U.S.D.A. FOREST SERVICE
RESEARCH PAPER NC—29
1969

DURABILITY TESTS OF WOODEN SIGNBOARDS

NORTH CENTRAL FOREST EXPERIMENT STATION
FOREST SERVICE
U.S. DEPARTMENT OF AGRICULTURE

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Durable Rustic Wooden Signboards

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The need for rustic wooden signs at public and private recreation sites has greatly increased since 1958. A growing population, a higher standard of living, increased leisure time, and the ease of travel have provided opportunities for more outdoor recreation. On National Forest recreation sites alone there were 279 million visits in 1960, and it is estimated there will be 700 million in 2000. This increase is making a tremendous impact on the estabishment of new recreation areas and the expansion and renovation of existing ones. All recreation sites, structures, roads, and trails that are being constructed or improved to meet the expected demand require signing for proper and safe use. Recreation site managers must plan for thousands of new road, trail, administrative, interpretive, and regulatory signs that will be attractive, functional, and durable.

Most recreation area signs are rustic in style and made of materials selected for their beauty, utility, and availability. Usually wood or wood-based materials are used, the letters are routed, and the boards are stained or enameled (fig. 1). Some rustic signs have artwork. All exterior signs are subjected to the weathering of sun, rain, wind, and attacks from decay organisms, insects, and vandals. Many of them must be refurbished or replaced after only 2 years.

The increasing demand for signs, their relatively short life, and spiraling labor and material costs prompted us to investigate ways of minimizing sign costs. Federal, State, and private sign shop procedures were studied; also, many signboards and finishes were tested in the laboratory and in four climatic areas of the United States. Then, from these studies, guidelines were developed for wood signboard material selection to help reduce the processing and maintenance costs and increase the service life of rustic signs.

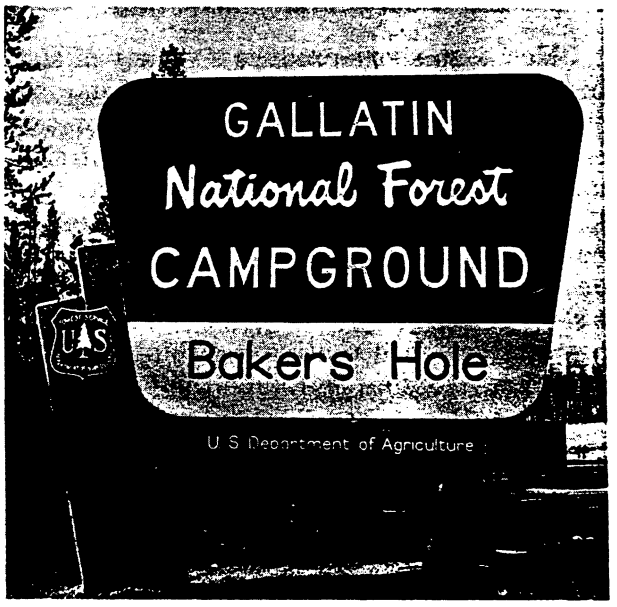

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FIGURE 1. — Medium density overlaid plywood is an excellent material for large signs. This 5- by 7-foot signboard has routed letters and is finished with brown and yellow enamels.

SELECTING SIGNBOARD MATERIAL

Manufacturing and field maintenance labor constitute the primary costs of a routed, wooden signboard. Often shop labor cost can be reduced by changing signboard materials. This has been accomplished in many cases by switching from edge-glued lumber to plywood for large signboards.[1] Changing to wood that holds finishes better has eliminated part of

[1] *American Plywood Association. U.S. Product Standard PS 1-66 for softwood plywood-construction and industrial. Reprod. Prod. Stand. Sec. Nat. Bur. Stand., 28 p., illus. 1966.*

the sign maintenance labor cost on federal recreation areas. These changes may mean higher material costs, but they usually result in less labor needed and lower total cost. Frequently, savings have been sought by buying inexpensive paints. But if a cheap paint fails in 2 years when a better one would last 4, it is obvious that the "savings" in original paint cost will be more than offset by the cost of refinishing.

Signboard Size and Shape

Most sign shops produce a variety of signboard sizes and shapes ranging from slat signs 4 by 12 inches to large recreation area entrance signs up to 8 by 12 feet. Slat signs up to 10 inches wide are easily made from standard widths of lumber. Larger signs can be made either by edge-gluing lumber to the desired width or by using plywood sheets. If a shop produces only slat signs, standard lumber that has good routing, finishing, and service characteristics is usually the best material. If many large signs are made, plywood is probably the best choice because labor is reduced and edge-gluing is eliminated.

Signboard size and material selection determine what shop facilities are needed. The shop manager must, therefore, know the sizes and shapes of signs he will produce and the facilities at his disposal before he can compare the total cost of production using either lumber or plywood. Usually, if orders for signs over 8 inches wide are anticipated, it is more economical to produce plywood signs than to produce lumber signs. Conversely, if only narrow slat signs will be produced, it is usually more economical to equip a shop to process dried and dressed lumber rather than plywood.

Slat sign production from lumber usually requires only crosscutting, routing, sanding, and finishing equipment. However, large edge-glued lumber signs require facilities and machines for clamping, planing, grooving, splining, and boring. In addition, planers and jointers require exhaust systems, and handling devices for the heavy signs are often needed. This equipment is expensive and may be utilized only part time. Furthermore, if rough green lumber is used, a dry kiln may be needed. If dressed, air-dried lumber is purchased, seasoning facilities may not be needed; but the cost of lumber in a large sign is then usually higher than plywood cost.

If plywood is used for large signs in lieu of lumber, less floor space is needed for carpentry work. Furthermore, large plywood signs can be efficiently produced with low-cost panel saws, portable electric 10-inch saws, sabre saws, sanders, and routers. If large signs are irregularly shaped, a medium density overlaid plywood is better than edge-glued lumber because layout can be done without regard to grain direction. The overlay hides the grain; sign blanks can be laid out with common edges for minimum sawing and maximum sheet utilization; material waste is reduced; and less room and labor for material storage and waste handling are required than if lumber were used.

