A comparison of various printing inks for pressure sensitive label application

Joe Cichon

Because printing inks today offer such a wide variety of characteristics, selecting one for a particular application requires a careful look at all the factors involved.

Although there are many different types of printing inks available for label application, there are many similarities among the various types of inks. All printing inks share the following essential characteristics:

1. They are intended to change the appearance or other properties of the substrate.
2. They must be liquid to be transferred through a press.
3. They must become solid once applied to the substrate.
4. They must stay (adhere) where they are printed during end use.

We will study the similarities and differences of the various types of printing inks used on label applications in the body of this paper.

Most printing inks are comprised of three major types of ingredients or mixtures of ingredients: colorants, vehicles, and modifiers. These ingredients may vary with the type of ink, but all inks must contain material from each of the three major raw material groups.

The colorants used in an ink can be of many different types, but the four most commonly used colorants are dyes, organic pigments, fluorescent pigments, and inorganic pigments. The fluorescent pigments are the most brilliant but are also the most fugitive to sunlight. A fluorescent red appears to be very bright because it has the ability to absorb violet, blue and green light energy and convert it into red light. A standard nonfluorescent colorant will simply absorb the complementary colors and dissipate the energy as heat.

Inorganic pigments are essentially based on minerals. Such pigments as chrome yellow, molybdate orange, cadmium red and titanium dioxide are all inorganic pigments. The inorganic pigments are usually very permanent and inexpensive; however, the lead-based pigments (chrome yellow, moly orange, etc.) have lost popularity because of increased concern over their toxicity. The most commonly used inorganic pigment today is titanium dioxide, which is considered relatively nontoxic. It is used in opaque whites.

Organic pigments are the most commonly used colorants in any type of ink. Most are synthesized from petroleum based products. The organic pigments can range in color and degree of fastness. They will generally withstand exposure to sunlight for at least three days before showing any color loss, but some of the organics can last for years in direct sunlight.

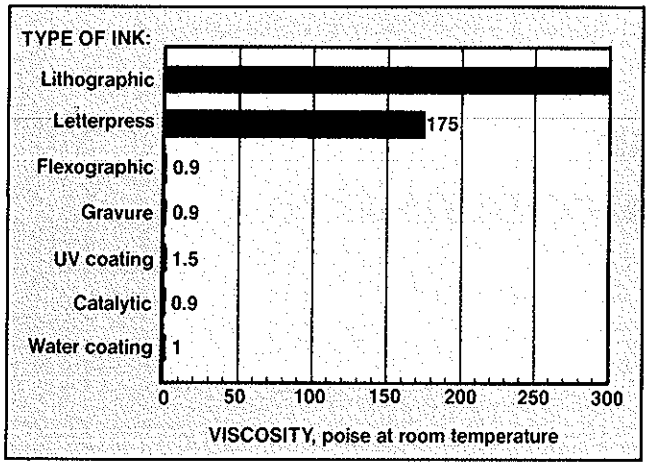
The dye colorants are used almost exclusively for flexo envelopes, bags and some labels. The dye-based colorants have a tremendous strength advantage over pigments and are very bright and clean. However, dyes have poor fastness properties, which make their use limited. Most dyes will fade in sunlight within two to three hours. They are also very sensitive to bleeding in alcohol and other chemicals. Most of the resistance properties of an ink will be determined by the colorant used in the formula.

The vehicle is the portion of the ink formula which carries the colorant through the printing press and to the substrate. It contains a mixture of resins, solvents, and special varnishes, and it will determine the printing or transfer properties of the ink. The vehicle is also responsible for the adhesion and gloss properties of the printed ink.

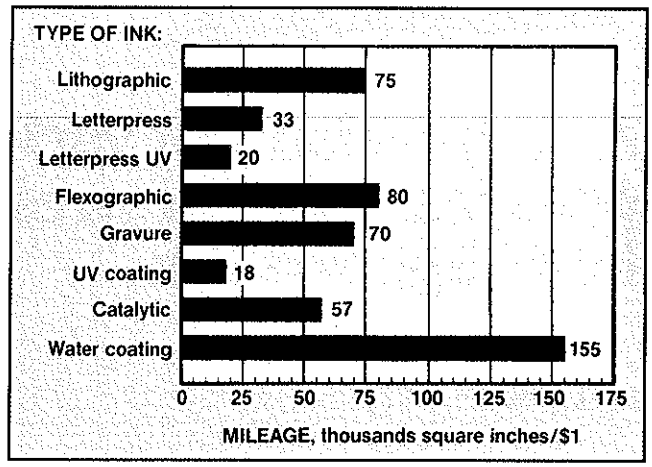
Additives make up the third group of materials. The additives include waxes, silicones, surfactants, catalysts, etc. These additives control some of the printing properties and also some of the properties of the dried film. The additives used in a sheetfed offset printing ink might be waxes such as polyethylene or Teflon for slip properties and a catalyst such as cobalt dryer to allow the vehicle system to cure more rapidly.

