Kirk-Othmer Encyclopedia of Chemical Technology.

STAINS, INDUSTRIAL

With few exceptions, stains used in wood finishing are formulated to improve the appearance of the substrate. Unlike paints, sealers, and topcoats, stains are utilized either to accentuate the natural beauty of the wood or to hide inherent defects found in most species of wood.

The application of stains to substrates includes spray, flow, dip, roll-coat, or hand application, ie, brush or rag methods. The type of application method used depends on the function of the stain itself as well the type of product being manufactured.

There are various types of wood stains and criteria used to choose the right type for a job. Although there are several distinct groups or types of stains, it is safe to categorize wood stains into two groups: dye stains and pigmented stains.

1. Dye Stain or Soluble Colors

A defining characteristic of dyes is the ability to dissolve in a given medium. Dissolution leaves no particles to refract or scatter light and thus a dye solution is transparent. A distinct advantage of a soluble-type stain is this transparency and brightness afforded by use of various dye types. Solubility is increased by agitation or heat, or a combination of the two.

1.1. Solvent Dyes

As the name implies, these dyes are popular because of their solubility in a variety of industrial solvents. Color strength, brilliance, lightfastness, and the ability to formulate with solvents other than alcohol and water have helped to increase their use and popularity. Because these dyes are soluble in solvents other than alcohol or water, the finisher may lessen the effect to the substrate itself. The moisture content of alcohols and the tendency of alcohol to draw moisture from the air during the drying process result in grain raising of the wood. Using solvents other than alcohols lessens this effect to some degree. These “smoothcoat” stains are used on certain species of wood to lessen the amount of grain rupture associated with moisture. Based on cell structure or quality, certain species of wood are prime candidates for solvent stains.

1.2. Acid Dyes

These dyes are sodium salts of color acids and are the most widely used dyes for nongrain-raising wood stains. Generally speaking, acid dyes have excellent brightness, strength, and lightfastness. They are partially soluble in alcohol, but perform best when initially incorporated in ethylene glycol or propylene glycol and later reduced in methanol. They exhibit excellent transparency.

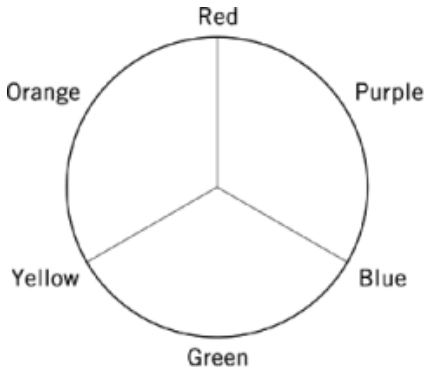

Fig. 1. Color circle, showing the relationship of colors.

2. Theory and Practice of Wood Staining

2.1. Color Mixing

The various types of dye powders used to make dye stains are blended to achieve the desired color. Most finishers purchase wood stains premixed to specified colors. In the wood-finishing industry, various shades of brown are the most common. These colors are usually blended from primary colors. Color-matching skills can be acquired only by practice, but the basic theory of color matching is relatively simple and easily understood. The basic theory of color matching can be demonstrated by using the color circle shown in Figure 1 (see Color).

In Figure 1 the three primary colors consisting of red, yellow, and blue are spaced equally, 120° apart. Between them are the secondary colors: orange, green, and purple. The secondary colors are made by combining the adjacent primary colors. Thus, a mixture of red and yellow produces orange, a mixture of yellow and blue produces green, and blue and red gives purple. Colors that are directly opposite one another on this circle are complementary colors that when mixed become varying shades of brown, the most commonly used color in wood stains. By slightly altering the levels in which each of these colors is present, literally thousands of variations of brown can be achieved. In most wood stains, black or a blue-black is used in place of a pure blue.

2.2. Types of Wood Stains

The term wood stain in this article applies only to those stains that are applied directly to the wood or over another wood stain. The types of stains used are dependent on the application, finished product, and regional terminology. Multiple wood stains are frequently used in the residential furniture industry to achieve a desired look. They include equalizers and nongrain-raising (NGR) stains.

2.2.1. Equalizers

In the majority of wood-finishing systems, there is a problem of matching up varying shades of colors in the natural wood. The lack of uniformity in the substrate may result from sapwood areas or mineral streaks. In the case of finishing assembled furniture, it may also be the result of incorporating different species of wood into the same piece. It is not unusual, for example, to see casegoods with cherry tops, maple drawer fronts, and poplar or gum rails. These differences in substrate color must be addressed during the early stages of finishing to ensure uniform appearance of the finished case.