Sign Use and Exposure

Signboard materials should have good finish-holding characteristics to minimize field refinishing and sign replacement costs. One exception to this principle occurs if signs are quickly destroyed by vandalism. There is no point in expending labor and materials for extended sign life if the expected life is only 1 year. However, many recreation signs are not extensively abused; and it usually pays to make such signs as durable as possible. For example, durable signs are economical in difficult access wilderness areas where sign replacement and maintenance costs would be excessive if frequent, long maintenance trips were necessary. In well patrolled areas where vandalism is minimized, durable signs are usually more economical than signs that last only one season.

Sign durability depends on the kind of construction material, how the sign is made and finished, and the severity of the environment. Solid wood material, plywood products, and finishes vary greatly in durability, de-

pending on the exposure conditions; and it is, therefore, important for sign manufacturers to know the exposure hazards and their effects.

Sunlight is detrimental to signs. Ultraviolet radiation degrades finishes and wood tissue. Intense and prolonged exposure to sunlight, such as occurs on south aspects and at high altitudes, will cause more rapid sign degradation than if the sign were on a north aspect or otherwise shielded (fig. 2). Protection by roofs and trees — especially conifers which provide continuous shade — prolongs sign life. Pigmented finishes are more sun resistant than most clear finishes.

Rain, snow, dew, and changing humidity cause moisture fluctuations that are damaging to wood and finishes. Windborne particles erode finishes. In some areas, atmospheric pollutants attack finishes. Warm, wet climates favor decay and insect attack. Sometimes woodpeckers, rodents, and game animals mutilate signs.

Sign location, the type of mounting, and exclosures can be used to resist the above hazards. But using durable materials is the first line of defense. For example, if decay is a serious hazard, as in the southeastern and Gulf States, naturally decay resistant or preservative-treated woods should be used. Where finishes erode quickly, erosion resistant paints or enamels and wood substrates that take and hold them well are more desirable than stains.

SELECTING SUBSTRATES

When the facts of sign production and exposure life are established, a manager can select a signboard if he knows the various signboard characteristics. Our laboratory and field exposure tests in four climatic areas were made to determine the routing and in-service performance characteristics of signboard materials finished with enamels, paints, stains, varnishes, and lacquers. These characteristics, plus information on moisture content, material grade, and wood grain charac-

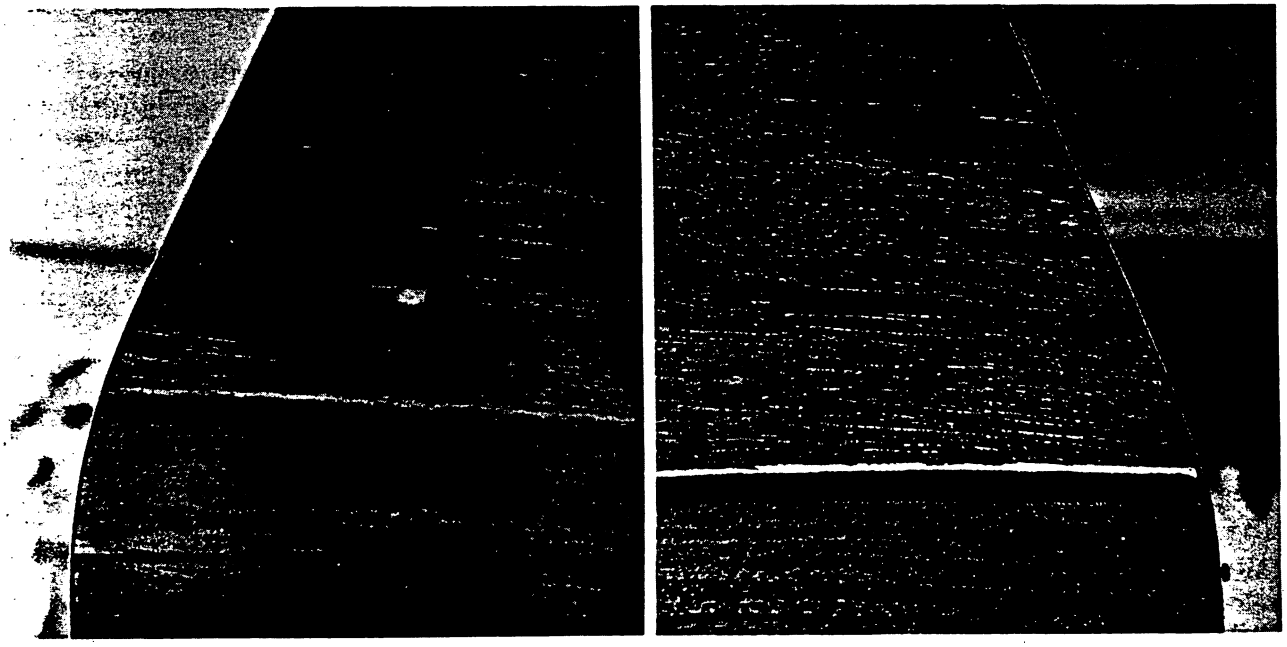

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FIGURE 2. — Left: North side of edge-glued redwood sign finished with a clear marine varnish. The varnish has yellowed but is intact. Right: South side of the same boards. The varnish has been broken down by intense sunlight; it is crumbling, peeling, eroding, and the wood substrate is a weathered gray.

teristics, are the facts sign builders need to consider when selecting materials.

Moisture Content

When wood is dried outdoors until it reaches an approximate equilibrium with the atmosphere, it is regarded as air-dry. The air-dry moisture content of wood may vary from 5 to 20 percent, depending on local climate. Air-dry wood will be relatively stable in outdoor use. Conversely, green wood will shrink in service causing warp, checks, splits, early finish failures, and a waste of labor and materials. Thus, to minimize drying degrade, signboard material should be air-seasoned to the average moisture content expected in service. For this reason many signbuilders keep their lumber stacked and stickered in unheated, well ventilated sheds. Signboards air-seasoned in one area may not be well suited for another area of different climate.

Grade

Both lumber and plywood vary in grade. The higher grades have fewer natural defects and cost more than the lower grades. The high grades of lumber will yield more, and larger, defect-free cuttings than the lower grades. However, for short slat signs, it is often more economical to use one of the lower grades of lumber and cut the short slats from the clear wood between defects. Also, some defects do not reduce the utility of a board for signs. When signboards are to be painted, naturally occurring stains in the wood are not objectionable. However, pitch pockets, bark pockets, the pith, knots, and splits should always be avoided.

