, the flexographic industry has realized that better solutions to the problem are pollution prevention and waste minimization programs, instead of just complying with the norms inflicted by the government.

The date May 30, 1999 was very important for the printing industry. That day the Environmental Protection Agency's (EPA) "Standards for Air Pollutant Emissions for the Printing and Publishing Industry" went into effect. These standards are expected to reduce Hazardous Air Pollutants

(HAP) from printing plants by as much as 5,500 tons per year per facility. The facilities targeted at this time are those catalogued as "major source," that is, facilities that emit more than 25 tons per year of combination pollutants.

The regulations concerning flexography apply, for now, only to Wide Web flexo. Printers will be expected "to limit their emissions to no more than 5% organic HAP applied per month, 4% of the mass of all material applied per month, or 20% mass of solids applied per month."[5] In order to achieve these goals, printers can either change to non- or low-HAP products (less than 4% applied material,) or rely on capture and control devices with at least 95% efficiency. Though the national or state regulations concerning air and waste water emissions must be obeyed by everyone, compliance with ISO standards is optional, but strongly recommended for printing and publishing companies.

Progressive flexographic printers would rather not be forced by government regulations into cleaner printing. Most of the people interviewed agreed that keeping the company clean was one of the most important factors for quality production today. Charles Heurich said "As we get into more pictorial printing, we need more cleanliness in the pressroom."[6] But, definitely the most emphatic remark came from Wray Peal: "You should be able to eat your lunch off the [pressroom's] floor."[7]

Endnotes to Part 5

[1] Bill Klein, *They Built an Industry* (Lima, Ohio: Fairway Press, 1994), 58.

[2] Fred Shapiro, "Flexo and the Environment," *Flexo* 18 (December 1993): 134.

[3] Ibid, 135.

[4] Ibid.

[5] Flint Ink Corporation, "New Air Pollutant Standard for Printing and Publishing," *Enviro Update* (Spring 1998): 1.

[6] Charles Heurich, interview by the author, FTA Forum 99, San Antonio, TX, 3 May, 1999.

[7] Wray Peal, interview by the author, FTA Forum 99, San Antonio, TX, 3 May, 1999.

Part 6

What Does the Future Hold?

The next few years may well bring forth revolutionary changes in printing that will make today's operations seem primitive by comparison.

— *The Mosstyper*

The aerospace industry has developed a whole new family of materials for building stronger and lighter machine parts. One of these materials is graphite carbon fiber which has replaced steel in the manufacture of anilox rolls. In 1994, Stan Hycner of Pamarco, developed the first carbon-fiber rolls, and since then, more than 400 have been produced flawlessly. The steel tubing in these rolls is replaced by carbon fiber which is twice as strong but only weighs one-tenth as much as steel. The rolls are then ceramic coated, ground, and polished, and laser-engraved according to the clients' demands.

Replacing steel rolls with carbon-fiber has many advantages. These include increasing doctor blade life because the roll deflection is reduced to one tenth of that of a traditional steel roller, and improving plant safety because it is easier to handle a 90 lb. roll than a 900 lb one. The reduction in roll deflection also increases anilox roll life. In addition to increasing press component life, this lack of deflection makes it possible to print uniform solids across the entire width of the press, especially in very wide ones. According to Art Ruge of Pamarco, "The carbon-fiber roll is certainly the beginning of the next generation of flexographic print quality."[1]

During the late 1980s the big question was: why can't flexography print as well as lithography? Simply put, flexographic presses could not lay down a thin enough ink flm. Before that, during the 1960s, Harper Corporation had developed a 60 degree hexagon cell for the anilox roll, recreating the same pat-

tern a honey comb does. thus the space available was maximized, making it possible to fit a grater number of cells per linear inch. This new cell pattern also helped reduce the ink film thickness to one that was comparable to what appeared on the last roll of a lithographic press ink train system. Up to this point, lithographic inking systems worked with ink film thicknesses of 1–3 microns, while flexo anilox rolls worked with thicknesses of 4–7 microns. In 1990, an 800 line per inch design with a 60 degree hexagon cell was developed by Harper, Graphic Packaging, and Du Pont for film printing and was a phenomenal success. This new roll could control ink film thicknesses to 0.5–1.5 microns and quickly became the industry standard.

In 1995 Chris Harper of Harper Corporation started experimenting with an idea that seemed like an impossible dream. He began developing an 1,800 line anilox roll. The common counts today range from 300-500 for solids, and 600-700 for halftones printed on a common impression press. By the end of 1998 he and an industry-wide team finally achieved that goal. The new high-cell-count roll was made possible by new laser technologies, but suffered from cell plugging on press. Another problem was that at 1,800 cells per inch, there was no color strength in the inks. According to Chris Harper, "after 1,200 lines per inch we start seeing diminishing returns."[2] Today, Chromas Technologies – known before as Webtron – has made many trials of these high-cell-count anilox rolls on various substrates, and the best results are given when used with UV inks that take longer to dry and thereby reduce plugging problems.

