This is an excerpt from the book

Understanding Wood

by R. Bruce Hoadley

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Figure 12.1 • Clear finishes protect the surface of wood and enhance the appearance. (Photo by Alec Waters)

chapter 12

FINISHING AND PROTECTING WOOD

The word finish in woodworking usually describes some final surface treatment that protects the wood and enhances its appearance. Most woodworkers agree that some form of protection is typically necessary. The matter of appearance, however, is more controversial, depending on individual taste and preference. In addition to the protection of finishes at the surface, protection may be needed throughout the wood, namely against fungi and insects. This aspect of protection will be discussed as a final topic of this chapter.

Let's first consider protection. It is usually desirable to protect wood surfaces from accumulating dirt and to create a surface that can be cleaned easily. Finishes may also protect against abrasion or indentation and prevent changes in color due to light or atmospheric pollutants. But their most important function is to impede the exchange of moisture with the atmosphere, thus helping to avoid the consequences of dimensional change.

On the subject of surface appearance, it is impossible to generalize because of the variation in circumstance and personal preference as to what looks best. Some woodworkers want to preserve wood in its natural state as much as possible, while others wish to change the wood in both color and appearance. Some prefer to retain any visible surface irregularity due to cell structure, while others desire a surface that is perfectly smooth. Some want a matte finish, others a high gloss. Some try to retain or even accentuate variation in figure and color, others attempt to achieve uniformity. In this chapter, I will concentrate on basic points about protection and appearance without regard to functional requirements or aesthetic preferences.

Achieving a good-looking finish on wood involves a combination of two elements, the **surface condition** of the wood and the **finishing treatment** applied to it (*Figure 12.1*). Although done separately, they are interrelated and must be planned with respect to one another. Certain surface conditions will call for particular treatments and vice versa, but there is no such thing as the single best combination for all projects. I have fun experimenting, and it seems I rarely finish two items in exactly the same way.

▸ SURFACE CONDITION

Most finishing instructions begin with surface preparation, emphasizing such things as proper sanding and dusting just prior to treatment. But the concern must begin long before that because surface condition is influenced by every step of woodworking, from sawing the log and drying the lumber to machining the surfaces and gluing the joints. It is appropriate to evaluate surface condition using four criteria: trueness, evenness, smoothness, and quality.

Trueness compares the actual to the intended geometry of the surface. Planed surfaces are expected to be flat, turnings are expected to be round, edges are expected to be straight, and so forth. Residual stresses due to improper drying of lumber and warp resulting from change in moisture content are the most common causes of cup, bow, and twist in flat surfaces. Similarly, crowning of surfaces near edges is often the result of careless sanding or planing.

An otherwise attractive and successful finishing job can be overshadowed by lack of trueness or **evenness** of the surface. Raised grain is a common cause, traceable to machining and moisture problems. The unevenness of elevated latewood can result from careless hand-sanding that scours more deeply into earlywood than latewood in uneven-grained woods, especially on flat-grained surfaces. A planer or jointer that is out of adjustment can leave chatter marks, chip imprints, or snipes on board surfaces. Raised, sunken, or mismatched joints can produce an uneven surface as a complication of poor gluing procedures. When these problems develop in a core material, they can telegraph through face veneer.

Surfaces may, of course, be intentionally made uneven with satisfying results. Sandblasting and scorching out earlywood to provide a textured surface are examples of novel techniques used successfully in both sculptured and paneled surfaces.

Smoothness is the absence of surface irregularity, such as the undulating knife marks left after machine-planing or the chatter marks left by careless scraping. Corrugations in veneer, especially those associated with knife checks, are further examples. Minute tearouts, which may occur when planing against the grain, destroy surface smoothness. (I do

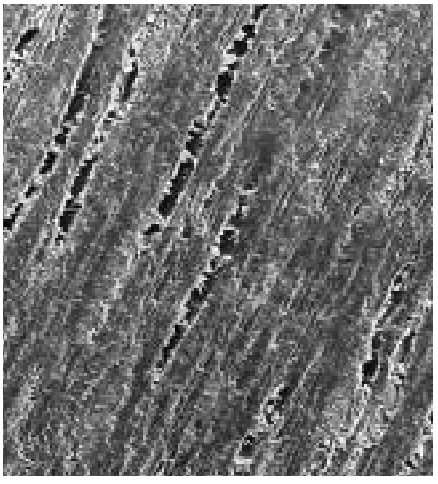

Figure 12.2 • Machine-planed maple shows open vessel elements, but smaller features are obscured by torn and pounded fibers. The knife has moved across the surface from lower left to upper right, burnishing the fibers into one another. (Photo by Stephen Smulski)

Figure 12.3 • When the surface is scraped with a steel scraper blade, torn and rolled wood tissue fills most of the wood vessels, and the surface becomes scratched by the minute ruggedness of the scraper's edge. 50X magnification. (Photo by Stephen Smulski)

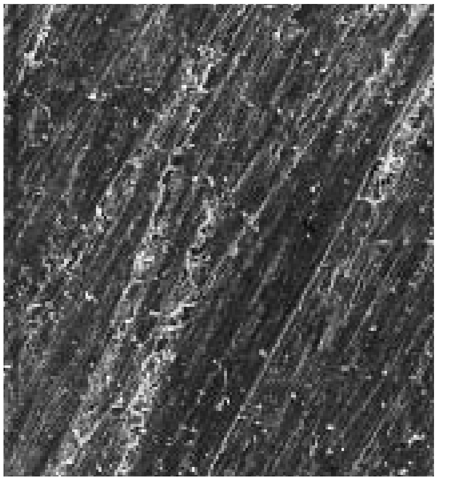

Figure 12.4 • The sample sanded with 220-grit paper looks much like the scraped surface, although there are more visible scratches. Dust, rather than torn fibers, seems to have filled the open vessels. A surface like this would feel quite smooth to the touch. 50X magnification. (Photo by Stephen Smulski)

not include the surface voids traceable to cell cavities as departures from smoothness because they are an inherent feature of wood, not of its condition.) Generally smoothness is measured by the depth and uniformity of the scratch pattern left from sanding. The smoothest surfaces result from hand-planing with the grain, scraping, and fine sanding (*Figure 12.2*, *Figure 12.3*, *Figure 12.4*).

Of equal importance is the **quality** of the surface cell structure in terms of the cell damage that results from forming the surface. The ideal surface for finishing could be produced by light skim cuts with a razor blade, which would cleanly sever exposed cell walls with no damage to the remaining structure. Such an ideal surface, however, can hardly be expected in common woodworking practice.

