Technology of Adhesives and Finishes

by Marc A. Williams

This is the fifth of a 10-part series of articles on furniture conservation written exclusively for the ANTIQUE REVIEW by a senior furniture conservator at the Smithsonian.

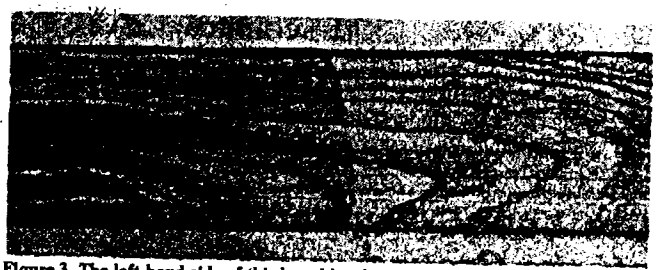

Figure 3. The left-hand side of this board has been coated with a finish, increasing the wood's color saturation and appearance of depth.

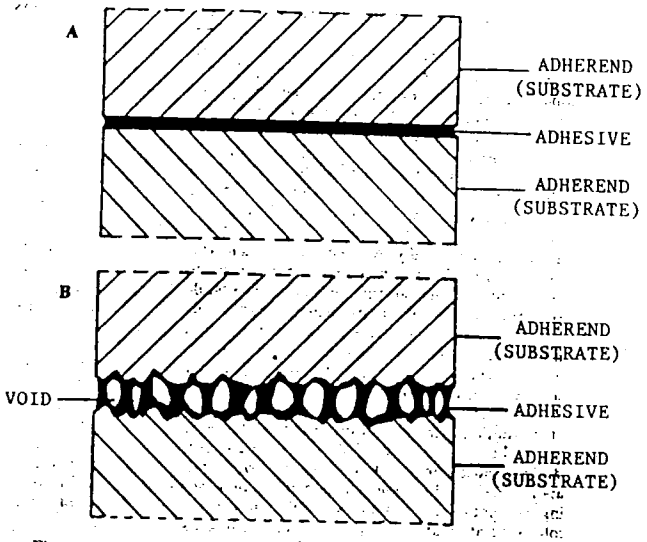

Figure 1. A) Idealized adhesive joint with smooth adherend surfaces and a continuous, uniform adhesive layer. B) Adhesive joint typical of solvent-based adhesives used for furniture. Adherend surfaces are uneven, causing a relatively large gap between them. As the adhesive dried, it shrank, resulting in voids in the adhesive and a weakened joint.

At this point in the furniture conservation series, the reader should have a basic understanding of the nature of wood. The first part of this article will examine one of the least visible but most important parts of furniture—the adhesives that hold it together. It will begin with an examination of general adhesive theory, followed by the types and properties of historic and modern adhesives. The second part of the article similarly will investigate finishes that have been used on furniture.

Materials being adhered to one another are called **adherends** or **substrates** (Figure 1A). In furniture, the adherends are usually wood to itself or another component material such as brass, ivory, mother of pearl, leather, or gesso. Not surprisingly, the material actually attaching the adherends is termed an **adhesive** and the attraction of the adhesive for the substrate is called **adhesion.**

The mechanism for adhesion requires that the adhesive, after setting, must have a strong attraction for the adherends. In addition, it must have strong **cohesion** or attraction for itself. An adhesive bond will fail when either the adhesive or the cohesive strength is exceeded or if the tensile strength of the substrate itself is exceeded. Therefore, the least strong component of the system limits the bond strength. In general, the smaller the space between the adherends (the tighter the joint), the stronger the adhesive bond. This is because the cohesive strength of most wood adhesives in a thick layer is usually lower than the cohesive strength of the wood or other adherend, thus weakening the overall bond strength. Large gaps are caused by substrates that are not smooth and even or by inadequate pressure during bonding.

