how PEG helps the hobbyist who works with wood

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Summary

Polyethylene glycol-1000 (PEG) is introduced to the hobbyist as an agent to dimensionally stabilize wood. Directions are given for mixing PEG solutions, preparing treating vats, and drying and gluing treated wood. Directions are also given for producing decorator clocks, bowls and other turnings, green wood carvings, statuary, and rifle stocks with maximum dimensional stability. "How to's" for protecting imported wood carvings and for preserving archaeological specimens are also included.

HOW PEG HELPS THE HOBBYIST WHO WORKS WITH WOOD

By

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You, the hobbyist, particularly appreciate wood, one of our abundant renewable natural resources.

You are well aware of the almost limitless advantages of wood: Ready availability, beauty, warmth, variety of color. You appreciate the favorable strength-to-weight ratio of wood, the good insulation properties, how easily wood can be worked, how easily it can be sanded and finished. You know, too, that wood can be treated to resist fire and attack by insects and decay organisms.

But wood is an exceedingly complex and variable material--not without certain deficiencies. You well know that wood shrinks and swells with changes in atmospheric moisture. This deficiency plus related problems of checking, splitting, warp, and broken glue joints are all too familiar to you. But, now there is help for this.

Treatment with polyethylene glycol-1000, commonly known as PEG, greatly improves the dimensional stability of wood. Many of the problems you have encountered while working on wood can now be minimized or eliminated.

What is PEG?

PEG is a white, waxlike chemical that resembles paraffin. A solid at room temperature, PEG melts at 104° F., has an average molecular weight of 1000, dissolves readily in warm water, is nontoxic, noncorrosive, odorless, colorless, and has a very high fire point (580° F.). Although chemically related to common antifreeze (ethylene glycol, a monomer), PEG is a polymer (many monomer units linked to form larger molecules) more closely related to various other polyethylene glycol polymers with substantially higher or lower molecular weights and different properties. PEG has its own unique properties not possessed by the others. Accordingly, none of the related chemicals can be successfully substituted for PEG in processing wood or wood products. Some hobbyists have learned this the hard way!

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[2] Maintained at Madison, Wis., in cooperation with the University of Wisconsin.

How PEG Stabilizes Wood

What exactly is meant by "dimensional stability?"

It is the extent to which a given material resists changes in dimension with variations in environmental factors. Steel, high in dimensional stability, expands only slightly with increases in temperature, and does not expand with variations in relative humidity. Wood, however, although little affected by changes in temperature, changes considerably in volume (shrinks and swells) with variations in moisture content. Thus, compared with a material like steel, wood is inherently low in dimensional stability.

However, when green or partially dry wood is soaked for an appropriate period in a 30 to 50 percent (by weight) solution of PEG, the wood does not shrink appreciably when dried. Equally important, wood thus treated and then dried swells very little when exposed again to high humidities. PEG enters the fine structure of the wood by diffusion, thus application of pressure is of little value. The large molecules of the chemical displace the natural moisture in the microscopic, lattice-like structure of the wood-fiber walls.

Heavily treated (bulked) wood retains its turgid (green) dimension indefinitely: thus the wood is permanently restrained from shrinking, swelling, or warping regardless of atmospheric humidity. For maximum dimensional stability, PEG must be diffused into the wood in amounts of 25 to 30 percent of the dry weight of the wood. This treatment reduces maximum potential shrinkage and swelling about 80 percent.

Rather sophisticated laboratory equipment is required to determine the amount of PEG taken up by wood. Anyone seriously interested in this subject can write to the U.S. Forest Products Laboratory, P.O. Box 5130, Madison, Wis. 53705, for information on the methods and equipment required.

PEG may also be used as a drying agent. Relatively light treatments will effectively prevent drying degrade in green wood bowls, art carvings, turnings, and other craft items. The objective is simply to get enough PEG into the outer shell of the preshaped project to prevent splitting, checking, and warp during drying.

Treating wood with PEG does not prevent the absorption of atmospheric moisture. PEG is even more hygroscopic than wood itself. However, PEG-treated wood will not swell appreciably as it absorbs moisture, whereas untreated wood will swell. Treated wood, not yet finished, when exposed to high humidities for long periods will become moist to the touch, and in extreme conditions will become oily if some PEG goes into solution on the wood surface. However, the appearance of treated wood properly finished with coatings that effectively lock the chemical into the wood is no different than untreated wood.

PEG treatment has no effect on color or odor of wood and only a slight effect on mechanical strength and hardness. The wax-impregnated fibers of treated wood have less tendency to fuzz and splinter than do those of untreated wood, and are much easier to machine and work with cutting tools. Treated wood can be efficiently sanded, stained, and glued, when the right techniques and materials are used.

Many common finishes do not adhere well to the rather waxy surface of PEG-stabilized wood. These include shellac, lacquer, linseed oil, and certain varnishes. Two types of polyurethane resin varnish and a Danish-oil type finish do adhere well to PEG-stabilized wood, and they effectively lock the stabilizing chemical into the wood.

How Moisture Content Relates to Shrinkage of Wood

Wood in its natural state in the trunk of a living tree contains from 30 to 300 percent of water (dependent largely on growth conditions and species) based on the weight of the ovendry wood. This water is (1) contained as free water in the cell cavities and the intercellular spaces of the wood and (2) held as absorbed water in the capillaries of the walls of wood elements, such as fibers and ray cells. The absorbed water relates to shrinkage. When all of the free water is removed and all of the absorbed water remains, wood has reached the fiber saturation point, approximately 30 percent moisture content for all species. Shrinkage occurs only when the moisture content of wood is reduced to some level below the 30 percent fiber saturation point. "Partially dry" wood refers here to wood that has not been dried to a moisture content of 30 percent or less.

The moisture content of wood, normally determined with a rather expensive electric moisture meter, can be measured in a home workshop as follows:

1. Cut three to five approximately l-inch square blocks from the piece of wood in question:
2. Remove all loose wood fibers and sawdust from the blocks;
3. With an ammunition reloading balance, a postage scale, or some equally accurate weighing device, obtain and record the green weight of each block;
4. Dry the blocks in an oven with temperature adjusted to about 220° F. until periodic weight checks indicate that a stable weight condition has been reached;
5. Then weigh the blocks rapidly directly from the oven and record the weights; and
6. Determine the moisture content according to the following formula:

$$\text{Moisture content (percent)} = \frac{\text{Original (green) weight - ovendry weight}}{\text{Ovendry weight}} \times 100$$

Any piece of wood will give off or take on moisture from the surrounding atmosphere until the amount of moisture in the wood balances that in the atmosphere. The moisture content of the wood at the point of balance is called the equilibrium moisture content, and is expressed as a percentage of the ovendry weight of the wood as determined here. For example, green fresh-sawed lumber exposed continuously to an environment of 90 percent relative humidity (R.H.) and 80° F. temperature will eventually reach a moisture content (M.C.) of 20 percent. At 65 percent R.H. and 80° F., it will reach 12 percent M.C.; and at 30 percent R.H. and 80° F., will be reduced to 6 percent M.C.

Wood, like many other materials, shrinks as it loses moisture and swells as it absorbs moisture from the atmosphere. When wood dries (with reduced R.H.) from its green to ovendry condition, it shrinks in volume by about 6 to 20 percent, depending on the species. When the hobbyist, through ignorance or neglect, uses wood that is insufficiently dry for the intended purpose, volume shrinkage of these magnitudes often results in partial or complete ruin of a painstakingly constructed project. Glue joints pop, tabletops warp and split, bowls and art carvings check and crack.

