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Painting and Finishing Wood for Use Outdoors

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ABSTRACT

The appearance of unprotected wood exposed outdoors changes markedly in a few months. Film-forming finishes, such as paint, provide the most protection for woods against sunlight and offer the widest selection of colors. A non-porous paint film is needed to retard the penetration of moisture and to reduce discoloration by wood extratives, paint peeling and checking. Paint is not a preservative and will not prevent decay if conditions are favorable. Because paint forms a coating on the surface, failures by cracking, blistering, and peeling are possible for a paint finish. To achieve optimum performance, both the substrate and coating must be carefully selected and used on well-designed and constructed structures that reduce the exposure of the coating to a minimum of sunlight, moisture, and fungal organisms. Woods vary in their paint-holding characteristics. Varnishes are generally short-lived as outdoor natural finishes.

In contrast to the film-forming finishes, the penetrating-type finishes do not form a film or coating on the surface and there is no failure of these finishes by cracking, peeling, or blistering. Quality of the substrate is not critical; it can be rough, smooth, weathered, knotty, flat grain, dense, porous, and of any wood species. The penetrating preservative and pigmented oil-base stains are easily maintained, essentially troublefree, and durable.

Construction practices and techniques can play a large role in determining the performance of wood used for outdoor exposure. Improper practices can cause early substrate and finish failure.
INTRODUCTION

The primary function of any wood finish (paint, varnish, wax, stain, oil, etc.) is to protect the wood surface, help maintain appearance, and provide cleanability. Unfinished wood can be used both outdoors and indoors without further protection. Wood surfaces exposed to the weather without any finish change color, are roughened by photodegradation and surface checking, and erode slowly. Wood surfaces exposed indoors may change color and accumulate dirt and grease if left unprotected without some finish.

Wood and wood-based products in a variety of species, grain patterns, textures, and colors can be finished effectively by many different methods. Selection of any finish will depend on the appearance and degree of protection desired, and on the substrates used. Since different finishes give varying degrees of protection, the types of finish, its quality, quantity and the application method must be considered in selecting and planning the finishing or refinishing of wood and wood products.

Light and water protection provided a wood surface by the surface treatment itself will be affected by the weather resistance of the bonding agents of the finish (drying oils, synthetic resins, latexes, etc.). These bonding agents are subject to photolytic degradation to some degree. The mechanism of failure of paints and other finishes has been described in great detail and will not be discussed further here. Performance of paints on wood and wood-based materials has also been studied extensively.

WOOD FINISHES

There are two basic types of finishes (or treatments) used to protect wood surfaces during outdoor weathering: (1) those that form a film, layer, or coating on the wood surface, and (2) those that penetrate the wood surface leaving no distinct layer or coating. Film-forming materials include paints of all description, varnishes, lacquers, and also overlays bonded to the wood surface. Penetrating finishes include preservatives, water repellents, pigmented semitransparent stains, and chemical treatments. Various finishes for exterior wood are summarized in Table 1.
Film-Forming Materials

Paints. --Film-forming finishes such as paint have long been used to protect wood surfaces. Of all the finishes, paints provide the most protection for wood against erosion by weathering and offer the widest selection of colors. A nonporous paint film will retard penetration of moisture and reduce problems of paint discoloration by wood extratives, paint peeling and checking, and warping of the wood. Proper pigments will essentially eliminate UV degradation of the wood surface. Paint, however, is not a preservative; it will not prevent decay if conditions are favorable for fungal growth. The durability of paint coatings on exterior wood is affected by variables in the wood surface and the type of paint.

Paints are commonly divided into the oil-base or solvent systems and the latex or waterborne paints. Oil-base paints are essentially a suspension of inorganic pigments in an oleoresinous vehicle which binds the pigment particles and the bonding agent to the wood surface. Latex paints are suspensions of inorganic pigments and various latex resins in water, and form porous coatings. Acrylic latex resins are very durable, versatile materials.

Varnishes.--The most attractive initial appearance for wood is no doubt obtained by use of clear varnishes. Other treatments either change wood color or cover it up completely. Unfortunately, clear varnish finishes require frequent maintenance to retain a satisfactory appearance. Numerous attempts have been made at using clear finishes having colorless UV light absorbers to help retain the natural color and original surface structure of wood. It is generally accepted that these absorbers are not effective and do not give long-lasting protection against light. Even using relatively durable clear synthetic resin varnishes, the weatherproof qualities of the wood/varnish system are still limited because UV light, which penetrates the transparent varnish film, gradually attacks the wood under it. Eventually, the varnish begins to flake and crack off, taking with it fibers of the wood which have been degraded photochemically. Durability of varnish on wood under action of the weather is limited and many initial coats are necessary for reasonable performance. Maintenance of the varnish surface must be carried out as soon as signs of breakdown occur. This may be as little as 1 year in severe exposures.

Penetrating Finishes

Water repellents. --A large proportion of the damage done to exterior woodwork (paint defects, deformations, decay, leakage, etc.) is a direct result of moisture changes in the wood and subsequent dimensional instability. The treatments can also be used as natural finishes for wood. Pre-treatment of wood with water repellents or water-repellent preservatives is very important in the finishing of wood for exterior uses.