The three basic types of adhesive setting mechanisms are **solvent evaporation,** exemplified by liquid hide glues or white glues (polyvinyl acetate emulsions), **thermosetting** as found with hot melts, and **chemical reaction,** such as epoxies and super glues (cyanoacrylates). Adhesives that set by solvent evaporation are characterized by shrinkage as the adhesive dries. If the bond gap is large, adhesive setting results in significant voids in the adhesive and a weakened bond (Figure 1B). Pure solvent setting adhesives are reversible, although aging can cause a loss of this property. Thermosetting adhesives normally have minimal shrinkage and are therefore good gap fillers. They usually are reversible with heating and with solvents. Chemically setting adhesives generally do not shrink and are also good gap fillers. However, since they react to become chemically different materials when they set, they are difficult, if not impossible, to reverse. Additionally, by their nature, many are less stable and are prone to more rapid deterioration than other types of adhesives. Many adhesives combine more than one setting mechanism and as such have properties that are characteristic of a combination of setting types.

As a general rule, wood adhesives are brittle and inflexible, although there are some exceptions to this, such as hot melts and rubber-based adhesives. Most are not able to flex enough to compensate for the potentially large dimensional change of wood in an uncontrolled environment, therefore resulting in bond failure.

Since the primary adhesive used on furniture through the early 20th century was hot hide glue, it would be helpful to examine its use and application. Hot hide glue is a protein adhesive refined from the skins, tendons, and hooves of various animals. It thermosets initially to a gel as it cools and completes its setting by water evaporation.

The gluing process begins as the wood surfaces are prepared and the joints are cut. A tight fit is necessary for a strong joint, as hot hide glue has very low cohesive strength in thick layers. The surfaces to be adhered are cleaned of dust and dirt. The glue is prepared by mixing dry flakes in water and heating in a double boiler. It is quickly brushed on both surfaces and the wood pieces aligned and clamped before it sets to a gel. The open time before setting can be extended by heating the components or by applying heated blocks to the joint after assembly. The excess squeezeout is removed with a dampened cloth. After drying, usually overnight, the clamps are removed.

There are many variables for error and a weakened joint. These include an incomplete spread of glue due to the short open time, a thick glue line because of rapid gelling or inadequate pressure, joint movement after setting has begun, or using old or overheated glue. It is not surprising, therefore, that many hot hide glue joints have failed.

For conservation purposes, the ethical principles of reversibility and long term stability severely limit the number of adhesives that can be used. The major ones are hot hide glue, liquid hide glue (basically the same material as hot hide with an ingredient added to allow it to remain liquid at room temperature), some polyvinylacetate emulsions (white and yellow glues), and occasional use of hot melts. There is still a great need for research into the appropriateness for conservation use of many different adhesives.

The three major functions of a finish are to moderate the interaction of moisture with wood, to provide an aesthetically pleasing appearance, and to protect against damage to the wood from use. In addition to conventional transparent finish coatings, the term finish also includes paint, gold and other metal leafs, and miscellaneous surface treatments.

Finishes slow diffusion of moisture into and out of wood, helping to prevent damage from relative humidity changes. To be completely effective, the finish must be applied evenly to all wood surfaces, including undersides, insides, and backs. Otherwise, uneven moisture content change caused by fluctuating relative humidity can cause warpage and possibly compression set or splits. Figure 2 shows typical summer to winter changes in moisture content of unfinished wood in an interior heated environment without relative humidity control. The application of a finish to all surfaces moderates the moisture content changes to the sine wave in the center of the figure (marked with the letter B). There is a great range in the effectiveness of different finish materials as vapor barriers and, therefore, a great variance in moderation effectiveness. Additionally, a thicker layer of a finish is a better barrier than a thinner layer of the same finish.

It should be noted that even an ideally-applied finish will not prevent moisture content change and the resulting dimensional change of the wood. It simply increases the amount of time necessary for this to occur. Additionally, historic furniture usually is not finished on all surfaces like the ideal example and, therefore, less protection is afforded from damage caused by relative humidity changes.

Aesthetically, transparent finishes enhance the grain pattern and saturate the wood colors (Figure 3). This is achieved by producing a smooth surface that scatters less light than the raw wood, thereby increasing color saturation. In general, the thinner and more even the finish, the more attractive the wood appears. Additionally, different types of finish materials have differing appearances and aesthetic appeal.