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1. Relative viscosity of printing inks



2. Relative mileage of printing inks



Ink construction

In manufacturing the various inks systems, the most difficult step is the dispersion of the pigment into the vehicle system. Most inks are made in three steps: dispersion and grinding of pigment into a vehicle, blending together the items, and final adjustment and quality control. The most time-consuming and expensive procedure is the pigment dispersion. The pigment is mixed slowly and carefully into the varnish mixture under high shear to achieve a good predispersion. Once the predispersion is made, the batch is then ready for final dispersion or grinding. Depending on the type of ink being produced, different techniques may be used: flushing, three-roll mill, shot mill, sand mill, ball mill, and other types of mills. Regardless of the type of milling operation used, the goal is the same—to reduce the size of the pigment particles in the ink system to below 3 microns in size.

Comparison of various ink systems

Let us compare the major ink types to one another for physical properties and usage.

Sheetfed and web-heat-set inks

Lithographic inks can be printed on many substrates, either as sheetfed inks or as web heat-set inks. The ink is selectively transferred to an oil-receptive printing image on a water-receptive printing plate. In order for the ink to selectively transfer properly, the formulation must be balanced for proper emulsification with water (fountain solution) when being printed. The viscosity of most litho inks, as indicated in **Fig. 1**, is around 200-300 poise. These inks can contain anywhere from 0% to 30% of ink oil solvents. Special formulated inks which contain no free solvent are often referred to as 100% solids inks and are required for most plastic substrates. For paper applications, the presence of about 20-30% of ink oil solvents helps increase the setting speed of "quick-set" inks.

The "quick-set" inks depend on two mechanisms for setting and drying. Evaporation and absorption of the solvents will give the inks their initial "set." The final cure is a chemical reaction known as oxidative polymerization. The vehicles, combined with the metal catalysts (such as cobalt acetate), react together in the presence of air. The reaction will slowly turn the liquid inks system to a plastic-like film of ink. The drying reaction will require from 3 to 24 hours. Heat-set inks are very similar to sheetfed inks except that the drying mechanism uses high temperatures (above 200°F) to evaporate the solvents away from the vehicle system in an oven. Press speeds of over 1800 ft/min can be achieved on web heat-set presses with these inks. One lb of sheetfed ink will cover approximately 300,000 in.^{2} if applied at a film thickness of around 0.1 mils (0.25 mils on last hard form roller). As indicated in **Fig. 2**, at an average ink cost of around $4.00 per lb, the ink will cover 75,000 in.^{2} per dollar.

The odor level of most sheetfed inks when dry is considered relatively poor but will, of course, depend on the type of formulation. Once cured by oxidation, sheetfed litho inks will have good water resistance, as well as resistance to mild soaps and diluted alcohols. Sheetfed offset inks are commonly used for printing on poly coated board, where the final product may be a frozen food carton. Resistance to strong solvents will be poor. Most heat-set offset inks will have poor resistance even to skin oil if the formulation is not specially modified.

Letterpress inks

Letterpress inks are transferred from a raised image printing plate. Since letterpress inks do not need to emulsify with fountain solutions as lithographic inks must, they are a little more diversified in nature. Except for the ultraviolet (UV) cured inks, letterpress inks are mainly used on paper substrates. Conventional oil-based letterpress inks can be identical to lithographic inks. As indicated in Fig. 1, the viscosity of most letterpress ink is slightly lower than sheetfed inks (around 75-200 poise). Most of the properties of conventional oil-based letterpress inks will be similar to those of lithographic printing inks. The major difference between the two types is that letterpress inks are generally weaker in strength and applied two to three times the film thickness. One lb of letterpress ink will cover about 100,000 in.^{2} The ink is usually applied at a film thickness of 0.3 mils (0.7 mils on the last hard form roller). Since the pigmentation of a letterpress ink is much lower, it results in a lower cost per lb than lithographic inks. At about $3.00 per lb, the

ink will cover 33,000 in.^{2} per dollar of ink cost (Fig. 2).

