Chapter 15

Finishing of Wood

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Contents

The primary function of any wood finish (paint, varnish, and stain, for example) is to protect the wood surface, help maintain a certain appearance, and provide a cleanable surface. Although wood can be used both outdoors and indoors without finishing, unfinished wood surfaces exposed to the weather change color, are roughened by photodegradation and surface checking, and erode slowly. Unfinished wood surfaces exposed indoors may also change color; moreover, unfinished wood is more difficult to clean than is finished wood.

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 a finish will depend on the appearance and degree of protection desired and on the substrates used. Because different finishes give varying degrees of protection, the type of finish, its quality and quantity, and the method used to apply the finish must be considered when finishing or refinishing wood and wood products.

Factors Affecting Finish Performance

Satisfactory performance of wood finishes is achieved when the many factors that affect these finishes are given full consideration. These factors include the effect of the wood substrate, properties of the finishing material, details of application, and severity of exposure. Some important considerations are reviewed in this chapter. Sources of more detailed information are provided in a list of references at the end of this chapter.

Wood Properties

Wood surfaces that have the least tendency to shrink and swell are best for painting. For this reason, vertical- or edge-grain surfaces are far better than flat-grain surfaces (Fig. 15–1), especially when the wood is used outside where wide ranges of relative humidity and periodic wetting can produce wide ranges of swelling and shrinking. In addition, because the swelling of wood is directly proportional to specific gravity, species with low specific gravity are preferred to those with high specific gravity. Vertical-grain heartwood

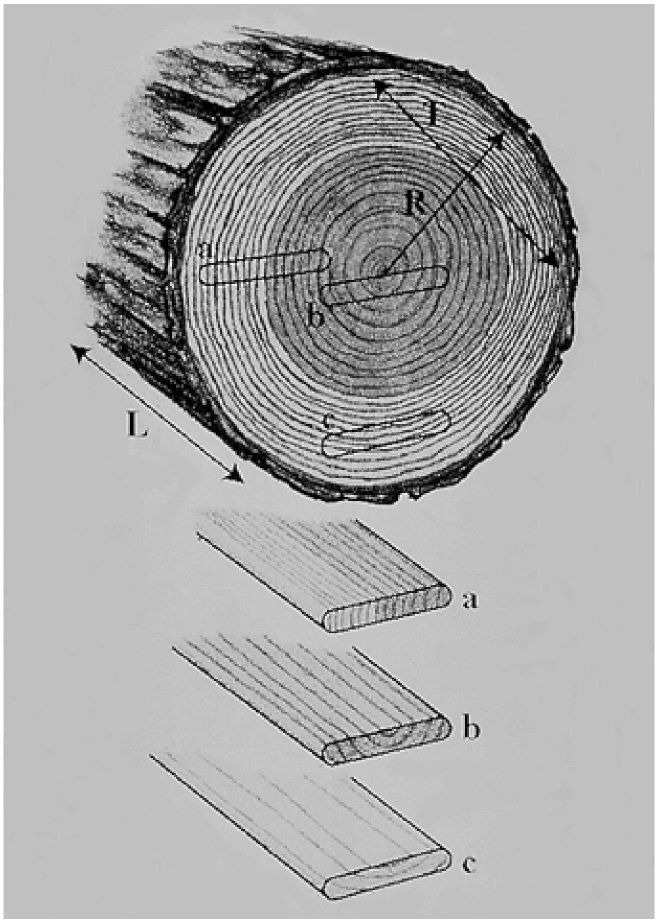

Figure 15–1. Lumber grain affects finish performance: (a) edge-grain (vertical-grain or quartersawn) board; (b) edge-grain board containing pith; (c) flat-grain (slash-grain or plainsawn) board. Arrows show radial (R), tangential (T), and longitudinal (L) orientation of wood grain.

of western redcedar and redwood are the species usually recommended for use as exterior siding and trim when painting is desired. These species are classified in Group I, woods with the best paint-holding characteristics (Table 15–1). Although vertical-grain surfaces of most species are considered excellent for painting, most species are generally available only as flat-grain lumber.

Very few wood species are graded according to vertical- or flat-grain specifications. Without a grade for marketing the lumber, there is no incentive for a mill to either cut to maximize the yield of vertical-grain lumber or to select vertical-grain lumber from the mill run. Exceptions are redwood and western redcedar, which are marketed in a range of grades, including vertical grain. The premium grade is all-heartwood and vertical-grain. This grade is usually sold as resawn bevel siding and it demands a high price; it is worthwhile for a mill to cut to maximize the yield of this grade. Most often, cutting is only practical with fairly large-diameter logs. For those species that are primarily available in small-diameter logs, the yield of vertical-grain lumber is small. It is not practical to cut the log to maximize the vertical grain because such cutting would substantially decrease overall yield from the log.

Species normally cut as flat-grain lumber that are high in specific gravity and swelling, or have defects such as knots or pitch, are classified in Groups II through V, depending upon their general paint-holding characteristics. Many species in Groups II through IV are commonly painted, particularly the pines, Douglas-fir, and spruce; however, these species generally require more careful surface preparation than do the vertical-grain (also called edge-grain) surfaces of Group I. Exterior paint will be more durable on vertical-grain boards than on flat-grain boards for any species with marked differences in specific gravity between earlywood and latewood, even if the species are rated in Group I (Fig. 15–2). Flat-grain lumber will hold paint reasonably well if it is used in areas protected from rain and sun, particularly if the wood is rough sawn or scuff sanded.

Other wood properties that affect wood finishing are defects such as knots and colored materials (extractives) in the wood. These colored materials include a wide range of chemicals with different solubilities in water, organic solvents, and paint polymers. Their effects on wood finishing are covered in detail later in this chapter. See Chapters 1 to 3 for more detailed information on wood properties.

Wood Extractives

Water-soluble colored extractives occur naturally in the heartwood of such species as western redcedar, cypress, and redwood. These substances give the heartwood of some species their attractive color, water repellency, and natural decay resistance. However, discoloration of paint may occur when the extractives are dissolved and leached from the wood by water. The water carries the extractives to the painted surface, then evaporates, leaving the extractives as a yellow to reddish brown stain on the paint. The water that gets behind the paint and causes moisture blisters also causes migration of extractives.

Wood also contains resins and oils that are insoluble in water. The type and amount of these compounds in lumber depend on the wood species. For example, many pines contain pitch and the knots of almost all wood species contain sufficient oils and resins to cause discoloration of light-colored paint. Since these oils and resins are organic in nature, they are similar chemically to oil-based and/or alkyd paints; therefore, they cannot be blocked by typical oilborne stain-blocking primers as can the water-soluble extractives. Latex-based formulations are also ineffective. Knots can be sealed prior to priming with shellac or similar finishes specifically formulated to block oils and resins. Because shellac is sensitive to moisture, it is essential to use it only over the knots and to seal it into the knots with a good paint system. In many species, bleeding of oils and resins from knots is a difficult problem. At present, there is no easy fix other than the extra step of sealing knots before priming.

