Polyurethane Finishes

Price tells as much as the label on the can

by Otto Heuer

Companies manufacturing polyurethane describe it as a stunning finish that is unbelievably tough. Even though some craftsmen complain that the glossy finish has an artificial, plastic look, it does wear well, resists scratches and other abrasions, and is virtually impervious to household chemicals and detergents, alcohol, even boiling water.

Picking the right polyurethane for your job can be a bewildering journey through a maze of cans: Urethane Finish; Polyurethane Varnish; Clear Gloss Urethane; Spar Urethane; Polyurethane Liquid Plastic; Polyurethane Reinforced Varnish; Spar Urethane Varnish. The composition labels on the cans are difficult to understand, and at times, remind me of the old saying about well-organized confusion. I know one man who was so confused he wasn't sure if he bought polyurethane or something being compared to polyurethane (he bought oil-based varnish).

Part of the confusion comes from the chemical complexity of polyurethanes. They are not merely blends of solvents and resins, but highly reacted chemical compounds. In contrast, lacquers are relatively simple mixtures of nitrocellulose (as a film-former), hard resins (to increase gloss), and plasticizers (to make the film more flexible). Traditional varnishes, mixtures of vegetable oils and natural or synthetic resins, are slightly more complex than lacquers. The varnish is heated during the manufacturing process, promoting chemical reactions among the components.

Because of the elaborate equipment needed to produce the complex polyurethane, many small- to medium-size finishing companies don't even manufacture it, They buy "concentrated" resins from some of the country's major chemical companies, blend it with their own ingredients, and market it under their own names. This may explain why I found so many similarities among various brands. I tested 15 clear gloss and 12 satin luster polyurethanes on wood and glass panels as I researched this article. The finishes were so consistently clear and strong I concluded that most of the differences in quality of finish had to do with application methods. Price is also an important factor. If you buy a brand-name product, you improve your chances of getting a good finish. If you buy a bargain-basement brand that's considerably cheaper than the brand-name ones, you're tilting the odds in favor of an inferior result.

The terms polyurethane and urethane have nothing to do with quality—both terms, along with names like urethane polymer and isocyanate polymer, refer to the same type of finish. The name game seems to be mostly a sales gimmick—a label advertising isocyanate polymer might scare people away. "Plastic" is another sales pitch. Although polyurethanes are chemically similar to plastics, the term "synthetic" would be more correct in describing polyurethane, epoxy, and other modern finishes.

Oil-modified polyurethanes are based on vegetable oils (linseed, soya, safflower and others) that have been reacted with polyhydric alcohol (glycerine or pentaerythritol) and diisocyanate. An alkyd-modified polyurethane is composed of the same oils and polyhydric alcohols, but the phthalic anhydride, which is the usual acidic ingredient reacted with the oils and alcohols, is partly replaced by a portion of diisocyanate. In both oil-modified and alkyd-modified mixtures the amount of.diisocyanate, the most expensive ingredient in the mixtures, affects the hardness, chemical and abrasion resistance, and drying speed of the film.

The chemical reaction that produces polyurethane must take place in a large (1,000 gallons or larger), closed, stainless steel reactor. The air in the vessel usually is replaced with carbon dioxide before the tank is heated, to prevent discoloration of the raw materials during the reaction. After the reaction is completed, the resinous mixture is cooled, then pumped from the reactor vessel into a thinning tank, where it is reduced with mineral spirits (or other petroleum distillates) until it is about 60% to 7096 non-volatile solids by weight.

I have formulated oil-modified polyurethanes for several small companies by blending these "concentrated" polyurethane resins with alkyds to improve adhesion and reduce cost, and for semi-gloss and satin mixtures, silicates as flatting agents to reduce gloss, and anti-settling agents to keep the silicates and the solvents from separating. At this point, small amounts of metallic dryers (cobalt, calcium and zirconium) are added. To prevent the polyurethane from skinning over in the can, anti-oxidant agents are also added. Then the mixture is thinned with mineral spirits until it is 45% to 50% solids by weight,

The type of oil used in the manufacturing process is a good guide to several aspects of finish quality, Polyurethanes are never water-white clear, but they have a tendency to darken to an amber color as they age. This is especially true if linseed oil is the base. With soybean oil mixtures, the dried film will be slightly lighter and have less tendency to darken with age. Polyurethanes based on safflower oil darken the least, and, therefore, are most suitable for finishing furniture and interior woodwork made of light-colored (not stained) woods like white pine, birch and maple.