Try to think of any surface in terms of cellular damage. One illustration of this point would be knife marks on a longitudinal surface. The surface may be true and even, and the knife marks may leave the surface amazingly smooth. With a well-sharpened planer, with lumber fed at a rate that produces 20 knife marks per inch, the knife marks would be imperceptible to the touch. One would certainly consider the surface smooth, yet the variation in cell damage along the surface can cause each knife mark to stand out as visually distinct. Microscopic examination reveals that variable light reflection from damaged cells, more than physical surface irregularity, is responsible for the visibility of the knife marks. This damage can be obscured by the more uniform pattern of damage that is created by fine sanding or scraping along the grain.

Another example relates to sanding. If you sand with the grain using 180-grit paper, the surface will feel quite smooth. Sand the same wood across the grain with 240-grit paper and it will also feel just as smooth, yet when this piece is stained, the scratches will show up because of the very different manner in which the surface cell structure was broken up, which in turn causes variations in the absorption of stain.

No point needs greater emphasis than sanding *parallel to* rather than *across* the grain. On abrasive paper, each granule of abrasive is a tiny cutter (*Figure 12.5*, *Figure 12.6*). Since most of these granule faces have negative cutting angles, a scraping type of chip forms (*Figure 12.7*). This cutting action carves out cell-wall material from the surface parallel to the grain, but when directed across the longitudinal cells, frayed and broken-out cell walls result. As in planing, wherever crossgrain occurs, sanding *with* the grain is preferable. Sanding end grain leaves some broomed-over cell material, so sanding in one direction will produce the most uniform surface damage.

Developing surface smoothness by sanding is best done using a progression of grit sizes, each of which produces a scratch pattern at least to the depth of the previous one (*Figure 12.8*). Resist the considerable temptation to skip

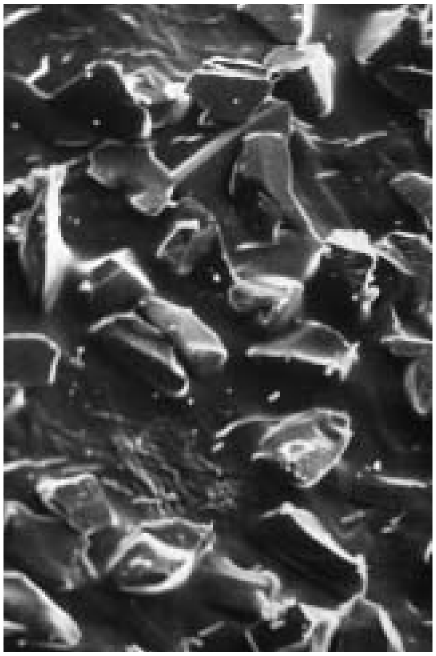

Figure 12.5 • This photomicrograph at 100X magnification shows the surface of a sheet of new 200-grit open-coat garnet sandpaper. Each granule on the paper acts like a tiny cutter that produces a scraping type of chip. (Photo by Stephen Smulski)

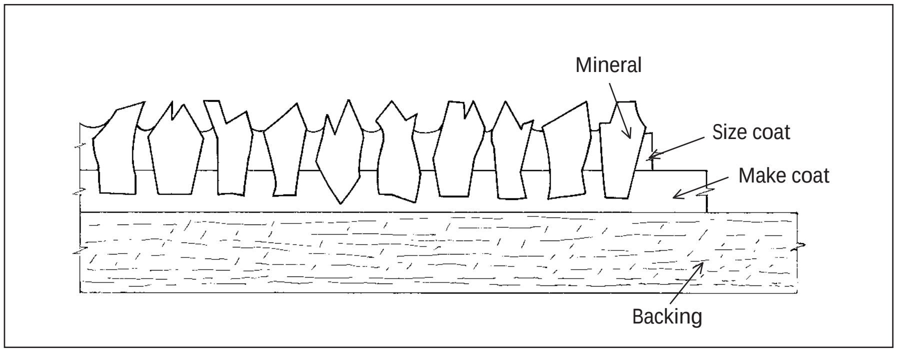

Figure 12.6 • Sandpaper is made up of mineral particles attached to a backing. The minerals adhere to the glue coat (properly called the make coat) and are locked in place with a size coat.

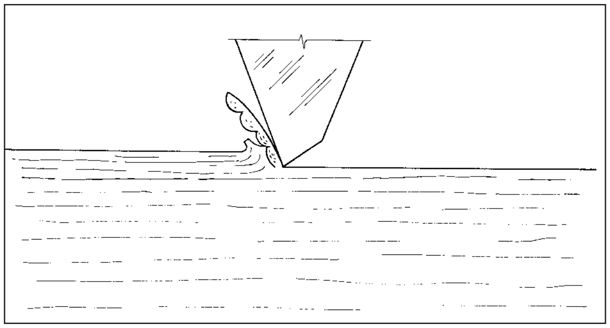

Figure 12.7 • The cutting action of a sandpaper particle yields a scraping type of chip.

