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Ink

By Judy K. Miller

Look around you and see whether you can spot any ink. In addition to the ink-printed words you are reading now, you may see more printing ink on a newspaper or poster. If you've been writing in a notebook, you'll see some ballpoint pen ink. And what about that blue-lined paper? Those lines were printed with ink. If you're having a snack, take a close look at that soda can and potato chip bag. Both have been printed with ink. Then there's the calendar on the wall and the wallpaper. Even some brands of toilet tissue are decorated with ink-printed designs.

The Egyptians used inks 4000 years ago to write official documents. Their writing products were primitive, but they contained the essential components: a pigment, a vehicle, and a substrate. The substrate is the surface that is printed upon and could be paper, parchment, or a Pepsi can. The Egyptians used papyrus—a coarse paper-like material made from a plant of the same name. For a pigment or coloring agent, the Egyptians used carbon soot. The vehicle is the liquid that carries the pigment from the pen to the substrate, then hardens to hold it there. The Egyptians used a mixture of water and plant gum.

Pigments

Without pigments there would be nothing to read—no letters on the substrate. Because the vehicle is a liquid, it is logical to assume that the pigment is *dissolved* in the vehicle, but it is not. The pigment is a finely ground insoluble solid that is *dispersed* in the vehicle. If it were dissolved, it would consist of separate molecules. Instead, each particle contains millions of molecules and is typically 0.00001 mm to 0.0005 mm in diameter. If the coloring agent were in solution, it would soak into the substrate with the vehicle, and the printing might show through on the back side of the paper. Because the pigments are dispersions, the large particles are deposited on the surface.

More than half the ink used in the United States is black, and most of the black pigment is made—like the Egyptian ink—of elemental carbon. The carbon may come from burning hydrocarbon fuels such as oil or natural gas, or from organic waste such as wood, vines, or bones. In every case, carbon-containing compounds are reduced to elemental carbon such as soot or lamp black. The end product contains only carbon but, depending on the source, the particles vary in size and light absorption.

Carbon also appears in colored pigments, but it appears here not as an element but as part of organic molecules (carbon is one of the elements in the molecule). An example of a blue pigment is shown in Figure 1.

Some pigments are inorganic (contain no carbon), such as titanium dioxide (white), lead chromate (yellow), cadmium selenide (red), and ferric ferrocyanide (blue).

Vehicles

The vehicle has a tough job. It must be a liquid so it can flow from the pen or printing press onto the substrate, and then, to hold the pigment in place, it must thicken to a near-solid condition—instantly. In addition, it must disperse the pigment but not dissolve it. This impossible list of requirements has kept ink chemists busy for decades.

There are four ways to make the vehicle change quickly: evaporation, absorption, oxidation, and polymerization. The Egyptians used a water solution of plant gums as the vehicle.After the ink was applied to the substrate, the water evaporated, which caused the gum to harden. Water-based inks are still used; you have probably complained about them when they were slow to dry on a humid day or streaked when the writing got wet.

To overcome the disadvantages of water-based inks, ink makers turned to oils; linseed oil became the vehicle of choice. Because oils are hydrophobic, they will not dissolve in water and the ink will not run if it gets wet. Made by squeezing oil from flax seeds, linseed oil is a mixture of oleic acid, linoleic acid, and linolenic acid (see Figure 2). Linseed oil solidifies by oxidation when it is exposed to air. The oxygen in the air causes linoleic and linolenic acids to polymerize—join to form much larger molecules. Ink makers call linseed oil a “drying oil” because it can solidify.

Another drying oil is tung oil, also known as chinawood oil. Tung oil is primarily made up of the glycerides (fat-like molecules) of eleostearic acid. The molecules in linseed oil have two double bonds, but eleostearic acid has three (Figure 3).

The alternate arrangement (double bond, single bond, double bond) makes tung oil oxidize and polymerize more readily, hence its superior performance as a drying oil.

Some drying oils still don't harden fast enough to meet the demands of modern printing presses. To speed things up, the linoleate salts of cobalt, lead, or manganese are added. These salts act as catalysts by carrying oxygen to the oil molecules.