Gloss polyurethanes tend to be tougher than the satin finishes, which contain transparent, inert silica powder that serves as a flatting agent. The light, fluffy silica has a tendency to float to the surface while the polyurethane is drying. Light rays striking these transparent particles tend to scatter, thus reducing the gloss. This loss of strength is insignificant on interior finishes, and you may decide you prefer the satin look because scratches and defects in the finish are less noticeable. Gloss finishes tend to magnify any

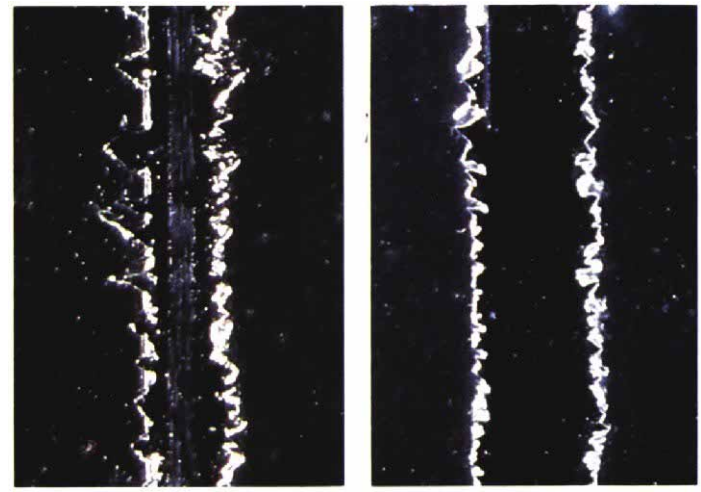
imperfections; satin finishes are more forgiving.

Manufacturers rate the durability of polyurethanes as an exterior finish at fair to good, depending on the climate. Linseed-based polyurethanes are slightly better than the other types and I'd recommend you use only these as an exterior finish. Patio furniture left outdoors during the spring and summer, but stored inside for the winter, should look good foe several seasons with this finish. This toughness also makes the linseed-based formulas better for floors and other heavy-wear areas.

Other types of polyurethanes are available, but are not recommended for small production and home shop use. These two-component industrial coatings are used on laboratory equipment, skis and tennis rackets, and as anti-graffiti shields in schools and on subways. Some stores specializing in automotive refinishing paints and enamels handle these finishes, but they're expensive, tricky to mix and apply, and usually available only in large quantities. Once the clear resin and catalyst are mixed, the finish thickens within 2 to 8 hours and even the strongest solvents can't stop it.

You might also find moisture-cured polyurethanes at your local hardware store, but avoid them unless you plan to work fast and use the whole can in one application. These polyurethanes harden quickly after being exposed to the air, and will continue to harden after the can is resealed. They're also very sensitive to impurities and tend to flake off if contaminated during application.

In trying to gauge the strength and quality of various polyurethanes, I applied the finishes to small panes of glass and a series of 6-in. by 12-in. panels of mahogany, walnut, cherry, and other woods. Since the glass won't absorb finish the way wood does, it is a good surface for checking the drying time of the film and determining if it is seedy (contains impurities), cloudy, or too viscous to flow out evenly. To check flow out, I poured a little bit of each sample on clean pieces of 6-in. by 10-in. window glass held in an upright position so the excess would flow off. Flow out can be a problem with polyurethanes. Their fast drying time prevents the film from flowing out and "bridging over" very small pores in the wood. If you hold the panels on an angle, you can sometimes see little pockmarks beneath the surface. I found these imperfections occurred when the finish was too thick—either it wasn't thinned properly or was applied in a too cold room For best results, the finishing area should be from 70°F to 80°F If you find your finish hasn't flowed properly, you may be able to wash off the partially dry film with mineral spirits. Otherwise, let it harden, then sand it with 600 grit wet/dry paper before applying another, thinner coat



To compare flexibility and chip-resistance, scratch the dried finish off a pane of glass with a coin. A brittle finish fragments (left). A more flexible one (right) peels off as a smoother strip.

