Dyes won't solve all wood coloring problems; but they will offer superior options and alternatives for most…

Dyes

The *Transparent* Alternative to Pigment Stains

This article will examine the versatility and ease of use of dyes. It will focus on the advantages of dye over pigment stains and will highlight some important distinctions between these two colorants. Hopefully, these distinctions will help avoid confusion as we move forward. Perhaps the most important distinction is found in the way that dyes color wood over and against the way color is achieved with pigment stains. Dyes are soluble chemicals that, depending on the type of dye, are dissolved in water, alcohol, or petroleum distillates (oil). When dye is applied to wood, a property defined as *chemical affinity* occurs between the dye and the wood. *Chemical affinity* can best be understood as a molecular attraction between chemical compounds (wood cellulose and liquid dye in this case) by which a new compound is formed. This affinity (or attraction) describes the tendency of dissimilar compound to combine by chemical reaction. Again, in our application the dissimilar compounds are the liquid dye and wood cellulose. This property of dyes results in the dye being absorbed by and combining with the cell structure of wood at the molecular level thereby actually changing the color of the wood as opposed to simply covering the wood with an opaque layer of pigment.

By comparison, pigment stain (hereafter referred to as "stain"), consist of insoluble solids (pigment) suspended in a binder. The purpose of the binder is to hold the insoluble solid pigment in place after the liquid component of the stain has evaporated (dried) or cured (reacted with the oxygen in the air). Absent the binder the dried pigment could be wiped, blown, or vacuumed from the surface. In the case oil-based stains the binder is simply varnish. The binder in "fast-dry" stains is lacquer, and in water-borne stains the binder is water-borne acrylic. Pigment has no *chemical affinity* for wood. Advertising claims notwithstanding, pigment *is not* absorbed by the wood, nor does a chemical change occur within the cell structure of the wood when stain is applied. Stain (pigment) colors wood by leaving an opaque film on the surface of the wood where the pigment settles into structure such as pores, sanding scratches and minute tare-out. The application of stain can

reasonably be viewed as applying very thin coat of paint to mask the natural color of the wood.

The only comparison between dyes and stains that can reasonably be made is that both color wood by ***wavelength-selective absorption***. Color, as we see it, is the result of the ability of the human eye to detect that portion of the electromagnetic spectrum composed of visible light. The human eye differentiates between colors within the visible spectrum based on the wavelength of reflected light. Visible light (color) resides within the wavelength range of 380nm to 750nm (violet through red). Ultra-violet light is not visible to the human eye because its wavelength is below 380nm. At the other end of the spectrum infra-red is not visible because its wavelength is above 750nm. With the exception of objects that generate light in the visible spectrum such as our sun, the stars, and man-made light sources such as light bulbs, objects are visible to us because they reflect light in the visible spectrum. The color that our eyes assign to the objects that we see is the result of wavelength absorption. If an object appears green to the human eye it is because the object has absorbed all wavelengths in the visible spectrum except those in the 495nm to 570nm wavelength range. If all light in the visible spectrum is absorbed the object appears black. If none of the visible spectrum is absorbed (all visible light is reflected) the object appears white.

As wood finishers, when we color wood, we are interested in altering reflected light in the visible spectrum. Since both dye and stain accomplish this objective, why should one be preferred over the other? There are several answers to this question, and we will examine them in the course of this article. But perhaps the most important reason to select dye over stain is revealed by the way in which the wavelength absorption properties of the wood are altered by these two coloring options.

When dye is applied to wood the reflective properties of the wood itself are altered at the molecular level as the dye combines chemically with the cells of the wood. The reflective properties of the wood are actually changed. There is no opaque film of insoluble pigment on the surface of the wood nor is there a binder (coat of finish) producing a film on the surface of the wood. The result is that the actual color of the wood is changed with no diminution of figure or loss of subtle grain detail.

By comparison, stain has no impact on the wood; instead, it alters wavelength absorption of the exposed surface of the wood by laying down an opaque film of pigment between the

surface of the wood and the eye of the viewer. In other words, wavelength absorption takes place within the opaque film of pigment applied to the surface of the wood, not within the wood. The color seen is not the altered color of the wood; it is the color of the film of opaque pigment on the surface of the wood. Depending on the stain used, this opaque pigment film can dramatically diminish the clarity of the grain and figure of the wood. The more pigment that is applied the more the subtle features of grain and figured are diminished.

What's in a name?

Given the quite different way in which dyes and stains color wood, it would seem apparent that any naming convention that equates the two would be misleading. While I have no expectation that the naming convention used in this article will be widely adopted, I will refer to these colorants as follow:

- ***Stain*** will refer to that method of coloring wood that employs an opaque pigment applied to the surface of the wood and held in place by a binder in which the *apparent* color is produced by the reflective properties of the pigment film.