Solvent pollution

In the past, organic solvents were often added to oil-based inks to make them more fluid. The solvents made the ink less viscous while it was being applied to the substrate, then made it more viscous when the solvents were absorbed into the substrate or evaporated into the air. The solvents gave a characteristic smell to the printer's shop as well as the pages of a freshly printed document. Typical organic solvents were low molecular weight alcohols such as methyl alcohol, ethyl alcohol, or isopropyl alcohol; glycols such as ethylene and propylene; ketones such as acetone; and hydrocarbons such as hexane, heptane, toluene, and xylene. But when these solvents evaporate, they add to our air pollution. The Federal Clean Air Act of 1970 dictates that such volatile compounds be limited to no more than 20% of the weight of the ink unless the printer installs equipment that traps and recovers the solvent vapors. The organic solvents have been replaced by special plasticizers.

In anticipation of more stringent pollution requirements, some ink makers are returning to water-based inks. The new formulations contain as much as 65% water but are not completely free of organic solvents. Alcohols and glycols are used to help dissolve the resin and to lower the water's surface tension.

Absorption and evaporation are affected by the nature of the substrate and the drying conditions. The more porous the substrate, the faster the drying by absorption; the warmer the environment, the more effective the evaporation. Printers sometimes use heat to help dry the printed ink.

Today, ink vehicles are mainly resins, which are polymers. Polymers are very large molecules made up of repeating parts. Resins originally came from natural sources such as pine trees and the like. Since the early 1900s, however, synthetic (man-made) resins have been used in ink because of their superior gloss, scuff resistance, and good adhesion to the substrate. An alkyd resin that is commonly used in ink vehicles might be made up of many repetitions of this structure (Figure 4).

Polymerization, known in the ink industry as heat-bodying, causes the resin to thicken and eventually harden.

There are four industrial processes for printing, and each process requires its own inks. In addition, the ink industry is working to reduce air pollution and improve color accuracy. It's no wonder that about 1 million new ink formulas are introduced each year.

SIDE BAR

Flap test

Modern printing presses are so fast that the ink must be adjusted without stopping the press. While a continuous roll of paper flies through at up to 30 miles per hour, a strobe light, flashing many times a second, freezes the printed image—makes it look as if it is not moving. This allows the operator to examine the four-color test strip and adjust the flow of each color ink on the fly.

If you disassemble a cereal box or cookie box, you may find a series of small rectangles printed in different colors. This is a test strip, which helps the printer control each ink in the four-color printing process. Most printers use subtractive inks that absorb the primary colors. On the test strip you will see yellow, which absorbs blue light; magenta (pinkish-red), which absorbs green; cyan (blue-green), which absorbs red; and black, which absorbs all colors. Combinations of these inks are printed as neighboring dots of varying sizes; they offer control of the entire spectrum.

CAPTIONS

Figure 1. This copper-based blue pigment is called phthalocyanine blue. The ink industry is continually trying to synthesize new pigments that will give more realistic images when used in combination with other colors.

This small laboratory press is used to test batches of printing inks. Most printing today is done by offset lithography, which exploits the fact that water and oil don't mix. The printing cylinder is made of aluminum, which is hydrophilic—easily wet by water. In areas that will be printed, such as text or photos, the aluminum is coated with a hydrophobic polymer that repels water but is easily coated with the oil-based ink. As the cylinder rotates, it comes into contact with water-coated rollers (not shown) and then ink-coated rollers, seen above.

The water coats the bare aluminum areas but not the polymer areas; the ink coats the polymer areas but not the wet aluminum. The cylinder transfers the ink to a second rubber-covered cylinder, which transfers it to the paper. Because the letters are reversed when transferred to the rubber cylinder, and reversed again when transferred to the paper, the letters read correctly on the original cylinder. The words you are now reading were printed by offset lithography.

Figure 2. Linseed oil contains a mixture of these fatty acids. The presence of double bonds makes them more reactive to oxygen in the air.

Figure 3. Tung oil, comprised largely of eleostearic acid, above, is often added to printing ink. Because it has three double bonds, it readily polymerizes to form a solid. Tung oil is also applied to furniture to give a hard, smooth finish.

Figure 4. Natural oils have largely been replaced by tougher, faster drying synthetics such as this alkyd resin. When dry, the ink would contain thousands of such linked structures.

BIOGRAPHY

Judy Miller teaches English at Virginia Hollis Community College and is the co-founder of the Appalachian Center for Poets and Writers.

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