Grain Orientation

Lumber signs should be made from vertical-grain boards. Flat-grain boards tend to develop loosened grain on the heart side. Loosened tips of summerwood bands eventually may shell from the board leaving a concavity, or they may feather out and give the slat a ragged appearance (fig. 3). However, the bark side of a flat-grain, planed board will not shell, splinter, and weather as fast as the heart side.[2] Some sign woods which tend to shell on the heart side of flat-grained boards are redwood, western redcedar, Douglas-fir, southern pine, and occasionally baldcypress and ponderosa pine.

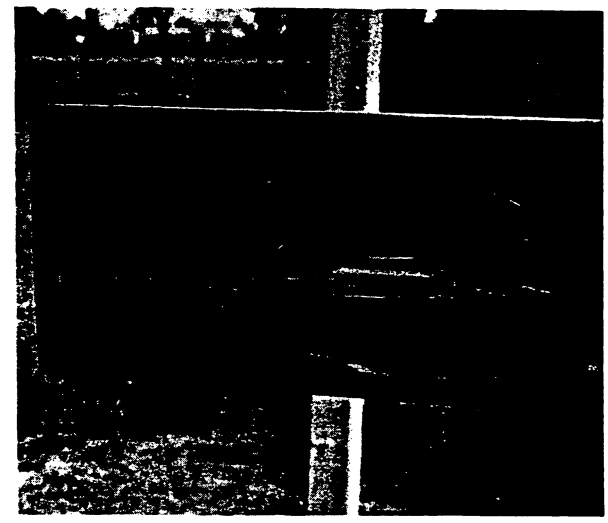

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FIGURE 3. — Loosened summerwood bands on the heart side of this flat-grain redwood slat were evident after 1 year of exposure.

Vertical-grain lumber shrinks and swells less in width than flat-grain lumber. It does not twist, cup, surface check, or split as much as flat-grain lumber. Most importantly, vertical-grain lumber of many species holds finishes better than flat-grain lumber. All these advantages are particularly important when large signboards are made from edge-glued boards.

Some builders of edge-glued signs use flat-grain boards and alternate the pattern of the annual rings. This has the advantage of minimizing overall cup in glued-up flat-grain boards. But in this type of construction half of each sign face will be the heart side of the boards which may develop unsightly loosened grain.

[2] *U.S. Department of Agriculture, Forest Service, Forest Products Laboratory. Raised, loosened, torn, chipped, and fuzzy grain in lumber. U.S.D.A. Forest Serv. Res. Note FPL-099, 15 p., illus. Forest Prod. Lab., Madison, Wis. 1965.*

Differences Between Plywood Products and Lumber

Softwood plywood is made from Douglas-fir, southern pine, white pine, redwood, Sitka spruce, sugar pine, and ponderosa pine. Only Douglas-fir plywood was tested, but softwood plywood of other species, particularly if it has a medium density overlay, should not be excluded from consideration. Many hardwoods are also used in plywood construction, but their use is primarily for interior work. Hardwood plywood with clear face plies and exterior-type glue lines are usually too expensive for rustic signs. For this reason these were not tested, even though some may perform very well.

The sign-use characteristics of softwood plywood differ from lumber in the following respects:

1. Plywood panels have greater uniformity in strength than edge-glued lumber panels of equal length and width.

2. Plywood shrinks and swells less than lumber, and dimensional changes are about the same along the panel and across the panel.

3. Plywood has greater resistance to splitting than lumber, but it face- and end-checks more than flat-grain lumber of the same species.

4. Plywood has little tendency to warp, whereas poorly seasoned lumber and lumber without straight grain may warp badly in service.

5. Plywood veneers contain lathe checks that may open and cause finish failure where the end grain appears on all four signboard edges. Lathe checks are not present in lumber, but seasoning end checks are often present.

6. Most plywood face veneers are 3/32 or ⅛ inch thick and routing letters deeper than ⅛ inch results in excessive bit wear at the abrasive plywood glue line. Thicker face veneers, available on special order, eliminate glue-line routing.

7. Many plywood inner plies contain voids where they are split or not tightly butted. Lumber sometimes contains pitch and bark pockets, but they are usually not as frequent as voids in exterior grade plywood.

8. Most plywood is dried to about a 12-percent moisture content, whereas lumber can be purchased ranging from an 8-percent moisture content to the green condition.

9. Plywood is available from some manufacturers as precut sign blanks; often the manufacturers can also provide prefinished or custom overlaid blanks.

10. Commercial standards for softwood plywood, PS 1-66 (see footnote 1), are established by the trade, and several trade associations exist to certify adherence to standards. Panel sizes are standardized in the plywood industry. Lumber grading standards are established and lumber is sold by grade, but differing production practices among lumber manufacturers result in lumber size differences.

Characteristics of Various Woods and Plywood Products for Signs

Wood properties and performance characteristics differ among and within wood species. The wood properties of importance to signbuilders are: (1) the ease of routing and working the wood, (2) gluability, (3) natural durability or ease of preservative treatment, (4) finishing characteristics, (5) the occurrence of extractive stains and resins and their effect on finishes, (6) dimensional stability, and (7) resistance to checking and raised and loosened grain. The first three of these warrant special mention.

Signboards that do not rout easily should not be dismissed from selection. Some wood substrates that are difficult to rout without burring the edges are otherwise very suitable for signboards. The medium density resin-impregnated overlays on Douglas-fir plywood burr when routed and letter edges must be cleaned up by a light hand sanding. However, the medium density overlay plywood is excellent sign material. Similarly, basswood and soft maple sometimes do not rout cleanly, but they are relatively stable and hold finishes well. Conversely, the substrate in our tests

which routed best — hardboard on Douglas-fir plywood — delaminated after 1 year of exposure. Blackgum and red oak rout fairly well, but blackgum warps and red oak face- and end-checks excessively.

Natural durability should not be overrated when selecting signboard materials. The heartwood of redwood and western redcedar is very durable, but grain loosening and shelling in flat-grain boards may destroy the sign long before other less durable woods fail from insect attack or decay. Moreover, many nondurable woods can be treated with a 5-percent solution of water-repellent pentachlorophenol in light oil to eliminate decay and insect hazard; and the treated wood can still be stained or painted. Hardwoods, pines, and sap baldcypress used in the Southern States should be treated.