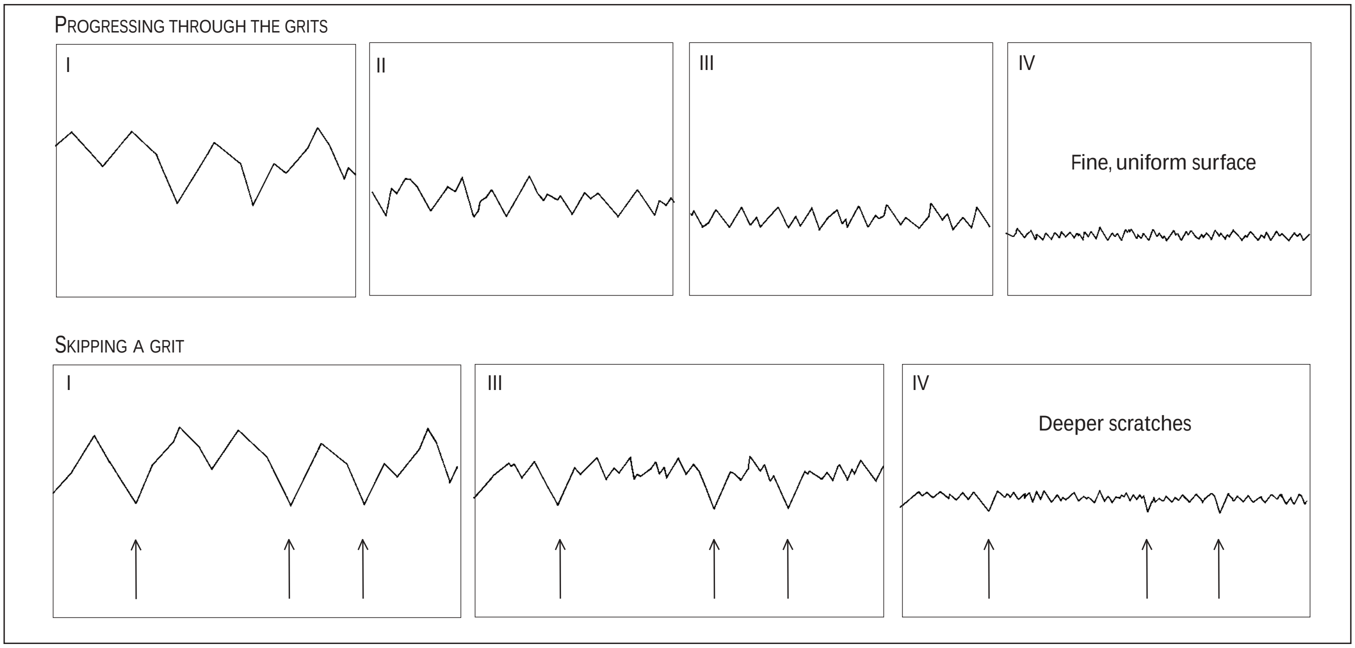

Figure 12.8 • Proper sanding requires progressing through ever-finer grits so that the finer scratch pattern of each replaces the coarser pattern of the previous grit (top). Skipping a grit will leave deep scratches in the finished surface (above).

grits in the progression; when you do so, the surface may look and even feel smooth, but the first coat of finish will reveal a few deep scratches left by the coarsest grit.

Other kinds of damaged cell structure, though apparently smooth, may later show variable light reflection or uneven stain or finish retention. Common problems are minute seasoning checks or compression failures that have gone unnoticed and hammer indentations or cell structure “bruises” below the surface from the action of rasp teeth. The glazed, pounded, and scorched surfaces produced by dull cutterheads can hardly be considered as having quality even if they are smooth. Such surfaces may show later problems of grain raising, uneven stain retention, or poor adhesion of coatings. In hardwoods having tension wood, surfaces may be sanded to apparent smoothness. However, the microscopic woolliness of the severed cell walls will result in blotchy staining.

In any machining process, some fragile projections of damaged cell-wall material remain on the wood surface. Eventual adsorption and desorption of moisture will cause these cell fragments to distort and to project out from the surface. Where a surface coating buries and locks them in place, the fragments may be of no consequence. Otherwise, the raising of surface debris may detract from smoothness.

It is therefore desirable to remove loose cell-wall material as a final step in surface preparation. To do so, simply wipe the wood surface with a slightly damp (not moist or wet) cloth. The ambient temperature must be warm and the relative humidity not high. The moisture from the cloth will be adsorbed quickly by the damaged cell-wall fragments, causing them to raise from the surface. The surface will soon reestablish moisture equilibrium with the environment without any significant increase in overall moisture content. The projecting “whiskers” can then be removed by very light sanding with very fine (600-grit) abrasive paper. The trick is to remove the whiskers without further abrading the surface, which will only produce more whiskers. An extremely smooth and high-quality surface can be produced in this manner.

Surfaces should regularly be wiped or blown free of dust during and after sanding. Accumulated dust may cause “corns” on the abrasive paper, which can mar the surface. In addition, excess dust packed into the cell structure can mar the finish, so the final cleaning should be thorough. An air hose or vacuum cleaner may help if you have one, and it’s a good idea to get in the routine of completing the cleaning job with a tack rag.

Commercially available tack rags seem well worth the money, but a fairly good one can be made easily from a lint-free cloth, such as an old handkerchief. Dampen the cloth slightly with turpentine, and sprinkle on a teaspoonful of varnish or lightly paint meager streaks of varnish across the cloth with a brush. Then thoroughly wring the cloth to distribute the varnish. It should feel tacky, not wet. Store it in a glass jar. To use it, whisk the surface lightly to pick up dust, repeatedly folding the cloth. When it has lost its effectiveness, discard it and make a new one. Commercial spray products (such as Endust) for treating household dust rags work quite well for me.

Surface quality must also be considered from the chemical standpoint. Chemical discoloration resulting from such things as sticker stain in drying or fungal activity may cause visual defects in the finish. Traces of previous finish, glue spills, or accidental contamination with such things as oil, wax, silicone spray, and other contaminants can interfere with the evenness of stain retention or the adhesion of finish coats. As with glues, bonding of finishes depends in large measure upon molecular adhesion. If there is any doubt as to possible contamination of the surface, a final sanding and dusting prior to finishing will promote good adherence.

The four criteria of surface condition must be considered separately. For example, a tabletop that is machined to true and even flatness may have poor quality if it has been sanded across the grain. On a carved surface, the trueness must be judged in relation to the desired shape. If the surface is produced by a sharp gouge properly used (with the grain), the surface may be of high quality but intentionally uneven. If the unevenness of a high-quality carved surface were undesirable, sanding might make the surface more even but at the same time might reduce its smoothness and quality. In a sense, the moisture content of the wood also should be considered a factor in surface condition, for if it changes after finishing, the trueness, evenness, or surface quality may be belatedly altered.

In considering finishing treatments for wood, there are no “right” answers, only countless alternatives. Function, aesthetics, time, and cost ultimately are the deciding factors. As with the drying of wood, a great deal of lore and tradition influences our modern practices, yet few areas of woodworking are so touched by modern advances. Although no subject as complex as finishing can be generalized or simplified, I have come to recognize three basic categories of surface treatment: coatings, that is, treatment **on** the surface; penetrating finish, that is, treatment **in** the surface; and **no** treatment at all.

▸ NO TREATMENT

Usually, some sort of surface application is required for protection and appearance, and the instances where no finishing treatment at all makes sense are apt to be few and far between. Yet too often tradition seems to force the assump-

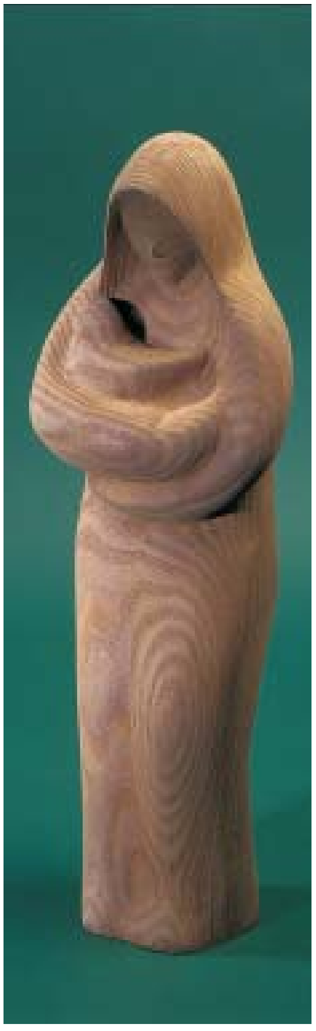

Figure 12.9 • This catalpa statue (standing 13 in. tall) was sanded with coarse sandpaper and left unfinished. (Photo by Randy O'Rourke)

Figure 12.10 • This white pine carving was made 32 years ago and finished with nothing at all. Periodic sanding with 400-grit sandpaper keeps its color bright and fresh. (Photo by R. Bruce Hoadley)

tion that something must be brushed, swabbed, wiped, or sprayed onto the surface of a completed work. Leaving the wood untreated is rarely considered.