To further complicate the problem, wood shrinks (and swells) differently in different directions or planes. For example, tangential shrinkage is greatest. That is, "flat sawed" boards sawed from the log parallel to the annual growth rings, approximately at right angle to a line (radial) from the pith center to the circumference, shrink much more (twice as much) as "quartersawed" boards sawed in the radial plane. That is why quartersawed lumber always sells for more than flat-sawed lumber. It shrinks much less in width, and is less apt to warp. Wood shrinks and swells least of all in the longitudinal (along the grain) direction. Longitudinal shrinkage and swelling is normally not a serious problem

The differential shrinkage of wood during the drying process, mainly the twofold difference between tangential and radial shrinkage, sets up enormous internal stresses that cause wood to warp (cup, twist, crook, and bow) during drying. Accordingly, during drying there is some warping and checking of lumber whether dried under controlled temperature and humidity conditions in a modern commercial dry kiln or air-dried "on the farm" with no control of atmospheric temperature and humidity. The main differences are that kiln-drying is faster, much more expensive, tends to minimize degrade due to warp, checking, and splitting, and is capable of reducing the moisture content of lumber to any desired level,

How dry (what M.C.) should lumber be before you use it for a particular project? Fortunately, there is a simple answer.

If you are making furniture or other items that in use will be exposed for at least part of the year to the arid environment of a heated home, office, or store in winter, all wood should be dried to a uniform 6 percent M.C. That is the moisture content to which all wood will be reduced on continuous exposure to the 30 percent R.H. and 73+ ° F. temperature of heated or air-conditioned buildings.

If you use wood of a higher moisture content, remember that for each 1 percent reduction in M.C. down to the equilibrium moisture content (6 pct.) for this atmospheric environment, the wood will shrink one-thirtieth of its total potential volume shrinkage. Shrinkage of this magnitude will result in internal stresses that can cause serious warp, checks, cracks, broken glue joints, and all the other problems you are familiar with.

If you use rough l-inch-thick "farm" or "small sawmill" lumber that has been air-dried outdoors for 6 months or so, and has about 18 to 20 percent M.C. in the Gulf States or 14 to 16 percent M.C. in most other parts of the country, the lumber should first be conditioned in a heated room for 4 to 6 weeks to reduce the M.C. to the desired 6 percent. Pile the lumber in layers separated by l-inch stickers to permit good air circulation around the boards. After drying, flatten one side of each board on a jointer to remove any warp, then surface (dress) to desired thickness, preferably in a planer, and use with assurance that it will perform satisfactorily.

Supposedly kiln-dried lumber purchased from a lumberyard or other supplier should similarly be conditioned. This is important!

PEG is not recommended for the routine processing of l-inch lumber destined for use in furniture, cabinets, and other indoor uses. It is not normally needed. Simply follow the suggestions for drying and conditioning to the proper M.C., and no serious problems should result.

If, however, a project requires lumber 1-1/2 inches or more in thickness, special problems must be considered. Thick lumber for indoor use is very difficult, time-consuming, and expensive to dry to the required uniform 6 percent M.C. For example even in the best of modern dry kilns, from 60 to 90 days are needed to dry 2-1/2-inch walnut planks to a uniform 6 percent M.C. The cost of this stock is accordingly high. However, the cost of using only partially dry thick stock for bowls, art carvings, gunstocks, and the like is apt to be even higher.

Do not depend on some magic finish or "sealer" to prevent bowls, carvings, and like items made from partially dry thick stock from degrade while losing moisture to equilibrium (6 pct. M.C.) with the arid environment of a heated room. No finish or coating material known will prevent the movement of moisture into and out of wood with variations in atmospheric humidity, Even the best, such as polyurethane and epoxy varnishes, only slow up the process. The end result is just as inevitable. The widely promoted wood 'sealers," although they may serve a useful function as a base for finish coats, have even less effect on moisture movement. Linseed oil, tung oil, and most other "natural" finishes are little better than goose grease or crankcase oil for effectiveness as moisture barriers, Although these finishes are fine, beautiful, and widely used, do not expect them to do what they are not intended to do.

Kiln-dried lumber does not always assure success. Most lumberyards and other suppliers store their lumber under cover, but it is exposed to ambient temperature and humidity. The stock you buy has probably absorbed moisture from the atmosphere up to 8 to 12 percent M.C., and is little better for your purpose than is air-dried farm lumber. Items made from this lumber are just as apt to warp, check, and split during the inevitable drying process. Normally, only in modern furniture factories is kiln-dried lumber stored in air-conditioned rooms and kept at the desired 6 percent M.C. until fabricated into the final product.

Here again, however, there is a simple, practical solution for the hobbyist. With PEG treat-

ment, it is possible to process flawless bowls, art carvings, lamp bases, candlesticks, gunstocks, and many other craft items from either green or partially dry thick stock. Another advantage is that raw material can be obtained at little or no cost. Odd chunks of green scrap wood, such as logging and sawmilling residues, are normally available for the asking and can be used. Bolts from the trunks or limbs of the dead or unwanted shade trees that are cut down almost daily in every large city can also be used.

With PEG treatment, it is also possible to process flawless, crack-free tabletops and other craft items from green log and limb cross sections (fig. 1).

Figure 1.--Stabilized disks. Top, PEG-stabilized tabletop, 38-inch diameter, cut from butt of 784-year-old redwood; bottom, king-size PEG-stabilized cross section through large boxelder burl.

M 126 056
M 126 475

Mixing PEG Solutions

The two solutions commonly used are 30 and 50 percent PEG by weight. Exactly 4.46 pounds of polyethylene glycol-1000 dissolved in 5 quarts of water yield 7 quarts of 30 percent solution with a specific gravity of 1.05 at 60° F. Ten pounds of polyethylene glycol dissolved in an equal weight of water (about 4.8 qt.) yield about 7.4 quarts of 50 percent solution with a specific gravity of 1.093 at 60° F. A precision hydrometer accurate for the desired range of specific gravities will help maintain the proper concentration of the solution during treatment.

PEG does not volatilize at the temperatures normally used in treating vats, but water does evaporate during long treating cycles, even in covered (but not airtight) vats. Accordingly, it is usually necessary to replace water lost by evaporation before chemical must be added to make up for that diffused into the wood during treatment.

Vats for Treating

Glass, earthenware, plastic, or similar types of containers are adequate for treating a limited number of small disks. A plastic trash container is an excellent treating vat. Metals, except certain types of stainless steel, should not be used because they react with extractives from the wood and form compounds that discolor the wood. PEG, however, is colorless.

A serviceable, one-time treating vat can be made from a fiberboard box lined with a heavy polyethylene bag or sheet. Cross sections of logs up to 60 inches in diameter have been successfully treated in circular vats roughly fashioned from scrap lumber or plywood and lined with a sheet of heavy plastic.

After the disk is placed in the vat, it should be supported by a few narrow strips of wood to permit free circulation of the solution beneath the disk; it should be weighted down with a rock to assure complete immersion. Stones or bricks can be nested in irregular or empty spaces around a large disk to raise the solution level to reduce the amount of solution needed for complete immersion.