- ***Dye*** will refer to that method of coloring wood that relies upon the application of a colorant dissolved in a solvent. When applied a chemical transformation of the reflective properties of wood itself takes place at the molecular level and no opaque film is applied to the surface of the wood.

Because of the significant differences in the way stains and dyes work I will also suggest that the term "***Dye Stain***" is at best an oxymoron and at worst an intentional deception. The term "dye stain" is equivalent to referring to a threaded metal fastener used to join two pieces of wood as a "screw nail". Both screws and nails are metal fasteners, and both can effectively join two pieces of wood; but, attempting to blur the quite different ways in which the two accomplish their assigned task by combining both names to define one or the other of them does a disservice to both.

Further complicating the picture, it *is* possible to combine dye and pigment in a single product as a number of manufacturers have done. It would be helpful to the consumer if the manufacturer would disclose this information on the label since there are implications to the finisher that should be considered when using these products. But since that is not likely to happen, we will explain how you can identify these products in your shop, and we

will refer to these products as ***Pigmented Dye***. Confusing the issue even more, there is at least one manufacturer selling a line of wood colorant labeled as "Penetrating Stain". *Some* of the colors in this product line are achieved by combining both pigment and dye (pigmented dye) in the same can. Other colors in the same product line are pigment only (stain) and still others are all dye. These are not trivial distinctions. Each of these methods of coloring wood brings its own set of application issues to the table. Yet the manufacturer offers no information to help the finisher distinguish these products from each other, even though these different methods of coloring may produce dramatically different results, even when applied to the same species of wood.

Types of Dye

Dyes are classified on the basis of the solvent in which they are best dissolved. There are four dye types used in the coloring of wood:

- Water-soluble dyes are those dyes best dissolved in water.
- Alcohol-soluble dyes as those dyes best dissolved in alcohol.
- Oil-soluble dyes as those dyes best dissolved in petroleum distillates such as naphtha, toluene, and xylene. Turpentine and solvent blends such as lacquer thinner can also be used.
- NGR (Non-Grain Raising) dyes are soluble in glycol ether. These dyes can be further *reduced* (thinned) by combining the pre-mixed dye with water, alcohol, or oil and are often referred to as multi-solvent dyes.

Water-soluble, alcohol-soluble, and oil-soluble dyes are sold in powdered form and are mixed by the user. NGR dyes are either packaged as a liquid concentrate for further dilution by the user or they are sold ready to use. There are also some powdered dyes that can be dissolved in either water or alcohol, though the selection of these dyes is limited and, as we will see later, what might at first appear to be an advantage (being able to dissolve the dye in multiple solvents) may actually be a disadvantage.

Selecting the Appropriate Dye

The biggest mistake that we see woodworkers make when selecting the appropriate dye for a project is the tendency to focus on the wrong property of the dye. Too many among us assume that "fast drying" is the most important criteria when "control" and "color fastness"

should be our primary focus. Fast isn't always a good thing. Neither is a higher price the mark of superiority in a given application. But I'm getting ahead of myself; let's back up and consider the relative properties of each of these dye types.

Water-soluble dyes are almost always the best choice, especially when we will be applying the dye by hand (sponge, brush, or rag). Water-soluble dyes give us the longest "open time" providing ample time to apply the dye and remove the excess. Because of the longer open time and the fact that the solvent for these dyes is water, dyes that are soluble in water penetrate deeper into the cell structure of the wood (water transport through wood structure occurs naturally). One of the immediate benefits of this is that water-soluble dyes are the most color fast (they don't fade as much over time as other dye types). Water-soluble dyes are the easiest to mix, the solvent is inexpensive and is non-toxic thus eliminating the need for ventilation. Finally, water-soluble dyes are available in the widest selection of colors and are by far the easiest to blend in order to achieve custom colors.

Alcohol-soluble dyes are the dye of choice for repairs and touch up when dissolved in shellac or "padding lacquer". Solubility in alcohol allows the finisher to adjust the color of shellac to mimic any grade and to adjust the color of the shellac to seamlessly blend the color of new wood to match the patina of aged wood on items being repaired. Beyond these applications we do not recommend alcohol-soluble dyes. Since they dry so quickly, they are virtually impossible to apply by hand without streaking. Further, their limited penetration owing to the rapid evaporation of the solvent makes them less color fast than water-soluble dyes.

