Clears and present dangers

by Steve Smith
Smith & Co.

Hello. I'm Steve Smith. I'm a paint chemist.

The editor of this publication tells me I have only 1,200 words or so to cover the subject of how and why clear wood coatings fail, and what can be done about it.

No problem. I could do it in twice that.

The reason we're starting with failure is because you want to give your customer a clear finish that really lasts, and help them to understand what is within their budget. The customer may want a glossy finish, or low sheen. The application may be interior or exterior. There are ways to do all this, and some products outperform others. Independent publications such as *The Practical Sailor* or *Consumer Reports* test some products, perform the testing in some more-or-less scientific manner, and give reasonably valuable side-by-side comparisons. Such comparisons are nice, but they do nothing to help you understand how to choose a better product, or how to get beyond the three-month-to-two-year lifespan of most clear coatings.

So, I want to talk to you about some of the fundamentals of coating design, with the goal of your becoming better able to produce a clear coating that lasts long enough to satisfy your customers, and if I get really lucky, someone will have a replacement cursor assembly for my 20-inch slide rule. It's related. Really.

We can understand how clear wood coatings exposed to the elements can last for years by learning how and why such coatings fail. The why is threefold: Water attacks the coating or the wood, ultraviolet light (which is an invisible part of both natural sunlight and interior fluorescent light) does the same, and the wood substrate moves.

These causes bring about different effects. The most obvious are yellowing, loss of gloss, tearing of the coating, cracking, and finally flaking of the coating. Somewhere along the line, the wood loses its originally attractive color and bleaches to gray.

Some of the above result from loss of flexibility, and this will manifest as a cracking, tearing, or peeling of the film. The main reason is degradation by UV light, which

slowly breaks molecular chains in the coating (a polymer made of many molecules intertwined and connected). When this happens, the molecular fragments (called "free radicals"; more about those later) will glue themselves onto neighboring polymer chains, making extra cross-links. These are extra branches in a chain, like rungs on a ladder. As more cross-links are made, the coating loses its elongation capability. That is to say, it becomes stiffer and cannot stretch as much as the natural expansion of the wood, and eventually cracks, tears, and flakes. Polyurethanes, traditional varnish, and any clear finish for that matter, will get more brittle with age. The reason old, flaking varnish curls outwards is that the outer surface becomes shorter than the inner surface, due to the extra surface cross-linking from the UV light.

There are special chemicals designed to trap and neutralize these free radicals before they can do their damage. They are called antioxidants (something like vitamin E, actually), and they work the same way your antioxidant vitamins work to keep you healthy.

Interestingly enough, conventional varnishes cure by a chemical reaction between the oil and the oxygen in the air. This is called oxidation, and the addition of antioxidants to a conventional varnish would poison the curing reaction. It is therefore impossible to add antioxidants to varnish, and thus any varnish will lose its flexibility fairly rapidly with exposure to the sun. Some chemically cured coatings, such as two-component polyurethanes, are compatible with both UV absorbers and antioxidants, and those have the best maintenance of gloss and flexibility. Versions which are VOC-compliant are available for high-end applications. My company has been making such coatings for over 15 years.

Evaporation of flexibilizing plasticizers is another reason coatings lose flexibility with age. Plasticizers are non-reactive chemicals, which some manufacturers add to a resin to make it less brittle. Used correctly, this may be a good thing. If an incorrect (or cheap) plasticizer is

Continued on page 52

Wood Work—

Continued from page 50

used, it will evaporate with age as it diffuses out of the material.

I personally have experienced a significant loss due to exactly this kind of failure. The sliding part (cursor) on my 20-inch slide rule was made with some plastic, which has shrunken and become brittle with age. (My father bought it for me when I was in high school...I was the only kid with a 20-inch in a belt scabbard.) Now the cursor is cracked in several pieces and does not glue back together well, and so is very difficult to use. If you have one you'd be willing to sell, please call me at 510/237-5986.