Table 15–1. Characteristics of selected woods for painting

Wood species	Specific gravity[a] green/dry	Shrinkage (%)[b] Flat grain	Shrinkage (%)[b] Vertical grain	Paint-holding characteristic (I, best; V, worst)[c] Oil-based paint	Paint-holding characteristic (I, best; V, worst)[c] Latex paint	Weathering: Resistance to cupping (1, most; 4, least)	Weathering: Conspicuousness of checking (1, least; 2, most)	Color of heartwood
Softwoods								
Baldcypress	0.42/0.46	6.2	3.8	I	I	1	1	Light brown
Cedars								
Incense	0.35/0.37	5.2	3.3	I	I	—	—	Brown
Northern white	0.29/0.31	4.9	2.2	I	I	—	—	Light brown
Port-Orford	0.39/0.43	6.9	4.6	I	I	—	1	Cream
Western red	0.31/0.32	5	2.4	I	I	1	1	Brown
Yellow	0.42/0.44	6	2.8	I	I	1	1	Yellow
Douglas-fir[d]	0.45/0.48[e]	7.6	4.8	IV	II	2	2	Pale red
Larch, western	0.48/0.52	9.1	4.5	IV	II	2	2	Brown
Pine								
Eastern white	0.34/0.35	6.1	2.1	II	II	2	2	Cream
Ponderosa	0.38/0.42	6.2	3.9	III	II	2	2	Cream
Southern[d]	0.47/0.51[f]	8	5	IV	III	2	2	Light brown
Sugar	0.34/0.36	5.6	2.9	II	II	2	2	Cream
Western white	0.36/0.38	7.4	4.1	II	II	2	2	Cream
Redwood, old growth	0.38/0.40	4.4	2.6	I	I	1	1	Dark brown
Spruce, Engelmann	0.33/0.35	7.1	3.8	III	II	2	2	White
Tamarack	0.49/0.53	7.4	3.7	IV	—	2	2	Brown
White fir	0.37/0.39	7.0	3.3	III	—	2	2	White
Western hemlock	0.42/0.45	7.8	4.2	III	II	2	2	Pale brown
Hardwoods								
Alder	0.37/0.41	7.3	4.4	III	—	—	—	Pale brown
Ash, white	0.55/0.60	8	5	V or III	—	4	2	Light brown
Aspen, bigtooth	0.36/0.39	7	3.5	III	II	2	1	Pale brown
Basswood	0.32/0.37	9.3	6.6	III	—	2	2	Cream
Beech	0.56/0.64	11.9	5.5	IV	—	4	2	Pale brown
Birch, yellow	0.55/0.62	9.5	7.3	IV	—	4	2	Light brown
Butternut	0.36/0.38	6.4	3.4	V or III	—	—	—	Light brown
Cherry	0.47/0.50	7.1	3.7	IV	—	—	—	Brown
Chestnut	0.40/0.43	6.7	3.4	V or III	—	3	2	Light brown
Cottonwood, eastern	0.37/0.40	9.2	3.9	III	II	4	2	White
Elm, American	0.46/0.50	9.5	4.2	V or III	—	4	2	Brown
Hickory, shagbark	0.64/0.72	11	7	V or IV	—	4	2	Light brown
Lauan plywood	—[g]	8	4	IV	—	2	2	Brown
Magnolia, southern	0.46/0.50	6.6	5.4	III	—	2	—	Pale brown
Maple, sugar	0.56/0.63	9.9	4.8	IV	—	4	2	Light brown
Oak								
White	0.60/0.68	8.8	4.4	V or IV	—	4	2	Brown
Northern red	0.56/0.63	8.6	4.0	V or IV	—	4	2	Brown
Sweetgum	0.46/0.52	10.2	5.3	IV	III	4	2	Brown
Sycamore	0.46/0.49	8.4	5	IV	—	—	—	Pale brown
Walnut	0.51/0.55	7.8	5.5	V or III	—	3	2	Dark brown
Yellow-poplar	0.40/0.42	8.2	4.6	III	II	2	1	Pale brown

[a]Specific gravity based on weight ovendry and volume at green or 12% moisture content.
[b]Value obtained by drying from green to ovendry.
[c]Woods ranked in Group V have large pores that require wood filler for durable painting. When pores are properly filled before painting, Group II applies. Vertical-grain lumber was used for cedars and redwood. Other species were primarily flat-grain. Decrease in paintability is caused by a combination of species characteristics, grain orientation, and greater dimensional change of flat-grain lumber. Flat-grain lumber causes at least 1 unit decrease in paintability.
[d]Lumber and plywood.
[e]Coastal Douglas-fir.
[f]Loblolly, shortleaf, specific gravity of 0.54/0.59 for longleaf and slash.
[g]Specific gravity of different species varies from 0.33 to 0.55.

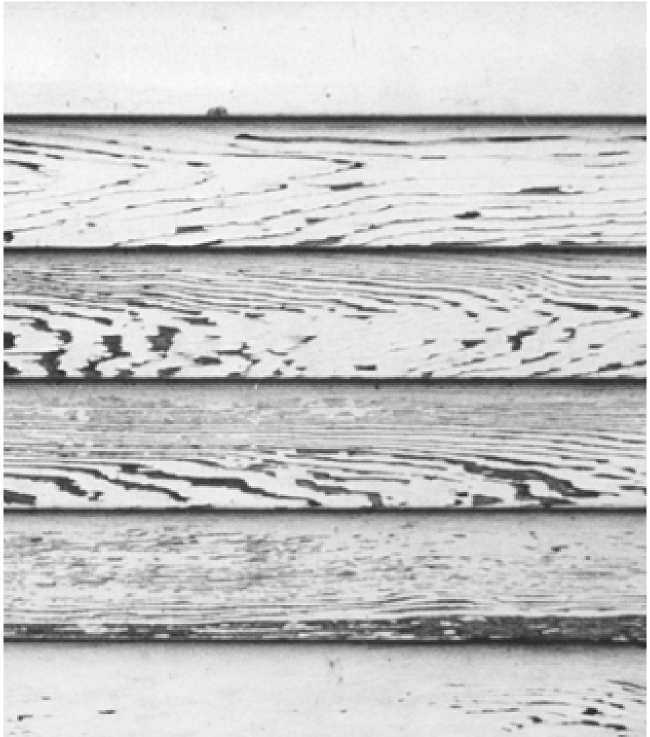

Figure 15–2. Paint applied over edge-grain boards (top and bottom) performs better than that applied to flat-grain boards (middle).

Wood Product Characteristics

Five general categories of wood products are commonly used in exterior construction: (a) lumber, (b) plywood, (c) finger-jointed wood, (d) reconstituted wood products (such as hardboard, oriented strandboard (OSB), and particleboard), and (e) preservative–fire-retardant-treated wood. Each product has unique characteristics that affect the application and performance of finishes.

Lumber

Although several alternative materials are being used for siding (such as vinyl, aluminum, OSB, and hardboard), lumber is still the preferred choice for siding in many areas of the country and for a variety of architectural designs. Many older homes have wood siding. The ability of lumber to retain and hold a finish is affected by species, grain orientation, and surface texture.

The specific gravity of wood varies tremendously among wood species (Table 15–1). The specific gravity of wood is important because denser woods generally shrink and swell more than less dense woods. In lumber, this dimensional change occurs as the wood gains or loses moisture. Excessive dimensional change in wood constantly stresses a paint film and may cause early paint failure. If two species have the same specific gravity but shrink and swell differently, their paintability will be greatly affected by dimensional changes. For example, redwood and western white pine have about the

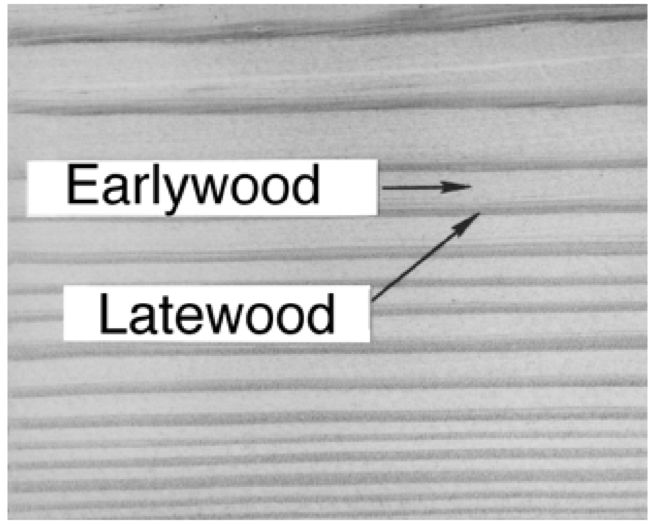

Figure 15–3. Earlywood and latewood bands in Southern Pine.

same specific gravity (0.38), but their shrinkage values for flat- and vertical-grain wood are different (4.4% and 2.6% for redwood and 7.4% and 4.1% for western white pine, respectively) (Table 15–1). Redwood has a paintability rating of I and western white pine, a rating of II. The greater dimensional instability of the flat-grain western white pine results in lower paintability compared with that of the vertical-grain redwood.