Protection from use is provided by finishes in several ways. Since finishes predominantly are on the surface of the wood, they will receive abrasion before the wood surface is reached. Obviously, if the abrasion is great enough, the wood will be damaged as the finish is fully penetrated. Finishes can also protect from spills, fingerprints, dirt, and pollutants. They are much easier to clean than the raw wood itself.

Common finish application methods are by rag, brush, spray, and French polishing. This latter technique involves a pad, called a rubber, into which is put

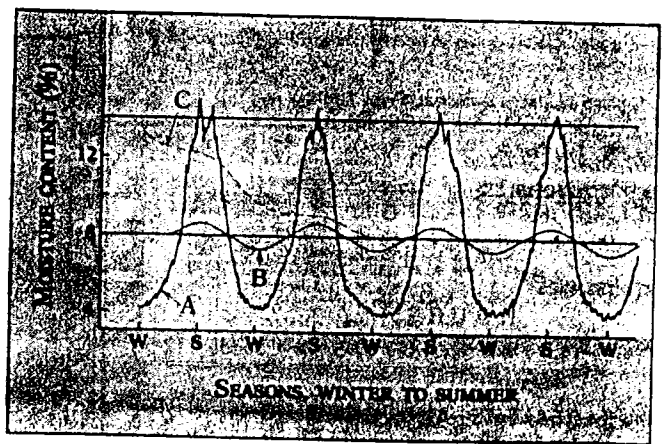

Figure 2. Typical summer to winter to summer fluctuations of wood moisture content caused by uncontrolled interior relative humidity in the temperate United States. The moisture content changes are accompanied by dimensional changes of the wood. (From Understanding Wood by Bruce Hoadley. Used with permission of

a little dilute shellac. The rubber is constantly moved over the surface, in essence depositing hundreds of extremely thin coats. French polishing requires extensive practice and even the most experienced polishers occasionally experience difficulties in achieving the desired appearance due to the great number of variables, including concentration of shellac, pad movement, dust, relative humidity, and rate of application.

Most application methods require that the finish material(s) be dissolved in a solvent to render them the proper consistency for application and leveling before they harden by evaporation of the solvent. Some finishes harden additionally by chemical reaction with oxygen in the air (called polymerization or, more specifically, crosslinking) and are thus no longer reversible in the original solvent. This is particularly true of oils and oil-based varnishes, and of modern polyurethanes. Other modern finishes set by a polymerization reaction begin when their two parts are mixed together, similar to the setting process of epoxies.

Gloss control of finishes can be done during application by the addition of inclusions such as cotton linter or silica, or by the use of a fast or a slow drying solvent. After drying, gloss can be affected by abrasion with sandpaper, steel wool, pumice, rottenstone, or other polishing compounds. High gloss results in greater wood color saturation and an appearance of depth. This is the result of more light being reflected from the wood surface to the eye of the viewer. Matting or dulling a finish causes scattering of light and thus a reduction of color saturation and depth.

Examination of cabinetmakers' recipe books of the 18th and early 19th centuries indicates a wide variety of materials were used for finishing and coloring. There is much discussion in these manuals of methods for obtaining high gloss finishes, contradicting the 20th century mythology of a preference for flat or mellow finishes.

The general types of materials mentioned in the recipe books included waxes, commonly beeswax; natural resins and gums such as dammer, sandarac, rosin, copal, and gum mastic; and oils including linseed, poppyseed, and walnut. Often several different materials were combined in the same finish. Shellac, refined from the exudate of the lac bug in Southeast Asia, did not come into prominence in the western world until the late 18th to early 19th centuries. It was extremely common through the 19th and early 20th centuries, when its use was greatly reduced after the introduction of synthetic finish materials.

Colorants added to finishes were essentially the same as those used for textiles and included materials such as alkanet root, dragon's blood, logwood, Brazilwood, cochineal, indigo, and verdigris. Most colorants were added to the finish, not the wood itself. Normally, color was applied directly to the wood only for chairs, although inlays were sometimes dyed completely through before application.