Where a coating bridges over two adjoining pieces of wood, relative motion may tear the film loose from the substrate without the film itself failing. The visual result of this is usually a whitish line appearing in the clear coating over the wood joint. As the coating lost its flexibility, it became stiffer, and stretched only with more difficulty. Eventually the force required to stretch the coating over the joint exceeded the shear strength of the wood or the peel strength of the coating's adhesive bond to the wood, and the coating tore loose to some degree on either side of the joint.

Water causes a loss of film strength. The film will tear more easily, and stretch less before it fails. The reasons are technical and have to do with chemical reactions between water and some kinds of plastics, acrylics, and some other chemical compounds, which lead to decomposition of the material. The chemist who formulates the coating would use better-quality materials to make a coating more resistant to this sort of degradation. Some urethanes, some epoxides, and the reaction products of certain natural oils (such as linseed oil or tung oil) or other kinds of resins (alkyds) are more resistant to water than some other materials, such as acrylic resins or some polyester resins. Fiberglass boats develop gel-coat blisters, which result from water attacking that polyester resin.

So what can you do?

A chain is only as strong as its weakest link, and so it is necessary not only to improve the varnish or other clear coating to obtain a longer life, but to improve the stability of the wood surface. This gives any topcoat something better to stick to.

There are many different definitions of the word "primer," depending on the specific function being performed. Manufacturers of clear coatings usually design some sealer-primer, adhesion-enhancing primer, or wood-stabilizing primer for use with their coating products. The oldest and simplest of these, used with any varnish, was to thin the first coat of varnish with mineral spirits and allow it to soak into the wood. This is commonly done today. Whatever the recommendation of the topcoat manufacturer for surface prep or primer, follow it.

My company manufactures a primer for wood that is compatible not only with our clear finish, but other manufacturers' alkyd or latex paints, or clear coatings or varnish es. It is called Clear Penetrating Epoxy Sealer, and impregnates the wood substrate with a water-repellent resin system made largely from the natural resins of wood itself. It bonds the wood surface fibers together and into the wood substrate, where there is open porosity. This gives a stronger surface, better attached to the bulk of the wood itself, and thus creates better water resistance of the wood substrate, as well as better topcoat adhesion. It bonds the coating to the wood with a tough, flexible adhesive, and this bond is stronger than the bond of varnish or other finishes directly to bare wood. Thus, the sealer glues down the topcoat, while the ultraviolet absorbers in the topcoat protect both wood and sealer from sunlight.

Wood consists of hollow fibers of cellulose (a kind of sugar, very tasty to fungus and termites) glued together by a material called lignin. Lignin is a very hard, strong resin, very resistant to water, but is decomposed very quickly by UV light.

UV light attacks almost everything. All organic compounds, whether synthetic or natural, will eventually be attacked and broken down by UV light. Even some of the best urethane paints will lose about half their gloss in two years of outdoor exposure. It is not enough to make a clear coating that is not much degraded by UV light—such a coating would simply transmit the UV light through to the wood underneath.

Therefore, UV absorbers were invented. The most effective are chemical compounds, which act as magnets for UV light. When a molecule of this absorber material captures a photon (light comes in small units called photons), it converts the energy of the UV photon into heat. When it does this, the molecule vibrates. The phenomenon is very much like ringing a bell. We know that if you strike a bell often enough, the bell will crack. The molecules of UV absorbers wear out in the same way. Eventually, they will die and no longer absorb light. The more absorbers the manufacturer puts in the clear coatings, the longer the coatings will last, assuming that high-quality ingredients are used and the coating itself is correctly designed.

Clear coatings containing UV absorbers must be applied to some minimum predictable film thickness, so that there are enough chemicals over the wood to afford protection and provide color stability for the wood. When the absorbers burn out, the wood will lose its color, becoming gray.

Well, I see by the bulging veins on my editor's neck that I'm about at the word limit, so I want to thank you for your attention and I trust this has been useful for you.

One last thing, in case you are wondering. You may have noticed I did not say how manufacturers keep coatings from losing their gloss. It's true; I didn't. I'm a paint chemist. We have our secrets.

Steve Smith is president of Smith & Co. in Richmond, CA. Steve has invented several wood restoration technologies and manufactures the associated products.