The shrinkage values given in Table 15–1 were obtained from drying wood from its green state to ovendry. The swelling rates would be about the same. The paintability values for western redcedar and redwood were obtained from vertical-grain lumber; other species were primarily flat-grain. Note that the shrinkage values for vertical-grain lumber are about half that of flat-grain lumber. The paintability rating for flat-grain lumber is probably at least one unit lower than that for vertical-grain lumber. The values given in Table 15–1 for oil-based paints were obtained from research conducted in the 1930s and 1940s using lumber from large-diameter logs. It is not known how the properties of lumber from small-diameter logs and new paint formulations would affect these ratings. Therefore, the ratings given in Table 15–1 should be used to rank paintability rather than obtain absolute paintability values.

Some species have wide bands of earlywood and latewood (Fig. 15–3). These distinct bands often lead to early paint failure. Wide, prominent bands of latewood are characteristic of the southern pines and Douglas-fir, and paint will not hold well on these species. In contrast, redwood and cedar do not have wide latewood bands, and these species are preferred for painting.

Grain orientation also affects paint-holding characteristics and is determined by the way lumber is cut from a log (Fig. 15–1). Most standard grades of lumber contain a high percentage of flat-grain lumber. Lumber used for board and batten, drop, or shiplap siding is frequently flat-grain. Bevel siding is commonly produced in several grades. The highest grade of redwood and western redcedar bevel siding is vertical-grain all-heartwood. Other grades of redwood and western redcedar may be flat, vertical, or mixed grain and may not be required to be all-heartwood.

The texture (roughness or smoothness) of the wood surface has an important effect on the selection, application, and service life of finishes. Until recently, a general rule of thumb for matching substrates to finishes was to paint smooth wood and stain rough-sawn wood. This easy rule of thumb no longer applies. Although it is true that penetrating finishes such as semitransparent stains give much better service life on rough-sawn wood compared with smooth wood, many film-forming finishes such as opaque stains and paints also give much better service life on rough-sawn wood. The paint adheres better, the film buildup is better, and the service life is longer on a roughened than a smooth (planed) surface, particularly when flat-grain lumber or siding is used. Surface texture is discussed in more detail in later sections of this chapter.

Plywood

As with lumber, species, grain orientation, and surface texture are important variables that affect the finishing of plywood. In addition, plywood contains small checks (face checks) that are caused by the lathe when the veneer is cut during plywood manufacture. Cycles of wetting and drying with subsequent swelling and shrinking tend to worsen face-checking of plywood veneer. Face checking sometimes extends through paint coatings to detract from the appearance and durability of the paint. Face checks can lead to early paint failure, particularly with oil or alkyd paint systems (Fig. 15–4). Latex primer and top coat paint systems generally perform better than oil or alkyd systems. For use as exterior siding, plywood is often overlaid with resin-treated paper (medium-density overlay (MDO)); MDO eliminates cracks caused by lathe checking and provides plywood with excellent paintability (equal to or better than that of Group I vertical-grain lumber).

Plywood for exterior use nearly always has a flat-grain surface, and if it is used for exterior wood siding, the surface is rough sawn. Smooth-sanded plywood is not recommended for siding, although it is often used for soffits. The flat-grain pattern in nearly all plywood can contribute to early paint failure. Therefore, if plywood is to be painted, take special care to prepare the surface and use high quality latex paint. Rough-sawn plywood holds paint much better than does smooth plywood. Smooth plywood should be scuff-sanded with 50-grit sandpaper prior to priming, and both smooth and rough plywood should be edge-treated with a water-repellent preservative. Penetrating stains are often more appropriate for rough-sawn than smooth-sawn exterior plywood surfaces.

Fingerjointed Lumber

In recent years, many mills have been producing lumber that consists of many small pieces of wood that are glued together and have fingerjoints to improve strength (Chs. 9 and 11). This process is done to eliminate knots and other defects from the lumber. The lumber is commonly used for fascia boards, interior and exterior trim, windows and doors, and siding. Although fingerjointed lumber contains no knots or other defects, the wood pieces are generally not sorted in regard to heartwood or sapwood or to grain orientation prior to gluing. However, with some suppliers, care is taken to decrease variability in fingerjointed lumber. For example, fingerjointed redwood siding is available in Clear All Heart vertical grain and Clear flat grain. Fingerjointed lumber is usually sold as a particular species, although this is not always the case. Because a particular board may contain pieces from many trees and in many grain orientations, the finishing requirements are determined by the worst piece of wood in a single board. It is quite common for paint failure to occur in a “patchwork” manner according to the paintability of the particular piece of wood in the board (Fig. 15–5). The finishing of fingerjointed lumber requires special care to ensure that the finish will adhere to the whole board. Rough-sawn lumber should hold paint better than will planed lumber. Planed wood should be scuff-sanded with 50-grit sandpaper prior to priming.

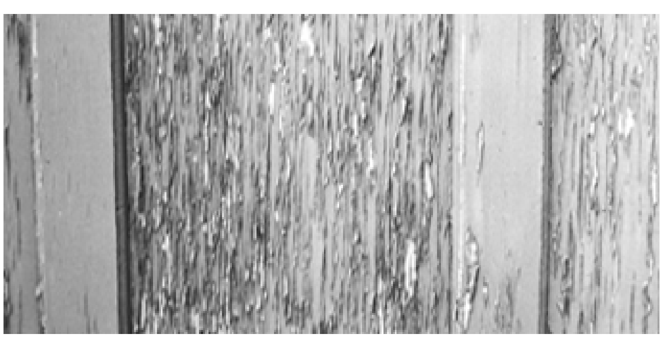

Figure 15–4. Early paint failure on plywood caused by penetration of moisture into surface face-checks.

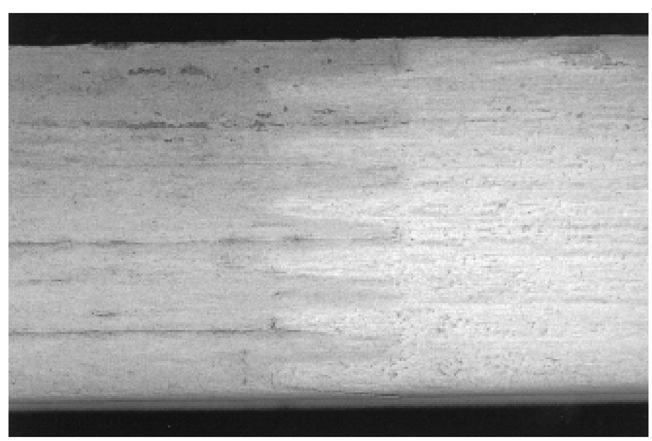

Figure 15–5. Differences in stain from extractives on fingerjointed yellow pine (probably ponderosa pine) painted with acrylic solid-color stain.

Particleboard and Similar Reconstituted Wood Products

Reconstituted wood products are those made by forming small pieces of wood into large sheets, usually 1.2 by 2.4 m (4 by 8 ft) or as required for a specialized use such as clapboard siding. These products may be classified as fiberboard or particleboard, depending upon the nature of the basic wood component (see Ch. 10).

Although wood characteristics such as grain orientation, specific gravity of earlywood and latewood, warping, and splitting are not considerations with reconstituted wood products, other characteristics must be addressed when finishing these products. The surface of fiberboard accepts and holds paint very well, and it can be improved with the addition of a resin-treated paper overlay. Film-forming finishes such as paints and solid-color stains will provide the most protection to reconstituted wood products. Some reconstituted wood products may be factory primed with paint, and factory-applied top-coats are becoming more common. The edges of these products are sensitive to moisture, and extra care should be used to assure that edges get a good coat of paint. Better yet, edges can be sealed with a paintable water-repellent preservative. Reconstituted wood products should not be finished with semitransparent stain or other penetrating finishes.

Fiberboard is produced from wood that is pulped by mechanical means. Hardboard is a relatively heavy type of fiberboard. The tempered or treated form of hardboard is designed for outdoor exposure and is used for exterior siding. Hardboard is often sold in 1.2- by 2.4-m (4- by 8-ft) sheets and in 152- to 203-mm (6- to 8-in.) widths as a substitute for solid-wood beveled siding.