How easily woods glue should be considered whenever large signboards are made from lumber. As a rule, softer and more porous woods glue easier than the harder woods. However, all the woods that are otherwise suitable for signs are relatively light and porous and glue well. Moreover, other factors, such as gluing pressure, wood surface quality, wood moisture content, and the type of glue, are vital to a good bond and they can be controlled. Thus, with proper methods hard, low-porosity woods can be bonded successfully. Only waterproof adhesives should be used. Water-resistant adhesives are unsatisfactory for edge-glued signboards.

We tested 11 softwoods, 7 hardwoods, and 7 plywood products, each with several finishes, to determine which sign materials are most suitable. We used materials available in each region of the United States and made artificial weathering tests in the laboratory and then tested them in the field for 2 to 6 years. In addition, the experiences of sign-shop personnel and the results of their tests were tabulated.

Our findings (summarized in table 1) indicate what can generally be expected in sign production and exposure. Descriptions are derived from rigorous tests of flat-grain boards; vertical-grain boards will perform better. Severe exposures will cause earlier and more frequent failures than mild exposures. Improper seasoning, machining, assembly, and finishing methods will, too. However, because all materials were tested in the same manner, relative differences indicate the performance that can be expected in most situations.

Flat-Sawn Boards

Flat-grain, planed incense cedar, baldcypress, Alaska yellow cedar, and yellow-poplar performed the best. Flat-grain soft maple and basswood were not as good as the above species but were entirely satisfactory (table 1).

Other flat-grain woods were less satisfactory for several reasons. The pines exuded resins that lifted finishes, and they did not rout well (fig. 4). Flat-grain redwood and western redcedar developed loosened grain on the heart side (fig. 3) and both contained black extractives that leached onto and discolored the surface (fig. 5). However, vertical-grain redwood and western redcedar slats did not develop loosened grain and stained less than the flat-grain slats. Cottonwood burred extensively when routed (fig. 4) and was not dimensionally stable. Red alder and blackgum (fig. 6) were also unstable and developed many checks (table 1).

Plywood Products

Plywood slat signs were made and tested in the same manner as flat-grain boards. However, because we tested only Douglas-fir plywood constructed with different grades of veneer and with different overlays, each product is described separately in more detail than can be presented in a table.

Exterior Douglas-fir Plywood

Exterior grade fir plywood with "A" grade veneer faces is available in widths to 60 inches and lengths to 144 inches. Other sizes with scarf joints are also available on special order. Fir plywood routs fairly well and takes

Table 1. — Characteristics of tested signboard wood materials for routed, rustic, flat-grained, slat signs

Material	Ease of routing	Ease of working	Ease of gluing	Natural durability	Ease of treating	Finish-holding ability	Extractive and resin bleedout 1/	Dimensional stability	Resistance to checking	Resistance to loosening of grain	Remarks	Overall rating for routed signs
SOFTWOOD LUMBER												
Sugar pine	Poor: burrs	Easy	Easy	Low	Moderate	Fair	Resin	Very good	Fair	Very high	Routs poorly, resin lifts finish	Not recommended
Northern white pine	Poor: burrs	Easy	Easy	Low	Moderate	Fair to good	Resin	Very good	Poor to fair	Very high	Routs poorly, resin lifts finish	Not recommended
Southern pine	Difficult	Difficult	Easy	Fair	Moderate	Poor	Resin	Fair	Poor	Very low	Routs poorly, resin lifts finish	Not recommended
Ponderosa pine	Poor: burrs	Easy	Easy	Low	Easy	Fair	Resin	Good	Poor	Moderate	Routs poorly, resin lifts finish	Not recommended
Sitka spruce	Poor: burrs	Easy	Very easy	Low	Difficult	Fair	None	Good	Fair	Very high	Routs poorly	Not recommended
Douglas-fir	Moderate	Difficult	Moderate	Fair	Very difficult	Poor	None	Fair	Poor to fair	Very low	Poor finish substrate	Not recommended
Coast redwood	Good	Fairly easy	Easy	Very high	2/	Very good 3/	Extractives: black	Very good	Fair	Very low	Bleedout, loosened grain	Vertical grain good 4/
Baldcypress	Excellent	Fairly difficult	Easy	Very high	Moderate	Very good	None	Good	Good	High	-	Good
Incense cedar	Good	Easy	Easy	Very high	2/	Very good	Extractives: slight	Very good	Good	Very high	-	Good
Western redcedar	Good	Easy	Easy	High	Very difficult	Very good 3/	Extractives: slight	Good	Good	Low	Bleedout, loosened grain	Vertical grain good 4/
Alaska yellow cedar	Excellent	Easy	Easy	Very high	2/	Very good	None	Good	Good	Very high	Limited availability	Good
HARDWOOD LUMBER												
Cottonwood	Poor: wools up	Difficult	Easy	Very low	Moderate	Poor	None	Poor	Poor	Very high	Routs very poorly	Not recommended
Red alder	Good	Easy	Easy	Low	2/	Good	None	Poor	Poor	Very high	Cups, checks	Not recommended
Red oak	Good	Fair	Moderate	Low	Easy	Fair	None	Poor	Poor	High	Excessive checking	Not recommended
Yellow-poplar	Excellent	Easy	Easy	Low	Difficult	Very good	None	Good	Good	Very high	-	Good
Soft maple	Moderate	Fairly easy	Moderate	Low	Moderate	Fair to good	None	Fair	Poor	Moderate	-	Fair
Basswood	Moderate: burrs	Easy	Easy	Low	Easy	Very good	None	Good	Good	Very high	-	Fair
Blackgum	Poor: burrs	Difficult	Difficult	Low	Easy	Very good	None	Poor	Poor	Very high	Twists frequently	Not recommended

1/: With oil stain finishes.
2/ No information
3/ Unless grain loosens.
4/ Flat-grain not recommended.

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FIGURE 4. — Flat-sawn, planed white pine (left) and ponderosa pine (center) burr slightly at the letter edges during letter routing. Loose fibers pick up paint and cause letter edges to appear ragged. Cottonwood (right) often wools up because it contains gelatinous wood fibers which do not cut cleanly.

stain and film-forming[3] finishes well. However, film-forming finishes crack on the exposed plywood edges due to the opening of lathe checks in the plies, and the finish fails earlier than on the faces. Douglas-fir plywood seldom develops loosened grain because the bark side of the face plies is always the face of the panel. Raised grain does develop, and finishes usually fail first over the raised, dense, summerwood bands. "B" grade inner plies in exterior grade plywood admit voids due to veneer splits and open butt joints between veneers in the same ply (see footnote 1). These voids are difficult to fill and finish if exposed by routing letters through the face plies of exterior plywood.