A good way to gauge the hardness or adhesion of a sample is to hold a nickel on end between your thumb and index finger and scratch the finish It may take two 01 three passes to scratch through a very hard finish If the dried finish scratches into little flakes or fragments, I'd call the film brittle If the edge of the coin cuts through the film and takes off a soap like cheesy strip, I d call the film flexible A flexible film will most likely be a better finish on wood, since it will not chip easily All of the brands I tested produced a film that was strong and flexible enough to be re

Reading the label

Confirms product is a urethane. Another commonly found term is isocyanate polymer.

Linseed-based polyurethanes make the most durable finish, but tend to darken more than other types. Soybean oil mixtures slightly lighter and darken less. Safflower mixtures darken the least.

Composition by Weight	
Non-Volatile	46%
Polyurethane fortified Linseed Oil Alkyd Resin	41.0%
Driers	0.3%
Silicates	2.5%
Ultra Violet Light Absorbers & Additives	2.2%
Volatile	54%
Non-Photochemically Reactive Petroleum Thinners	54.0%
MO–159	100.0%

Percentage of solids, the finish material left on the surface when the solvent dissipates, indicates thickness of film.

Metallic solutions (cobalt, calcium and zirconium) to speed drying.

Flatting agents (silicates) to reduce gloss. Found in satin-type finishes. The silica decreases film strength, but the effect is insignificant for most interior applications.

Added to exterior finishes to increase resistance to sunlight.

Solvents complying with state and federal air pollution regulations. Thin with mineral spirits for maximum cutting power, use regular spirits, not odorless kind.

Additives include anti-settling agents in satin finishes (to prevent silicates from separating out of solvent) and anti-oxidants (to prevent finish from skinning over in can).

Spraying polyurethanes and other varnishes

by Nancy Lindquist

In our furniture shop people ask for "that plastic finish" on their fine furniture, so they can enjoy the beauty of the wood without "doing anything" to take care of it. "Miracle" finishes don't exist, but apparently miracles happen everyday in the marketing of furniture finishes. Urethanes are known for their toughness, but like any other finish, they're only as tough as the wood they protect and I don't think they are the best choice for every piece of furniture. I choose polyurethane for interior floors, trim work, bar tops and table surfaces subjected to heavy wear, marring, heat and water exposure. The best way I've found to apply polyurethanes and varnishes is spraying, which eliminates brush marks and many of the contamination problems that can mess up a finish.

Because of their high solids content, polyurethanes and varnishes have tremendous "build." Unlike lacquers, in which each coat dissolves the previous coat to form a single or monolithic film, varnishes and polyurethanes form distinct layers that are stacked on top of each other. This makes adhesion to the wood and between coats a primary concern.

For good adhesion, use the same polyurethane or varnish finish for the entire job, from the first sealer coat to the final top coat. Commercial sanding sealers are less expensive, faster drying, and easier to sand, but they may reduce the bond between the wood and the top coats. In contrast, a thinned coat of polyurethane will penetrate deeply into the pores of the wood to provide a better grip for subsequent layers. A heavy coat of the finish, however, may bridge the wood pores and reduce adhesion. The wood should be clean and free of wax, grease or oil. I wash the raw wood with naptha and clean rags before I begin. Scuff-sanding between coats gives the polyurethane layers a mechanical bond that helps adhesion. Heavy oil glazes floated between the finish coats, thick staining, or fillers will cause adhesion problems.

I spray polyurethane and other varnishes with a conventional cup gun with a general purpose or standard lacquer fluid nozzle and either a standard lacquer air cap or a lacquer primer air cap, if the finish is a little cool to spray. The gun must be clean. Before using it, I clean the gun by spraying and backflushing with lacquer thinner, and then blow air through the gun until the solvent has evaporated. After spraying, I clean the gun with mineral spirits first, then lacquer thinner.