Particleboard is manufactured from whole wood in the form of splinters, chips, flakes, strands, or shavings. Flakeboard is a type of particleboard made from relatively large flakes or shavings. Oriented strandboard (OSB) is a refinement of flakeboard in that the flakes have a large length-to-width aspect ratio and are laid down in layers, with the flakes in each layer oriented 90° to each other as are veneers in plywood (Ch. 10). Particleboard that is to be used outdoors must be overlaid with either wood veneer or resin-treated paper; exterior particleboard can be finished in the same way as are other paper over-laid products. As with fiberboard, special care must taken to assure a good paint film on the edges of particleboard.

Treated Wood

Wood used in severe outdoor exposures requires special treatment for proper protection and best service. The most common hazard in such exposures is decay (rot) and insect attack, particularly by termites. Marine exposure also requires wood to be protected with special treatment. Many building codes require fire-retardant treatment of wood for some uses.

When wood is used in situations with high decay and termite hazards, it is usually treated with a wood preservative. The three main types of preservatives are (a) preservative oils (such as coal–tar creosote), (b) organic solvent solution (such as pentachlorophenol), and (c) waterborne salts (such as chromated copper arsenate (CCA)) (Ch. 14). These preservatives can be applied in several ways, but pressure treatment generally provides the greatest protection against decay. Wood preservatives may also improve the wood's resistance to weathering, particularly if the preservative contains chromium salts. Chromium-containing preservatives protect wood against ultraviolet degradation, an important factor in the weathering process.

Wood treated with waterborne preservatives, such as CCA, can be painted or stained if the wood is clean and dry. Wood treated with a water-repellent preservative, by vacuum-pressure or dipping, is paintable. Wood treated with coal–tar creosote or other dark oily preservatives is not paintable; even if the paint adheres to the treated wood, the dark oils tend to discolor the paint, especially light-colored paint.

Fire-retardant treatment of wood does not generally interfere with adhesion of paint coatings, unless the treated wood has extremely high moisture content because of its increased hygroscopicity. Fire-retardant-treated wood is generally painted according to the manufacturer's recommendations rather than left unfinished because the treatment and subsequent drying often darken and discolor the wood. It is critical that wood to be used outside be treated with only those fire-retardant treatments that are specifically recommended for outdoor exposure.

Weathering

Weathering is the general term used to describe the degradation of materials exposed outdoors. This degradation occurs on the surface of all organic materials, including wood and finishes used on wood such as paints and stains. The process occurs through photo-oxidation of the surface catalyzed by ultraviolet (UV) radiation in sunlight, and it is augmented by other processes such as washing by rain, changes in temperature, changes in moisture content, and abrasion by windblown particles. The weathering process can take many forms depending on the exposed material; in general, the process begins with a color change, followed by slow erosion (loss of material) from the surface. The surface initially develops slight checking; with some materials, deep cracks may ultimately develop. Weathering is dependent on the chemical makeup of the affected material. Because the surface of a material may be composed of many different chemicals, not all materials on the surface may erode at the same rate.

Effect on Wood

The surface of wood consists of four types of organic materials: cellulose, hemicellulose, lignin, and extractives. Each of these materials is affected by the weathering process in a different way. The extractives (that is, the material in the wood that gives each species its distinctive color) undergo changes upon exposure to sunlight and lighten or darken in color. With some wood species, this color change can take place within minutes of exposure. Changes in the color of the surface are accompanied by other changes that affect the wettability and surface chemistry of the wood. The mechanism of these early changes is not very well understood, but these changes can have a drastic effect on the surface chemistry of wood and thus the interaction of the wood with other chemicals, such as paint and other finishes.

From 20% to 30% of the wood surface is composed of lignin, a polymeric substance that is the adhesive that holds wood celluloses together. Because lignin is affected by photodegradation more than are celluloses, lignin degrades and cellulose fibers remain loosely attached to the wood surface. Further weathering causes fibers to be lost from the surface (a process called erosion); but this process is so slow that on the average only about 6 mm (1/4 in.) of wood is lost in a century (Fig. 15–6). This erosion rate is slower for most hardwoods and faster for certain softwoods. Other factors like growth rate, degree of exposure, grain orientation, temperature, and wetting and drying cycles are important in determining the rate of erosion. Table 15–2 shows erosion rates for several wood species that were measured over a 16-year period.

Water and the swelling and shrinking stresses set up by fluctuations in moisture content accelerate erosion. Cyclic wetting and drying roughen the surface, raise the grain, cause differential swelling of earlywood and latewood bands, and result in many small, parallel checks and cracks. Larger and deeper cracks may also develop. Fewer checks develop in woods with moderate to low specific gravity than in those with high specific gravity, and vertical-grain boards have fewer checks than do flat-grain boards. Flat-grain lumber frequently warps as well.

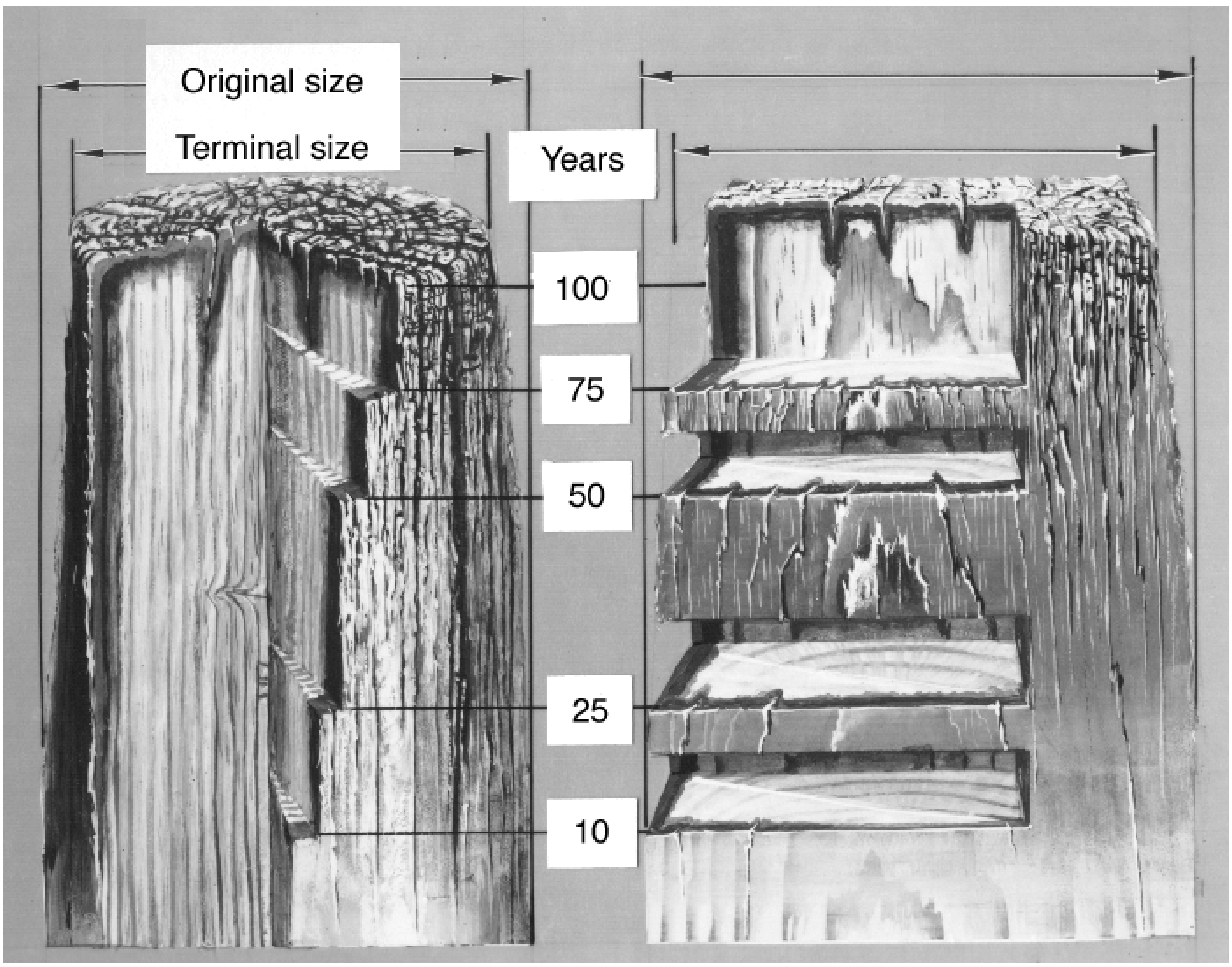

Figure 15–6. Artist's rendition of weathering process of round and square timbers. As cutaway shows, interior wood below surface is relatively unchanged.