Equalizers can be either pigmented or dye-type stains used to tone down or lighten dark areas of wood prior to finishing. Although it is not as effective, equalizing is sometimes done in place of bleaching. Because

there are no white dyes, white pigment or pearl essence is usually incorporated with the dyes to achieve the desired look.

Another form of equalizing stains is through the use of sap stain. Color differences between the sapwood and late-growth area of the lumber can be made uniform by using this type of stain. Sap stains are usually alcohol-based dye stains that tie lighter areas of the wood into darker areas. Transparency of sap stain and equalizers is important to ensure a natural, nonpainted appearance.

2.2.2. NGR Stains

Nongrain-raising stains are usually sprayed overall and contribute the greatest to the overall undertone color of a finished piece. These stains are also sometimes referred to as body stains or overall stains. They are usually dye-type and can be formulated, depending on the type of dye powder and solvent system, to minimize the effect of the stain on the substrate.

The color and effect produced by NGR stains and any stain mixture depend on several factors other than the colors or type of dyes used. Those factors include strength of the mixture, the amount applied, the type of substrate, and the solvent system used for the stain. The role of the wood stain is not to provide protection; rather, the primary function of the stain is to impart color effects by accentuating grain patterns. The transparency and brightness needed to enhance the natural beauty of the wood are optimized by using dye-type stains for wood.

3. Pigmented Stains

Pigment colors are finely divided color particles that do not dissolve in any available solvent; they can only be dispersed by grinding them in a liquid. The wood stains discussed thus far, with the exception of equalizers that incorporate white or pearl essence, generally are more transparent and brighter than pigmented stains. There are, however, certain wood stains that can be formulated with pigments and still give the finish a desirable look. These pigmented wood stains are used in a variety of applications, and in many instances such use shortens the number of steps needed to achieve a desired appearance. Pigmented wood stains are used commonly in the finishing of kitchen cabinets, where shorter finishing systems are desirable. Also, pigmented wood stains are popular with “do-it-yourselfers.”

There are a large number of pigments to choose from when formulating a stain. Three basic groups of pigments were used in the industry, ca 1996: (*1*) natural or earth colors consisting of umbers, siennas, yellow oxide, and red oxide. Vandyke brown is also a natural pigment, but it is of organic rather than mineral origin.

(*2*) Organic pigments are carbon compounds which are usually derived from coal-tar bases or petroleum. Organic pigments include carbon and lampblack, which are derived from natural gas by incomplete combustion. Other examples of organic pigments include lithols, toluidines, and phthalocyanines (see Pigments, organic).

(*3*) Chemical pigments or synthetics may be metal compounds. A good example is white titanium dioxide. Other chemical pigments include cadmium sulfide colors, iron blue, and several synthetic versions of iron oxides.

3.1. Penetrating Stains

Penetrating or no-wipe stains are used in a variety of applications. The most common use of these direct-to-wood stains is on small-pore species of wood. Maple, cherry, and coniferous species such as pine are good candidates for penetrating stains.

As the name implies, these stains are sprayed on and require little if any wiping. The solvent itself penetrates into the pore and allows the pigment and a small amount of binder to remain on the surface. These stains usually are composed of an oil-type vehicle and a combination of earth pigments reduced in a combination

of aliphatic and aromatic hydrocarbons such as naphtha and toluene. The solvent system itself plays a big role in the appearance of the stain owing to the varying degrees to which solvents penetrate. Restrictions on the use of certain aromatic hydrocarbons have affected the manner in which these stains work.

The transparency and brightness of dyes cannot usually be duplicated through the use of pigments. However, optimum clarity and look can be achieved when using pigmented stains by consideration of such factors as the amount of pigment contained in the stain and the type. Application also plays a significant role in the strength and transparency of a stain. Usually the finisher wants to avoid a painted look when using penetrating stains.

Advantages of penetrating stains are numerous. The stains are commonly applied by either spraying or dipping, the latter being the most economical method of staining. Additionally, pigments used in penetrating stains are generally less expensive than dyes. Because of the uniform appearance provided by penetrating stains, many finishing applications utilize penetrating stains as the only color step.

