BY JEFF JEWITT

Understanding Wood Stains

At it's core staining wood simply means to color it without obscuring the grain. Well as all woodworkers know, staining wood can be a nightmare. All sorts of things can go wrong at the staining stage and these include splotching, bleeding color, stain doesn't "take", color doesn't look like the sample, color fading and so on. Finishers usually learn to deal with problems by trial and error, working through countless samples or giving up entirely.

In the professional world of woodworking and finishing - knowledge is power. While the performance of the basic materials used in stains have improved in the last fifty years - their basic properties haven't. The purpose of this article is to acquaint the non-scientist with the basic physics and chemistry of the materials of stains - pigments, dyes, solvents and binders. Understanding how these materials interact with wood will hopefully give finishers more confidence in application and problem-solving stain application.

STAIN CLASSIFICATIONS

p are three classes of stains - pigment-based, dye based and chemical based. Pigment stains use a fine, inert, colored powder as the colorant. Dye stains are based upon a soluble organic chemical dyestuff. The third class, chemical dyes, are based upon a colored precipitate that is formed within the fibers of the wood by a reaction between an applied chemical and chemicals normally present in the wood. While this type of staining can produce some interesting effects - they're rarely used in industrial and professional finishing. Although industrial finishing technicians use the term "colorant" instead of dye or pigment, it's important for finishers to grasp the basic science involved with the difference between the two.

I. Pigment Stains

Pigment stains are the most common stain used in this country. You find them in every paint and hardware store as well as specialty finishing suppliers. There are three ingredients required to make a pigment stain, pigment, binder and carrier.

PIGMENT - pigment is a finely ground, inert, colored powder. They can be natural or man-made, organic or inorganic. By organic we generally mean containing carbon along with hydrogen and oxygen, as well as nitrogen and sulfur. Pigments are classified industrially according the chemistry of the main colorant. While any pigment can be used to stain wood - the ones that find the most use are: Iron Oxides - iron oxide is the yellowish to reddish-brown inorganic constituent that makes rust brown and clay red. The natural iron oxides are dug up out of the earth, washed and ground into pigment and some of these are called the earth colors -the sienna's, umber's and ochre's. The burnt form (burnt sienna, burnt umber) is the raw pigment that has been calcined - or heated to the point just below melting which confers a redder shade to the pigment. A pigment called Van Dyke brown is also in this group but somewhat incorrectly because it is composed of mostly organic matter with only a small amount of iron. The natural iron oxides are well-suited as wood stains because they contain a high silica content which makes them transparent (what technicians call a low refractive index) and they are muted in color which mimics wood-tones well. Synthetic iron oxides are available in red or yellow shades. They are more opaque (high refractive index) - which makes them ideally suited for use in paints, but they can be used in stains in micronized form (ground very fine), usually in combination with the earth pigments.

Synthetic Blacks and Whites - since there are no naturally occurring pure black pigments -carbon, in the form of charred bones (bone-black or drop black) and lampblack are used. For white pigments zinc white and titanium white are used.

Synthetic Organic Pigments - are made by complex chemical processes and produce the bright reds, blues, yellows, oranges, greens and violets that you see in inks and paints. Organic pigments are chemically similar to many of the dyes discussed below.

BINDER -- pigment will not adhere to a wood surface on it's own. It needs a binder or "glue" to stick it the wood surface. Many of the binders used are the same resins that we use as finishes - oils, alkyds, urethanes, acrylics and lacquers.

CARRIER - a mixture of pigment and binder is too thick to be applied easily with a brush, rag or spray gun, so a liquid carrier is added which is simply a solvent that's compatible with the binder. Organic solvents like mineral spirits are the dominant ones and faster drying solvents can be used such as toluene. Recent environmental legislation has pushed the need for less polluting solvents - so water-compatible binders such as acrylics and urethanes are increasing. The combination of the binder/carrier is called the vehicle or medium and it determines the flammability, dry-time and non-yellowing characteristics (acrylics).

II. DYE STAINS

Dye stains are composed of only two components - a dye and a carrier. While at the surface this may seem to be a simpler arrangement than a pigment stain- dyes are little more complex to understand

DYE - a dye is a complex organic chemical derived from petroleum products like benzene, toluene and naphthalene. Through chemical processes such as nitration and sulfonation, these chemicals are processed into dye intermediates such as aniline which are processed further by special operations like diazotization to give the final product - a dry chemical powder. These powders can be dissolved in various to yield colored solutions which can be applied to wood. The conventional classification used for many years in woodworking has been to classify dye powders as water-soluble, alcohol soluble and oil soluble dyes. While this classification serves as an adequate framework - it has also given rise to erroneous generalizations about dye performance (like alcohol dyes are not lightfast). The classification used by the dye industry provides a more accurate classification. While there are thousands of dyes used in everything from textiles to plastics - there are only several types used in woodworking applications.

Basic dyes - these dyes possess a base-like chemical group. These type of dyes were among the first dyes synthesized in the late 1800's. They can be water or alcohol soluble and although very vivid, they possess overall poor lightfastness.

Acid dyes - these dyes possess an acid-like group which confers water solubility upon the dye but are so named because in textile dyeing they are used with some sulfuric or acetic acid in the water solution. Overall -these dyes possess average to very good lightfastness.

Direct dyes - these dyes are similar to acid dyes but have such an affinity for certain textiles (like cotton) that they need only be applied in aqueous solution.