Table 15–2. Erosion of earlywood and latewood on smooth planed surfaces of various wood species after outdoor exposure[a]

Wood species	Avg SG[b]	Erosion (µm) after various exposure times[c]											
		4 years		8 years		10 years		12 years		14 years		16 years	
		LW	EW	LW	EW	LW	EW	LW	EW	LW	EW	LW	EW
Western redcedar plywood	—	170	580	290	920	455	1,095	615	1,165	805	1,355	910	1,475
Redwood plywood	—	125	440	295	670	475	800	575	965	695	1,070	845	1,250
Douglas-fir plywood	—	110	270	190	390	255	500	345	555	425	770	515	905
Douglas-fir	0.46	105	270	210	720	285	905	380	980	520	1,300	500	1,405
Southern Pine	0.45	135	320	275	605	315	710	335	710	445	1,180	525	1,355
Western redcedar	0.31	200	500	595	1,090	765	1,325	970	1,565	1,160	1,800	1,380	1,945
Redwood	0.36	165	405	315	650	440	835	555	965	670	1,180	835	1,385
Loblolly pine	0.66	80	205	160	345	220	490	—	—	—	—	—	—
Western redcedar	0.35	115	495	240	1,010	370	1,225	—	—	—	—	—	—
Southern Pine	0.57	95	330	180	640	195	670	—	—	—	—	—	—
Yellow-poplar	0.47	—	220	—	530	—	640	—	—	—	—	—	—
Douglas-fir	0.48	75	255	175	605	225	590	—	—	—	—	—	—
Red oak	0.57	180	245	340	555	440	750	—	—	—	—	—	—
Ponderosa pine	0.35	130	270	315	445	430	570	Decay	Decay	Decay	Decay	—	—
Lodgepole pine	0.38	105	255	265	465	320	580	475	745	560	810	—	—
Engelmann spruce	0.36	125	320	310	545	390	650	505	795	590	950	—	—
Western hemlock	0.34	145	320	310	575	415	680	515	1,255	600	1,470	—	—
Red alder	0.39	—	295	—	545	—	620	—	920	—	955	—	—

[a]Data from three studies are shown. Specimens were exposed vertically facing south. Radial surfaces were exposed with the grain vertical.
[b]SG is specific gravity.
[c]All erosion values are averages of nine observations (three measurements of three specimens). EW denotes earlywood; LW, latewood.

The time required for wood to become fully weathered depends on the severity of the exposure. Once weathered, and in the absence of decay, stain, and mildew, wood remains nearly unaltered in appearance (Fig. 15–7). As a result of weathering, boards tend to warp (particularly cup) and fasteners are loosened. The tendency to cup varies with the specific gravity, width, and thickness of the board. The greater the specific gravity and the greater the width in proportion to thickness, the greater the tendency to cup. For best resistance to cup, the width of a board should not exceed eight times its thickness. Warping also is more pronounced in flat-grain boards than in vertical-grain boards.

Biological attack of a wood surface by microorganisms is recognized as a contributing factor to color change or graying of wood. This biological attack, commonly called mildew, does not cause erosion of the surface, but it may cause initial graying or an unsightly dark gray and blotchy appearance. These color changes are caused by dark-colored fungal spores and mycelia on the wood surface. In advanced stages of weathering, when the surface has been enriched by cellulose, it may develop a silvery-gray sheen. This formation of a bright, light gray, silvery sheen on weathered wood occurs most frequently where micro-organism growth is inhibited by a hot, arid climate or a salty atmosphere in coastal regions. The microorganisms primarily responsible for gray discoloration of wood are commonly found on weathered wood (see subsection on mildew under Finish Failure or Discoloration).

Effect on Paint Adhesion

Although the erosion of the wood surface through weathering is a slow process, the chemical changes that occur within a few weeks of outdoor exposure can drastically decrease the adhesion of paints subsequently applied to the weathered surface. It is fairly obvious that a badly weathered, powdery wood surface cannot hold paint very well. This fact is not so obvious for wood that has weathered for only 2 to 3 weeks. The wood appears sound and much the same as when it was installed. The extent of damage to the wood surface after such a short exposure has yet to be determined. However,

Figure 15–7. Weathered surfaces of softwood after 15 years of exposure in Madison, Wisconsin.

long-term outdoor exposure of panels that had been preweathered for 1, 2, 4, 8, or 16 weeks before being painted showed a direct relationship between preweathering time and the time when the paint started to peel. For panels that had been preweathered for 16 weeks, the paint peeled within 3 years; for panels preweathered for only 1 week, the paint peeled after 13 years. Panels that were not preweathered showed no sign of peeling after 13 years. The paint system was a commercial oil–alkyd primer with two acrylic latex top-coats over planed all-heartwood vertical-grain western redcedar.

Several other wood species were tested in addition to western redcedar. In general, there was a direct relationship between wood specific gravity and amount of time the wood could be exposed without a deleterious effect on paint performance. More dense wood species such as Douglas-fir and the southern pines showed no preweathering effect until they had been preweathered for 3 to 4 weeks. For species with low specific gravity, it is essential to finish the wood as soon as possible after installation, or better yet, to preprime it before installation. The wood could be back-primed at the same time (see section on back-priming).

The best remedy for restoring a weathered wood surface is to sand it with 50- to 80-grit sandpaper. Sanding can easily be done by hand using a sheet rock sander. This tool consists of a sanding pad attached to a pole with a swivel connection. Large areas of siding can be quickly scuff-sanded to remove the weathered surface. Even if wood has not been weathered, scuff sanding provides a much better surface for painting, increases the service life of the paint, and improves the paint bond.

Effect on Wood Finishes

Finishes used on wood also undergo surface photodegradation because the primary ingredient that holds a paint film together or seals the wood surface is an organic polymer and thus is susceptible to photo-oxidative degradation. The UV radiation in sunlight breaks down the polymer in paint, causing a slow erosion similar to that which occurs on wood. The pigments in paint are not usually affected by UV radiation. Therefore, as film-forming finishes such as paints or solid-color stains weather, they do so by the slow breakdown of the polymer, which loosens the pigments. The surface becomes chalky because of the loose pigments. Eventually, these pigments and the degraded polymer erode from the surface. The rate of weathering primarily depends on the resistance of the polymer to UV radiation. Paints and stains based on acrylic polymers are more UV-resistant than those based on oil and oil–alkyds. Weathering is strictly a surface phenomenon on the finish, and as with wood, a painted surface can be attacked by mildew.

Control of Water or Moisture in Wood

Moisture Content

The moisture content of wood is the amount of water contained in the wood (see Ch. 3). Moisture content includes both water absorbed into the wood cell wall and free water within the hollow center of the cell, and it is expressed as a weight percentage. The amount of water that wood can absorb (that is, that can be bound in the cell wall) depends on the wood species; most species can absorb about 30% water. This limit to the amount of water that can be bound in the wood cell wall is called the fiber saturation point. Wood can reach the fiber saturation point by absorbing either liquid water or water vapor.

The amount of water vapor that can be absorbed primarily depends on the relative humidity (RH) of the surrounding air. If wood is stored at zero RH, the moisture content will eventually reach 0%. If wood is stored at 100% RH, it will eventually reach fiber saturation (about 30% water). Of course, if kept at a constant RH between these two extremes, the wood will reach a moisture content between 0 and 30%. The moisture content is controlled by the RH, and when the moisture content is in balance with the RH, the wood is at its equilibrium moisture content. This rarely happens because as the RH changes so does the moisture content of the wood, and atmospheric RH is almost always changing. It varies through daily and seasonal cycles, thus driving the moisture content of wood through daily and seasonal cycles. See Chapter 3 for a more detailed discussion of moisture content and equilibrium moisture content.

Equilibrium moisture content cannot be changed through the application of finishes. The only way that finishes can affect absorption of water or water vapor is to affect the rate at which absorption occurs. Finishes can decrease daily and seasonal moisture absorption and desorption, but they do not change the equilibrium moisture content. See the section on moisture-excluding effectiveness of finishes for discussion of this topic.