As with any new development, this new anilox roll creates a challenge for the rest of the industry. Charles Heurich says "1,800 [lines per linear inch] is a dream, presses are not qualified."[3] Jerry Shields of Graymills, Harry Mosher and Wray Peal agree with Charles Heurich, and support Chris Harper. But Sam Gilbert of Sun Chemical notes that "with an 1,800 anilox roll we are going back to flat rollers;"[4] Incredibly, Chris Harper supports Mr. Gilbert's point of view and describes his anilox roll engraving technology as "precisely controlling the pores on the surface [of the anilox roll.]"[5] Another person that supports this thinking is Dilip Shah from Chromas Technologies, who believes that "[1,800 anilox rolls] is pushing it a little too far."[6] Mr Shah, who is the manager of Demo Printing, insists that 1,800 anilox rolls are not feasible for commercial work, since too much time is wasted in controlling ink release and

avoiding plugging. Mr. Shah's point of view corresponds with that of Ariel Reyes, Cyrel Technician and Expert for DuPont in Colombia. He says that in order to print with an 1,800 anilox roll you need 200 line per inch screens; these screens can only be obtained through digital technology which can hold dots of up to 0.5%. But these dots are so small, it is possible that they will break from the plate during the washing stage of the process.

On other fronts, Harper Corporation is constantly researching how to make anilox rolls more efficient. Right now they are working on another new development which has not yet been made public. All that is known is that the research has to do with yag engravings for use in narrow web presses. These new engravings increase the ink volume by making cells deeper, though a persistent problem of releasing ink from the cells must effectively be solved.

Flexography is constantly "stealing" markets from other printing processes. According to Wray Peal, the future of flexography appears to be in the folding carton business. The only problem is that printing can not be an inline process because diecutters do not perform to the same speeds that presses do. Another effect of flexography's growing markets, is the new way they are being defined. According to Jim Feeney, narrow web is considered less than 24 inches, mid-wed from 24 to 44 inches, and wide web anything above 44 inches.[7]

The beginning of the 1990s was also influenced by the application of computerized technology for improving productivity, efficiency, and quality. One of the best examples of this is the use of video inspection equipment for registration control. Video controls have been available to the industry since the 1950s. The first device was called Scan-A-Web and it was as wide as the press but the operator could only see 2 inches at a time. Scanners appeared on the market once press speeds surpassed 100 feet per minute. Before that, operators developed the ability to move their body at the same pace as the web in order to check registration. However, when jobs were two or three around, there was no assurance the same image was being viewed each time. Other options available are pin register systems for wide webs, and microscopically controlled videos for narrow-web presses.

Some of the advantages of video inspection include presses that can run on average twenty per-

cent faster, waste reduction of six percent, quality improvements, and faster set ups. However, this technology is much more accepted by wide web printers; the narrow web industry still prefers the basic visual systems. The growing popularity of video inspection systems is a response to various forces in the marketplace. Some of these are: run length pressure – today it is measured in hours, not days or weeks as it used to be, increased use of color in packaging, inventory management, and management concerns such as affordability and ROI (Return on Investment).

Digital printing is already here and seen by many as a threat to all traditional printing processes. Most people in the flexographic printing business do not see it as a threat, since it is not suited for printing long runs. Can anyone imagine printing enough bread bags to cover the daily US consumption on a digital printer? Digital printing is seen more as an opportunity – a complement to flexography.

Such is flexography's past, notes Charles Weigand in *Flexography, Principles and Practices.* "With exciting new developments happening all the time, its future is undoubtedly just as bright."[8]

Endnotes to Part 6

[1] Art Ruge, "The Evolution of the Anilox Roll," *FLEXO* 23 (May 1998): 106.

[2] Chris Harper, telephone interview by author, 18 July, 1999.

[3] Charles Heurich, interview by the author, FTA Forum 99, San Antonio, TX, 3 May, 1999.

[4] Sam Gilbert, interview by the author, FTA Forum 99, San Antonio, TX, 4 May, 1999.

[5] Harper.

[6] Dilip Shah, interview with author, Chromas Technologies, Fort Lauderdale, FL, 21 July, 1999.

[7] Jim Feeney, "Are You Prepared for the 21st Century?" Talk presented at FTA Forum 99, San Antonio, TX, 2 May 1999.

[8] *Flexography, Principles and Practices* (Ronkonkoma, NY: FTA and FFTA, 1991), 14.

Chapter 6

Conclusion

Flexography is a process that is barely a hundred years old. During this time it has grown from "Bibby's folly" and a very poor quality printing process to a multi-billion dollar-a-year business. New developments are constantly appearing, even as I write this. However. the future of flexography, and of the whole printing industry, relies on its people, as well as on its technological developments. People that come into the industry have to be more skilled and companies will have to invest in training these people to compete effectively.

Future studies of this topic might include any technical developments that have occurred since the period covered by this essay. Other possibilities are in-depth studies of specific areas of flexography, including inks, substrates, presses, and plates. Someone else may be interested in analyzing the effect of environmental regulations on this printing process. Another possible area of study is the development of flexography around the world, in Europe or Japan for example, instead of concentrating on the U.S., as I have done. Also, much work could be done on patent research.

Part 6 of Chapter 5 only notes the developments that have taken place in the last couple of years. The effect of these developments should also be studied in the future. One that will have a great impact on traditional printing processes, not just flexography, is digital printing.

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