Growth of molds, bacteria, and fungi during long treatment can be prevented by adding borax or sodium pentachlorophenolate to the PEG solution, to a 1 or 2 percent concentration.

PEG solutions can be reused indefinitely by adding chemical (or water) to maintain at the desired concentration. When not in use, they should be stored in glass containers.

Hobbyists and small commercial users of PEG usually construct 50- to 100-gallon capacity treating vats of 1/2-inch exterior grade Douglas-fir plywood glued together with resorcinol or some equally water-resistant adhesive. This type of tank is frequently lined with fiberglass, the kind used to cover wooden boats.

For best results, treating tanks should be equipped with electric heating elements (with built-in thermostat) of the type used in water heaters. It is desirable to cover the sides, bottom, and especially the cover, with fiberglass insulation (4 in.) to conserve heat. In a production operation, the PEG solution is normally circulated periodically with a pump system activated by a cycle timer. Brass or copper pipe fittings are not objectionable if they are a 1 ways completely covered by the solution.

Commercial operators who treat with PEG frequently employ stainless steel vats similar to those used by the dairy and food-processing industries.

Treating Schedules. for Wood Disks

Disks from fresh-cut wood should be wrapped in plastic or immersed in water to keep in green condition until they can be treated with PEG. Cross sections from dead tree trunks or sound portions of old logs, regardless of when cut, are essentially "green" for this purpose. However, they should be soaked in water for 2 or 3 days before treating; this assures good penetration of the stabilizing chemical into the wood.

The soaking time to obtain sufficient penetration of PEG into disks, or cross sections, to protect them against splitting and checking depends on the concentration and the temperature of the treating solution, the size and thickness of the disks, and the species of wood. Diffusion of the chemical into wood can be greatly accelerated by increasing the temperature and the concentration of the solution.

The treating schedules in the following tabulation are based on experience with walnut:

Solution concentration and temperature	Suggested period of soak for walnut disks--	
	Up to 9 inches in diameter and 1 to 1-1/2 inches thick (Days)	More than 9 inches in diameter and 2 to 3 inches thick (Days)
30 percent, 70° F.	20	60
50 percent, 70° F.	15	45
30 percent, 140° F.	7	30
50 percent, 140° F.	3	14

Treating time will generally vary with the density of the wood. Walnut, a medium-density wood, has an average specific gravity of about 0.55 on a green volume, dry weight basis. For cross sections of lower density woods such as white pine, spruce, redwood, and the "soft" hardwoods (soft maple, cottonwood, willow, and others), soak for one-half to two-thirds the time suggested for walnut. For the higher density woods like hard maple, yellow birch, beech, the oaks, and apple, double or triple the treating period. Elevated temperatures are normally required for fully effective treatment of very dense woods, such as manzanita, mesquite, desert ironwood, and burls of most species.

Some experimentation is usually required to work out the best treating schedule for disks of a given size, thickness, and species. It should be pointed out that the wood in the core of certain tree trunks is so defective that even with PEG treatment flawless disks cannot be processed therefrom, The pith center of all trees tends to be punky, have incipient fractures due to wind action, sometimes is partially decayed, and always is weaker than the more normal wood formed later in the life of the tree. Some trees have much poorer pith centers than do others, and wood of this type should not be used for hobby projects.

Drying Treated Disks

For drying, pile the treated disks and separate with dry stickers. under cover in a well-ventilated room or building, preferably a room heated in winter. Time needed for air-drying will vary with thickness of disks, temperature, and relative humidity. Treated cross sections up to 4 inches thick and 40 inches in diameter will dry sufficiently for finishing if placed 6 to 8 weeks in a heated room in winter. Thinner, smaller disks will dry much faster in a similar environment. Stored outdoors in the summer, even under cover, drying takes somewhat longer than in a heated room, However, since treated disks shrink very little during drying, it is not essential that they be completely or uniformly dry before work on them is started. It is only necessary that the surface 1/4 inch be sufficiently dry to sand well and accept the finish.

Bark normally loosens and falls away from untreated log cross sections as they dry because the wood shrinks away from the encircling band of bark, Since treatment with PEG largely prevents this shrinkage, bark firmly attached prior to treatment will remain so indefinitely regardless of how dry the stabilized disks become.

Protecting Valuable Thick Stock During Drying

Thick planks of certain species and grades of wood are almost impossible to dry free of degrade (checks, splits) either by air-drying followed by a long period of conditioning in a heated room or by kiln-drying in a controlled environment. For example, highly figured walnut gunstock blanks with a large proportion of burl, butt, stump, or crotch figure are very difficult to dry defect free. The wild grain patterns--knot swirls, interlocked, distorted, and other abnormal grain--so rare and beautiful in a finished stock are very prone to splitting, checking, and warp.

Because of the high values (up to $100 for a single blank) and the great risk of loss involved, treatment with PEG is fully justified. In a recent study, 40 highly figured green walnut gunstock blanks, all 2-1/2 inches thick, were randomly divided into two groups, Twenty were kiln-dried under a relatively mild schedule developed for walnut stock blanks. About one-third of these blanks dried to 6 percent moisture content had deep checks and splits, and would have been graded as culls. This confirmed general industry experience with this class of material.

The other twenty were soaked in water for a few days, then treated for 10 days in a 50 percent water solution of PEG maintained at 140° F. They were dried rapidly to 6 percent moisture content under drastic conditions. The moisture was literally baked out of them at temperatures up to 200° F. with no humidity control. All were in perfect condition--free of checks, splits, honeycomb, and warp. Probably equally good results could have been obtained by treating at ambient temperature for a longer period, 6 to 8 weeks.

This simple, relatively inexpensive and effective preventative treatment is, of course, recommended only for rare, highly figured defect-prone walnut blanks of the type described here. Conventional drying methods are adequate for generally straight-grained material.

The objective here was simply to get enough PEG into the outer shell to provide protection during drying. PEG penetration was not great, and most if not all of the treated wood will be cut away in shaping the finished stocks from these blanks. The stocks will be no more stable than those from untreated wood, but they will be free of seasoning checks and splits.

Processing Lumber for Maximum Dimensional Stability

We do not recommend routine PEG treatment for lumber destined for indoor use such as for furniture. Treatment is too expensive, and is not normally necessary. However, PEG treatment is essential for lumber used in special products for which a high level of dimensional stability is needed to meet exacting performance requirements. Examples include laminated stocks for precision rifles, straight edges, patterns, essential structural parts for large cameras, and mounting blocks for large metal engravings.

To attain maximum possible dimensional stability in lumber it is necessary to diffuse PEG into the wood to minimum retentions of 25 to 30 percent of the dry weight of the wood. This level of treatment can only be achieved at high temperatures. When 1-1/4-inch-thick lumber is treated sufficiently long at high temperature to attain the desired 25 to 30 percent PEG in the center 1/8 inch of the boards, the surface 1/8 inch will have taken up approximately 40 percent PEG. Thus, the wood near the surface of the boards is somewhat over-treated to attain the minimum required level of treatment in the center of the boards. The existence of this gradient, which becomes more pronounced as thickness (and treating time) is increased, makes it impractical to treat, for maximum stability, lumber more than 1-1/4

inches in thickness.

If greater thicknesses of stable lumber are required, as in certain patterns and target gunstocks, they are most efficiently achieved by laminating (gluing together flatwise) boards previously stabilized in thickness of from 3/4 to 1-1/4 inches.