The more you work with wood and the more deeply you come to understand it, you become more sensitive to the value of natural tactile surfaces and have greater appreciation for the appearance of wood in the raw. Here more than ever, however, the surface condition, especially smoothness and quality, is vitally important. The longer I work with wood, the more I am able to recognize those special cases where the absence of finish can be the most gratifying treatment for wood (*Figure 12.9*).

Certain items, if kept indoors, really need no finish. These are often decorative, such as carvings and sculpture, but may also be functional, such as trays, bowls, and utensils. They often will be made of a single piece of wood, which can change dimension without affecting function or appearance. For example, I have a small abstract carving of eastern white pine (*Figure 12.10*). Its smooth, dry surface is light in color with only a subtle growth-ring figure displayed at the surface. Any treatment of the surface would bring out this figure too strongly. About as often as you might oil or polish a coated item, I simply resand the surface lightly with 400-grit paper to remove any accumulated dirt, dust, and discoloration from handling. After 32 years, it still looks fresh and clean.

For such items as utensils and tool handles, the normal dirt accumulation and surface abrading from handling create a finish that is both unique and appropriate. Many years back I needed a netmaker's needle, so I whittled one out of black cherry and put it to work immediately without coating it with anything. The years of use have given it a finish I would never trade for anything that comes in a can. I also marvel at the natural finish that develops on well-worn hammer and wheelbarrow handles, railings, and chair arms once

Figure 12.11 • The unfinished finish of this carved catalpa grouse, obtained from weathering for many years, was more appropriate to the nature of the carving than any finish made. (Photo by R. Bruce Hoadley)

the original coating of paint or varnish has worn off. Unfinished wood typically darkens or "ages" more rapidly than wood protected with coatings, especially coatings that contain ultraviolet filters. However, the anticipation of color change can be an integral part of the design of any wooden object, and the patina developed over time on a wood surface can be a valuable asset.

The no-treatment finish also has fantastic potential for outdoor wood objects as well. But the effects of the elements will be far more drastic and complicated, and the changes that will take place must be understood and anticipated. We somehow seem obsessed with the idea that everything must be made to last forever. Consequently, we often fail to take advantage of nature's own progression. Why not consider a finite life for an object and allow gradual deterioration to take place, especially where the effect is beautiful?

In nature we see examples of fallen trees and weathered driftwood where silvery-gray sculptured surfaces surpass all human creativity. In building design and architecture, the natural aging of materials has long been used to both decorative and functional advantage. Likewise, sculpture can become more and more attractive as the ravages of time erode the surface and establish a venerable graying, as in the totems of the Pacific Northwest. By sensible selection of wood species and intelligent sculptural design, this deterioration can be programmed into the life of the piece. If a decay-resistant species is chosen and the design permits water to run off, deterioration can be restricted to surface weathering. Many years ago, I carved a ruffed grouse and set it out on a post next to my driveway (*Figure 12.11*). It was carved out of catalpa and left unfinished. Over time, the weathered surface of grays and browns became more appropriate to the subject of the carving than any finish I could have applied. Because it was mounted "high and dry" and because catalpa is quite resistant to decay, it remained intact for about 25 years. Toward the end, the beak eroded back and the tail split, so it was "retired." If I had it to do over, I'd use the same nonfinish.

The weathering of wood is a combination of physical, mechanical, and chemical effects. The wetting and drying of the surfaces cause expansion and compression set followed by shrinkage, resulting in surface checking. Water that freezes and expands in the surface leads to further breakdown. Ultraviolet radiation also causes the surface structure to deteriorate. Windborne particles abrade the surface. Despite all this, weathering alone will remove only about ¼ in. of wood per century from exposed surfaces.

Normally the breakdown of lignin leaves a cellulosic residue on the surface, which along with water staining produces a predominantly gray color. Dark woods tend to lighten as they weather, and light woods tend to darken. Some species develop a silvery-gray color, others a dark gray or a brownish tinge. However, the moisture condition of the wood can complicate the process, especially when it remains high enough to allow fungi to grow. In such cases, uneven surface discoloration and darkening may result before normal weathering develops. Commercial "bleaching oils" that contain water repellents and fungicides are used as an initial treatment for exposed shingles and boards to give temporary, superficial protection until natural weathering takes over. Understanding and using natural weathering to advantage seems to be among the lost arts. But it frequently is far more gratifying to understand and work with nature than to strive for results in defiance of natural forces.

COATING TREATMENTS

The most universally used finishes are the transparent coating treatments applied to the surface. The word varnish is sometimes used loosely to include any or all such treatments. Usually, however, it refers more specifically to those clear finishes consisting of tough resins dissolved in oil-based solvents. When the solvent, or vehicle, evaporates, the resin hardens, or polymerizes, and remains firmly adhered to the wood surface.

Modern varnishes are specified according to their resins. The newer synthetic varnishes, especially urethanes, are applied by hand easily and are extremely tough. Various chemical additives can produce a full range of surfaces from high gloss to dull satin. A varnished surface is highly resistant to water and alcohol.

Another traditional favorite is shellac varnish, usually called simply shellac. It is quick drying, easily applied, adheres well, and although not as water-resistant as other varnishes is generally appropriate for interior surfaces. Shellac is a natural gum secreted by the lac bug, an insect found in southern Asia. The finish is prepared by dissolving this gum in denatured alcohol. When applied, the alcohol quickly evaporates, leaving a film of shellac. The shellac can be resoftened by alcohol, however, so the finish is not effective on surfaces where alcoholic beverages might be spilled.

The third major coating finish is lacquer. The principal variety has a nitrocellulose resin in a vehicle such as amyl acetate. Lacquers are crystal clear and available in formulations suited to either spraying or brushing. They harden by loss of solvent but do not build layers as thick as most varnishes.

In recent years, concerns about environmental air quality have prompted legislation in many states to limit the volatile organic compounds (VOCs) released by finishing materials. As a result, chemists have new formulations of old recipes and some new finishes altogether.

Clear water-based finishes are one of this class, and while relatively new to the market, they are growing in popularity. When they first came on the scene, water-based finishes were embraced by woodworkers for their ease of cleanup and quick drying times, even though they were not as durable as the old oil-based finishes. New formulations of water-based finishes are tougher and more UV-resistant, and they are beginning to rival the old standbys for suitability in a wide variety of conditions.