Stains. --When inorganic pigments are added to water-repellent preservative solutions or to similar transparent wood finishes, the mixture is classified as a semitransparent penetrating stain. Addition of pigment provides color and greatly increases the durability of the finish.
The pigmented penetrating stains are semitransparent, permitting much of the wood grain to show through, and penetrate into the wood without forming a continuous layer. Therefore, they will not blister or peel even if excessive moisture enters the wood. The durability of any stain system is a function of pigment, resin content, preservative, and water repellent. Their performance during outdoor exposure has received a great deal of attention. Weather resistance of these surface finishes is improved by increasing pigment content, increasing moisture repellency, and increasing the quantity of material applied.

Penetrating stains are suitable for both smooth and rough-textured surfaces; however, their performance is markedly improved if applied to rough-sawn, weathered, or rough-textured wood. They are especially effective on lumber and plywood that does not hold paint well, such as flat-grained surfaces of dense species. Stains can be prepared from both solvent-base resin systems and latex systems. Latex systems do not penetrate wood surface, however. Penetrating stains can be used effectively to finish such exterior surfaces as siding, trim, exposed decking, and fences. Commercial finishes known as heavy-bodied or opaque stains are also available, but these products are essentially similar to paint because of their film-forming characteristics. Such "stains" do find wide success on textured surfaces and panel products such as hardboard.

WOOD PROPERTIES

Satisfactory performance of wood finishes is achieved when full consideration is given to the many factors that affect finishes. These factors include the effect of the wood substrate, the properties of the finishing material, details of application, and severity of exposure to elements of the weather (Table 2).

Wood surfaces that shrink and swell the least are the best for painting. For this reason, vertical- or edge-grained surfaces are far better than flat-grained surfaces of any species, especially for exterior use where wide ranges in relative humidity and periodic wetting can produce wide ranges in swelling and shrinking (Figure 1).

Also, because the swelling of wood is directly proportional to density, low-density species are preferred over high-density species. However, even high-swelling and dense wood surfaces with flat grain can be stabilized with a resin-treated paper overlay (overlaid exterior plywood and lumber) to provide excellent surfaces for painting. Medium-density, stabilized fiberboard products with a uniform, low-density surface or paper overlay are also a good substrate for exterior use. Vertical-grained western redcedar and redwood, however, are probably the species most widely used as exterior siding to be painted. These species are classified as those woods easiest to keep painted. Edge-grained surfaces of all species actually are considered excellent for painting, but most species are generally available only as flat grain lumber.
Many wood products of lumber, plywood, shingles, and fiberboard are prepared with a roughsawn and absorptive surface that enhances the durability of stains by providing for better penetration.

Such wood properties as high density, flat grain, and tight knots detract from paintability of boards but do not necessarily affect their finishing with penetrating preservatives and stains. These finishes penetrate into wood without forming a continuous film on the surface. Therefore, they will not blister or peel even if excessive moisture penetrates into wood.

Plywood

Exterior plywood with a rough sawn surface is commonly used for siding. Smooth-sanded plywood is not recommended for siding, but it is often used in soffits. Both sanded and rough sawn plywood will develop surface checks, especially when exposed to moisture and sunlight. These surface checks can lead to early paint failure with oil or alkyd paint systems. Quality acrylic latex primer and topcoat paint systems generally perform better. The flat-grained pattern present in nearly all plywood can also contribute to early paint failure. Therefore, if smooth or rough sawn plywood is to be painted, special precautions should be exercised. Penetrating stains are often more appropriate for rough sawn exterior plywood surfaces.

Reconstituted Wood Products

Reconstituted wood products are those made by forming small pieces of wood into large sheets, usually 4 by 8 feet or as required for a specialized use such as beveled siding. These products may be classified as fiberboard or particleboard, depending upon the nature of the basic wood component.

Fiberboards are produced from mechanical pulps. Hardboard is a relatively heavy type of fiberboard, and its tempered or treated form designed for outdoor exposure is used for exterior siding. It is often sold in 4- by 8-foot sheets as a substitute for solid wood beveled siding.

Particleboard are manufactured from whole wood in the form of splinters, chips, flakes, strands, or shavings. Waferboard and flakeboard are two types of particleboard made from relatively large flakes or shavings.

Some fiberboards and particleboard are manufactured for exterior use. Film-forming finishes such as paints and solid color stains will give the most protection to these reconstituted wood products. Some reconstituted wood products may be factory primed with paint, and some may even have a factory-applied top coat. Also, some may be overlaid with a resin-treated cellulose fiber sheet to provide a superior paint base.