Rough-sawed green walnut boards of nominal 1-inch thickness can be treated for maximum dimensional stability by soaking for 30 days in a 50 percent PEG solution maintained at 140° F. Three-quarter-inch-thick boards of walnut can be similarly stabilized by soaking in such a solution for 25 days; and 1-1/4-inch-thick boards, for 45 days.

The same treating schedules can be used with equal success for green lumber of red oak, sycamore, yellow birch, myrtlewood, soft maple, true mahogany, Hawaiian mango, Hawaiian koa, monkeypod, mesquite, and sapwood of hard maple. Probably many other hardwoods in the same general density range can be similarly treated with equal success,

There are, however, certain exceptions. For example, the heartwood of hard maple is impossible to treat with PEG by any known practical method. Cherry lumber invariably honeycombs in the treating vat when treated according to the schedule developed for walnut. However, 1-inch-thick cherry boards can be successfully stabilized by soaking for 45 days in a 50 percent PEG solution maintained at 110° F.

In the treating vat, layers of unsurfaced green lumber should be separated by stickers to permit free movement of the solution around each board. Circulating the PEG solution periodically with a pump system activated by a cycle timer is also advocated.

Heavily PEG-treated lumber is so stable that it can be air-dried or kiln-dried in a drastic schedule with little or no loss due to drying degrade. There will be no surface checking and warp, and end splitting will be minimal regardless of how rapidly the remaining moisture is removed. Heavily treated green wood rifle stocks have been successfully dried in 8 hours in an electric oven (220° F.).

Gluing PEG-Treated Wood

Although many common glues, including the popular white glue (a polyvinyl), do not work well on PEG-treated wood, several widely available high-quality glues do work well. Among them are two-component waterproof resorcinol and epoxy glues of various brands. The hobbyist's old standby, the urea-resin type, also works well, but is not quite as resistant to water.

For best results it is important to use a good PEG solvent on the wood surface to cut the wax and expose the fibers just before the glue is applied. For critical joints that require maximum structural strength, as in laminated stock blanks, scrub the surface with a toluol-soaked cloth. When dry, wash again with wood alcohol just before you apply the glue. For less critical joints, the toluol step can be omitted.

Finishing Treated and Dried Disks

When disks are sufficiently dry for working, smooth both surfaces on a sharp jointer or with a hand plane; for small cross sections, smooth by sanding with coarse grit. Probably the best technique to smooth very large disks is with a router. Mount the router above the disk on a plank frame constructed to permit horizontal movement in two directions at a constant height. After smoothing, sand the faces of the disk with coarse grit. If the grit loads up with waxy sawdust, clean the sandpaper with a wire brush, preferably in a stream of warm water to dissolve the accumulated PEG. After coarse sanding, sponge the surface with warm water and finish sanding with 3/0 and then with 6/0 wet-or-dry sandpaper.

Then bleach the disk to bring out the natural

color of the wood, to accentuate the contrast between heartwood and sapwood, and to remove the accumulation of iron compounds and natural pigments that often forms near the surface of treated wood, especially during high-temperature soaking, For the bleach, dissolve 2 heaping tablespoons of oxalic acid crystals in a half glass of hot water, and apply liberally with a brush. Wear rubber gloves, and keep the solution out of eyes. After an hour or so, neutralize the excess acid by sponging with cloth dampened with dilute solution of household ammonia. Let dry for 1 day, resand with fine grit, then finish according to either of the following systems:

1. A built-up finish with varnish. Apply, at 1-day intervals, four or five coats of a newly developed moisture-cure-type of polyurethane resin varnish. Sand well between each coat with 220 or finer sandpaper. This type of varnish will set up rapidly on a wet surface or when exposed to atmospheric moisture, is extremely hard and durable, and most importantly, is quite effective in sealing PEG in the wood during prolonged periods of high humidity. However, when properly formulated to meet these use requirements, this special type of varnish is so thick and sticky it tends to leave brush marks and other surface imperfections. For best results the moisture-cure-type base coating should be followed with one or two finish coats of any good grade of a conventional (chemically hardened) polyurethane varnish that is easy to apply and is widely used on furniture and interior trim, (The first finish coat over the moisture-c&e base may take as long as 2 days to set up. However, subsequent coats will set up in 12 hours or less.) Then polish with pumice in oil lubricant, using care not to cut through the final finish coat of the conventional polyurethane varnish, and buff with a paste wax.

For products that are less difficult to finish than treated log disks, the base coats of moisture-cure-type polyurethane are not normally needed. Examples include gunstocks, bowls, carvings, and similar products with a minimum of exposed end grain that are not apt to be exposed in use to extremely high humidities for prolonged periods. For these products, use conventional polyurethane varnishes. They are easy to apply, adhere well to treated wood, and are fairly hard, durable, and beautiful.

2. An oil finish. Of the many oil-type “natural” finishes tested, only a Danish-oil penetrating finish performed satisfactorily over PEG-stabilized wood, especially end grain. This finish is easy to apply. If tabletops or other items made of PEG-stabilized log disks are apt to be exposed in use to long periods of high humidities, this is probably the best finish to use. It may also be used with equally good results for less critical applications, That is, for gunstocks, bowls, carvings, and other PEG-treated products.

Special instructions are needed for tabletops, decorator clocks, and other items to be finished with bark attached. Do not use any type of varnish on PEG-treated bark, Bark is so porous that during treatment it absorbs much greater quantities of PEG than does wood. Therefore, during prolonged periods of high humidity, the hygroscopic PEG in the bark sops up so much atmospheric moisture that the bark becomes sufficiently water soaked to ruin any built-up varnish finish. Use only Danish-oil on bark. It penetrates into the porous structure, does not form a thick continuous surface film, and will therefore withstand high humidities. If a varnish finish is preferred on a tabletop with bark attached, then first give only the bark portion two coats of Danish-oil. Then apply the various varnish coats as directed to the entire flat surface of the top; this includes the sanded edge of the oil-finished thin ribbon of bark around the circumference. Use care not to run varnish over the edge onto the rough surface of the oil-finished bark.

Stabilized Disks Exposed to Weather

PEG-stabilized disks are sometimes used for paving outdoor patios and for rustic steps that can be in contact with moist soil. Thus these disks must be protected against attack by insects (termites, borers) and decay organisms. Also, since PEG is soluble in water, it will eventually leach out of unprotected treated disks exposed to repeated rains. The protection needed against insects, decay, and leaching is probably best provided by applying a good water-repellent preservative stain that contains both a wax to shed water and an active insecticide-fungicide such as pentachlorophenol. Good water-repellent preservative stains are available at most paint stores or directions for preparing and mixing them can be obtained from the U.S. Forest Products Laboratory. The more wax and pigment you use in the formulation, the better will be performance under adverse conditions.

Apply several coats of the water-repellent preservative to the previously stabilized disks before installing in an outdoor exposure, and add one coat annually thereafter. For outdoor use you should also consider using a species of wood with high natural resistance to insects and decay, such as the heartwood of redwood, cedar, white oak, or cypress. Before PEG treating, cut away the outer band of the less resistant sapwood.

Producing Specific Products

Decorator Clocks

The clock frame and face are usually made from a blank sawed at a 45° angle from a large limb or from the trunk of a small tree. Each should be about 2-1/2 inches thick and be PEG-stabilized as has been described for green log and limb cross sections.

