

*Printing Ink: A Backgrounder*

# Ink in Your World

It's a simple fact that most people don't think often about printing ink, and yet it plays an important role in our daily lives.

Each day ink appears on thousands of pages of newspapers and magazines, catalogs and brochures. It is on the products that line the shelves of the supermarket, the hardware store and office supply outlet. From the bar code on a price tag to the vinyl flooring in our kitchens, from the greeting on our birthday cards to the billboard beside the road, we rely on printing ink to educate, inform, and entertain us—and to make our lives easier and more enjoyable.

Businesses, too, depend on printing—and ink—to deliver their messages to customers, whether it's in packaging, sales literature, advertising, retail point of purchase displays, labels or annual reports.

The US printing and publishing market is a nearly \$200 billion dollar industry, made up of 65,000 firms and more than 1.5 million employees. It consumes approximately two billion pounds of ink per year, valued at more than three and a half billion dollars.

Figure # illustrates where all that ink is used.

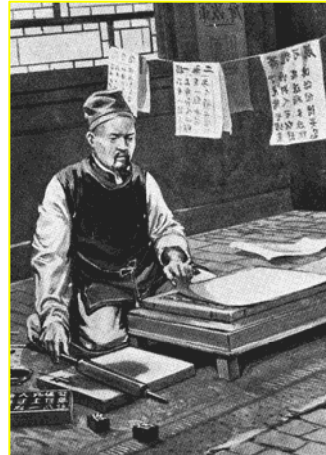
Bureau of Census figures indicate that there are more than 200 printing ink companies in operation in the United States. They run in size from those with fewer than 10 employees to those employing thousands. Some serve only local customers. Others are international in scope.

These inkmakers operate modern production plants and support extensive sales organizations. They serve as a source of high quality supplies and competent technical support for their customers. And whether large or small, progressive inkmakers engage in continuous research and development.

Research has moved printing ink from a craft to a science. Coupled with advances in organic and colloidal chemistry research has allowed the industry to produce inks for modern high-speed publication printing, packaging printing and printing on a wide variety of surfaces and materials.

## An ancient tradition

Although ink was used for writing by the Egyptians and Chinese as early as 2600 BCE, nearly 3000 years would pass before the Chinese brushed the ink onto carved wooden blocks in the earliest attempts at imprinting.



Efforts to create the first moveable type came in the 11<sup>th</sup> Century, when Pi-Sheng formed individual Chinese characters of clay, and later of wood. The undertaking was defeated, however, by the sheer number of characters required.

Printing moved into

Europe in the Middle Ages with the introduction of paper in the 12<sup>th</sup> Century. Until that time, manuscripts had been tediously reproduced by hand on parchment made from animal skins. But parchment was time-consuming to produce and expensive. Furthermore, hand-copied manuscripts couldn't keep pace with a growing demand for religious tracts, poetry and other literature. By the 14<sup>th</sup> century, paper made from rags had replaced parchment for general use and whole pages of text and illustrations were being printed using single carved blocks of wood and water-soluble writing inks.

Printing made another leap forward in the early 15<sup>th</sup> Century when Johann Gutenberg made another attempt at producing moveable type. An experienced goldsmith, Gutenberg crafted precise moulds for the English letter forms, and successfully cast metal type. A single mould could be used to reproduce multiple copies of high quality type which could then be set together to create lines of text. In 1456, Gutenberg revolutionized printing when he produced his 42-line Bible.

Famous for this breakthrough in moveable type, Gutenberg is less well known for his breakthrough in ink, which added to the Bible's beauty.



When Gutenberg found that existing water-based inks were too fluid to remain on his metallic type for a clean transfer to paper, he adapted techniques used by artists of the time who were moving from water-based