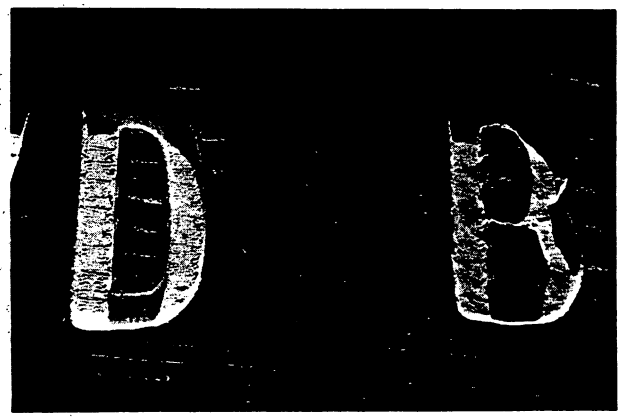

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FIGURE 5. — This redwood slat with one coating of a water repellent cedar color stain finish was discolored by dark extractives leaching to the surface after 21 months of exposure with less than 20 inches of rainfall.

[3] *Film-forming finishes do not penetrate the wood. We tested paints, enamels, lacquers, and varnishes.*

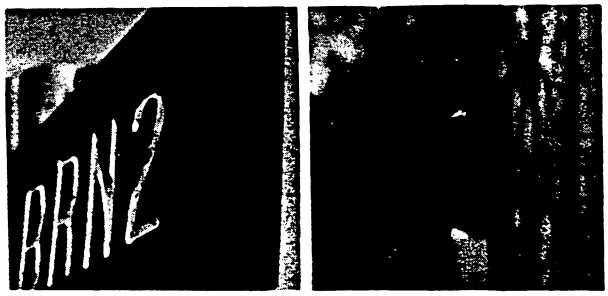

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FIGURE 6. — Unstable woods check and warp when subjected to cycling moisture conditions. Red alder (left) developed numerous end checks. Blackgum (right) twisted badly due to interlocked grain developing uneven stresses while cycling.

Interior grade fir plywood should never be used for outdoor signs as the glue line is not waterproof and the plies will delaminate in a hot, wet exposure. Exterior fir plywood has a waterproof glue line that will not delaminate if it is properly made.

Marine Douglas-fir Plywood

Marine grade plywood differs from exterior plywood primarily in the grade of the inner plies. Marine plywood has solid (one piece) "B" grade veneer inner plies without voids. In other respects marine plywood is similar in performance and characteristics to exterior plywood. Where large signboards are desired with stained finishes that show the grain, this plywood makes a good substrate (fig. 7).

F-519076

FIGURE 7. — This Douglas-fir marine plywood sign has held its water-repellent stain well for 4 years. Raised grain and dense summerwood bands would have caused early failure if film-like coatings were used.

Medium Density Overlaid Fir Plywood

Medium density overlays are resin impregnated cellulose fiber sheets containing about 20-percent (by weight) thermosetting phenol- or melamine-type resins (see footnote 1). The medium density overlay is bonded to the faces of exterior Douglas-fir plywood. This product is designed specifically for painted signs (fig. 1). The overlay is opaque, it masks face veneer patches and the grain pattern, and it overcomes checking. When routed, the overlay burrs and it must be sanded smooth before finishing. The overlay takes and holds stains, paints, and enamels well, usually holding longer than the best bare wood substrate. If unfinished, the overlay will turn gray. Where large opaque-finished signboards are desired, this is one of the most suitable materials available.

High Density Overlaid Fir Plywood

This overlay is made of cellulose fiber sheets impregnated with phenol or melamine thermosetting resins not less than 40 percent by weight (see footnote 1). This overlay is usually a natural translucent color, but is also available in several colors depending on the manufacturer. The overlay is on exterior grade Douglas-fir plywood, and it is not intended for painting. Reflective sign sheeting can be directly applied to it, but it must be cleaned with steel wool and a solvent before applying enamel. The high density overlay is difficult to rout, it tends to chip, and is very abrasive on router bits. However, it is an excellent substrate for reflective sheeting overlaid signs that are not routed.

Acrylic Overlaid Fir Plywood

Acrylic overlays are cellulose fiber sheets containing thermoplastic resins pigmented with waterproof colors. They are similar to the medium density overlay and are available in at least four colors — green, red, blue, and white. We tested specially prepared brown overlays on exterior Douglas-fir plywood and found they weathered well with fairly good color stability. Routing and edge checking characteristics were the same as the standard medium density overlay. If finishing is required on this overlay, the surface should be cleaned with steel wool and a solvent, such as xylol. If the desired sign colors are available, this is a good material for large signboards.

Plastic Overlaid Fir Plywood

Exterior Douglas-fir plywood with a polyvinyl fluoride plastic sheet overlay is available in many colors from several manufacturers. The plastic overlay has excellent color stability and is very durable. The plywood edges check as in exterior fir plywood. The greatest disadvantage of this material is its routing characteristics. The polyvinyl fluoride overlay does not cut; it tears, flaps aside, and leaves a ragged, feathered edge when routed with conventional core box bits. This is due to the lack of rigidity in the film. We found this could be overcome by using down-cutting, spiral flute routing bits. However, the bits must be newly sharpened and they will only rout 400 to 600 lineal inches before resharpening is needed. The film can be painted after it has weathered for a year, or immediately if the purchaser specifies adherable surfaces.

Hardboard Overlaid Fir Plywood

Standard or tempered hardboard faced fir plywood panels with and without polyvinylfluoride plastic overlays were tested artificially and in field exposures. The hardboard routs well and is well suited to take and hold paints. However, none of the products tested was waterproof, a prime requisite for signs. The hardboard swelled and eventually began to separate near the plywood-hardboard glue line. Plastic overlays did not enhance signboard life because the hardboard edges were exposed, and the plastic overlays were permeable to moisture.

These products were manufactured for interior use and were not designed by the manufacturer for exterior use. Before our tests we were warned that the product was not waterproof, and our tests in no way reflect on the quality of the product for its intended use.