Following treatment, each section should be dried, sanded, and finished exactly as for disks: this should include the special attention to the bark that has been suggested. Then select the best face; mark the point where the hands should be located, and drill a small pilot hole through the blank. Turn the blank over, place in drill press, and bore a hole in the back large enough in diameter to accommodate the mechanism of the round electric clock, and just deep enough so that the shank of the clock works will protrude sufficiently through the front face to permit anchoring with a brass hex nut and proper mounting of three hands.

Make a paper template so that the hour markers can be properly positioned. The markers can be made of sapwood of maple, holly, or any other light wood. They are 1/8 inch square and of different lengths. The markers can be attached to the clock face with contact cement (fig. 2).

Bowls and Other Turnings

You can start your bowl with green or partially dry wood. Simply rough turn the bowl from green stock to a wall thickness about 3/8 to 1/2 inch if finished thickness dimension is to be 1/8 to 1/4 inch. The base can be 3/4 inch or more in thickness. Next, transfer the precarved green wood bowls to the PEG treating vat.

If blocks of wood are used that are partially dry, they should first be soaked in water for a few weeks. As a minimum, if partially dry wood is used, soak the rough-turned bowls in water for several days prior to PEG treatment. This assures adequate diffusion of the large molecules of the chemical into the wood.

Period of soak again depends on the species of wood, the thickness and shape of the bowl, and the concentration and temperature of the PEG solution. For rough-turned green wood bowls, such as described, and of walnut, poplar, ash, red oak, koa, mango, apple, elm, sapwood of hard maple, myrtlewood, white pine, and southern yellow pine, a 3-week soak in a 30 percent PEG solution at 73° F. proved adequate. Equally good results can be obtained in a much shorter time, 3 to 7 days, by increasing the PEG concentration of the solution up to 50 percent and the temperature to 140° F.

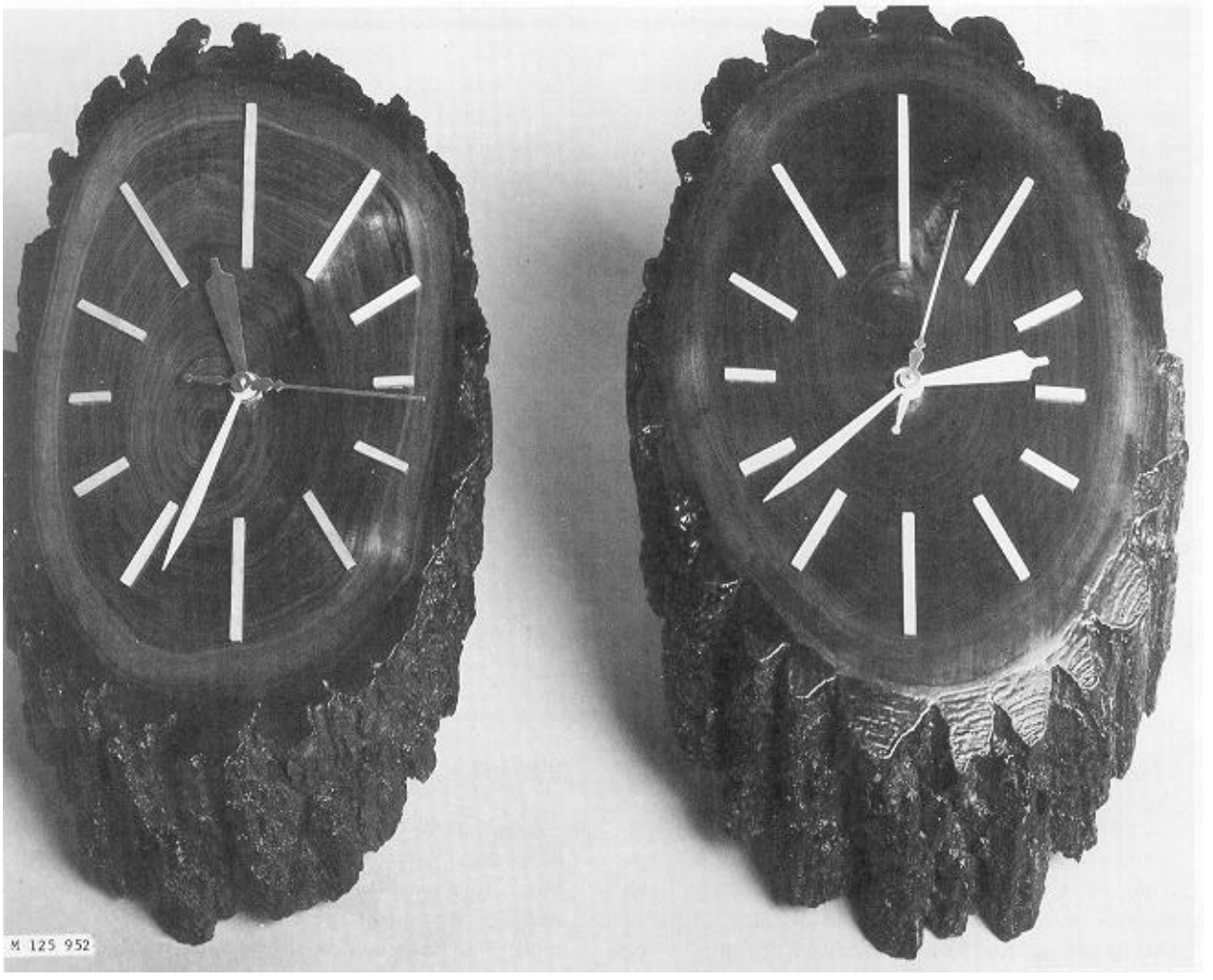

Figure 2.--Decorator clocks result from PEG-stabilized, bias cuts through large limbs of walnut left in woods by commercial logger.

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Bowls from burls and very dense heavy woods, inclusive of many tropical hardwoods, are much more difficult to treat than are the species mentioned. Bowls of some species can be adequately treated only at elevated temperatures. For best results the hobbyist should develop treatment schedules (solution concentration, temperature, period of soak) specifically suitable for his product, wood species, and end use.

After treating, the rough-turned bowls should be air-dried, preferably in a heated room, for 3 to 4 weeks. If treatment is adequate, they will not develop checks, cracks, or splits during the drying process. The only exception will be areas of large hard knots, into which little PEG penetrates; in these areas some fine checks normally develop when thoroughly dry. If objectionable, avoid large knots in selecting raw material. Thanks to PEG stabilization differential shrinkage is minimized. Your bowl should be round rather than slightly elliptical, typical of so many wooden bowls.

When sufficiently dry for finishing, replace the bowl on the lathe and turn to final desired dimensions. In the process you will remove the waxy accumulation of PEG that formed on the treated

surfaces; this facilitates sanding and finishing. Sand thoroughly, preferably on the lathe, bleach, and finish with polyurethane varnish, Danish-oil, or the systems to be described.

Probably the safest finish for the inside of a bowl to hold food is olive oil, linseed oil, or some equally safe vegetable oil. only the outside surface of the bowl should be finished with one of the more durable, attractive finishes that have been described (fig. 3). PEG is widely used in cosmetics, ointments, lotions, suppositories, and as binders for pharmaceutical tablets, and has been declared safe for these uses.