Even with a flat, true surface, achieving a fine smooth finish with a varnish-type coating takes some effort. The surface should be freshly sanded to avoid raised whiskers, and then cleaned with a tack rag. Woods with open grain—that is, which drink up finishing material, as redwood does—are often sealed before the final finish goes on. Suitable sealers include a dilute coat of shellac, a special lacquer sealer, or a dilute coat of the final finish itself. When you want a perfectly smooth surface, woods with large open pores such as oak or walnut should be given a coat of paste wood filler. Like much advice in finishing, fillers are a matter of taste, not an obligatory step. If you like the surface open pores impart, there is no rule requiring you to fill them.

Once the surface is prepared, it's vital to take the time to study the label on the can. It will specify suitable staining and sealing materials and will typically warn against incompatible solvents or stains. It may also say something about timing, since many modern resin varnishes must be recoated within a specified time or else the second and subsequent coats will not bond with the first.

A frequent difficulty encountered in applying varnish-type finishes in the home shop or small commercial shop is dust. The surface tension around a dust particle landing in a film of wet finish causes a noticeable blemish, which must later be sanded out. For those who must do finishing in the same location as woodworking, it is impossible to produce even a reasonably dust-free surface. The faster-drying lacquer and shellac finishes have an advantage in these situations.

A photographer offered me a great trick for reducing airborne dust particles in a workroom. About a day or two before the finishing job, "dust" around the room to remove much of the dust and stir up the rest. Then set up a 20-in. window fan in the middle of the room with a 20-in. by 20-in. furnace filter sprayed with Endust or equivalent against the intake side. Over the next 24 to 48 hours, redust the flat surfaces in the area. Meanwhile, the fan will recycle the air in the room many times, and the filter will catch most of the airborne dust. The difference will be evident by the change in color of the filter, as well as by the drastic reduction of dust specking on the subsequent finishing work.

Bubbles are another problem. They sometimes result from striking the brush off on the side of the can, then the bubbly varnish drips back onto the liquid surface in the can and makes the remaining varnish bubbly. Keep the bubbles out of your varnish by striking off the brush into an empty coffee can. A few bubbles are to be expected, but if the varnish is thinned properly they will break within a few minutes and the film will settle without a blemish.

Temperature change can also cause serious bubble problems. I stumbled onto this fact one time when I decided to avoid my dusty cellar shop and varnish a yellow birch candlestand in the most dust-free room in the house—the dining room. I spread my drop cloth, set everything up, dusted the room, and returned to the cellar to let any remaining dust settle. Meanwhile, I strained the varnish and got the brush worked in. I brought the candlestand upstairs to the dining room, gave it a last whisk with a tack rag, and started by varnishing the underside of the top. Everything appeared to be going well, but as I finished the second leg I noticed the first leg was speckled with bubbles. As I brushed out the bubbles on the first leg, I could see more developing on the second leg. I was baffled. The brush was in perfect condition, and the varnish can was virtually free of bubbles.

After long puzzling moments of watching bubbles appear before my eyes, I realized that each bubble developed at the end of a vessel opening. Then came the dawn. The cellar was considerably cooler than the dining room. When I brought the work into the warmer room, the air inside the wood gradually began to expand. Each vessel had become a minute bubble pipe! I've since verified my observation through controlled experiments in the laboratory. Since then I always make certain that a piece to be varnished is kept at an even temperature or moved from a slightly warmer to a slightly cooler location just before finishing. No more bubble problems of that type.

Since everything I varnish seems to wind up with dust specks, I sand lightly between coats with 280-grit paper on a flat block just enough to knock the tops off the dust spots, then go over the whole surface lightly with 5/0 steel wool followed by a tack rag. After the final coat, I use 600-grit paper on a good flat block and work carefully to level every high spot flush with the surroundings. Here is where corns on the paper cause trouble. Next, I rub with pumice and oil, then with rottenstone and oil. Last is a rub with lemon oil or sometimes paste wax. No question about it, this method makes an attractive finish, but during all these stages of work you really become aware that you are working on the finish coating, not upon the wood.

PENETRATING FINISHES

The third general type of finish is *in* the wood, not on the surface. Oil finishes, or penetrating resin-oil finishes such as Watco and Minwax, are in this category. To apply, the finish is simply flooded onto the surface and as much as possible is allowed to soak in. Additional finish is applied to any dry spots that develop. After 15 to 30 minutes, any remaining liquid is removed from the wood surface, and the surface is buffed dry in the process. Most of the finish remains in the cell cavities or is absorbed by the cell walls. Only an imperceptible amount covers the exposed wood surfaces. Repeated coats give more complete and deeper treatment and result in a very slight build on the surface. Enough finish remains to accent the figure of the wood, but there is the illusion that none really covers the surface (*Figure 12.12*). This finish is a delightful compromise when the natural wood surface is preferred but some protection is needed. A penetrating oil finish also can fill the open pores of the wood if it is sanded with fine-grit wet-dry paper while it is soaking in. This makes a fine paste of wood mixed with finishing material, and subsequent buffing pushes this mixture into the pores and levels the surface.

Linseed oil is a traditional favorite, but since it does not harden completely, it may later bleed out on the surface. It

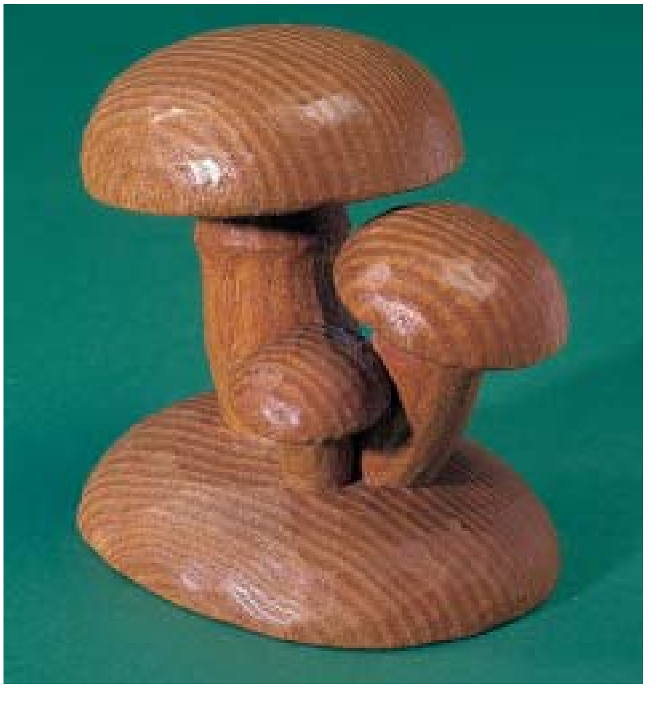

Figure 12.12 • This catalpa carving of mushrooms stands 5 in. tall and is finished with several coats of Watco oil and a coat of paste wax. (Photo by Randy O'Rourke)

also attracts dirt, yellows in color, and darkens the wood. Commercial penetrating finishes have resins that polymerize in time and become permanently set in the wood, consolidating and hardening the surface.