Treated Wood

Wood is sometimes used in severe outdoor situations where special treatments and finishes are required for proper protection and best service. These situations involve the need for protection against decay (rot), insects, fire, and harsh exposures such as marine environments.
Although not generally classified as wood finishes, preservatives in wood do protect against weathering in addition to decay, and a great quantity of preservative-treated wood is exposed without any additional finish. There are three main types of preservatives: (1) the preservative oils (e.g., coal-tar creosote), (2) the organic solvent solutions (e.g., pentachlorophenol), and (3) waterborne salts (e.g., chromated copper arsenate). These preservatives can be applied in several ways, but pressure treatment generally gives the greatest protection against decay. Higher preservative content of pressure-treated wood generally results in greater resistance to weathering and improved surface durability. The chromium-containing preservatives also protect against ultraviolet degradation, an important factor in the weathering process.

Water-repellent preservatives introduced into wood by a vacuum-pressure or dipping process (NWMA Industry Standard 4-81) are paintable. Coal-tar creosote or other dark oily preservatives are not paintable because they tend to stain through paint, especially light-colored paint, unless the treated wood has weathered for many years before painting.

The fire-retardant treatment of wood does not generally interfere with adhesion of decorative paint coatings, unless the treated wood has an extremely high moisture content because of its increased hygroscopicity. It is most important that only those fire-retardant treatments specifically prepared and recommended for outdoor exposure be used for that purpose. These treated woods are generally painted according to recommendations of the manufacturer rather than being left unfinished because the treatment and subsequent drying often darken and irregularly stain the wood.

INTERACTIONS OF WEATHER, CONSTRUCTION VARIABLES, AND FINISHES

Controlling Effects of Light

Finishes always weather fastest on the sides of a building that receive the most light. In the degradation of surfaces by photo-oxidation, the ultraviolet portion of the light spectrum, which is the high-energy portion, is the most damaging. Clear coatings are embrittled and check. After checks develop, rain and dew have ready access to the wood substrate. Subsequent cycles of wetting and drying produce serious water staining of the wood under the coating and in time, flaking of the clear coating from the wood. In paint, pigment particles serve as effective ultraviolet absorbers, so paint degrades more slowly than clear coatings. In addition, very shallow checks develop which gradually loosen and cause chalking or erosion of the paint surface. Chalking of colored and tinted paints is a common cause of fading.

The photodegradation of wood is an important aspect of how it weathers. Wood which had weathered badly before painting will have deep valleys of degraded earlywood between sharp ridges of the more photo-resistant latewood. This kind of surface is not very good for painting, and a paint coating is likely to crack over the ridges of latewood. However, weathering of the wood surface is beneficial when a penetrating finish is employed.
Weathering permits the wood to adsorb and retain much more of the preservative or pigment stain, so the finish is more durable.

In addition to light's degradative effects, it also produces heat. Absorption of radiant energy in dark-colored coatings may produce surface temperatures of 100°C or higher under favorable conditions. When the wood surface is hotter than the rest of the board, moisture in the wood substrate moves away from the surface; when the surface is cooler, moisture moves toward it.

Heat of absorbed radiant energy is a problem in the application of paint, particularly dark-colored paint. If paint is applied too thickly on a cool surface which is subsequently warmed by the sun, blisters may form in the paint due to rapid volatilization of paint thinners. This problem is avoided by spreading the paint in only moderate thicknesses and on a surface which has already been warmed by the sun.

By Pigmentation. — Adverse effects, particularly the photodegradation effect of sunlight, can be readily retarded in many ways. Addition of pigment to clear coatings effectively protects both wood and coating. This technique is used to great advantage in plastic overlays made of polymers which are transparent to ultraviolet light. Because the polymers are transparent and do not absorb ultraviolet, they have long life out-of-doors. When applied to wood, such clear polymers permit ultraviolet to attack the wood surface under the coating; this leads to early separation of clear coating from the wood.

By Construction Factors. — The feature most widely employed in construction to protect wood from sunlight is roof overhang. When a 4-foot-wide overhang is provided, approximately two-thirds of a conventional one-story side wall is protected from exposure to full sunlight. If clear natural finishes are desired, such as on exterior doors, they must be protected by either recessing the entrance or using appropriate loggia construction. Gable-end constructions can be utilized on the north side of the buildings while hip-roof construction provides protection on all sides of a house. A-frame designs of course, also give generally good protection.

Vertical siding patterns may also be beneficial in reducing the effects of light and weathering. Water drains better off vertical boards than off horizontal boards. Vertical siding is also slightly more resistant to sunlight than beveled horizontal siding because it is less perpendicular to the incident sunlight.

Controlling Effects of Outside Water

Rain and dew account for large volumes of water that come in contact with exterior wood surfaces. This kind of wetting can produce cracking and peeling failure in paint and clear coatings. Water can pass through cracks in the coating and produce peeling. Leaks in the roof, inadequate drainage of water from valleys on steep roofs, or the formation of ice dams on the roof also allow outside water to enter side walls and damage the paint. Decay can develop where excessive penetration of water occurs in joints of untreated wood that have a low natural resistance to decay.
The discoloration of paint by the water-soluble extratives on woods such as western redcedar and redwood may be evidence of outside water damage. When the discoloration is a rundown or streaked pattern, it indicates water is getting behind the horizontal siding and running down at breaks in the lap joint. This kind of discoloration is commonly caused by ice dams. An overall diffused pattern of discoloration, on the other hand, indicates penetration of rain and dew through thin layers of porous paint.