The PEG process for bowls can also be used for table lamp bases and stems, floor lamps, candlesticks, serving trays, and a great variety of other turnings, also made of green scrap wood, including limbs of trees,

Green Wood Carvings and Statuary

The procedure for carvings and statuary is essentially the same as that for bowls. Rough-shape carving or statue from green wood very close to final dimensions. When not working on the carving, immerse it in water or wrap in plastic film to prevent drying. If the base portion is rather massive, hollow it from the bottom or drill holes up into it. This tends to relieve natural stresses in the wood, minimizes the tendency to split, and more importantly permits penetration of PEG into a high hazard area from both outside and inside; thus better treatment is ensured. Then treat in PEG solution.

Since most carvings and statues will be somewhat thicker than bowls, treat about twice as long as bowls, After treating, air-dry, add final details, sand, bleach, and finish with one of the two systems recommended for stabilized wood.

If a carving is so large it would be impractical or too expensive to treat by soaking, melt some PEG and brush it on the carving or statue. Then wrap the carving in plastic film to keep the humidity high; this facilitates diffusion of the molten chemical into the wood. Repeat this operation about four times at l-week intervals. Remove the plastic, air-dry, and proceed as suggested. This technique, not as sure-fire as ***soaking,*** frequently produces good results, and will minimize checking and splitting (fig. 4).

Rifle Stocks with Maximum Dimensional Stability

Two methods can be used to make rifle stocks that will not shrink, swell, or warp at any extreme of atmospheric humidity, from the aridity of the Mojave Desert to the stifling humidity of an Amazon jungle. Chemically stabilized stocks can even withstand complete immersion in water for extended periods with no appreciable change in dimension.

Stable stocks for target rifles, because of their large size, especially their width, are best made by laminating heavily treated and dried l-inch boards into blanks of the required size. Normally the blanks are three-, five-, or seven-ply, depending on the thickness needed. The target stocks are then shaped from the dry, stabilized laminated blanks. The much smaller stocks for sporter rifles may be made from laminated blanks, usually three-ply, but they may also be made from solid wood.

Fresh-sawed green blanks of the required size are first shaped and completely inletted on a multiple-spindle duplicator to within 1/8 inch of the final finished dimension (fig. 5). They are then treated for 10 to 14 days, depending on the thickness of critical areas, in a 50 percent PEG solution maintained at 140° F. This schedule is designed to attain the required 25 to 30 percent PEG retention in the thin critical areas around the action and barrel groove, where a high level of dimensional stability is essential for top performance of precision rifles. Additional treatment would result in deeper penetration of the chemical into the thick part of the butt, where a high level of stability is unimportant to performance. This would also result in an undesirable increase in the weight of sporter stocks.

Since treated wood does not shrink appreciably in drying, there is less wood substance (mass) in a given volume of dry treated wood than in an equal volume of untreated wood seasoned by conventional methods. A properly stabilized solid-wood sporter stock is little or no heavier than a comparable untreated stock.

The treating schedule given here is suitable for precarved stocks made from fresh-cut, green blanks of the following species: Walnut, mango, koa, yellow birch, sycamore, myrtlewood, sapwood of hard maple (including bird's eye), true

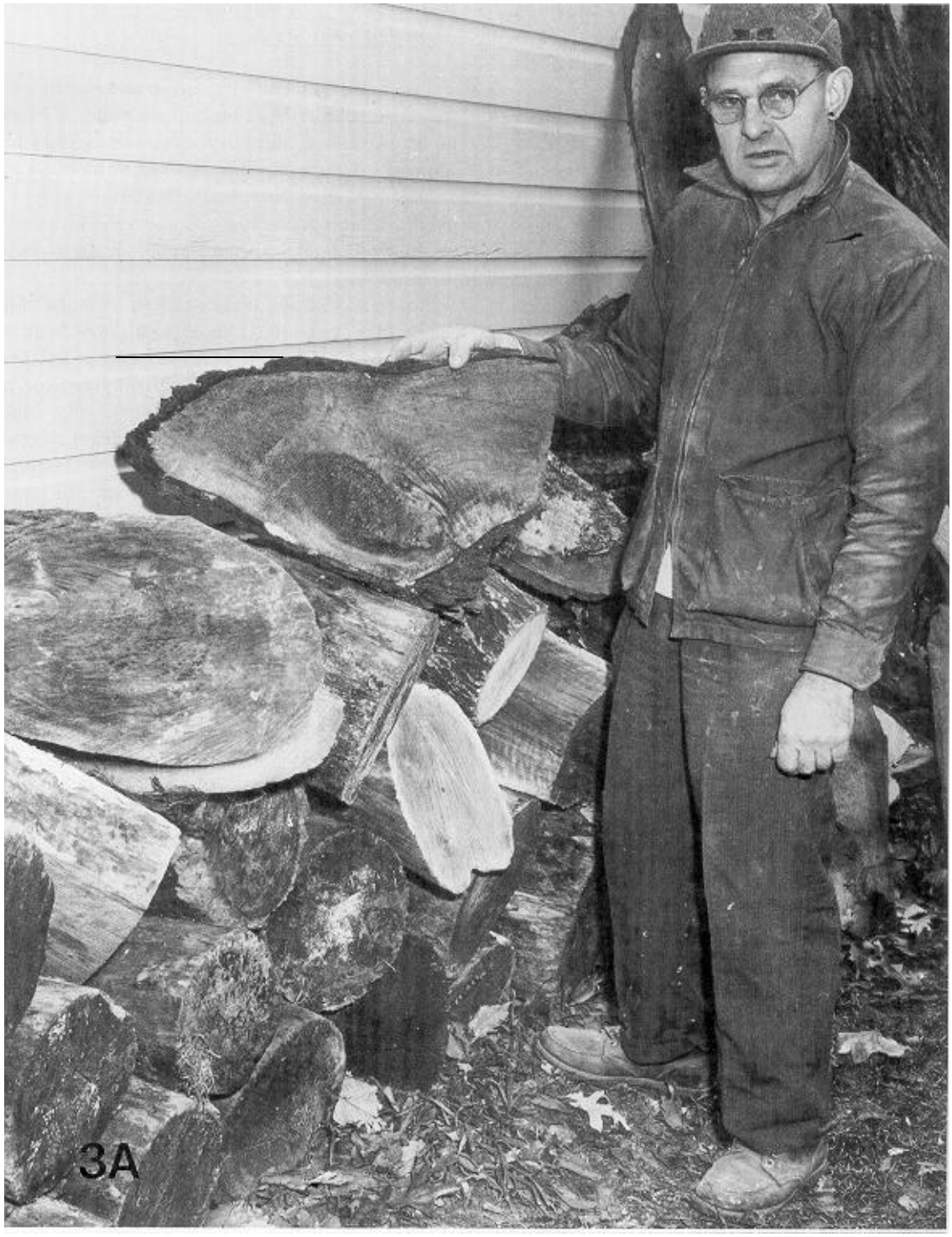

Figure 3A and B.--Sawmill and logging waste (3A) can provide the raw material for the bowls shown in 3B. The bowls were rough-shaped from green scrap wood, PEG-treated, air-dried, turned to final dimension, sanded, given finish, and polished.