Contrary to the rather frequent claims by dealers, very few pieces exist with original transparent finishes intact. Of the few that have managed to survive the stripper's lairs, virtually all have been adulterated with innumerable types of polishing and cleaning materials and truly can not be called original.

Twentieth century finishes include synthetic waxes refined from petroleum products (microcrystalline), chemically modified oil-based varnishes, lacquers (nitrocellulose and acrylic), and chemically reactive two-part finishes.

For conservation treatments, by far the most common finish material is shellac. Waxes are often used on top of existing finishes. As more conservation research is completed, materials such as specific types of acrylic resins are gaining popularity.

The three basic components of a paint are the pigments, medium, and vehicle. **Pigments** impart color and opacity to paints. They are finely ground powders that originally were natural earths and currently include synthetic materials. The **medium** binds the pigment particles together and to the surface when the paint has dried. Common mediums include oil (oil paints), egg (tempera), casein (milk paint), acrylic resin (acrylic paints), and other materials, including various varnishes. The **vehicle** is the solvent used to dissolve the medium and produce a workable paint consistency.

Generally, paint is applied directly on the wood surface of furniture, although it may be applied over gesso (a chalk or whiting and gelatin mixture) or varnish. Lack of adequate flexibility of paints on wood is a common problem, resulting in cleavage, flaking, and loss of paint.

Metal leaf, extremely thin sheets of nearly pure metal, commonly gold or silver, is normally applied over a gesso ground, although occasionally leaf will be applied as a highlight over varnish or paint. Often, a thin layer of bole (extremely fine clay mixed with dilute gelatin) is applied over the gesso prior to the laying of the leaf. Gesso is very brittle and is the victim of severe cleavage and loss when applied over wood substrates that are not in a controlled environment. Because of its thinness, metal leaf is very easily damaged by abrasion and even regular cleaning can cause complete loss.

At this point in the furniture conservation series, the reader should have a good understanding of the nature of the major materials composing furniture. The next article will examine how these materials are interrelated in furniture construction.

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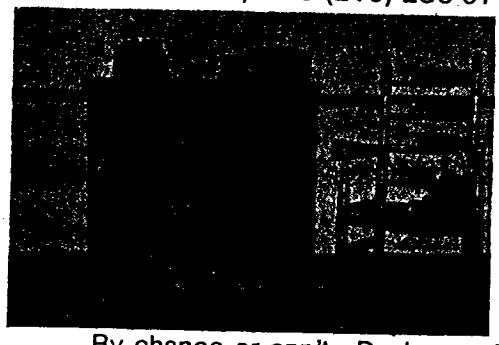

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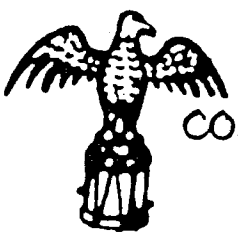

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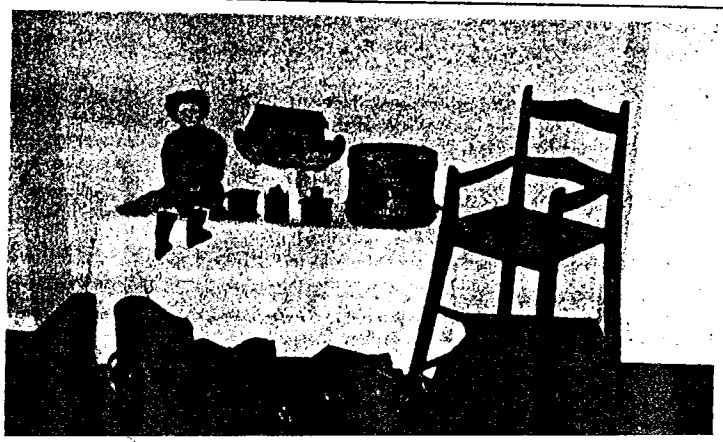

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