Discoloration can further be produced by fungal growth (mildew or mold) on the surface. This failure is also associated with the dew pattern of the house.

By Construction Factors. -- Most exterior water problems resulting from rain are eliminated with properly designed roofs, valleys, gutter, and overhang. Proper use of metal flashing in critical areas is most important. Flashing should be used at the junction of a roof and a wood or masonry wall, at chimneys, over exposed doors and windows, at siding material changes, in roof valleys, and other areas where rain or melted snow may penetrate into the house. Wide overhangs, are most effective in reducing the amount of rain and dew that wet exterior side walls.

Where coating failure is associated with ends of boards and joints between boards, or when extractive discoloration is present, the best precautionary step is to apply a water-repellent preservative before painting. Window and door trim of a species susceptible to decay should be factory treated with water-repellent preservative. If not, they should be treated liberally on the site before painting. After treating, prime the surface with nonporous paint. Larger cracks and openings should be caulked after treating and priming. Painting untreated sapwood and species low in decay resistance usually enhances the possibility of decay.

Formation of ice dams on horizontal roof edges and valleys on houses in north temperate zones can be largely eliminated by providing insulation in the attic floor to arrest heat losses. In addition to insulation, the attic space should be vented.

Controlling Effects of Inside Water

Water from inside a building can attack paint on the outside by diffusing through the walls. This water can come from such faulty conditions as leaks in plumbing, or shower spray on a bathroom wall that is not properly sealed. Or it may result strictly from conditions of high humidity.

Water vapor inside the building can be a source of many gallons of water daily. In the winter time, this moisture is attracted toward the cold surfaces of the outer walls. If the outer walls have no vapor barrier or a poorly installed one, the water vapor passes into the walls and condenses to liquid in the sheathing and siding. In very cold weather, it may condense into frost, and later be melted by the warm spring sun. The condensed water vapor soaks into the siding and wets the paint. This problem is called cold-weather condensation and is a common cause of paint blistering and peeling. Discoloration patterns can also occur from the movement of water-soluble extratives out to the surface of paint.
By Construction Factors.—To avoid paint failure by cold-weather condensation, the following procedures are suggested:

1. Increase the resistance to the penetration of water vapor by using a vapor barrier and insulation in side walls.

2. If paint is peeling on gable ends, increase insulation and ventilation in the attic.

3. Relative humidity in the house should be reduced during cold weather.

By Penetrating Stain.—The most blister and peel resistant of all finishes are the semitransparent penetrating stains. These oil-based finishes are virtually blister- and peel-proof because they form no coating on the surface. The penetrating stains are therefore excellent finishes wherever a serious interior moisture condition is involved but must be applied to bare wood surfaces.

Controlling Effects of Organisms

Fungal organisms such as mold and mildew are a common cause of discoloration on wood and paint surfaces. Such growth usually does no serious damage to either house or finish system but it does detract from the appearance. It is also evidence, that moisture and temperature conditions may be favorable for the growth of other fungi which could cause decay. Many times it is difficult to distinguish between fungal staining and dirt collection. Usually an identification by microscopic examination is required to be certain of the fungal growth.

Fungi are most likely to grow on surfaces that remain wet for long periods of time. For this reason, it is not uncommon to see fungal growth on the exterior house paint which is wet by dew. These areas are usually the surfaces between studs where the surface cools quickly by radiation and the insulation in the wall between the studs prevents warming of the exterior surface with heat from inside the house. The painted area over studs and around nails, however, usually remains free of fungal growth because the area is warmed by heat from within.

Control of fungal staining and decay problems is achieved through either the selection of wood species that have a high natural resistance to decay or by the use of wood treated with a fungicide or water-repellent preservative. Where greater resistance is needed, liberal brush treatment or even pressure treatment with a preservative is advisable. Exterior wood trim, such as windows and doors, commonly made of pine sapwood, should always be treated with water-repellent preservatives before painting or staining. Treatment not only retards fungal growth in the paint but also reduces penetration of water at joints which accelerates paint peeling and decay in wood.

Fungal growth in finishes is controlled also by the addition of fungicides (mildewcides) to the finish. The use of fungicides in latex and flat alkyd-base paints is quite important because these paints, being porous,
will hold water on the surface which favors fungal growth. In severe conditions, paints which are pigmented with zinc oxide are recommended to control fungal growth.

The inhibition of fungal growth on wood surfaces is an effective method of achieving an attractive natural finish. Wood treated at regular intervals with a water-repellent preservative solution, remains free of graying by fungi and weathers to a light tan color which is natural in appearance.

APPLICATION OF WOOD FINISHES

Paint

Proper surface care and preparation before applying paint to wood is essential for good performance. Wood and wood-based products should be protected from the weather and wetting on the jobsite and after they are installed. Surface contamination from dirt, oil, and other foreign substances must be eliminated. It is best to paint wood surfaces as soon as possible, weather permitting, after installation.