Oil-soluble dyes are infrequently used by themselves. They are the least color fast of the powdered dyes. They can be used effectively to adjust the color of pigmented dye products (those products introduced above that contain both pigment and dye). They can also be used effectively to tint oil/varnish blends (a.k.a. "Danish Oil"). When using these dyes to tint or adjust the color of oil-based products it is best to dissolve them in lacquer thinner so they will combine better with the oil-based material.

NGR dye become the product of choice when the dye is being sprayed and it will be difficult or inconvenient to wipe the excess from the surface. These dyes, especially in concentrated form, are also the easiest to use when mixing dye with another finish to make a "toner" or "glaze". Of all the dyes considered, the pre-mixed NGR dyes are the most toxic when sold

in ready-to-use form since they are mixed with methanol. It is also important to understand that if NGR dye concentrates are diluted with water they will completely lose their NGR properties. Finally, since the pre-mixed NGR dye concentrates can be dissolved in water, alcohol, or petroleum distillates they can also be re-dissolved in those same solvents. Thus, if these dyes are used directly on wood any finish that is subsequently applied over these dyes will have the potential to re-dissolve them causing them to "bleed" into the topcoat. For this reason, we recommend that these dyes only be top coated with a sprayed finish (no physical manipulation of the dye as the finish is applied) or that they be mixed with the intended finish as a "toner". This is the major disadvantage of multi-solvent dyes in general.

What is really in the can?

Earlier we introduced products that contain both pigment and dye and defined them as "pigmented dye". We also said that several manufacturers produce a product line, generally referred to as "penetrating stain" in which some of the colors are derived from pigment alone, some colors are a combination of pigment and dye and some are composed of dye alone. In no case do any of these manufacturers make it easy for the finisher to know which method of coloring is employed in these products. Since, as we have learned, pigment and dye color wood much differently we believe it is important for the finisher to know how color is achieved. Issues of grain and figure clarity and susceptibility to "blotching" are closely tied to these distinctions. For example, we recently had a customer who had regularly (and successfully) used one of these products that colored only with dye. When he had need of a darker color on a maple project, he logically selected a darker "stain" from the same manufacturer. The results were a disaster; the finish was blotchy, and the subtle grain detail was virtually obliterated. Why? He had used the same product (just a different color) from the same manufacturer that he has used successfully in the past. This time, however, the outcome was dramatically different because the darker color he selected was "stain", all pigment with no dye. Worst of all, the finisher had no idea what he had purchased; he didn't know that the color he had successfully used in the past contained no pigment. Neither did he understand that the color that failed so miserably consisted of only pigment. Nothing on the label alerted him to the differences. All he knew was that he has "used the same stain", just a different color.

So, if the manufacturers won't give us the information we need, how are we to determining

if the "stain" on our shelves contains only pigment, contains pigment and dye, or contains only dye? We take advantage of what we have already learned about the properties of pigment and dye. Pigment is an insoluble solid; it does not dissolve; it does not go into solution. If left undisturbed the heavy pigment particles will settle to the bottom of the can. Dye, on the other hand, is a soluble chemical that is fully dissolved in its solvent. It will never settle to the bottom of the can, no matter how long the can sits on the shelf. Armed with this information we can easily determine what is in the can. Allow the can of "stain" to sit undisturbed for a day or two then carefully remove the lid. Insert a wooden stir stick and slowly move it across the bottom of the can, then remove the stick and observe the result.

- If we see a glob of pigment on the end of the stick but there is no color on the stick itself, we know that the product in the can contains only pigment. It is ***stain***.
- If there is no glob of pigment on the end of the stick, but the stick is colored we know that the product in the can contains only dye. It is ***dye***.
- If there is a glob of pigment on the end of the stick *and* the stick is colored, we know that product in the can contains both pigment and dye. It is ***pigmented dye***.

When coloring easy to stain ring-porous hardwoods such as oak, ash and hickory none of this is particularly important. Ring-porous woods are easy to color with virtually any colorant. However, if we are coloring diffuse-porous hardwoods such as birch, maple, and cherry it will be a good idea to avoid products that contain pigment or consist of pigment and dye. These are the colorants most likely to produce *blotching*.

Fixing Dye Mistakes

There are relatively few problems that can occur when working with dye. Those problems that do arise, more often than not are related to issues of mixing concentration and improper color selection. The easiest way to avoid these is to apply the entire finish schedule to a story board before committing to your project. A story board is simply a sufficiently large sample of the same wood used in your project to which you will apply the proposed finish schedule. Prepare the story board for finishing *exactly* as you have prepared your project. A board 4" to 6" wide and 25" to 30" long with shallow saw blade wide groves cut at 5" to 6" intervals the length of the board will allow the finishes to see every step of the finishing process. Leave the first segment of the story board unfinished. Apply the dye, mixed in the intended concentration to all of the segments from the second

to the end of the board. When the dye is fully dry apply the next step in the finish schedule from the third segment to the end of the story board. Continue in this fashion until all of the proposed finish steps have been applied and then compare the result (the last segment) to your expectation. If the outcome is not exactly as expected it is a fairly simply matter to go back through the story board segments to see where the problem arose and make the necessary corrections.