Wood exposed outdoors cycles around a moisture content of about 12% in most areas of the United States. In the Southeast, average moisture content can be slightly higher and in the Southwest, the average can be lower (9%) (Ch. 12, Table 12–1). Daily and annual moisture content will vary from these average values. In general, for wood exposed outdoors, moisture content decreases during the summer and increases during the winter. (For wood in interior use in northern climates, moisture content increases during the summer and decreases during the winter.) Even in very humid areas, the RH is rarely high enough for long enough to bring the moisture content of wood above 20%. Wood that is warmed by the sun experiences a virtual RH far below the ambient RH. Wood will dry faster and become drier than expected given the ambient RH. This is why checking often occurs on decking boards; the surface is much drier than the rest of the board. Shrinkage of the top portion of the board commensurate with this dryness goes beyond the elastic limit of the wood at the surface and checks form parallel to the grain.

As mentioned, fiber saturation is the greatest amount of water that can be absorbed by wood via water vapor absorption. This absorption is rather slow compared with the moisture changes that can occur through absorption of liquid water. Liquid water can quickly cause the wood to reach fiber saturation, and it is the only way to bring the moisture content of wood above fiber saturation. Liquid water must be present. Liquid water can reach wood through windblown rain, leaks, condensation, dew, melting ice and snow, and other ways. As wood continues to absorb water above its fiber saturation point, the water is stored in the hollow center of the wood cell; when all the air in the hollow center has been replaced by water, the wood is waterlogged and moisture content can be as high as 200%. The sources and ways by which wood can get wet sometimes seem endless. The result is always the same—poor performance, both of the wood and of the finish.

Wood decay (rot) cannot occur unless the moisture content of the wood is near fiber saturation. This requires water. Water also causes peeling of paint. Even if other factors are involved, water accelerates paint degradation. Fortunately, the moisture content of lumber can be controlled. But all too often, this critical factor is neglected during the construction and finishing processes. It is best to paint wood when its average moisture content is about that expected to prevail during its service life. Painting at this time can prevent a drastic change in wood dimension, which occurs as wood equilibrates to ambient conditions. The moisture content and thus the dimensions of the piece will still fluctuate somewhat, depending on the cyclic changes in atmospheric RH, but the dimensional change will not be excessive. Therefore, film-forming finishes (such as paints) will not be stressed unnecessarily, and service life should be better.

The recommended moisture content for wood used in exterior applications varies somewhat depending on climatic conditions. These conditions include, but are not limited to, coastal exposure, rainfall, elevation, and wind. However, problems associated with changes in moisture content should be minimized if the moisture content is between 9% and 14%. Most lumber is kiln dried to less than 20% moisture content before shipment. Material that has been kept dry during shipment and storage at the construction site should be close to the desired moisture content.

Lumber is often marketed for construction purposes in the kiln-dried condition, but it is sometimes exposed to moisture later during shipping, storage, and/or at the construction site. Wood that is obviously wet and sometimes discolored may not give optimum performance. If wet wood is used, it will dry in service, but shrinkage and accompanying warping, twisting, and checking can occur. If the moisture content of the wood exceeds 20% when the wood is painted, the risk of blistering and peeling is increased. Moreover, dark water-soluble extractives in woods like redwood and western redcedar may discolor the paint shortly after it is applied.

Plywood, particleboard, hardboard, and other wood composites undergo a significant change in moisture content during manufacture. Frequently, the moisture content of these materials is not known and may vary depending on the manufacturing process. To improve the service life of the finish, wood composites should be conditioned prior to finishing, as are other wood products.

Water Repellents

The control of water and/or water vapor requires different types of finishes. Water repellent is a generic name for a wide variety of sealers and wood treatments that change the surface properties of wood so that the wood sheds liquid water. Water repellents have almost no effect on the transmission of water vapor; that is, they have little effect on the change in wood moisture content caused by changes in RH. Water repellents work exceptionally well to retard the absorption of water into the end grain of wood, the most absorptive of the wood surfaces. Although water repellents do not stop all water absorption, they are an excellent treatment for wood used outdoors because they inhibit the absorption of liquid water during rain, yet allow the wood to dry after rain. Water-repellent formulations usually include a mildewcide or a wood preservative and are then referred to as water-repellent preservatives. These finishes are discussed in greater detail in later sections of this chapter.

Finish Moisture-Excluding Effectiveness

The moisture-excluding effectiveness of a finish is a measure of its resistance to the transmission of water vapor to the finished wood. It is basically a measure of the permeability of a coating to water vapor. It is not a measure of water repellency. Moisture-excluding effectiveness is determined by comparing the moisture pickup of a coated specimen with that of a matched uncoated control. A coating that blocks all moisture would be 100% effective; however, no coating is entirely moisture proof. There is as yet no way of completely keeping moisture out of wood that is exposed to prolonged periods of high RH. As wood is exposed to varying RH conditions, it absorbs or desorbs moisture depending on the RH. A coating that is effective at excluding moisture merely slows absorption or desorption of moisture; it cannot change the equilibrium moisture content (Ch. 3).

To achieve a high degree of moisture-excluding effectiveness, it is necessary to form a moisture barrier on the wood surface. In addition to repelling liquid water, this film will slow the diffusion of water vapor into or out of the wood. Water-repellent treatments differ from moisture-excluding coatings in that they do not slow the absorption–desorption of water vapor. They repel liquid water only. For example, a water-repellent treatment, which may have no moisture-excluding effectiveness against water vapor, might have more than 60% water repellency when tested using standard immersion tests. The high degree of protection provided by water repellents and water-repellent preservatives to short periods of wetting by liquid water is the major reason they are recommended for exterior finishing.

The protection afforded by coatings in excluding moisture from wood depends on a great number of variables. Among them are coating film thickness, defects and voids in the film, type of pigment, chemical composition of the oil or polymer, volume ratio of pigment to vehicle (pigment volume concentration), vapor-pressure gradient across the film, and length of exposure. Values in Table 15–3 indicate the range in protection against moisture in vapor form for some conventional finish systems when exposed to continuous high humidity. The degree of protection provided also depends on the kind of exposure.

Porous paints, such as latex paints and low-luster (flat) or breather-type oil-based paints formulated at a pigment volume concentration usually above 40%, afford little protection against moisture. These paints permit rapid entry of water vapor and water from dew and rain unless applied over a nonporous primer or pretreated with a paintable water-repellent preservative. In addition to being porous, latex finishes contain surfactants that can encourage absorption of water into the coating and wood, particularly just after the coating has been applied. It is thought that these surfactants wash out of the coating after a short time, but detailed information on this is not available.

The moisture-excluding effectiveness of coatings changes only slightly with age. As long as the original appearance and integrity of the coatings are retained, most effectiveness remains. Paint that is slowly fading or chalking will remain effective at excluding moisture; the paint is still effective if there is a glossy film underneath the chalk (which can be removed by rubbing). Deep chalking, checking, or cracking indicates serious impairment of moisture-excluding effectiveness.

The numerical values for percentage of effectiveness in Table 15–3 should be considered relative rather than absolute because the percentage of effectiveness varies substantially with exposure to moisture conditions. The values for effective coatings (≥60%) are reliable in the sense that they can be reproduced closely on repeating the test; values for ineffective coatings (<20%) must be regarded as rough approximations only. These percentages are based on average amounts of moisture absorbed per unit surface area by newly coated and uncoated wood panels. In addition, the values were determined from specimens coated on all sides. Since wood used in normal construction is seldom coated on all sides, the actual absorption–desorption will differ from the values listed in Table 15–3.

Effect of Finish on Liquid Water and Water Vapor Absorption

The various dimensions of wood and wood-based building materials are constantly changing because of changes in moisture content, which in turn are caused by fluctuations in atmospheric RH as well as the periodic presence of free moisture such as rain or dew. Water repellents provide protection against liquid water but are ineffective against water vapor (humidity). Film-forming finishes such as paint and varnish shed liquid water and retard the absorption of water vapor, provided the films are thick enough. Because film-forming wood finishes like paint will last longer on stable wood, it is desirable to stabilize the wood by finishing it with a water-repellent preservative as the first step in the finish system. As mentioned previously, there is no way to completely eliminate the changing moisture content of wood in response to changing RH. The coating simply slows down the rate at which the wood changes moisture content.