To achieve maximum paint life, follow these steps:

1. Wood siding and trim should be treated with a paintable water-repellent preservative or water repellent. Water repellents protect the wood against the entrance of rain and dew and thus help to minimize swelling and shrinking. They can be applied by brushing or dipping. Lap and butt joints and the edges of panel products such as plywood, hardboard, and particleboard should be especially well treated because paint normally fails in these areas first. Allow at least 2 warm, sunny days for adequate drying before painting the treated surface. If the wood has been dip treated, allow at least 1 week of favorable weather.

2. After the water-repellent preservative or water repellent has dried, the bare wood must be primed. As the primer coat forms a base for all succeeding paint coats, it is very important. For woods with water-soluble extratives such as redwood and cedar, the best primers are good quality oil-based and alkyd-based paints. Some stain-blocking acrylic latex-based primer paints are now also available for use over these woods. The primer seals in the extratives so that they will not bleed through the top coat. A primer should be used whether the top coat is an oil-base or latex-base paint. For species which are predominantly sapwood and free of extratives, such as pine, a high-quality acrylic latex top coat paint may be used as both a primer and top coat. Enough primer should be applied to obscure the wood grain. Do not spread the primer too thinly. Follow the application rates recommended by the manufacturer. A primer coat that is uniform and of the proper thickness will distribute the swelling stresses which develop in wood and thus help to prevent premature paint failure.

3. Two coats of a good-quality acrylic latex house paint should be applied over the primer. If it is not practical to apply two topcoats to the entire house, consider two topcoats for fully exposed areas on the south and west sides as a minimum for good protection. Areas fully exposed to
sunshine and rain are the first to deteriorate and therefore should receive two coats. On those wood surfaces best suited for painting, one coat of a good house paint over a properly applied primer (a conventional two-coat paint system) should last 4 to 5 years, but two coats can last up to 10 years (Table 2).

4. One gallon of paint will cover about 400 square feet of smooth surface area. However, coverage can vary with different paints, surface characteristics, and application procedures. Research has indicated that the optimum thickness for the total dry paint coat (primer and two topcoats) is 3.5 to 5 mils or about the thickness of a sheet of newspaper. The quality of paint is usually, but not always, related to price. Brush application is always superior to roller or spray application, especially for the first coat.

To avoid future separation between paint coats, the first topcoat should be applied within 2 weeks after the primer and the second coat within 2 weeks of the first. As certain paints weather, they can form a soaplike substance on their surface which may prevent proper adhesion of new paint coats. If more than 2 weeks elapse before applying another paint coat, scrub the old surface with water using a bristle brush or sponge. If necessary, to remove all dirt and deteriorated paint, use a mild detergent then rinse well with water, and allow the surfaces to dry before painting.

To avoid temperature blistering, oil-base paints should not be applied on a cool surface that will be heated by the sun within a few hours. Temperature blistering is most common with thick paint coats of dark colors applied in cool weather. The blisters usually show up in the last coat of paint and occur within a few hours or up to 1 or 2 days after painting. They do not contain water.

Oil-base paint may be applied when the temperature is 40°F or above. A minimum of 50°F is desired for applying latex-based or waterborne paints. For proper curing of these latex paint films, the temperature should not drop below 50°F for at least 24 hours after paint application. Low temperatures will result in poor coalescence of the paint film and early paint failure.

To avoid wrinkling, fading, or loss of gloss of oil-base paints and streaking of latex paints, the paint should not be applied in the evenings of cool spring and fall days when heavy dews form during the night before the surface of the paint has thoroughly dried. Serious water absorption problems and major finish failure can also occur with some latex paints when applied under these conditions.

Solid Color Stains

Solid color stains may be applied to a smooth surface by brush, spray, or roller application; but brush application is best. These stains act much like paint. One coat of solid color stain is considered adequate for siding, but two coats will provide significantly better protection and longer service. These stains are not generally recommended for horizontal wood surfaces such as decks and window sills. Acrylic latex solid color stains are generally superior to all others.
Unlike paint, lap marks may form with a solid color stain. Latex-based stains are particularly fast-drying and are more likely to show lap marks than those with an oil base. To prevent lap marks, follow the procedures suggested under application of semitransparent penetrating stains.

Semitransparent Penetrating Stains

Semitransparent penetrating stains may be brushed, sprayed, or rolled on. Brushing will give the best penetration and performance. These solvent borne stains are generally thin and runny, so application can be messy. Lap marks may form if stains are improperly applied. They can be prevented by staining only a small number of boards or one panel at a time. This method prevents the front edge of the stained area from drying out before a logical stopping place is reached. Working in the shade is desirable because the drying rate is slower. One gallon will usually cover about 200 to 400 square feet of smooth surface and from 100 to 200 square feet of rough or weathered surface.

For long life with penetrating oil-base stain on rough sawn or weathered lumber, use two coats and apply the second coat before the first is dry. Apply the first coat to a panel or area in a manner to prevent lap marks. Then work on another area so that the first coat can soak into the wood for 20 to 60 minutes. Apply the second coat before the first coat has dried. (If the first coat dries completely, it may seal the wood surface so that the second coat cannot penetrate into the wood.) About an hour after applying the second coat, use a cloth, sponge, or dry brush lightly wetted with stain to wipe off the excess stain that has not penetrated into the wood. Otherwise stain areas which did not penetrate may form an unsightly surface film and glossy spots. Avoid intermixing different brands or batches of stain. Stir stain occasionally and thoroughly during application to prevent settling and color change.