3.2. Toners and Tinted Sealers

These materials are usually pigments dispersed in nonpenetrating lacquers. In some instances, solvent or spirit dyes can be used to improve clarity. The solids of the vehicle can be adjusted to control the depth of penetration into the substrate.

Toners can be used in a variety of applications, depending on the substrate and the effect desired. They can be sprayed either directly onto the wood or over other wood stains. The solids of toners are usually low (5–15 wt %) and generally require the use of a washcoat or sealer prior to topcoating.

Although the difference between toners and tinted sealers may not be clearly defined, it is usually the role of the tinted sealer to provide both color and sealing properties. Therefore the tinted sealer usually is higher in solids and provides the majority of color to the finish. There has been a resurgence of popularity of tinted sealers, owing to the appeal of blonde or natural finishes. The fact that tinted sealers are becoming more popular may be the result in part of their ability to fill the roles of both stain and film builder within a finishing system.

Both toners and tinted sealers provide uniform pigment distribution without penetration. The use of more transparent pigments can also provide acceptable clarity, but with limited depth and contrast.

4. Overtone Stains

4.1. Washcoats

Although washcoats are not classified as stains, the role they play in the staining procedures makes it important to examine the properties they bring and the contribution they make to the finishing process. Washcoats for wood finishing can be defined as thin coats of sealer applied to control the amount of penetration and subsequent staining from overtone stains and fillers. Naturally, the solids content of a washcoat determines the amount of penetration of an overtone stain. Washcoats are usually sanded prior to application of a glaze, wiping stain, or filler. Therefore the extent of the sanding also plays a role in the penetration and staining action.

Washcoats perform the following roles in the finishing process: (*1*) they form a thin film to protect the wood stain(s) from the effects of handling, or the solvent from subsequent finishing steps; (*2*) they raise and stiffen wood fibers to enable the surface to be sanded prior to application of wiping stains and fillers, and this sanded, smooth, hard surface facilitates the wiping and clean-up of fillers and other wiping steps; (*3*) they seal the surface of the wood and wood pores to prevent pinholes and blistering when fillers are used on large-pore substrates; and (*4*) by controlling the solids of a washcoat, the amount of penetration of overtone stains can be controlled.

The solids content of a washcoat is usually 5–12 wt %. It is important that washcoats leave a very thin film of material to allow the proper amount of sealing and to prevent bridging the pore, which would result in blistering of subsequent build coats.

4.2. Fillers

Wood fillers are applied directly over the washcoat in a multistep operation. First the filler is reduced according to the manufacturer's specifications and applied, usually by spray. The filler is then worked into the pores of the wood in a circular motion using a rag or pad, either by hand or by machine. Following this vigorous step to ensure that each pore is thoroughly filled, the filler is then wiped in the direction of the grain to clean up residue or wiping marks. At this point, it is imperative that the filler be allowed to dry. This is accomplished by either allowing it to dry overnight or by force-drying it in an oven. Fillers that are not properly dried will eventually shrink, and full fill is not achieved.

Fillers (qv) perform two significant functions: they fill pores and give color to the pores.

4.3. Glazes and Wiping Stains

Some applications such as kitchen cabinet finishing utilize wiping stains direct-to-the-wood. In most fine furniture applications, wiping stains and glazes are applied over the washcoat or sealer step.

These overtone stains are normally composed of pigments, oils, solvents, and driers. The important quality of glazes and wiping stains is the ability to apply a color coat which can be wiped on and then highlighted to add depth and contrast to the overall appearance of the finish.

These wiping coats are usually sprayed on and then wiped with rags to varying degrees, depending on how much color and effect the finisher desires from the wiping coat. In many instances, the material is then brush-blended into corners and recesses to give uniform coverage and appearance. After the glaze has been wiped and brush-blended, the finisher usually highlights or strikes through areas of glaze, using steel wool or some other abrasive material to give contrast or accentuate certain grain patterns or characteristics such as cathedrals or knots.

The wiping and blending properties of a wiping stain are important considerations when formulating these types of products. A good glaze must not be sticky or bite into the sealer and must stay open long enough to be wiped, brushed, and worked to the desired level by the finisher. Long working times are important, yet these stains must be recoatable within a reasonable period of time. Unless the stains are formulated correctly, the glaze or wiping stain may cause poor intercoat adhesion or discoloration when lacquer topcoats are applied.