Film-forming finishes slow both the absorption of water vapor and drying of wood (Fig. 15–8). Aluminum flake paint is a laboratory formulation designed to block water vapor movement into wood. It is about 80% effective at blocking water vapor absorption compared with water vapor absorption in an unpainted control. Almost all common wood finishes, both oil and latex, are less effective than aluminum flake paint at blocking water vapor absorption. However, oil-based formulations are more effective than latex formulations. The coating slows the rate of drying. In cyclic high and low RH, the moisture content of the wood increases with time (Fig. 15–9).

The moisture-excluding effectiveness described in the previous section was obtained from specimens consisting of single pieces of wood that were painted on all sides. In normal construction, wood is seldom coated on all sides. In addition to absorbing water vapor, paint coatings usually crack at the joint between two pieces of wood, particularly if they have different grain orientations (and thus different dimensional stability). Water enters the wood through these cracks and is trapped by the coating, thus causing an increase in moisture content much higher than that shown in Figure 15–9.

Table 15–3. Moisture-excluding effectiveness of various finishes on ponderosa pine[a]

Finish	No. of coats	Moisture-excluding effectiveness (%)			Finish	No. of coats	Moisture-excluding effectiveness (%)		
		1 day	7 days	14 days			1 day	7 days	14 days
Linseed oil sealer (50%)	1	7	0	0	Alkyd house primer paint	1	85	46	24
	2	15	1	0	(tall maleic alkyd resin)	2	93	70	49
	3	18	2	0		3	95	78	60
Linseed oil	1	12	0	0	Enamel paint, satin	1	93	69	50
	2	22	0	0	(soya/tung/alkyd;	2	96	83	70
	3	33	2	0	interior/exterior)	3	97	86	80
Tung oil	1	34	0	0		4	98	92	85
	2	46	2	0		5	98	93	88
	3	52	6	2		6	98	94	89
Paste furniture wax	1	6	0	0	Floor and deck enamel	1	80	31	18
	2	11	0	0	(phenolic alkyd)	2	89	53	35
	3	17	0	0		3	92	63	46
Water repellent	1	12	0	0	Shellac	1	65	10	3
	2	46	2	0		2	84	43	20
	3	78	27	11		3	91	64	42
Latex flat wall paint	1	5	0	0		4	93	75	58
(vinyl acrylic resin)	2	11	0	0		5	94	81	67
	3	22	0	0		6	95	85	73
Latex primer wall paint	1	78	37	20	Nitrocellulose lacquer	1	40	4	1
(butadiene–styrene resin)	2	86	47	27		2	70	22	8
	3	88	55	33		3	79	37	19
Alkyd flat wall paint	1	9	1	0	Floor seal	1	31	1	0
(soya alkyd)	2	21	2	0	(phenolic resin/tung oil)	2	80	37	18
	3	37	5	0		3	88	56	35
Acrylic latex house	1	43	6	1	Spar varnish	1	48	6	0
primer paint	2	66	14	2	(soya alkyd)	2	80	36	15
	3	72	20	4		3	87	53	30
Acrylic latex flat	1	52	12	5	Urethane varnish	1	55	10	2
house paint	2	77	28	11	(oil-modified)	2	83	43	23
	3	84	39	16		3	90	64	44
Solid-color latex stain	1	5	0	0		4	91	68	51
(acrylic resin)	2	38	4	0		5	93	72	57
	3	50	6	0		6	93	76	62
Solid-color oil-based stain	1	45	7	1	Aluminum flake pigmented	1	90	61	41
(linseed oil)	2	84	48	26	urethane varnish	2	97	87	77
	3	90	64	42	(oil-modified)	3	98	91	84
FPL natural finish (linseed-	1	62	14	3		4	98	93	87
oil-based semitransparent	2	70	21	6		5	98	94	89
stain)	3	76	30	11		6	99	95	90
Semitransparent oil-based	1	7	0	0	Polyurethane finish, clear	1	48	6	0
stain (commercial)	2	13	0	0	(two components)	2	90	66	46
	3	21	1	0		3	94	81	66
Marine enamel, gloss (soya	1	79	38	18	Polyurethane paint, gloss (two	1	91	66	44
alkyd)	2	91	66	46	components)	2	94	79	62
	3	93	74	57		3	96	86	74
					Paraffin wax, brushed	1	97	82	69
					Paraffin wax, dipped	1	100	97	95

[a]Sapwood was initially finished and conditioned to 26°C (80°F) and 30% RH, then exposed to the same temperature and 90% RH.

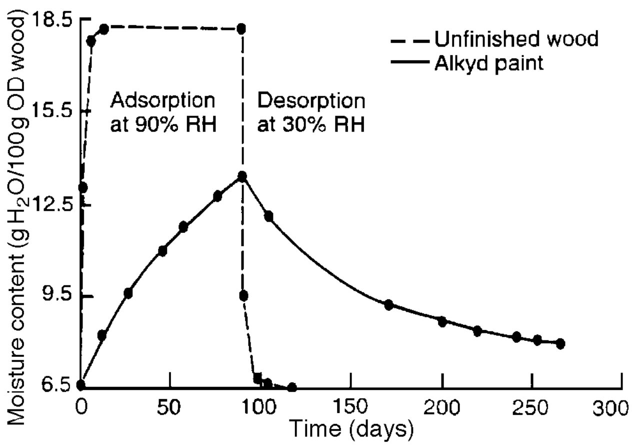

Figure 15–8. Change in moisture content of ponderosa pine sapwood finished with three coats of aluminum pigmented alkyd paint and exposed to 90% and 30% RH at 26˚C (80˚F), compared with moisture content of unfinished wood.

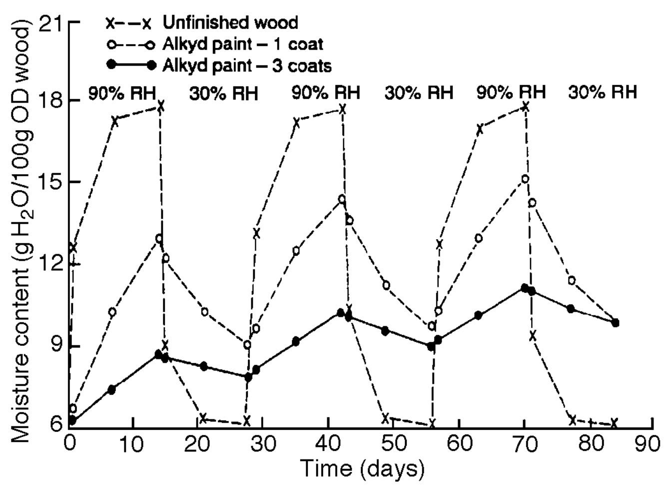

Figure 15–9. Change in moisture content of ponderosa pine sapwood finished with three coats of aluminum pigmented alkyd paint and exposed to alternating cycles of 90% and 30% RH at 26˚C (80˚F), compared with moisture content of unfinished wood.

The paint film inhibits drying, as shown. This retardation of drying can have a drastic effect on the durability of painted wood fully exposed to the weather. The moisture content of the wood can approach the range where decay fungi can become active. This type of wood paint failure usually occurs on painted fences and porch railings that are fully exposed to the weather (Fig. 15–10). Applying a water-repellent preservative or priming the end grain of wood used in these applications inhibits the absorption of water at the end grain and thus works in concert with the coating to keep the wood dry.

For a coating to be effective in minimizing moisture content changes in the wood, it must be applied to all surfaces,

Figure 15–10. Decay in wood railing fully exposed to weather.