CAUTION: Sponges or cloths that are wet with oil-base stain are particularly susceptible to spontaneous combustion. To prevent fires, bury them, immerse them in water, or seal them in an airtight metal container immediately after use.

A two-coat system on rough wood may last as long as 10 years in certain exposures due to the large amount of stain absorbed. By comparison, if only one coat of penetrating stain is used on new smooth wood, its life expectancy is 2 to 4 years; however, succeeding coats will last longer (Table 2).

Water Repellents

The most effective method of applying a water repellent or water-repellent preservative is to dip the entire board into the solution. However, brush treatment is also effective. When wood is treated in place, liberal amounts of the solution should be applied to all lap and butt joints, edges and ends of boards, and edges of panels where end grain occurs. Other areas especially vulnerable to moisture, such as the bottoms of doors and window frames, should not be overlooked. One gallon will cover about 250 square feet of smooth surface or 100 to 150 square feet of rough surface. The life expectancy is only 1 to 2 years as a natural finish, depending upon the wood and exposure. Treatments on rough surfaces are generally longer-
lived than those on smooth surfaces. Repeated brush treatment to the point of refusal will enhance durability and performance. Treated wood that is painted will not need re-treating unless the protective paint layer weathers away (Table 2).

FINISHING PORCHES AND DECKS

Exposed flooring on porches and decks is sometimes painted. The recommended procedure of treating with water-repellent preservative and primer is the same as for wood siding. After the primer, an undercoat (first top coat) and matching second top coat of porch and deck enamel should be applied. These paints are especially formulated to resist abrasion and wear.

Many fully exposed decks are more effectively finished with only a water-repellent preservative or a penetrating-type semitransparent pigmented stain. These finishes will need more frequent refinishing than painted surfaces, but this is easily done because there is no need for laborious surface preparation as when painted surfaces start to peel. Solid color stains should not be used on any horizontal surface such as decks because early failure may occur.

FINISHING TREATED WOOD

Wood pressure treated with waterborne chemicals, such as copper, chromium, and arsenic salts (CCA-treated wood) which react with the wood to form an insoluble residue, presents no major problem in finishing if the wood is properly redried and thoroughly cleaned after treating. Wood treated with solvent or oil-borne preservative chemicals, such as pentachlorophenol, is not considered paintable until all the solvents have evaporated. Solvents such as methylene chloride or liquified petroleum gas evaporate readily. When heavy oil solvents with low volatility are used to treat wood under pressure, successful painting is usually impossible. Even special drying procedures for wood pressure treated with the water-repellent preservative formulas that employ highly volatile solvents do not restore complete paintability.

Woods that have been pressure treated for decay or fire resistance sometimes have special finishing requirements. All the common pressure preservative treatments (creosote, pentachlorophenol, water-repellent preservatives, and waterborne) will not significantly change the weathering characteristics of woods. Certain treatments such as waterborne treatments containing chromium reduce the degrading effects of weathering. Except for aesthetic or visual reasons, there is generally no need to apply a finish to most preservative-treated woods. If needed, oil-base, semitransparent penetrating stains can be used but only after the preservative-treated (except waterborne) wood has weathered for 1 to 2 years depending on exposure. The only preservative-treated woods which can be painted or stained immediately after treatment and without further exposure are CCA-treated woods. The only requirement is that the wood be properly dried.
after treatment. Manufacturers generally have specific recommendations for good painting and finishing practices for fire-retardant and preservative-treated woods.

MARINE USES

The marine environment is particularly harsh on wood. The earlier discussion on wood weathering indicated that the natural surface deterioration process occurs slowly. Marine environments speed up the natural weathering process to some degree, and wood is often finished with paint or varnish for protection. Certain antifouling paints are also used for protection against marine organisms on piers and ship hulls.

For best protection, wood exposed to marine environments above water and above ground should be treated with a water-repellent preservative, painted with a suitable paint primer, and topcoated (at least two coats) with quality exterior products. Any wood in contact with water or the ground should be pressure treated to specifications recommended for inground or marine use. Such treated woods are not always paintable. As indicated earlier, the CCA-treated woods are paintable when dry and clean.

Natural finishes (varnishes) for marine-exposed woods need regular and frequent care and refinishing. Varnishes should be specially formulated for harsh exposure and be applied in three- to six-coat thicknesses for best performance.

SUMMARY

Film-forming finishes, such as paint, provide the most protection for wood against sunlight and offer the widest selection of colors. A nonporous paint film, is needed to retard the penetration of moisture and to reduce discoloration by wood extraves, paint peeling, and checking. Paint is not a preservative and will not prevent decay if conditions are favorable. Because a coating has been formed on the surface, failure by cracking, blistering, and peeling are possible for a paint finish. To achieve optimum performance, both the substrate and coating must be carefully selected and used on well designed and constructed structures that reduce the exposure of coating to a minimum of sunlight, moisture, and fungal organisms.