SELECTING FINISHES

Signboards are finished for two reasons: to give the surface the desired appearance and to protect the wood from weathering. Thus, finish selection involves color, gloss, and the impression the sign is meant to convey to the viewer. Rustic signs are usually shades of brown or green that blend with the scenery but are plainly visible through the use of contrasting or reflective letter paints.

Finishes protect the wood from weathering by keeping the moisture content of the wood reasonably uniform, particularly near the surface. This reduces the tendency of the wood to shrink and swell and subsequently check and split. Pigmented finishes also provide the wood protection from the sun's ultraviolet rays.

How well finishes perform depends on several factors: the kind of wood used, the type of finish used, and how the finish is applied.

Kind of Wood

In the first year of sign exposure the kind of wood used for a finish substrate has comparatively little effect on the performance of the finish. If failures occur the first year, it is more likely due to the type and composition of the finish. But once a finish begins to deteriorate due to embrittlement, the kind of wood substrate determines subsequent finish behavior.[4]

How well coatings perform on softwoods depends on several factors. One of the most important is the amount and distribution of the summerwood, because summerwood provides poorer anchorage for coatings than springwood. Thus, on flat-grain boards with wide summerwood bands, as in Douglas-fir and southern pine, embrittled paint fails earlier than on other flat-grained softwoods (such as the white pines) that do not have dense, wide summerwood bands. The effect of dense summerwood bands is reduced if vertical-grain boards are used because the summerwood bands are narrowest on the faces of such boards, other factors remaining equal. Furthermore, using vertical-grain boards avoids the problem of finishing the heart side of dense softwoods that often develop loosened grain. Redwood and western redcedar vertical-grain slats perform well as finish substrates.

Softwood resins and extractives may also affect finishes. Resin bleedout may lift finishes, discolor them, or have a harmful chemical effect on lead and zinc paints. Extractives in redwood and western redcedar may leach out and discolor surfaces finished with stains or emulsion paints (fig. 5), but extractives often improve the durability of linseed oil paints.

As in the softwoods, the lighter hardwoods hold coatings longer than the dense hardwoods. Furthermore, hardwoods with fine pores hold coatings better than hardwoods that have large pores. For this reason, it is often necessary to apply a filler to large-pored hardwoods so coatings can bridge the pores.

[4] *Browne, F. L. Wood properties and paint durability. U.S. Dep. Agr. Misc. Public. 629, 10 p., illus. 1962.*

Kind of Finish

Several finishes are commonly used on signs. These can be classified as opaque or transparent. Coatings containing pigments are opaque and include enamels and paints. Examples of transparent finishes are varnishes, clear lacquers, and shellac.

Enamel

Enamels are natural or synthetic varnishes or lacquers to which opaque pigments have been added. Varnish enamels are usually the most durable finishes. Pigmented nitro-cellulose lacquers are brittle and not durable (fig. 8). Varnish-base enamels form smooth, tough, elastic films with better wearing properties than paints and transparent finishes (fig. 1). Furthermore, enamels dry faster than oil paints. However, enamels differ greatly in their properties according to their formulation. What may appear on the market as two identical finishes by different manufacturers will, in fact, be quite different in their performance characteristics. We tested several enamels: some were the most durable finishes tested and lasted 6 years without failure; others were less durable than the best paints we used. Coincidently, the best enamels were the most expensive.

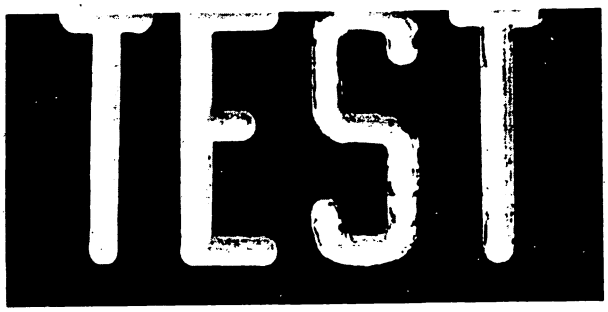

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FIGURE 8. — Puddled yellow lacquer failed after 2 years of exposure. The letters TE were primed and are cracked; the letters ST were not primed and the lacquer has peeled away.

Paints

Paints consist of finely ground pigments in a liquid vehicle. Two general types are in widespread use on signs: oil paints and emulsion paints. In oil paints the vehicle is a mixture of oil and resin and a volatile thinner, such as turpentine. When the oil paints dry, the vehicle binds the pigments together in a uniform tight film that has relatively low water permeability. In emulsion paints, made by combining pigments with resin particles dispersed in water, the water evaporates leaving the particles of pigments surrounded by resin in a film that is not usually as uniform or as tight as oil paint films. Thus, water vapor generally passes through emulsion paints more readily than through oil paints, and water vapor blistering may be greatly reduced. Such emulsion paints are sometimes called exterior latex or water-base paints.

The most widely used emulsion paints for signs are the acrylic resin and vinyl resin types. Both types usually dry faster, are more fade resistant, and spread easier than oil paints. However, the emulsion paints may require more coats to build up the same thickness as an oil paint; and they can be stained by extractives (see footnote 4). We found that some exterior emulsion paints are very durable and some are almost useless. Furthermore, emulsion paint durability depends on how long the film has cured before it is exposed to rain. An emulsion we exposed 5 days after application was nondurable, whereas the same emulsion on the same substrate was very durable when it cured 4 weeks before exposure.

Oil paints varied less in performance characteristics than the emulsion paints. If properly applied, the oil paints (linseed oil, soya oil, or fish oil vehicles) will last more than 3 years without failures on wood signs. Oil paints designed primarily for use on metal should not be overlooked. One of the most durable paints we tested was a two-coat system of paint for metal (fig. 9). Some house paints of the chalking type have good dur-

ability, but they fade when pigmented, and chalk runoff often discolors the lower parts of a sign.

F-519078

FIGURE 9. — Brown metal paint and yellow reflectorized letter enamel on this baldcypress slat had no failures after 2 years at a severe Gulf Coast site exposed to two hurricanes and frequent cycles of rain and hot sun.