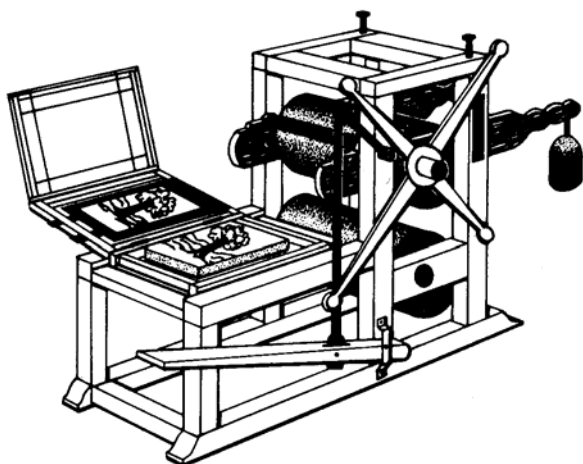
tempera paints to oil-based paints. The tempera paints were made from pigment and water with egg yolk used as binder. Applied to plaster and wood, they dried rapidly, with little flexibility. The artists began using linseed oil pressed from flax seed, heating it to produce a thicker or thinner oil, depending upon their need. This oil-based ink was used by Gutenberg, and by the beginning of the 17th Century, traditional water-based printing inks were becoming obsolete.

With the introduction of moveable type, printing became more widely available, and demand grew. Printers who had previously made their own inks now found the process too time-consuming and difficult.

Thus, for the first time, ink making became a commercial process, and ink makers willing to take the trouble to grind pigments into fine powders and determine the correct proportion of varnish for the different pigments found themselves in a viable business.

### New Processes, New Inks

Over time, as printing processes evolved and new techniques were developed, ink makers were called upon to develop new ink formulations as well.



In the 1790's the introduction of direct lithography required inks to have increased water-resistance.

By the end of the 19<sup>th</sup> Century, direct lithography had evolved to offset lithography, which used a thinner ink film and thus required stronger inks to achieve the same results.

Two other printing processes were introduced at about this time as well: aniline printing which eventually evolved into today's flexographic process, and photogravure printing, now known simply as gravure. Both of these printing processes required fast-drying inks.

Although linseed oil continued to be the main vehicle in printing inks until the middle 1930s, scientific advances in coal tar dyes, synthetic pigments, new solvents and better vehicles, were driving inkmaking into the modern age.

The growth of the petrochemical industry in the 1940's further contributed to this change, producing new organic pigments, synthetic resins, polymers, solvents and additives. Today, of the approximately 56,000 raw materials used in inks, 80 percent are petrochemical derivatives, and 15 percent come from the forest industry.

Each advancement in the printing process, each new piece of equipment, each addition to the growing list of materials that can be printed, demands further chemical and physical changes in printing inks. In essence, most of today's printing inks are custom made products, with nearly one million new ink formulae being created each year.

While historically much of the technology used by inkmakers has been drawn from the paint and coatings industry, today the ink industry's own chemists and physicists work closely with universities to develop new pigments, polymers, solvents and additives that will optimize ink performance.

### Three Legged Stool

Printing inks are basically colored coatings applied to a surface by means of one of the printing processes: offset lithography, letterpress, gravure, flexography, screen or inkjet. The printing surface or substrate can be any of a wide variety of materials: paper, carton stock, fibre and corrugated board, metal, plastic, glass, rubber, nylon, cellophane, film and metal foil.

The most intricate problem encountered by the printing ink industry is formulating inks for the infinite different combinations of substrates and presses on which they run. Process, type and speed of the press, the method of drying, the surface and other characteristics of the substrate, and the end use of the final printed product must all be taken into consideration.

Each of these factors in combination with the others during printing requires specific properties and performance features in the ink.

The ink, substrate and press must work together to achieve the desired results. In effect, they form the three legs of a stool that support the end product. Each contributes to the success of a printing application, and, as with a three-legged stool, if any one of them comes up short, the result is rocky.

In a sense, every print job begins at the end—with what is being printed and its requirements. The physical size of the job, the number of copies to be run and the end use will dictate the printing process, the substrate to be used, and the ink properties.

- Newspaper inks are a good example. They are formulated to dry by absorption with the ink oils being absorbed into the soft newsprint. This process leaves the black colorant sitting on the surface where it is susceptible to rub-off. While resins and drying oils exist that would bind the

color to the paper, their cost makes them impractical for general use on highly disposable newspapers.

- In contrast, a limited-edition coffee table book might be run on an offset sheetfed press, using high quality, glossy stock and premium vegetable-oil-based inks in process colors. There might be a gloss and matte varnish and an extra color—perhaps a gold metallic—to add brilliance. These printing requirements would dictate—and merit—a more costly set of raw materials.
- A food wrapper might require use of a film substrate to ensure product freshness. It would likely be printed on a flexographic press using water-based liquid inks with pigments that have been approved for food contact by the FDA.
- Labels for a household cleaner might be printed on a gravure press using polyethylene foam and alkali-resistant solvent-based inks

Of the three legs of the stool, ink is the most adaptable. Once a substrate is manufactured and purchased, it can't be adjusted. And though settings can be adjusted on a press, the fundamental physics of its operation and design limit the degree of such adjustments. Thus, difficulties encountered during a press run are frequently resolved through adjustments to the ink.