In contrast to the film-forming finishes are the penetrating-type finishes. Because there is no coating formed on the surface, there is no failure by cracking, peeling, and blistering. Quality of the substrate is not critical; it can be rough, smooth, weathered, knotty, flat grain, dense, porous, and of any species. The penetrating preservative and pigmented oil-base stains are low in cost, easily maintained, essentially trouble-free, and durable. Further, because peeling and blistering failures have been eliminated, the dependence of the finish on design and construction factors has been decreased.
Bibliography


The Forest Products Laboratory is maintained at Madison, Wis., in cooperation with the University of Wisconsin.
Figure 1.--Edge-grained (vertical-grained, quartersawed) board (A), and flat-grained (plainsawed) board (B) cut from a log.

(M 148 631)
<table>
<thead>
<tr>
<th>Finish</th>
<th>Initial treatment</th>
<th>Appearance of wood</th>
<th>cost of initial treatment</th>
<th>Maintenance procedure</th>
<th>Maintenance period of surface finish</th>
<th>Maintenance cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pressure, hot and cold tank steeping</td>
<td>Brushing</td>
<td>Grain visible. Brown to black in color, fading slightly with age</td>
<td>Medium</td>
<td>Brush down to remove surface dirt</td>
<td>5-10 years only if original color is to be renewed; otherwise no maintenance is required</td>
<td>Nil to low</td>
</tr>
<tr>
<td>Waterborne preservatives</td>
<td>Pressure, hot and cold tank steeping</td>
<td>Grain visible. Greenish in color, fading with age</td>
<td>Medium</td>
<td>Brush down to remove surface dirt</td>
<td>None, unless stained, painted, or varnished as below</td>
<td>Nil, unless, stains, varnishes, or paints are used. See below</td>
</tr>
<tr>
<td>Organic solvents preservatives</td>
<td>Pressure, steeping, dipping, brushing</td>
<td>Grain visible. Colored as desired</td>
<td>Low to medium</td>
<td>Clean and repaint</td>
<td>7-10 years</td>
<td>Medium</td>
</tr>
</tbody>
</table>

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Table 1. Exterior wood finishes: Types, treatment, and maintenance

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(Map 1 of 3)
<table>
<thead>
<tr>
<th>Finish</th>
<th>Initial treatment</th>
<th>Appearance of wood</th>
<th>cost of initial treatment</th>
<th>Maintenance procedure</th>
<th>Maintenance period of surface finish</th>
<th>Maintenance cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>Water repellent</td>
<td>One or two brush coats of clear material or, preferably, dip applied</td>
<td>Grain and natural color visible, becoming darker and rougher textured</td>
<td>Low</td>
<td>Clean and apply sufficient material</td>
<td>1-3 years or when preferred</td>
<td>Low to medium</td>
</tr>
<tr>
<td>Stains</td>
<td>One or two brush coats</td>
<td>Grain visible. Color as desired</td>
<td>Low to medium</td>
<td>do.</td>
<td>3-6 years or when preferred</td>
<td>Do.</td>
</tr>
<tr>
<td>Clear varnish</td>
<td>Four coats (minimum)</td>
<td>Grain and natural color unchanged if adequately maintained</td>
<td>High</td>
<td>Clean and stain bleached areas, and apply two more coats</td>
<td>2 years or when breakdown begins</td>
<td>High</td>
</tr>
</tbody>
</table>

Table 1 ----- Exterior wood finishes: Types, treatment, and maintenance—con.
Table 1 --- Exterior wood finishes: Types, treatment, and maintenance\(^1\)--con.

<table>
<thead>
<tr>
<th>Finish</th>
<th>Initial treatment</th>
<th>Appearance of wood</th>
<th>Cost of initial treatment</th>
<th>Maintenance procedure</th>
<th>Maintenance period of surface finish</th>
<th>Maintenance cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>Paint</td>
<td>Water repellent, prime, and two top-coats</td>
<td>Grain and natural color obscured</td>
<td>Medium to high</td>
<td>Clean and apply top-coat; or remove and repeat initial treatment if damaged</td>
<td>7-10 years(^4)</td>
<td>Medium</td>
</tr>
</tbody>
</table>

\(^1\)This table is a compilation of data from the observations of many researchers.

\(^2\)Pentachlorophenol, bis(tri-n-butyltin oxide), copper naphthenate, copper-8-quinolinolate, and similar materials.

\(^3\)With or without added preservatives. Addition of preservative helps control mildew growth.