Glycol-based or water washable letterpress inks are based on the polar glycol-type solvents. Since these solvents easily mix with water, these inks are classified as water washable. The glycol-based letterpress inks are generally lower cost than the oil-based letterpress inks. These inks do not polymerize as the oil-based inks do and therefore are not as good for rub and resistance properties. The inks achieve the solid state by penetration of the solvent into the substrate and some evaporation of the solvent. In many cases it may require a full week for the inks to develop complete water resistance. Mileage for glycol inks would be the same as for oil-based letterpress inks.

Ultraviolet cured letterpress inks achieve the transition to the solid state via photo polymerization. A high-intensity ultraviolet light source is used to achieve an almost complete cure of the inks in fractions of a second. The rate at which the inks can be cured is limited only by the number of curing units which can be on the press. Most letterpress UV inks will cure at a rate of 100 ft/min per every 200 watt/linear in. bulb. Thus with three 200 watt/linear in. bulbs, a running speed of 300 ft/min can be achieved. The physical properties of UV cured letterpress inks are similar to other letterpress inks. The UV cured inks show a tremendous advantage over other inks in that the polymers formed in the curing process are extremely strong and resistant to most solvents or other chemicals. As a result of the strong resistance properties, UV inks and coatings have become very popular for special chemical and pharmaceutical labels. The cost per lb for UV inks is generally higher than other letterpress inks due to the higher costs of the vehicles and special pigments and the increased handling costs, since the mixtures are light sensitive.

Flexographic inks

Flexographic inks, like letterpress inks, are transferred to the substrate by a raised image plate. The viscosity of flexographic inks is much lower than that of lithographic or letterpress inks. The viscosity of flexographic inks is usually adjusted at printing time but in most cases is printed at 70 centipoise (a viscosity similar to water). The inks achieve the solid state by evaporation of the solvents away from the hard resin. In some cases, when printing on paper, the inks will achieve some solidification by absorbing into the substrate.

Solvent-based flexographic inks are usually based on alcohol soluble resins and can contain as much as 70% by weight of volatile solvent. The inks can be dried at very high speeds, depending on the type of heating and air circulation provided to dry the ink. Run speeds on a web of 1200 ft/min are common on paper, and 600 ft/min are common on plastics. The inks can be successfully applied to a variety of substrates, including foil, cellophane, vinyl, paper, polystyrene, and many more. The finished ink film shows very low odor properties. The inks have very good water resistance properties and are commonly used on polyethylene bags for frozen foods. One drawback of the standard flexo inks is that they have very poor alcohol resistance. If they are to be used on a package containing alcohol, they may require overcoating with UV cured or catalytic cured top coatings, or lamination with a clear film.

There are two major types of colorants used in solvent-based flexographic inks. Pigments similar to those used in other ink systems are common, but dyes are a very common colorant in flexographic inks. The dye-based colorants have a tremendous strength advantage over pigments and are very bright and clean. However, dyes have poor fastness properties which make their use limited. Most dyes will fade in sunlight within two to three hours. They are also very sensitive to exposure or bleeding in alcohol and other chemicals. When used to coordinate or match items printed by another printing process, dye-based inks can exhibit a tremendous metamerism problem. The colors will appear to match under only one light source. If the source of illumination is changed, the colors will no longer appear the same.

Water-based flexographic inks must be water reducible at the press, but once printed and dried, they must be water resistant. There are two basic mechanisms used to achieve this chameleon property. An acid type of resin which is not water soluble can be dissolved in an alkaline water solution. By making a water solution of ammonia or other types of amines, the acid resin can be dissolved. The inkmaker will then balance the pH of the ink to maintain water dilutibility. After the ink is printed and the amine is evaporated from the film, the ink is completely water resistant. Another mechanism used to make water insoluble resins water reducible is to emulsify extremely small particles of polymer into a water system. After the water is evaporated, the resin particles come together and coalesce into a solid mass again.