## Ink Basics

Every printing ink is formulated from three basic components: a colorant, a vehicle system to carry the colorant, and additives such as waxes and driers. Colorants may be dyes, but more often are pigment-based. They may be in powder form (dry toner), in a concentrated paste dispersion known as a flush, or in a liquid dispersion. Vehicles are made up of oils (petroleum or vegetable), solvents, water, or a combination of these. Most vehicles also contain resins, which serve to bind the colorant to the printing surface. Additives can include waxes, driers and

other materials that add specific characteristics to an ink or to the dried ink film.

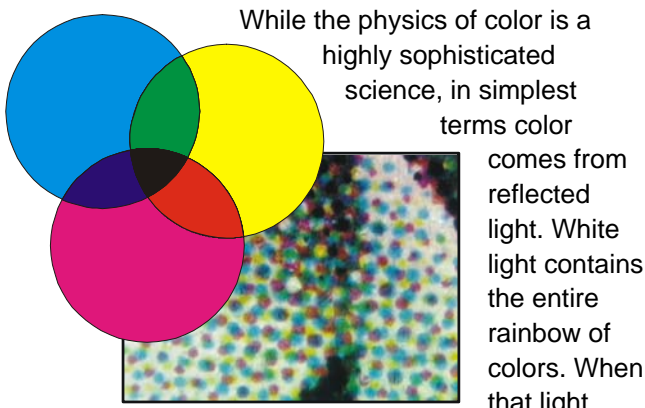
Together, these ingredients produce the key properties of ink: visual properties, runnability properties and end-use performance properties.

### Visual Properties

Visual properties of inks are a function of the colorant or pigment, in relation to the vehicle system used. They

include color, transparency or opacity, and gloss. Inks are manufactured in a seemingly endless rainbow of colors. Through careful pigment selection, ink formulators can produce inks that faithfully reproduce the hottest new lipstick color for a cosmetic ad or a classy new car color in an automotive brochure.

But these specialty matches make up only a very small percentage of the total ink produced. By far, the most widely used ink color is black. Then come cyan, magenta and yellow which are used in process printing to create the millions of colors so familiar to us in printed matter.



While the physics of color is a highly sophisticated science, in simplest terms color

comes from reflected light. White light contains the entire rainbow of colors. When that light

passes through a filter or is separated by a prism or raindrop we see the individual colors in the light spectrum. An ink film acts as a filter on the light reflected from the printed surface, e.g., a red ink film allows the red segment of the reflected spectrum to pass through while blocking the rest of the colors. Because printed surfaces vary in color and in reflectance, they, too, will affect the reflected color. Thus, various ink colors printed individually or “trapped” one on top of the other create different filter effects resulting in different visible colors. Similarly, these same ink colors printed on different substrates will result in visible colors that are different yet.

When we refer to ink color, we are most often speaking of hue or shade—whether the ink is red or blue or green or purple. Secondly, we might describe its strength or saturation, also termed chroma. Thirdly, we might indicate how light or dark it is—a reference to its purity or value.

The physical and chemical nature of a pigment—the size and even the shape of its particles—contribute to the refractive nature of the colorant, and thus to its hue. The amount of pigment used affects an ink’s color strength, and the type of vehicle used can affect

both the hue and the value of the ink color. The color of the vehicle itself, its ability to wet the pigment articles, and even the chemical interaction between the vehicle and pigment can affect the shade or purity. Finally the color of the substrate, and its drying/absorption properties affect the printed color results.

The choice of colorant and the degree to which it is dispersed through the vehicle are the most important factors in determining the transparency or opacity of an ink.

The substrate will also affect the amount of light that is reflected back through the ink film; gloss and matte paper, transparent film and metallic surfaces will have considerably different reflective capacities, making the printed ink film appear more or less opaque accordingly.

Gloss refers to an ink’s own ability to reflect light, and depends upon the lay or smoothness of the ink film on the substrate surface. Generally, the higher the ratio of vehicle to colorant, the smoother the lay, and the higher the gloss. Application of a thicker ink film tends to improve gloss while penetration into the substrate tends to reduce it.