Semi-Opaque Pigmented Stains

We also tested the semi-opaque pigmented stains that differ from paints in that they do not form a film but penetrate the wood. These stains consist of ground pigments in an oil vehicle with some drying oil or varnish and relatively large amounts of coal tar or petroleum solvents.[5] These stains do not raise the grain, and the colors are fairly light resistant. Furthermore, pigmented oil stains that penetrate wood surfaces do not blister, crack, or peel. They are very durable on rough-sawn lumber, but on planed surfaces of signs they erode in about 4 years (fig. 10). However, stain finishes are easily refurbished. Often a roller-applied coat of boiled linseed oil will brighten a stain that has not lost its pigmentation.

Varnishes

This type of transparent finish includes many formulations composed of plant or synthetic resins, with drying oils, volatile thinners, driers, and plasticizing ingredients. The film properties depend largely on the proportions of each ingredient and the type of resin used. These varnishes dry by evaporation and oxidation or by resin polymerization.

F-519079

FIGURE 10. — After 4 years of exposure, this yellow-poplar sign slat is in good shape, but the water repellent stain has eroded and exposed the bare wood. This can be easily refurbished and be more durable than originally. Paints and enamels last longer on yellow-poplar but are more difficult to refurbish than stains.

Transparent finishes on signs are usually not satisfactory. Ultraviolet radiation causes photochemical degradation of the finishes and of the wood fibers holding the finish (fig. 2). We tested epoxies, polyesters, "marine" and other varnishes and none was entirely satisfactory. They checked, cracked, curled, flaked, and peeled after 2 years of exposure and were almost gone after 6 years (fig. 11).

Lacquers

Clear lacquers composed of resins and cellulose esters, usually nitrocellulose, solvents, and plasticizers, are rapid drying. However, the lacquer film is brittle and dimensional changes in the substrate often rupture the film. If lacquer is puddled too thickly in routed letters, a dry film forms over the top before the bottom portions have dried. Because lacquer dries by vaporization of the solvents, the vapors are trapped beneath the top film until they bubble and rupture the film. These bubbles leave an unsightly crater in the film and form weak spots that fail quick-

[5] *U.S. Department of Agriculture, Forest Service, Forest Products Laboratory. Forest Products Laboratory natural finish. U.S.D.A. Forest Serv. Res. Note FPL-046, 5 p. Forest Prod. Lab., Madison. 1964.*

ly. Clear lacquers are not durable on signs and usually begin to fail in less than 1 year. They are ruptured by dimensional changes in the substrate, and they break down quickly from ultraviolet light radiation.

F-519080

FIGURE 11. — This redwood sign was finished with a two-part epoxy resin clear finish advertised as the most durable finish available. It failed after 2 years due to ultraviolet light degradation. What finish is left after 6 years is badly cracked, curled, and peeled and can be brushed away. Note failure of the decal.

How the Finish Is Applied

Assume that a sign manufacturer is making routed rustic signs and has decided to use vertical-grain incense cedar for slat signs and medium density overlaid plywood for large signs. Both types of signs will be finished with a yellow enamel for the routed letters and a brown enamel for the background. What is the best way to apply the finish?

Three procedures are in wide use and each has its advantages and disadvantages:

Procedure 1 (recommended method).

a. Rout the letters in the unfinished signboard.
b. Wire brush the routed channels to remove loose fibers and sand any burred edges.
c. Spray the entire signboard and letter channels with a primer that is suitable for both the letter and background enamel.
d. Spray the routed area with the finish letter coat using a mask to limit letter enamel on the background but not between letters.
e. Roll on the background enamel with a short nap roller squeezed fairly dry to avoid running enamel into letters.

Procedure 2.

a. Spray or roll on the background enamel primer and one or two top coats.
b. Rout the letter channels.
c. Puddle in the letter enamel primer from an oilcan or squeeze bottle.
d. Puddle in the letter enamel top coat.

Procedure 3.

a. Same as steps a and b in Procedure 1.
b. Puddle in the letter primer and top coats.
c. Roll on the background enamel primer and one or two top coats.

Procedure 1 is the best method for the following reasons: Spraying of letter enamels is usually better than puddling because more even coats can be applied by spray. Puddling (Procedures 2 and 3) requires little skill but results in a coating that is too thin on the sides of the routed letter channels and too thick in the channel bottom. This usually results in early failures (figs. 12, 13, and 14).

Both the prime and top coats of the letters are continuous coatings, whereas, in Procedures 2 and 3 the puddled letter finishes have no continuity between letters and do not cover any areas also covered by the background finish. Thus, there often is an area of the routed letter edge which receives little finish and leads to early failure of both letter and background finishes.

Some sign builders try to take shortcuts in sign finishing. One most frequently used is the one-coat system. Even the best paints and enamels perform poorly if they are not applied over a primer (figs. 15 and 16). One thin coat wears out early, and one thick coat