4.4. Shade Stains

These stains are usually applied after the sealer or first topcoat and are typically sprayed on specific areas to compensate for uneven color distribution during the initial finishing process. For instance, perhaps the glaze was wiped too clean on an edge. Rather than going back to restain or glaze that small area, the finisher can spray a small amount of this shade stain on the desired area and achieve the same result in a fraction of the time.

Another common use of the shade stain is to enhance the contrast or depth of the finish. This is usually the role of the glaze, but when additional contrast is needed, the finisher may elect to shade certain areas. Care must be taken not to apply too much shade, which can result in a painted or artificial appearance.

4.5. Pad Stains

More progressive or higher end furniture finishers add color or pad stains to enhance grain patterns, produce shadows, and create hues found only in exceptionally fine veneers and woods. These pads are applied at varying levels to create the illusion of the third dimension.

Pad stains are divided into two groups: spray pads and hand pads. The difference between them, not surprisingly, can only be defined by the means of application. Like the shade stains, they are usually applied over the sealer or first topcoat and subsequently are topcoated themselves.

The primary purpose of the pad stains is to accent figures. An example of this may be following a V-shaped grain pattern or cathedral or adding artistic value to an otherwise uninteresting piece of wood. Grain patterns of wood sometimes may be too geometric, as is often the case with oak or ash. In such instances, a pad stain may be used to break up the monotony of the grain. Spray pads are frequently used when attempting to add some relief to an otherwise monotonous grain configuration. Crossfire or mottled patterns on bland substrates can simulate Crossfire Maple or English Oak.

4.6. Distressing Stains

Interest and charm can be added to furniture by the deliberate infliction of imperfections. These imperfections may be caused by physical distress such as hammers, files, nails, chains, or rocks or caused by finish distress such as “fly specking” or staining to simulate past abuse, such as waterstains caused by the careless placement of a drinking glass.

Physical distressing is usually a part of the initial finishing procedure and is done in the white wood stage. Finish distressing is normally part of the latter phases of the finishing operation. Like the pad and shade stains, distressing stains are usually applied over the sealer or between coats of topcoat.

5. Environmental Considerations

Most of the stains discussed are solvent-borne and therefore possess inherent properties such as flammability, toxicity, and reactivity. Those properties make it necessary to observe safe handling practices when using or storing wood stains. Adequate ventilation and avoidance of any source of possible ignition are key in the use and storage of these materials. Personal protection when using stains should include safety glasses or goggles, respirators, aprons, and rubber gloves. Overexposure to certain solvent vapors may cause respiratory damage or impaired judgment, whereas prolonged skin contact may result in skin irritations or even neurological effects.

Provisions of the Clean Air Act have resulted in the regulation of certain wood finishing applications. Residential and Institutional Furniture and Kitchen Cabinet Industries are under regulations which specify the amount and types of solvent emissions allowed. The size and location of a finishing facility determine the extent of the effect stemming from the regulations.

These regulations are based in part on the amount of solvents in relation to the amount of solids. Most wood stains are low solids materials which rely on their transparency and their ability to penetrate and dry fast. Those characteristics themselves put great emphasis on the type of solvents that are used to formulate stains. The low solids content of wood stains limits the scope of solvent substitution or reformulation.

A good example of the effect of regulations on wood stains is the issue surrounding methanol (qv). Methanol is the most widely used solvent for wood stains because of its fast-drying properties, low cost, and the solubility of dyes in methanol. Because methanol is listed by the U.S. EPA as a hazardous air pollutant (HAP), and because of the extremely low solids of wood stains, it is most likely that wood stains such as NGR, body stains, and sap stains will need to be reformulated before the end of the twentieth century.

BIBLIOGRAPHY

"Stains, Industrial" in *ECT* 1st ed., Vol. 12, pp. 722–740, by W. H. Peacock, American Cyanamid Co.; in *ECT* 2nd ed., Vol. 18, pp. 654–671, by W. H. Peacock, American Cyanamid Co.; in *ECT* 3rd ed., Vol. 21, pp. 484–491, by R. S. Bailey, Lilly Industrial Coatings, Inc.

General References

1. Assorted publications on related subject matter, including writings of the late J. A. Hager, Guardsman Products Inc., High Point, N.C.
2. Technical data, Sandoz Chemical Corp., Charlotte, N.C., 1996.
3. Technical data, Crompton and Knowles Corp., Charlotte, N.C., 1996.

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