\(^4\)Using top-quality acrylic latex topcoats.
Table 2 — Finishing methods for exterior wood surfaces: Suitability

<table>
<thead>
<tr>
<th>Type of exterior wood surfaces</th>
<th>Water-repellent preservative</th>
<th>Stains</th>
<th>Paints</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Suitability</td>
<td>Expected life</td>
<td>Suitability</td>
</tr>
<tr>
<td></td>
<td>Yr</td>
<td>Yr</td>
<td>Yr</td>
</tr>
<tr>
<td>Siding:</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cedar and redwood</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Smooth (vertical grain)</td>
<td>High</td>
<td>1-2</td>
<td>Moderate</td>
</tr>
<tr>
<td>Rough sawn or weathered</td>
<td>High</td>
<td>2-3</td>
<td>Excellent</td>
</tr>
<tr>
<td>Pine, fir, spruce, etc.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Smooth (flat grain)</td>
<td>High</td>
<td>1-2</td>
<td>Low</td>
</tr>
<tr>
<td>Rough (flat grain)</td>
<td>High</td>
<td>2-3</td>
<td>High</td>
</tr>
<tr>
<td>Shingles</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sawn</td>
<td>High</td>
<td>2-3</td>
<td>Excellent</td>
</tr>
<tr>
<td>Split</td>
<td>High</td>
<td>1-2</td>
<td>Excellent</td>
</tr>
<tr>
<td>Plywood (Douglas-fir and southern pine)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sanded</td>
<td>Low</td>
<td>1-2</td>
<td>Moderate</td>
</tr>
<tr>
<td>Textured (smooth)</td>
<td>Low</td>
<td>1-2</td>
<td>Moderate</td>
</tr>
<tr>
<td>Textured (rough sawn)</td>
<td>Low</td>
<td>2-3</td>
<td>High</td>
</tr>
<tr>
<td>Medium-density overlay&lt;sup&gt;5&lt;/sup&gt;</td>
<td>--</td>
<td>--</td>
<td>--</td>
</tr>
<tr>
<td>Plywood (cedar and redwood)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sanded</td>
<td>Low</td>
<td>1-2</td>
<td>Moderate</td>
</tr>
<tr>
<td>Textured (smooth)</td>
<td>Low</td>
<td>1-2</td>
<td>Moderate</td>
</tr>
<tr>
<td>Textured (rough sawn)</td>
<td>Low</td>
<td>2-3</td>
<td>Excellent</td>
</tr>
</tbody>
</table>

(Page 1 of 3)
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<tr>
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<th>Paints</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Suitability</td>
<td>Expected life'</td>
<td>Suitability</td>
</tr>
<tr>
<td></td>
<td>Yr</td>
<td></td>
<td>Yr</td>
</tr>
<tr>
<td>Hardboard, medium density'</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Smooth</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Unfinished</td>
<td>- -</td>
<td>--</td>
<td>- -</td>
</tr>
<tr>
<td>Preprimed</td>
<td>- -</td>
<td>--</td>
<td>- -</td>
</tr>
<tr>
<td>Textured</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Unfinished</td>
<td>- -</td>
<td>--</td>
<td>- -</td>
</tr>
<tr>
<td>Preprimed</td>
<td>- -</td>
<td>--</td>
<td>- -</td>
</tr>
<tr>
<td>Millwork (usually pine):</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Windows, shutters, doors,</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>exterior trim</td>
<td>High'</td>
<td>--</td>
<td>Moderate</td>
</tr>
<tr>
<td>Decking:</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>New (smooth)</td>
<td>High</td>
<td>1-2</td>
<td>Moderate</td>
</tr>
<tr>
<td>Weathered (rough)</td>
<td>High</td>
<td>2-3</td>
<td>High</td>
</tr>
</tbody>
</table>
Table 2 — Finishing methods for exterior wood surfaces: Suitability\(^1\) — con.

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<thead>
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<th>Stains</th>
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<tbody>
<tr>
<td></td>
<td>Suitability</td>
<td>Expected life(^2)</td>
<td>Suitability</td>
</tr>
<tr>
<td>Glued-laminated members:</td>
<td></td>
<td>Yr</td>
<td></td>
</tr>
<tr>
<td>Smooth</td>
<td>High</td>
<td>1-2</td>
<td>Moderate</td>
</tr>
<tr>
<td>Rough</td>
<td>High</td>
<td>2-3</td>
<td>High</td>
</tr>
<tr>
<td>Waferboard</td>
<td>--</td>
<td>--</td>
<td>Low</td>
</tr>
</tbody>
</table>

\(^1\)This table is a compilation of data from the observations of many researchers. Expected life predictions are for an average continental U.S. location; expected life will vary in extreme climates or exposure (desert, seashore, deep woods, etc.).

\(^2\)Development of mildew on the surface indicates a need for refinishing.

\(^3\)Smooth, unweathered surfaces are generally finished with only one coat of stain, but roughsawn or weathered surfaces, being more absorptive, can be finished with two coats, with the second coat applied while the first coat is still wet.

\(^4\)Expected life of two coats, one primer and one topcoat. Applying a second topcoat (three-coat job) will approximately double the life. Top-quality acrylic latex paints will have best durability.

\(^5\)Medium-density overlay is generally painted.

\(^6\)Semitransparent stains are not suitable for hardboard. Solid color stains (acrylic latex) will perform like paints. Paints are preferred.

\(^7\)Exterior millwork, such as windows, should be factory treated according to Industry Standard IS4-81. Other trim should be liberally treated by brushing before painting.