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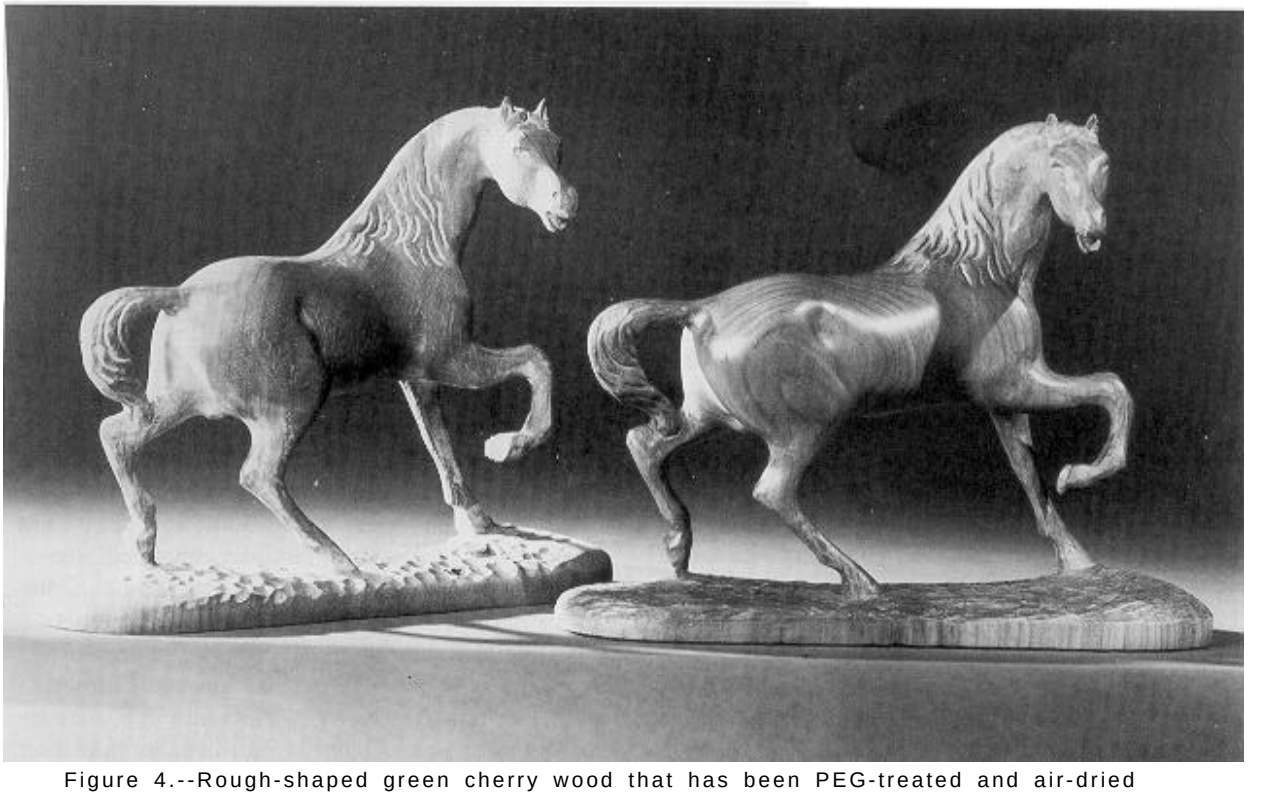

Figure 4.--Rough-shaped green cherry wood that has been PEG-treated and air-dried (left) evolves into finished carving that has been sanded, finished, and polished.

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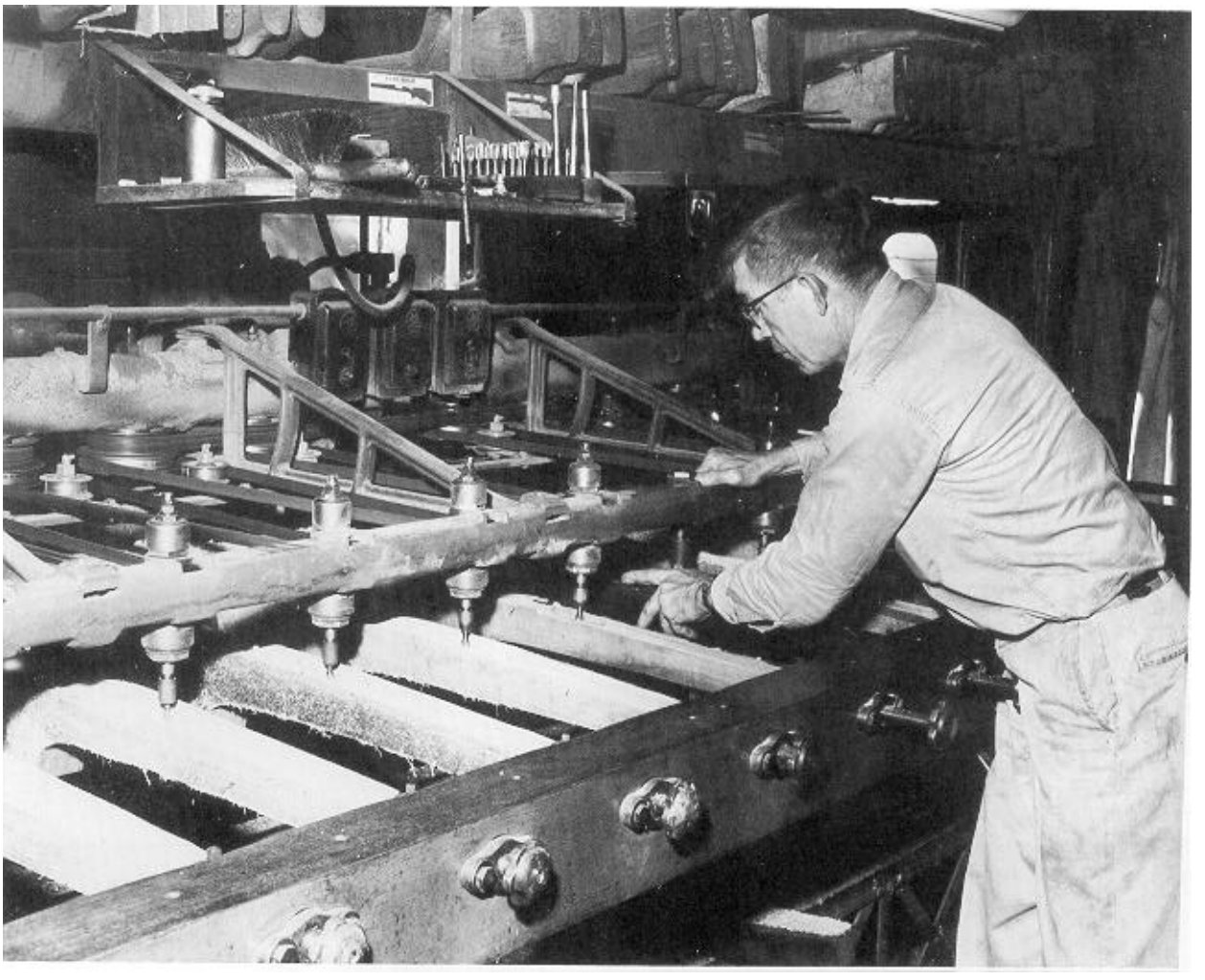

Figure 5.--A master stockmaker shapes and inlets sporter rifle stocks from green, fresh-cut walnut blanks. The stocks will be PEG-treated and kiln-dried to 6 percent moisture content.

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mahogany, and mesquite. It will probably work equally well for most other hardwoods of the density range suitable for rifle stocks. However, it will not work for cherry. Precarved cherry stocks should be soaked in PEG for about 45 days at a lower temperature, 110° F., for equally good results.