### Runnability Properties

Runnability is a term unique to printing. It applies to the trouble-free interaction between the ink and the press, the paper and the press, and finally, the ink and paper. The inks used in the different printing processes require different runnability properties in order to travel in optimal fashion through the press to the substrate. In addition, they must adhere to the substrate and dry properly.

Runnability requirements increase in importance as press speeds increase. Body, temperature stability, length, tack, adhesion and drying all contribute to the runnability of an ink and are primarily a function of the *vehicle system* used in the ink.

*Body* refers to the consistency, stiffness or softness of an ink. Viscosity is a related term that refers to the flow characteristics of soft or fluid inks. Ink body and viscosity requirements vary widely by printing process. In general, letterpress and offset lithographic inks are fairly thick or “viscous” (much like paste or honey). On press, they move through a series of rollers called the ink train where the action of the

rollers spreads the ink into a thin film for transfer to the blanket and/or plate and onto the substrate. Flexographic and gravure printing inks are much more liquid (more like milk), so that they flow easily into and out of the engraved cells on anilox rollers (flexo) and print cylinders (gravure).

Temperature stability in an ink is important in allowing it to withstand the heat generated by the friction that occurs as the ink moves through the rotating rollers and cylinders. If an ink vehicle is not sufficiently stable, the increased temperature can have a deleterious effect on an ink's body and therefore on its runnability.

Yet another quality, length, describes an ink's tendency to form long threads when stretched or pulled. *Long* inks flow well but form long filaments that have a tendency to sling or mist, especially on high-speed presses. *Short* inks have the consistency of butter and flow poorly. They tend to build up on rollers, plates or blankets. Inks with the best runnability are neither excessively long nor short.

*Tack* is the stickiness of an ink, or the force required to split an ink film between two surfaces. With paste inks, tack is critical to the proper transfer of ink through the ink train to the plate and/or blanket and then to the substrate. Tack also determines whether the ink will pick the surface of the paper; ink tack that is higher than the strength of the paper surface will tear it. Tack affects whether inks will trap properly in multi-color printing. The first-down color should have the greatest tack without picking the stock; succeeding colors usually need progressively less tack for proper trapping. Tack also influences whether an ink prints in sharp lines and images or squashes out on the plate, blanket or substrate.

*Drying* properties of an ink are critical for a number of reasons. The most obvious is that a printed piece cannot be handled or used until the ink has developed film integrity. In addition, however, the way an ink dries can reduce air pollution, improve energy efficiency, and even improve productivity in the pressroom by allowing faster printing and converting.

In most cases, the first phase of ink drying is setting; immediately upon being applied to the stock, the liquid portion of the ink begins to evaporate into the air or to penetrate the stock, causing the ink to

thicken. Setting is followed by actual drying via one or more possible mechanisms: absorption, oxidation, evaporation, or polymerization. The specific mechanism is determined by the relationship between the printing process itself, the ink vehicle system, and the substrate.

Inks that are applied to an absorbent substrate such as newsprint or corrugated board dry by *absorption*. The liquid portion of the ink penetrates the substrate, leaving an ink film on the surface. Depending upon the printing process, this ink film may undergo additional drying procedures.

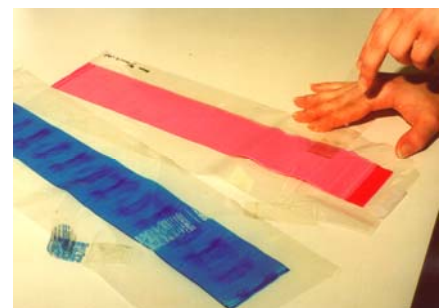
In *oxidation*, components in the ink's oils chemically combine with oxygen in the atmosphere to form a semisolid or solid ink film. It often occurs in combination with absorption. Oxidation can be accelerated by the use of driers in the ink formulation or by the application of heat or infrared radiation to the printed piece.

Since non-porous substrates such as plastic films and glass cannot absorb ink vehicles, they require inks that dry either through *evaporation* or by *polymerization* (e.g., radiation curing). In the former, vehicle solvents evaporate, leaving resins and other materials behind to bind the pigments to the substrate. Evaporation from the inks must be rapid enough for complete drying, but not so rapid as to cause instability while the inks are still running on press.