Sometimes, even when using dyes, we create problems for ourselves by getting the color wrong, or by mixing the dye to a darker or lighter concentration than we wanted. When we get a pigment stain wrong, we are pretty much limited to learning to like our mistake. The binder in stain makes color and intensity adjustments all but impossible. It is possible to darken the color by adding more stain, but this only serves to make the pigment film even more opaque thus further diminishing the clarity of the grain and figure of the wood. If we use dyes these problems become minor annoyances and temporary frustrations—they can all be fixed fairly easily.

The dye color is too dark

If our working mixture was too strong, the color produced is darker than we wanted, we can make the color lighter by simply diluting the dye in place and making the remaining color lighter. Remember, there is no binder in dye so by doing nothing more complicated than reintroducing solvent to the dry dye thus re-dissolving the dye, making the dye concentration weaker, even though it has already been applied, becomes a simply matter. Wetting the surface with solvent allows us to wipe away excess color until we reach the intensity that we want. This is much easier with water-soluble dye due to the longer open time; but the color of any type of dye can be made lighter in this way.

The dye color wrong

Again, we can take advantage of the fact that dye has no binder, so even a wrong color mistake is not locked in place. Question! Can two dyes be mixed together to produce a new color? Sure; and the process of mixing is quite simple. So, from the previous example of re-dissolving dye in place after it has been applied in order to reduce the concentration, why can’t we also re-dissolve the dye using the solvent in dye of a different color? We can! For example, just as it is possible to mix a bit of green dye to kill some of the red before the dye is applied, it is also possible to mix dyes after they have been applied by applying a

different color to the dye that has already been applied and has dried. We can mix the dye on our project with another dye color and achieve the same result that we would have achieved had we mixed the two colors prior to application. Consider the impossibility of this repair with a colorant that contains a binder.

Removing the dye color

It is a simple matter to remove the dye with a solution of household bleach diluted with distilled water. A solution of 20% bleach sponged or spray on the surface and kept wet until the bleach has removed the offending color will allow us to recover from a poor color choice and begin again. The removal of dye color is again possible because there is no binder in dye. Once the color is removed neutralize the bleach with a distilled water rinse before allowing the surface to dry. It is then a simple matter of lightly sanding and beginning anew our finish schedule.

Conclusion

In his book, *Understanding Wood Finishing*, Bob Flexner makes the point that "of all the steps in wood finishing, staining causes the most problems". He goes on to offer the opinion that many woodworkers avoid coloring wood altogether, opting instead for the "natural look" because they find stains so difficult to use. Rather than risking "blotching", streaking, uneven color rendition and finish incompatibility (bleeding of the color into the topcoat) they simply set aside any consideration of adding color, even when the proper application of color will enhance their work.

My experience echoes that of Flexner. Of all the finishing problems that we are asked to solve, stain disasters top the list. Even among experienced woodworkers who have been finishing for years, unexpected staining results are common. Frequently these problems are related directly to the finisher's failure to understand the properties of the "stain" he is using. More often than not this misunderstanding is a direct result of the failure of the manufacturer to adequately (and accurately) communicate the nature of their product to the user. In this article I have attempted to define and clarify the distinctions between pigment stains and dyes. In the process I have identified the properties of both in terms of how they go about adding color to wood. Included is my own approach to product naming in an attempt to help woodworkers distinguish between products that color with pigment,

those that color with dye and those that contain both pigment and dye. This article has examined how these two product options, dye and stain, color wood and has compared their relative versatility and ease of use. Hopefully, along the way I have encouraged those of you who have never used dyes to add them to your finishing schedule. I am convinced that once you experience the versatility and ease of use of dyes you will never again return to the color-in-a-can approach to coloring wood. I am also convinced that by using dyes you gain control over what Flexner accurately describes as the step that "causes the most problems". You will then be equipped to move on to other finishing techniques that will bring even more interest and excitement to your wood finishing experience.

Finally, it is not the point of this article to suggest that stains have no place in finishing wood. They do. I simply believe that dyes, and in particular water-soluble dyes, are the best and most versatile way to color wood. Stains (pigment) can be effectively used as a "glaze" to achieve special effects. These techniques are covered in other articles.