After stabilization, the precarved stocks can be dried equally successfully either rapidly in a kiln under drastic conditions without fear of degrade or air-dried followed by conditioning to 6 percent M.C. in a heated room.

The stabilized stocks should be sanded, bleached, and finished as described for the other treated wood products. These stocks can also be glass bedded. Simply scrub the wood with alcohol to cut the wax **just** before the bedding compound is applied.

It should be emphasized that this treatment works only on green or partially dry wood. Not on long-dry stocks! When wood is dried below the fiber saturation point (30 pct. M.C.) certain irreversible chemical and physical changes take place in the cell walls that prevent effective stabilization. You can get PEG into dry wood by water soaking previous to treatment, but the effect is not the same.

Protecting Imported Carvings

Almost all wooden carvings from tropical countries--southeast Asia, equatorial Africa, tropical Latin America, and other areas of high humidity--are carved from partially dried wood. Consequently, the majority of these carvings will check and split badly when brought into the United States and exposed to our relatively low relative humidities. Many carvings are ruined after only 1 or 2 weeks in the arid environment of our heated and air-conditioned stores, offices, and homes (fig. 6).

At the first sign of checking or splitting, the carvings should be immersed in water until they can be treated. If incipient cracks swell shut as the wood regains its turgid "green" condition, then it is certain that PEG treatment will be

Figure 6.--Many of the carvings imported from tropical countries develop the serious checks and splits shown above while they dry out in the arid environment of our heated and air-conditioned stores, offices, and homes.

M 121 881

completely successful. The cracks will remain closed, and no others will develop when the carvings are later dried to the 6 percent M.C. reached in a heated room.

If, however, the cracks do not completely close as the wood swells when immersed in water, these cracks will remain open in the treated and subsequently dried carving. All that can then be accomplished with PEG treatment is the prevention of further damage. Preventing further checking and splitting, to the point of ruin, can be an advantage. Use the schedules recommended for green wood bowls and carvings for treating the carvings with PEG after they have been thoroughly soaked in water. It is better to overtreat than undertreat. Many extremely dense hard tropical hardwoods are difficult to treat at ambient temperatures. For adequate penetration of the chemical into these woods, it may be necessary to increase the temperature of the solution to 100° F. or more. An electric water-heating element, preferably with a thermostat, is safe and efficient.

After treating, air-dry carvings for about 3 to 6 weeks (depending on size and shape), preferably in a heated room. Water-soaking and treating will, fortunately, remove most of the shoe polish or cheap varnish with which these carvings were originally finished, but remove the remainder by sanding. Then bleach, sand, and refinish with the finish suggested for bowls and green wood carvings, For imported carvings we strongly recommend the Danish-oil finish.

If carvings can be treated when purchased while the wood is still in the essentially green condition, they can be fully protected against future checking and splitting (fig. 7).

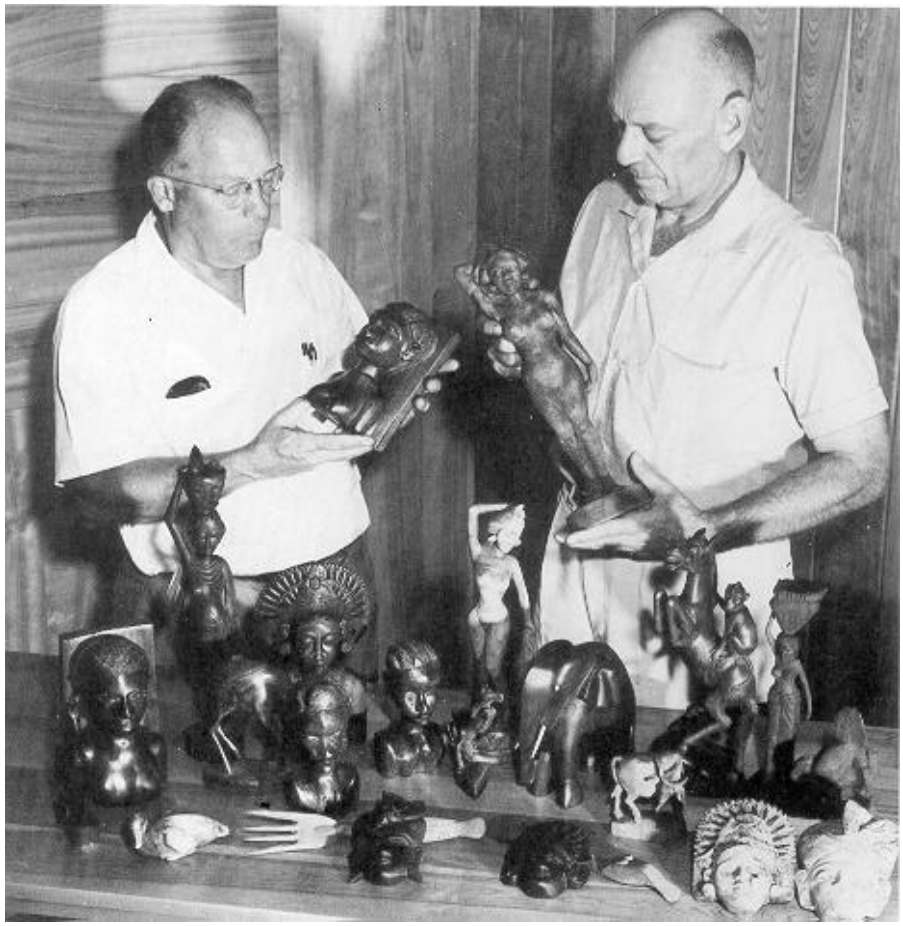

Figure 7.--The carvings shown from Southeast Asia were PEG-treated on arrival in this country; thus they were protected against drying degrade.

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Preserving Archaeological Specimens

Archaeologists and other scientists who dig in old bogs and who probe the depths of the oceans frequently find wood artifacts they want to preserve. Usually these artifacts are badly deteriorated by marine insects or various bacteria and decay organisms that dissolve much of the carbohydrate portion of the wood and leave mainly the resistant lignin. When these partially decomposed wooden artifacts are exposed to drying they break down into fragments or become dust.

If not too badly disintegrated, however, they can be preserved by treating with PEG-1000. Most of, these artifacts can be successfully treated by soaking 3 to 4 weeks in a 50 percent PEG solution at ambient temperature. The PEG readily diffuses into the partially deteriorated, water-soaked fine structure of the wood, supports it, and keeps it intact during the drying process. For badly deteriorated artifacts it may be necessary to start with a less concentrated PEG solution and to use a polyethylene glycol polymer of higher molecular weight, such as PEG-1540 to even PEG-4000. For extreme deterioration it may be best to start with a liquid, like PEG-400, and then gradually increase to the higher molecular weights until the desired result is attained.

Fungicides used improperly can be injurious to man, animals, and plants. Therefore, for safe and effective usage it is essential to follow the directions and heed all precautions on the labels.

Store fungicides in original containers--out of reach of children and pets--and away from foodstuff.

Some of the distributors from whom small amounts of polyethylene glycol can be procured include:

Robert M. Albrecht
8635 Yolanda Avenue
Northridge, California 91324

Crane Creek Company
P.O. Box 5553
Madison, Wisconsin 53705

Wilkens-Anderson Company
4525 West Division Street
Chicago, Illinois 60651

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