Solvent dyes - dyes that dissolve in certain organic solvents. They are sub- classified as spirit soluble (alcohol) or oil soluble (soluble in vegetable and mineral oils as well as hydrocarbon based solvents like mineral spirits and toluene)

Metallized dyes - some dye groups like acid and solvent dyes can be improved from a lightfastness standpoint by incorporating a metal ion into the molecule. The metal most used is chromium, although cobalt and copper are also used.

CARRIER - dyes dissolve best in certain solvents but the carrier does not have to contain 100% primary solvent. Alcohol can be added to water-soluble dyes, and oil-soluble dyes can have varying amounts of other solvents like alcohol and ketones. Water-soluble metallized acid dyes can be dissolved in glycol ether type solvents, then let down with methanol. This is the typical formulation of the so-called NGR stains.

The Difference Between Dyes And Pigments

There are three main physical differences between dyes and pigments and these affect the working qualities and performance of the stain. The differences are size, how they attach to the wood and lightfastness.
Size - The difference between pigments and dyes can be best visualized by their size. Pigment particles in most wood stains are about 1-2 microns. (1 micron =1/1000 meter) That means that you can see them under a magnifying glass. When a pigment stain is applied to the surface of a piece of wood and wiped off, the discrete pigment particles get lodged in pores, crevices and scratches, any cavity that's larger than the size of a pigment. On ring porous woods like oak - the stain accentuates the pore structure because more pigment is deposited in the pores than in the flat grain between. On diffuse-porous wood like birch - the pigment stains more evenly. On very dense, close grained woods like hard maple, the pigment stains very light because the surface cannot hold much pigment. Because 1-2 microns is well above the wavelength of visible light (.4 - .7 microns or 400-700 nanometers), pigments absorb light (to produce color) and block it's transmission by reflecting it. If built up too thickly to achieve dark effects, pigment stains can obliterate wood grain but if used correctly can add contrast and depth.

By comparison, dye molecules are much smaller- it would be like comparing a soccer ball (pigment) to the head of a pin (dye). Dye molecule size results in several other differences. Dye colors evenly - regardless of the density or pore structure of the wood and light is not blocked by the dye molecule, it's absorbed and transmitted. This gives dyes their unique ability to accentuate grain and subtle figure even though the dye color is bold and dark.

Method Of Attachment

Pigment requires a binder to glue it to the surface of wood because it's an inert substance that's merely suspended in a carrier/binder. A dye is in solution and to understand how a dye "sticks" to wood it's important to be able to visualize dyes at the molecular level - something easy for chemists but not so for the average person. Both the dye and the substrate being dyed (wood) are chemicals - possesing certain characteristics which chemists call functional groups. At the molecular level these groups can be visualized as open pockets of electrostatic charges (+ or -) or acid-base characteristics. In dyes, the functional group can serve as a method of attaching the dye to the wood. Acid and direct dyes can attach themselves through molecular electromagnetic forces like zillions of tiny little magnets, basic dyes can have an acid-base attraction (wood is acidic) while solvent dyes are just absorbed into the wood (which is why oil and alcohol dyes have more of a tendency to bleed) . This is why dyes do not require a binder like pigment does. Water dyes penetrate the deepest because wood is hydrophilic (water-loving), but water causes the wood fibers to swell - which raises the grain. Non-grain raising solvents are used in industrial finishing because of the extra time necessary to re-sand the surface.

Lightfastness

The performance difference between dyes and pigments is in lightfastness. Since light is comprised of electromagnetic radiation - it can have a destructive effect on both pigments and dyes, but dyes are most vulnerable. Light destroys colored objects by breaking electronic bonding within the molecule. An inorganic molecule such as iron oxide has very stable, strong molecular forces which hold the atoms in the molecule together. The energy in sunlight is not sufficient to break these bonds. Conversely - the bonds that hold an organic dye molecule together are much weaker - and sunlight is ultimately able to disrupt or break the bonding arrangement which causes the color to fade. This is why there are no dyes rated for exterior use. Some dyes are more lightfast than others - and the best performance can be expected from the metallized dyes. A common misconception is that alcohol dyes are not lightfast, but the solubility of a dye does not determine its lightfastness, it's chemistry does. Alcohol soluble basic dyes have been used in woodworking for so long that they've given a bad rap to all alcohol dyes in general. The metallized alcohol/ketone soluble dyes such as those made by Ciba-Geigy and BASF are very light-stable - even if compared to all other dyes. Benzotriazole additives available that can be added to finishes to mitigate dye fading and wood patination. These additives are called UV absorbers and they work on a process called tautomerism, in which harmful UV is absorbed and dissipated as harmless heat. The iron oxide pigments, titanium white and carbon black are all lightfast - even under harsh conditions. Some organic pigments are not as lightfast and while fine for interior use, aren't rated for exterior conditions.

Future Trends

New chemical production methods have enabled manufacturers to produce micronized pigments. These particle sizes are significantly smaller than the conventional pigments used in wood stains. The small size of these pigments allow the even coloring and transparent effect of a dye, (the size of the pigment is below the wavelength of visible light) but with lightfastness ratings of pigments. Although they are available on a special-order commercial basis to factories, they eventually will be filtering down to mainstream finishing availability soon.

Jeff Jewitt is a writer, teacher and manufacturer of finishing products from North Royalton, Ohio. He is the author of Hand Applied Finishes and two companion videos, Coloring Wood and Applying Topcoats (Taunton Press).