A real advantage of oil finishes in the small shop is that there is no trouble from dust because any remaining liquid is wiped free. They are truly quick and easy to apply. However, experience soon reveals that the time saved in finishing with oils might well be invested in preparing the surface. Penetrating finishes are the acid test of surface condition, especially smoothness and quality, because every imperfection is not only exposed by lack of surface build but is in fact accented even more than if the wood were left unfinished. It really pays to "de-whisker" the surface because the real quality of an oil finish is determined by the surface quality of the wood itself. This is in contrast to a varnish finish, which masks many slight imperfections, scratches, and tearouts in the wood and where the final surface belongs to the varnish, not to the wood.

Figure 12.13 • Black shoe polish with a top coat of paste wax makes an attractive finish for this 11-in.-tall eastern white pine carving. (Photo by R. Bruce Hoadley)

COMBINATIONS AND COMPROMISE

I love to experiment with finishes, and it seems I always wind up trying something I've never tried before (*Figure 12.13*). I especially like to try to amalgamate varnish and oil finishes (*Figure 12.14*). A good starting point is a mixture of one part boiled linseed oil, one part alkyd varnish, and two parts turpentine. Go heavy on the turpentine for better penetration; go heavy on the varnish for more build. Don't go heavy on the linseed oil, but you might substitute something else, such as tung oil. The result is somewhere in between a varnish finish and a commercial penetrating finish. It wipes on dust-free but gives more build, depending on proportions.

Over the years I have become intrigued with tung, or chinawood, oil. It is about as close to the one-shot all-purpose finish as I can imagine. Tung oil is an aromatic natural drying oil that is obtained from the nut of the tung tree (*Aleurites* spp.), originally from China but now grown extensively in the southern United States. Commercial preparations contain a drying agent and can be used as purchased. Tung oil can be applied directly to the wood surface much as other oil finishes, but it's a good idea not to allow it to remain more than about 15 minutes before wiping clean. This is because it sets up more quickly than most oil finishes. After a couple of hours drying, the surface can be recoated. It gives a better build than the usual penetrating oil finishes, and it holds up well outdoors. I have found it to be the most satisfactory treatment for outdoor thresholds. I have also used it for everything from kitchen furniture to woodcarvings and wooden jewelry.

Figure 12.14 • This black walnut carving measures 8 in. tall and is finished with an oil/varnish mixture. The hair has been rough-sanded, the face fine-sanded, and the chisel marks were left on the neck. (Photo by Randy O'Rourke)

SLOWING MOISTURE EXCHANGE

Although a primary objective of finishing treatments is to prevent moisture exchange, no finish is totally effective at doing so. Given enough time, moisture will be adsorbed into wood from a humid atmosphere or will escape to a dry atmosphere through any finish. But as discussed earlier, the important role of the finish is to retard the rate of exchange enough to buffer the temporary extremes of high and low humidity. Obviously, some finishes are better than others in this respect. The effectiveness of a particular finish may also be affected by the number of coats applied and the time of exposure to a different humidity level.

Research conducted at the U.S. Forest Products Laboratory at Madison, Wisconsin, under the leadership of

TABLE 12.1—Moisture-excluding effectiveness of various finishes on ponderosa pine*.

Finish	No. of coats	Moisture-excluding effectiveness (%) 1 day	7 days	14 days
Linseed oil sealer (50%)	1	7	0	0
	2	15	1	0
	3	18	2	0
Linseed oil	1	12	0	0
	2	22	0	0
	3	33	2	0
Tung oil	1	34	0	0
	2	46	2	0
	3	52	6	2
Paste furniture wax	1	6	0	0
	2	11	0	0
	3	17	0	0
Water repellent	1	12	0	0
	2	46	2	0
	3	78	27	11
Latex flat wall paint (vinyl acrylic resin)	1	5	0	0
	2	11	0	0
	3	22	0	0
Latex primer wall paint (butadiene-styrene resin)	1	78	37	20
	2	86	47	27
	3	88	55	33
Alkyd flat wall paint (soya alkyd)	1	9	1	0
	2	21	2	0
	3	37	5	0
Acrylic latex house primer paint	1	43	6	1
	2	66	14	2
	3	72	20	4
Acrylic latex flat house paint	1	52	12	5
	2	77	28	11
	3	84	39	16
Solid-color latex stain (acrylic resin)	1	5	0	0
	2	38	4	0
	3	50	6	0
Solid-color oil-based stain (linseed oil)	1	45	7	1
	2	84	48	26
	3	9	64	42
FPL natural finish (linseed-oil-based semitransparent stain)	1	62	14	3
	2	70	21	6
	3	76	30	11
Semitransparent oil-based stain (commercial)	1	7	0	0
	2	1	0	0
	3	21	1	0
Marine enamel, gloss (soya alkyd)	1	79	38	18
	2	91	66	46
	3	93	74	57

Finish	No. of coats	Moisture-excluding effectiveness (%) 1 day	7 days	14 days
Alkyd house primer paint (tall maleic alkyd resin)	1	85	46	24
	2	93	70	49
	3	95	78	60
Enamel paint, satin (soya/tung/alkyd; interior/exterior)	1	93	69	50
	2	96	83	70
	3	97	86	80
	4	98	92	85
	5	98	93	88
	6	98	94	89
Floor and deck enamel (phenolic alkyd)	1	80	31	18
	2	89	53	35
	3	92	63	46
Shellac	1	65	10	3
	2	84	43	20
	3	91	64	42
	4	93	75	58
	5	94	81	67
	6	95	85	73
Nitrocellulose lacquer	1	40	4	1
	2	70	22	8
	3	79	37	19
Floor seal (phenolic resin/tung oil)	1	31	1	0
	2	80	37	18
	3	88	56	35
Spar varnish (soya alkyd)	1	46	6	0
	2	80	36	15
	3	87	53	30
Urethane varnish (oil-modified)	1	55	10	2
	2	83	43	23
	3	90	64	44
	4	91	68	51
	5	93	72	57
	6	93	76	62
Aluminum flake pigmented urethane varnish (oil-modified)	1	90	61	41
	2	97	87	77
	3	98	91	84
	4	98	93	87
	5	98	94	89
	6	99	95	90
Polyurethane finish, clear (two components)	1	48	6	0
	2	90	66	46
	3	94	81	66
Polyurethane paint, gloss (two components)	1	91	66	44
	2	94	79	62
	3	96	86	74
Paraffin wax, brushed	1	97	82	69
Parafin wax, dipped	1	100	97	95

**Sapwood was initially finished and conditioned to 28ºC (80ºF) and 30% RH, then exposed to the same temperature and 90% RH.*

Source: The Wood Handbook: Wood as an Engineering Material. *Gen. Tech. Rep. FPL-GTR-113, Madison, WI: U.S. Department of Agriculture, Forest Service, Forest Products Laboratory, 1999.*

Dr. William Feist, investigated the moisture-excluding effectiveness of different finishes on a standard wood sample. The effects of multiple coats and different periods of exposure were included in the study. A summary of the results is given in *Table 12.1*. Although the values listed in and of themselves have little direct meaning, the numerical data give an excellent basis for comparative rating among the finishing materials listed.