Not all brands of finish spray easily. I've had good results with Pratt & Lambert products. I thin the material as little as possible and deliver it at the lowest air pressure that will make it flow without obvious spray texture. (For technical fanatics this is a viscoscity of between 14 to 16 seconds at room temperature with a #2 Zahn cup. My air pressure at the regulator is between 30 and 35 PSI with a 25-ft. hose.) It's no problem on tabletops to adjust the flow by trial and error—thinning the finish to reduce viscosity and manipulating the fluid valve to change the spray pattern. On vertical surfaces, though, you risk applying finish that's too thin and runs, or of spraying such a heavy coat that it sags. If you're accustomed to spraying lacquers, polyurethane will feel heavy and clumsy because of its higher solid content and lower viscosity. I always test the finish first on a vertical sample board so I can adjust my spray pattern and see how much I can apply before it sags. If you run out of patience before you get

moved from the glass after 24-hours drying time by lifting one edge of the film with a razor blade. After 72-hours drying time, none of the films could be easily peeled off the glass.

In applying the finish on wood, I followed the instructions on the labels, let each coat dry as directed, then sanded lightly between coats with 600-grit paper. Make sure you follow the manufacturer's instructions on recoating times. If you let polyurethane cure more than about four hours, the film becomes so hard and inert that the solvents in the following coats won't soften the previous coats enough to allow the new material to adhere. If you wait too long between coats and have to scuff-sand before applying another coat, do so carefully—you don't want any scratches in the film. Avoid using steel wool for the scuff-sanding—the fuzzy fibers will stick in the finish. In most cases, the best looking and most durable finish comes from three to four thin coats rather than two heavy ones.

Most of the manufacturers recommend that polyurethanes be reduced 10% to 20% by volume with mineral spirits for a first coat on unfinished wood. This thinned mixture penetrates the wood much more effectively than unreduced polyurethane, which is viscous enough to stay on the surface. Subsequent coats may be applied without thinning, but I recommend you thin the top coat about 5% if the label states that the finish is 45% to 50% non-volatile solids. Always use regular mineral spirits, which has more cutting power than the odorless kind. This will enable you to thin the polyurethane without drastically altering the percentage of film-forming solids, thereby interfering with proper drying.

For applying the top coats, I used a foam-type applicator instead of a bristle brush. Even the best brushes leave some marks on the surface, whereas the foam brush (urethane foam) produces a very smooth film. For best results, dip the applicator in the finish, just as you would a brush, and apply it cross-grain, feathering out the strokes in opposite directions. The finish should flow together smoothly. If you soak the foam applicators in mineral spirits you might be able to clean and reuse them, but they're so inexpensive I just discard them.

Labels on many brands warn the user: "Do not shake the can, but stir the contents of the can before using." Shaking may pro-

the gun adjusted, you can always brush the verticals and try a different brand next time.

Apply the finish in a clean, controlled environment and keep the area dust-free while the finish is drying. Before spraying, I sweep sanding dust and overspray in my spray booth, then sprinkle water on the floor around the project to reduce static that might attract dust. A plastic drop cloth suspended over my drying area prevents direct fallout from my tar roof. I also like to change into clean clothes and wear a cap to keep personal touches out of the finish. Eliminate traffic in the area until the surface is "tack free." Your nose is a good guide on when the finish is dry. If you can't smell solvent, it's safe to touch the surface. (The rest of the time I wear an organic solvent respirator.)

Besides the bugs and junk in the air, watch for contaminants in the can. You may have problems if you leave the lid off while you're sweeping up, or if you use an improperly cleaned brush containing traces of old stain or dried varnish. Varnish won't redissolve after it dries. You must strain out the dried specks of cured varnish, called seeds, by filtering the finish through a paper-cone strainer. Some finishes just come seedy; it's a measure of quality for the finish to be clear in the can. If the finish looks cloudy or foamy, something is probably wrong. When you thin the finish, always use the solvent recommended by the manufacturer, who's the only one that really knows what's in that can.