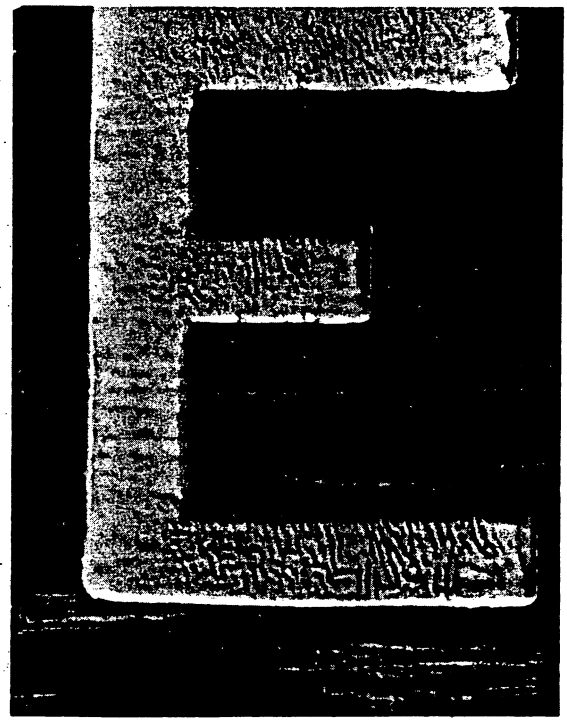

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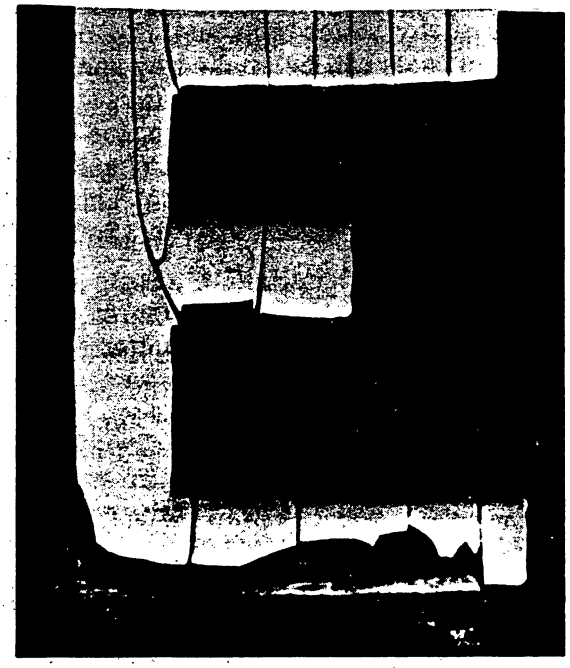
FIGURE 12. — A linseed oil house paint dried with a wrinkled surface because it was puddled too heavily in one coat.



F-519082

FIGURE 13. — Cross grain cracking of house paint puddled in letter channels resulted in sign failure after 2 years.

F-519083

FIGURE 14. — This alkyd resin enamel is durable, but a single thick application destroyed its durability. The letters were unsuitable after 18 months of exposure.

F-519084

FIGURE 15. — A ponderosa pine slat with a single application of yellow reflective coating brushed into the letter channels — 4 years of southern exposure caused flaking and failure (see fig. 16).

F-519085

FIGURE 16. — A ponderosa pine slat with priming before finishing with yellow reflective coating — same exposure as slat in figure 15. This finish is in excellent condition after 4 years of exposure.

cracks too soon and later scales. If coatings are sprayed so that the total thickness is 5 mils (5 thousandths of an inch) with a two-coat system (primer plus one top coat), they usually perform quite well. A three-coat system, i.e., primer and two top coats, is usually better but requires additional labor.

Another faulty shortcut is to stretch finish coverage by the addition of inexpensive vehicle fluid, usually linseed oil, or solvents. This increases greatly the chance of the paint wrinkling as it dries. Usually the additions are unnecessary because high-quality paints and enamels are sold ready to apply except for stirring. Only recommended thinners should be added as necessary for proper flow, and they should be added according to the manufacturer's recommendations.

A SUMMARY OF GUIDELINES

The following recommendations are based on established wood properties, artificial weathering tests, and field exposure tests in four climatic regions of the United States. These materials are not the only ones which will serve well for signs, but they are the best of those we tested. Species availability within each region has been considered.

For large signs, regardless of geographic location, the best material is medium density overlaid Douglas-fir plywood.

For slat signs, recommended materials vary with location:

Region	*Recommended species*
Pacific Northwest	Vertical-grain incense cedar Alaska yellow cedar, redwood, or western redcedar
Lake States and Northeast	Basswood or soft maple if incense cedar is not available
Southeast	Baldcypress or yellow-poplar
Southwest and dry Western States	Vertical-grain incense cedar, redwood, or western redcedar

Softwood slat signs should be clear, heart, vertical-grain boards, not over 8 inches wide, and seasoned to the moisture content they would be expected to average in service. Basswood and soft maple perform fairly well flat-grained, need not be heartwood, and can be economically made from No. 1 Common lumber. However, hardwoods should be treated with a water repellent preservative to help prime the wood and prevent decay. Plywood with medium density overlays should have solid "B" grade veneer first and inner plies without splits and voids. If possible, first plies should be 5/32-inch thick so that letters can be routed to a depth of ⅛ inch without going through the first ply.

These woods should give at least 4 years of service if high-quality enamels with good priming are spray- or roller-applied. Some emulsion paints will not dry quickly and may fail early in wet climates. Lacquers are brittle and fail early, and clear coatings break down sooner than pigmented coatings in sunlight. Where a rustic appearance is desired, a pigmented water-repellent stain applied to rough sawn, vertical-grain redwood or western redcedar gives excellent results. It is easily applied, and after some weathering, a second coat can be rolled on that is more durable than the first. Every finish varies according to the manufacturer and should be tested and judged on its own merits on the intended substrate and in the environment where it must serve.

Cooper, Glenn A.

1969. Durable rustic wooden signboards. N. Cent. Forest Exp. Sta., St. Paul, Minn. 15 p., illus. (U.S.D.A. Forest Serv. Res. Pap. NC-29)

The most durable and practical rustic signs are made of clear, heart, vertical-grain incense cedar or redwood boards for slat signs, and medium-density overlaid plywood for large signs.

OXFORD: 835x3 signboards:812:832.282

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SOME RECENT RESEARCH PAPERS OF THE NORTH CENTRAL FOREST EXPERIMENT STATION

Timber Management Guide for Shortleaf Pine and Oak-Pine Types in Missouri, by K. A. Brinkman and N. F. Rogers. U.S.D.A. Forest Serv. Res. Pap. NC-19, 15 p., illus., 1967.

Selection of Superior Yellow Birch Trees, A Preliminary Guide, by Knud E. Clausen and Richard M. Godman. U.S.D.A. Forest Serv. Res. Pap. NC-20, 10 p., illus., 1967.

Stabilizing Eroding Streambanks in Sand Drift Areas of the Lake States, by Edward A Hansen. U.S.D.A. Forest Serv. Res. Pap. NC-21, 12 p., illus., 1968.

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Proceedings of the Eighth Lake States Forest Tree Improvement Conference, September 12-13, 1967. U.S.D.A. Forest Serv. Res. Pap. NC-23, 60 p., illus., 1968.

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Topography and Soil Relations for White and Black Oak in Southern Indiana, by Peter R. Hannah. U.S.D.A. Forest Serv. Res. Pap. NC-25, 7 p., illus., 1968.

A System for Classifying Wood-Using Industries and Recording Statistics for Automatic Data Processing, by E. W. Forbes and R. W. Rowe. U.S.D.A. Forest Serv. Res. Pap. NC-26, 22 p., illus. 1968.

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Prescribed Burning Weather in Minnesota, by Rodney W. Sando, U.S.D.A. Forest Serv. Res. Pap. NC-28, 8 p., illus. 1969.

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- Participating with all State forestry agencies in cooperative programs to protect, improve, and wisely use our Country's 395 million acres of State, local, and private forest lands.
- Managing and protecting the 187-million acre National Forest System.

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