It is easy to imagine that the first coat of finish, while penetrating, may disperse itself into the cell structure. After curing, however, it provides a barrier that concentrates subsequent layers at the surface to form a more complete barrier. It would seem then that in the case of penetrating finishes, multiple coats are especially crucial to developing moisture retardance. It is also important to recognize the difference between moisture-repellant finishes and moisture-excluding finishes. A moisture repellent is highly effective in preventing the intrusion of liquid water but may have no effectiveness in retarding the passage of molecular water vapor.

If there is anything worse than no moisture barrier at all, it's an uneven moisture barrier, which allows moisture to be adsorbed or desorbed unequally in different areas of the wood. In carcase pieces, for example, it is tempting to work conscientiously on the exposed surfaces and forget the insides. It is crucial that all sides of every board receive equal finish. The concept of balanced construction also applies to finishes. Forgetting this is a major cause of surface cupping. For this reason, many experienced cabinetmakers finish all the wood in a carcase before final assembly, taking care not to drip finishing material onto gluing surfaces, which can be protected with masking tape. In frame-and-panel construction, this is the only way to be sure that an unfinished line will not appear along the edge of a raised panel. It is also an effective way to avoid having to rub down finish in tight corners.

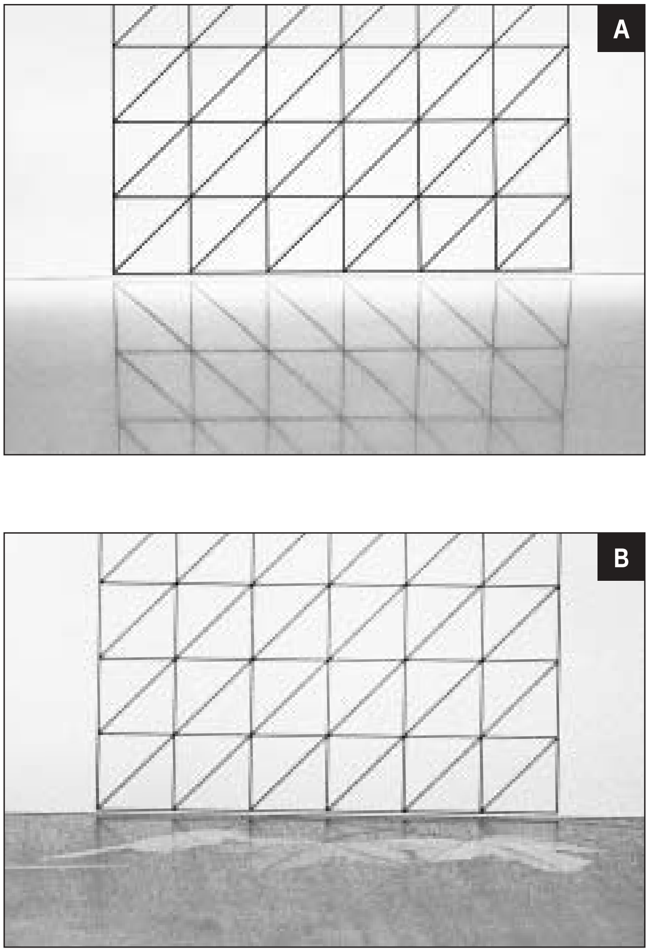

Figure 12.15 • The smoothness and gloss of a finish are indicated by how it reflects a black-lined target card. Surface roughness is indicated by distortion or breakup of the lines. Glueline creep will show as an abrupt breakup in diagonal vertical-line reflections. (A) Reflection on Formica over plywood. (B) Reflection on a marquetry tabletop. (Photos by Richard Starr)

EVALUATION OF FINISHED SURFACES

One of the most effective ways to evaluate the quality of finished surfaces is by observing line patterns reflected at low angles across a surface. You need only a target card with boldly ruled horizontal, vertical, and diagonal lines (*Figure 12.15*). Hold this card perpendicular to the surface, and examine the lines reflected on the surface. The clarity of the reflection will reveal the relative uniformity of gloss developed in the finish. Waviness or discontinuities in the lines will indicate the lack of surface trueness, evenness, and smoothness. Generally, such defects as sunken joints, raised grain, and lathe checks can be pinpointed.

PRESERVATIVE TREATMENT OF WOOD

When wood is used in a location where its moisture content can range above 20%, finished or not, wood-inhabiting fungi will probably take up residence. Termites and carpenter-ant infestations are also encouraged by high moisture content, and some insects are troublesome even in dry wood. Certain wood species have heartwood extractives that resist the attack of fungi and are termed decay-resistant or durable woods (see *Table 2.1* on p. 44), while certain woods have selective resistance to insect attack. In many cases, however, where conditions favorable to biological deteriora-

TABLE 12.2—Penetration of the heartwood of various softwood and hardwood species*.