Mileage of flexographic inks will vary considerably, depending on the application viscosity and other parameters. One lb of dye-based ink might cover as much as 400,000 in.^{2}/lb. One lb of pigment-based ink may only cover about 150,000 in.^{2}/lb of ink. Typical films applied with the flexo process would range in thickness from 0.08 mil to 0.3 mils wet. On the average, one lb of flexographic ink will cover 200,000 in.^{2} At an average cost of around $2.50 per/lb, the ink will cover 80,000 in.^{2} per dollar. Water-based or solvent-based, the ink costs will be very similar.

Gravure printing inks

The gravure printing process utilizes an image etched into a chrome-plated metal plate or cylinder. The ink is applied to the etched area of the plate and wiped away from the nonetched part of the plate. The image is then transferred directly from the metal plate to the substrate. Due to the hardness of the printing plate, only relatively smooth substrates can be used. Gravure inks are very similar to flexographic inks in most properties. As a matter of fact, most flexographic ink can be printed by the gravure process without any major problem. (Don't, however, try to print with a gravure ink on a flexo press.) Because the ink does not touch anything other than the metal plate and the substrate in the gravure process, gravure inks can be based on any solvent system which will not attack the metal in the plate. The typical gravure printing ink will contain about 60%–70% solvents. The solvents most commonly used are ketones, esters, alcohols, aromatics, aliphatics, and water.

The resistance properties of dry gravure inks will be similar to those of flexographic inks, except that the gravure inks will have much better alcohol resistance. The

gravure inks achieve the solid state during drying, the same as the flexographic inks, by evaporation of solvent and some penetration. The vehicle system used for gravure inks can be based on many different synthetic and natural resins.

The gravure process can apply approximately twice as much ink as the flexographic process does. Usual film thickness of application is 0.30 mils wet. Typically one lb of gravure ink will cover about 175,000 in.^{2} At an average cost of $2.30 per lb, the ink will cover 70,000 in.^{2} per dollar.

Specialty coatings

Ultraviolet cured coatings

Ultraviolet cured coatings can be applied in several printing applications: flexographic, letterpress, sheetfed offset, roller coater, or silk screen. The coatings contain no solvents (100% solids). Coatings can be made for application over any other printing process. The viscosity of coatings will vary depending on the application but will usually be about 90 centipoise. The UV coatings give protection similar to that of lamination because a plastic material is literally being formed on the surface as the material cures. UV coatings cure at a rate slightly faster than UV inks. Once again the UV coatings are cured by photopolymerization. A good film of UV coating can have a 60° gloss of above 90% on paper. A typical coating weight applied on UV coating is about 0.35 mils, or about 83,000 in.^{2} per lb. At a coating cost of about $4.50 per lb, the coating will cover 18,400 in.^{2} per dollar. In addition to the very high gloss, the UV coatings are very resistant to most organic solvents and acids.

Catalytic coatings

A catalytic coating can have a lower application cost than a UV coating. Catalytic coatings are cured by mixing an acid catalyst into the main coating just prior to using. The solvents must be evaporated before the reaction can be completed. The acid and heat together initiate the final reaction between a melamine-type material and an alkyd (or polyester). The coatings are generally applied on a roller coater device and require about 250°F oven exposure for about 10 seconds. Once cured, the coatings show product resistance similar to that of UV cured coatings. Most of these coatings contain from 30%–50% organic solvent. These coatings are applied wet at about 0.35 mils. One lb of mixed coating will cover about 85,000 in.^{2} At a cost of $1.50 per lb, the coating will cover about 57,000 in.^{2} per dollar. Water-based catalytic coatings are also available but will only work well on nonalkaline papers.

Water-based coatings

Water-based coatings can be applied by gravure, flexography, dampener coaters on a lithographic press, or other types of coating equipment. The physical and chemical properties of waterbased coatings will be similar to those of water-based inks. These coatings generally contain around 50%–60% volatile matter, i.e., water. These coatings are usually applied at a film thickness of around 0.15 to 0.30 mils wet. At an average cost of around $1.10 per lb, the material will cover 155,000 in.^{2} per dollar.

Additional sources of information

For more information, see "Chemistry for the Graphic Arts" by Dr. Paul J. Hartsuch, Graphic Arts Technical Foundation, 1983; "Printing Ink Handbook" by the National Association of Printing Ink Manufacturers; "The Lithographer's Manual" by Raymond N. Blair, Graphic Arts Technical Foundation, 1979; and "Flexography Principles and Practices" by the Flexographic Technical Association.□

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