In radiation curing, all of the components in the ink remain on the surface of the substrate, but are *polymerized* into a hard film by the use of ultra-violet light or electron beam energy to trigger a chemical reaction. UV-curable inks require the presence of a photo-initiator, while EB-curable formulations do not.

*Adhesive characteristics* of inks are critical as well.

For successful printing, an ink must adhere to the substrate for the life span of the product, whether it's on paper, board,



film, foil, plastic, metal, glass or rubber. Here again

the vehicle system is most responsible for an ink's adhesive properties, although colorants can have an effect depending upon their chemical compatibility with the vehicle system and the ratio of pigment to vehicle.

As with drying, adhesion can occur in several ways. On absorbent substrates, vehicle penetration is key. On non-absorbent surfaces the vehicle resin's ability to form a continuous film and its chemical affinity for the substrate are most important. Ink solvents provide the wetting and flow-out of ink to give the continuous film necessary for good adhesion. Solvents can also soften substrates such as PVC to promote both physical and chemical bonding. Selection or formulation of the proper vehicle is essential to proper adhesion.

### End Use Properties

Ink makers not only have to consider all of the conditions that have to be met for successful print production, they must also formulate a product that takes into consideration the finishing process and the end use of the printed article.



Folding cartons, for example, may be printed, diecut, scored, folded, glued and delivered in one continuous operation. These inks must be formulated to dry quickly to an especially tough, rub-resistant surface in order to

withstand this physical converting process as well as the ultimate filling and shipping.

Paper napkins, towels, wallpaper and the like often are "creped" or embossed with a design either during or after printing. Other printed surfaces may be laminated. Beer or food containers may undergo

sterilization or pasteurization. Inks for posters require lightfastness.

Some bread wrappers and milk containers are waxed after printing to make the paper moisture resistant. Inks for this purpose must be formulated with pigments and vehicles that will not bleed in hot wax.

Selected waxes, lubricants, gums and starches are used together with pigments and vehicles to lend these and other decorative and functional properties to inks.

Because most printed articles are subject to rub or abrasion over time, all inks are formulated for some degree of *abrasion resistance*. Resistance can come from the resin used in the vehicle, the level of pigment dispersed in the ink, or the method used for dispersion. Surface and slip compounds such as waxes can be added to provide additional abrasion resistance as they move to the surface of the dried ink film.

*Heat resistance* in inks is important where pasteurization or heat sealing procedures will be used. The vehicle system must not soften nor the color decompose when exposed to high temperatures.

*Lightfastness* of an ink is important in poster printing, art reproduction, labels, and point of purchase displays. It is a function of ambient conditions, length of exposure, substrate and ink film thickness, but primarily the pigments used.

Pigments and resins have varying degrees of resistance to acids, alkalis, oils, fats, detergents and other substances and must be selected carefully. Inks used on cartons or labels must be able to withstand contact with the contents of the packages. Where food is involved, compounds must be chosen that won't affect the food's flavor.

Finally, an ink exposed to the weather or saltwater will have to use colorants that resist fading under the physical and chemical attack by these elements.

### Good Information Produces Good Formulations

At times, printing problems may occur when an ink manufacturer is not fully informed about the particular substrate to be printed. Others can be traced to pressroom operations. Still others occur in the final applications. Regardless of their source, many of these problems can be avoided by the proper

formulation of the ink or corrected through modifications of the ink on press.

As we have seen, ink ingredients can make inks transparent or opaque, glossy or dull, metallic or fluorescent, light-fast or rub-proof, heat resistant or chemical resistant. Inks for soap wrappers and detergent cartons can be alkali and soap resistant, and inks for outdoor displays can be light and water-resistant. Inks for shipping containers can be scuff and scratch resistant, and inks for food packages can be odorless. Inks on liquor labels can be alcohol resistant, and inks for boilable or microwaveable food containers can resist high temperatures.

Inks can be properly formulated to avoid quality problems such as picking, poor trapping, strike through, set-off, dot distortion and tinting

It is obvious that having the right ink formulation is key to the success of a printing job. It should also be apparent that creating the right ink formulation depends upon having sufficient information to select the proper combination of colorant, vehicle and additives. The ink formulator must have comprehensive information on the printing and finishing process, the substrate and the end use of the printed product.

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