Ease of treatment	Softwoods	Hardwoods
Least difficult	Bristlecone pine (*Pinus aristata*) Pinyon (*P. edulis*) Ponderosa pine (*P. ponderosa*) Redwood (*Sequoia sempervirens*)	American basswood (*Tilia americana*) Beech (white heartwood) (*Fagus grandifolia*) Black tupelo (blackgum) (*Nyssa sylvatica*) Green ash (*Fraxinus pennsylvanica*) Pin cherry (*Prunus pensylvanica*) River birch (*Betula nigra*) Red oaks (*Quercus* spp.) Slippery elm (*Ulmus rubra*) Sweet birch (*Betula lenta*) Water tupelo (*Nyssa aquatica*) White ash (*Fraxinus americana*)
Moderately difficult	Baldcypress (*Taxodium distichum*) California red fir (*Abies magnifica*) Douglas-fir (coast) (*Pseudotsuge menziesii*) Eastern white pine (*Pinus strobus*) Jack pine (*P. banksiana*) Loblolly pine (*P. taeda*) Longleaf pine (*P. palustris*) Red pine (*P. resinosa*) Shortleaf pine (*P. echinata*) Sugar pine (*P. lambertiana*) Western hemlock (*Tsuga heterophylla*)	Black willow (*Salix nigra*) Chestnut oak (*Quercus prinus*) Cottonwood (*Populus* spp.) Bigtooth aspen (*P. grandidentata*) Mockernut hickory (*Carya tomentosa*) Silver maple (*Acer saccharinum*) Sugar maple (*A. saccharum*) Yellow birch (*Betula alleghaniensis*)
Difficult	Eastern hemlock (*Tsuga canadensis*) Engelmann spruce (*Picea engelmannii*) Grand fir (*Abies grandis*) Lodgepole pine (*Pinus contorta* var. *latifolia*) Noble fir (*Abies procera*) Sitka spruce (*Picea sitchensis*) Western larch (*Larix occidentalis*) White fir (*Abies concolor*) White spruce (*Picea glauca*)	American sycamore (*Piatanus occidentalis*) Hackberry (*Celtis occidentalis*) Rock elm (*Ulmus thomasii*) Yellow-poplar (*Liriodendron tulipifera*)
Very difficult	Alpine fir (*Abies lasiocarpa*) Corkbark fir (*A. lasiocarpa* var. *arizonica*) Douglas-fir (Rocky Mountain) (*Pseudotsuga menziesii*) Northern white-cedar (*Thuja occidentalis*) Tamarack (*Larix laricina*) Western redcedar (*Thuja plicata*)	American beech (red heartwood) (*Fagus grandifolia*) American chestnut (*Castanea dentata*) Black locust (*Robinia pseudoacacia*) Blackjack oak (*Quercus marilandica*) Sweetgum (redgum) (*Liquidambar styraciflua*) White oaks (*Quercus* spp.)

**As covered in MacLean (1952).*

Source: The Wood Handbook: Wood as an Engineering Material. *Gen. Tech. Rep. FPL-GTR-113, Madison, WI: U.S. Department of Agriculture, Forest Service, Forest Products Laboratory, 1999.*

tion cannot be avoided and where resistant species are not available, the best alternative may be to treat the wood with a substance that will give it the desired durability. Such chemicals are called **wood preservatives.** (This term sometimes includes treatments to make the wood nonflammable, although the term **fire-retardant** is preferred for such materials.)

The ideal preservative would readily penetrate the wood and be permanently toxic to fungi and insects, safe to handle, colorless, compatible with coatings and finishes, and of course, inexpensive. No one chemical has yet been developed that has all of these attributes, but a wide array of chemicals with various advantages has emerged for specific purposes.

Coal-tar creosote has been used commercially to preserve such things as railroad ties and utility poles. Oil-borne preservatives, such as pentachlorophenol and copper naphthenate, and some water-borne preservatives, mostly salts of copper, zinc, chromium, and arsenic, also have been employed—each of these has specific advantages and disadvantages. As regulations regarding preservatives are constantly changing, many of the preservatives widely used in the past are now banned for use in buildings where human contact may occur. EPA-approved proprietary brands are available at retail building-materials dealers.

The key to the performance of preservatives is penetration. Only areas of the wood that are penetrated by preservative chemicals will be protected. A first consideration, then, is choosing the most penetrable wood. Generally, sapwood or species with low extractive content (e.g., ponderosa pine)—often those that have the least natural decay resistance—are the best choices for preservative treatment. *Table 12.2* groups selected species according to ease or difficulty of penetration by preservatives. Except for very thin pieces, the only way to attain any worthwhile degree of penetration is under pressure. Commercially, this is done by using cylinders that produce pressures up to about 150 psi and sometimes also by using vacuum treatment or elevated temperatures. Since such operations are beyond the capability of the average woodworker, it is usually most logical to buy commercially treated lumber for use where constant moisture problems prevail.

Building materials treated with wood preservatives are now commonly available at retail lumberyards. The treated products include dimensioned lumber, posts, landscape timbers, fencing, and plywood. Perhaps the most common preservative used in treating retail products is chromated copper arsenate (CCA), which is recognizable by the olive-green color it imparts to the wood.

Nonpressure treatments include soaking, dipping, and brush application. For any use involving contact with the soil or constantly wet or moist conditions, such as fence posts or sills lying on bare ground, nothing less than immersion in preservative for several days will be worth the expense and effort. The wood should be at least air-dried to facilitate penetration and to ensure that no further drying occurs after penetration, which might open checks and thus expose untreated wood.

Where possible to do so safely, heating the treating solution will improve penetration. Heating the wood expands and drives out air from the cell structure; when allowed to cool, the remaining air contracts, drawing the preservative solution into the cell structure. Cutting open a test piece can indicate the degree of penetration, while commercial preparations are available for determining the penetration of colorless materials.

Brush-and-dip methods give only superficial treatment and should be relied upon only where the wood needs surface protection, as with aboveground parts of a structure exposed to intermittent rainfall. Total immersion for a few minutes will do a far better job than brush treatment for reaching vulnerable voids such as bolt holes, deep end checks, splits, and loose knots. Dipping or flooding the surface may give fairly good end penetration, but side-grain penetration by either method may be as little as 1⁄32 in., varying somewhat according to species.

The most common mistake in using surface treatments is applying them after rather than before construction. Consider an outdoor structure such as a deck, porch, bench, boardwalk, railing, or flower trellis. During a rain, water seeps and settles into joints and crevices and is absorbed by the wood, especially at concealed end-grain surfaces such as the bottom ends of vertical posts resting on horizontal surfaces. After the rain, most exposed surfaces, particularly side-grain surfaces, dry quickly enough that fungal activity does not make significant progress. However, in hidden joints, water is held longer, absorption is prolonged, and drying is delayed.

The hidden surfaces of joints are therefore the most vulnerable places, and preservatives brushed on after construction seldom reach them. For this reason, every effort should be made to apply preservative to bolt holes, joint surfaces, and inside mortises before assembly. In nailing exposed horizontal surfaces such as deck boards or stair treads, nail heads should be driven in flush. Setting nails below the surface exposes end grain and creates a water pocket.

Preservative treatment, especially superficial brush treatment, can never compensate for poor design of an item. For exterior structures, promoting runoff and preventing entrapment of water should be primary considerations. Many modern fungicidal preservatives are both water-repellent and fungicidal; these are marketed as water-repellent preservatives. In combination with good design, brush application of these preservatives can be quite effective. Remember, however, that no brushed-on preservative will last forever. The chemical itself eventually leaches out of the wood, becomes diluted, or simply degrades after prolonged exposure to the weather. This deterioration takes place from the exposed surfaces inward, another reason why depth of penetration is so important.