One brand's "satin" sheen looks like what another brand calls "semi-gloss," so you may have to experiment to find the look you want. The manufacturer's idea of what's "satin" may not match yours. Mix the finish just enough to lift any flatting agents that have settled to the bottom of the can and blend them evenly with the solvents. Overmixing may create bubbles that will pop and make craters in the finish film. Undermixing may produce an uneven sheen. Make a sample chip for each product you use to serve as a reference for future jobs.

When you apply the finish, it helps to use the automotive technique of first spraying a light "tacky" coat with very little overlapping on verticals. When you come over this with a wet coat, it will hold easier without sagging. On tops I want an even film thickness and texture, not only for a smooth finish but for an even sheen. I'll first spray across the grain and then, with a second pass, go with the grain for an even, full wet coat. It is very tempting to put on more in one coat because it looks so great when you spray the tops, but thin coats dry most evenly.

Temperature and humidity also affect finish quality. With polyurethanes and other varnishes, temperatures below 65°F and high humidity slow drying time and invite runs and sags. I think the labels should read, "dries in four hours unless you live in Missouri where it may take three days!" Temperatures above 85°F may cause the finish to dry too quickly, leaving a skin over the surface that traps solvents and uncured finish underneath. Direct sunlight or strong drafts on the wet finish also trap solvents and prevent even drying. The older the finish, the longer it takes to dry. If the finish is too thick and cold to apply, warm it by placing the can in a sink full of warm water.

Polyurethanes also differ from varnishes in that they don't rub out or flow under friction. A gloss finish will polish well if you apply liquid polishes and buff. For lesser sheens, practice until you can spray cleanly enough to avoid rubbing the surface. If you do try to rub the surface, you risk uneven glossy or hazy patches and scratches. If you want a rubbed finish, apply varnish.

It's ironic that one disadvantage of varnishes and polyurethanes is that they do build so fast. The biggest complaints about polyurethane involve putting too much on. If you spray the surface, you'll be using thinner coats and be able to control the thickness of the film more easily than if you were brushing it on. If you spray or wipe a couple of really thin coats of urethane on a nice piece of wood, most people would never question your saying it was an "oiled" finish. This is something most purists would hate to admit, but others know it's true and use this fact to their advantage. □

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duce air bubbles in the applied films. When these air bubbles burst, they create small pinholes, or, if the finish dries before the bubbles break, you're left with air pockets in the film. The labels also warn against applying polyurethane over lacquer sealer, shellac, traces of varnish removers containing paraffin, wood fillers or pigmented wiping stains containing stearates or other waxy substances that will prevent the polyurethane from adhering,

Adhesion problems arise whenever polyurethane is applied over another finish. For the polyurethane to adhere, you must scuff the old finish enough to provide a mechanical bond between the roughened surface of the old finish and the fresh coat of polyurethane. Sand the old finish carefully, using 400-grit paper for gloss and 320- or 280-grit for satin. Follow the direction of the grain, but don't go down to the bare wood. Remove dust and debris with mineral spirits on a clean, lint-free rag. This will clean the surface as well as a tack rag, and you don't risk leaving any oily residue to contaminate the surface. Touch up any surface defects, such as scratches and bare spots. Apply a thin coat of polyurethane, and let it dry several hours before sanding with 600-grit paper and applying another coat.

Proper ventilation is needed whenever you apply polyurethane. Dry, cured polyurethane films are non-toxic, according to federal guidelines, but be careful with the liquid. With spray applications, use a respirator—every label I saw indicated that breathing the spray was harmful and dangerous. Don't get any in your eyes and avoid prolonged skin contact. If the label states flammable, do not use the material near open flames, pilot lights electric sparks or similar hazards. Throw used rags into a pail of water to prevent possible spontaneous combustion.

Polyurethane can look as good as most varnishes, and offers a number of advantages over varnish. It dries faster, thereby reducing the chance of dust contamination, cures at a lower temperature, has a higher gloss, and has better wear and water resistance. Polyurethane is also easy to maintain. You don't even have to worry about waxing the finish—just buff it with a soft cloth periodically. □

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