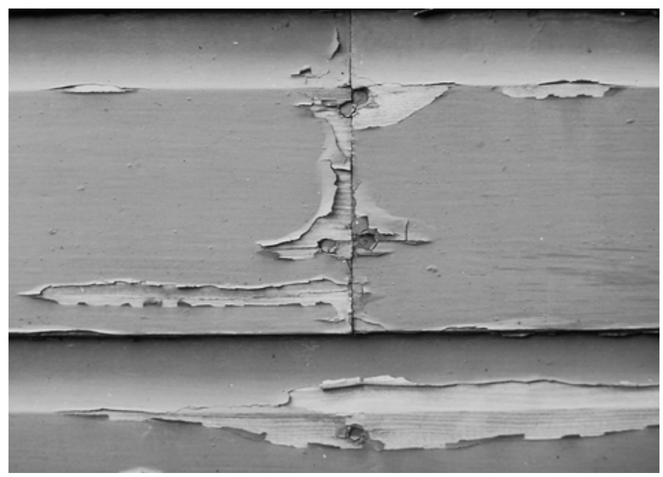

Figure 15–11. Paint failure at ends of boards.

particularly the end grain. The end grain of wood absorbs moisture much faster than does the face grain, and finishes generally fail in the end grain first (Fig. 15–11). Coatings with good moisture-excluding effectiveness that are applied to only one side of the wood will cause unequal sorption of moisture, increasing the likelihood that the wood will cup (warp). When finishing siding, it is important to allow the back side of the wood to dry, particularly if it is finished with paint with high moisture-excluding effectiveness. Applying a water-repellent preservative or primer to the end grain and back of siding (see section on back-priming) prior to installing the siding improves resistance to water yet allows the siding to dry. Cupping can be minimized by using vertical-grain lumber and by minimizing the aspect ratio.

In those houses where moisture moves from the living quarters to the outside wall because of the lack of a vapor barrier (or a poor vapor barrier), the application of moisture-excluding finishes to the outside will not prevent paint peeling. In fact, finishes with higher moisture-excluding effectiveness are more prone to fail by peeling because they trap moisture.

Types of Exterior Wood Finishes

The types of exterior finishes for wood are separated into two groups, those that penetrate wood and those that form a film. As a general rule, penetrating finishes tend to give a more "natural" look to the wood. That is, they allow some of the character of the wood to show through the finish. Also, in general, the more natural a finish, the less durable it is. Natural finishes may be penetrating finishes such as semi-transparent stains or film-forming finishes such as varnish. The penetrating natural finishes generally give better performance and are easier to refinish. This section also addresses weathered wood as a "finish."

The properties, treatment, and maintenance of exterior finishes are summarized in Table 15–4. The suitability and expected life of the most commonly used exterior finishes on several wood and wood-based products are summarized in Table 15–5. The information in these tables should be considered as a general guideline only. Many factors affect the performance and lifetime of wood finishes.

Table 15–4. Initial application and maintenance of exterior wood finishes[a]

	Initial application			Maintenance		
Finish	Process	Cost	Appearance of wood	Process	Cost	Service life[b]
Water-repellent preservative	Brushing	Low	Grain visible; wood brown to black, fades slightly with age	Brush to remove surface dirt; remove mildew	Low	1–3 years
Waterborne preservative[c]	Pressure (factory applied)	Medium	Grain visible; wood greenish or brownish, fades with age	Brush to remove surface dirt; remove mildew	Nil, unless stained or painted	None, unless stained, or painted
Organic solvent preservative[d]	Pressure, steeping, dipping, and brushing	Low to medium	Grain visible; color as desired	Brush and reapply	Medium	2–3 years or when preferred
Water repellent[e]	One or two brush coats of clear material or, preferably, dip application	Low	Grain and natural color visible, becoming darker and rougher textured with age	Clean and reapply	Low to medium	1–3 years or when preferred
Semitransparent stain	One or two brush coats	Low to medium	Grain visible; color as desired	Clean and reapply	Low to medium	3–6 years or when preferred
Clear varnish	Three coats (minimum)	High	Grain and natural color unchanged if adequately maintained	Clean, sand, and stain bleached areas; apply two more coats	High	2 years or at breakdown
Paint and solid-color stain	Brushing: water repellent, prime, and two top-coats	Medium to high	Grain and natural color obscured	Clean and apply top coat, or re-move and repeat initial treatment if damaged	Medium	7–10 years for paint;[f] 3–7 years for solid-color stain

[a]Compilation of data from observations of many researchers.
[b]For vertical exposure.
[c]Although wood treated with waterborne preservative may be left unfinished, it is best to finish it with water-repellent preservative or semitransparent stain. See maintenance of water repellent and semitransparent stain.
[d]Pentachlorophenol, bis(tri-n-butyltin oxide), copper naphthenate, copper-8-quinolinolate, and similar materials.
[e]With or without added preservatives. Addition of preservative helps control mildew growth.
[f]If top-quality acrylic latex top-coats are used.

Table 15–5. Suitability and expected service life of finishes for exterior wood surfaces[a]

Type of exterior wood surface	Water-repellent preservative and oil: Suitability	Water-repellent preservative and oil: Expected life[b] (years)	Semitransparent stain: Suitability	Semitransparent stain: Expected life[c] (years)	Paint and solid-color stain: Suitability	Paint and solid-color stain: Expected life[d] (years): Paint	Paint and solid-color stain: Expected life[d] (years): Solid-color stain
Siding							
Cedar and redwood							
Smooth (vertical grain)	High	1–2	Moderate	2–4	High	4–6	3–5
Rough-sawn	High	2–3	High	5–8	Moderate	5–7	4–6
Pine, fir, spruce							
Smooth (flat grain)	High	1–2	Low	2–3	Moderate	3–5	3–4
Rough (flat grain)	High	2–3	High	4–7	Moderate	4–6	4–5
Shingles							
Sawn	High	2–3	High	4–8	Moderate	3–5	3–4
Split	High	1–2	High	4–8	—	3–5	3–4
Plywood (Douglas-fir and Southern Pine)							
Sanded	Low	1–2	Moderate	2–4	Moderate	2–4	2–3
Textured (smooth-sawn)	Low	1–2	Moderate	2–4	Moderate	3–4	2–3
Textured (rough-sawn)	Low	2–3	High	4–8	Moderate	4–6	3–5
MDO plywood, cedar and redwood[e]	—	—	—	—	Excellent	6–8	5–7
Sanded	Low	1–2	Moderate	2–4	Moderate	2–4	2–3
Textured (smooth-sawn)	Low	1–2	Moderate	2–4	Moderate	3–4	2–3
Textured (rough-sawn)	Low	2–3	High	5–8	Moderate	4–6	3–5
Hardboard, medium density[f]							
Smooth-sawn							
Unfinished	—	—	—	—	High	4–6	3–5
Preprimed	—	—	—	—	High	4–6	3–5
Textured							
Unfinished	—	—	—	—	High	4–6	3–5
Preprimed	—	—	—	—	High	4–6	3–5
Millwork (usually pine)[g]	High[h]	—	Moderate	2–3	High	3–6	3–4
Decking							
New (smooth-sawn)	High	1–2	Moderate	2–3	Low	2–3	1–2
Weathered (rough-sawn)	High	2–3	High	3–6	Low	2–3	1–2
Glued-laminated members							
Smooth-sawn	High	1–2	Moderate	3–4	Moderate	3–4	2–3
Rough-sawn	High	2–3	High	6–8	Moderate	3–5	3–4
Oriented strandboard	—	—	Low	1–3	Moderate	2–4	2–3

[a]Data were compiled from observations of many researchers. Expected life predictions are for average location in continental United States; expected life will vary in extreme climates or exposure (such as desert, seashore, and deep woods).
[b]Development of mildew on surface indicates need for refinishing.
[c]Smooth, unweathered surfaces are generally finished with only one coat of stain. Rough-sawn or weathered surfaces, which are more adsorptive, can be finished with two coats; second coat is applied while first coat is still wet.
[d]Expected life of two coats, one primer and one top-coat. Applying second top-coat (three-coat job) will approximately double the life. Top-quality acrylic latex paints have the best durability.
[e]Medium-density overlay (MDO) is generally painted.
[f]Semitransparent stains are not suitable for hardboard. Solid-color stains (acrylic latex) will perform like paints. Paints are preferred.
[g]Windows, shutters, doors, exterior trim.
[h]Exterior millwork, such as windows, should be factory treated according to Industry Standard IS4–99 of the Window and Door Manufacturer's Association. Other trim should be liberally treated by brushing before painting.

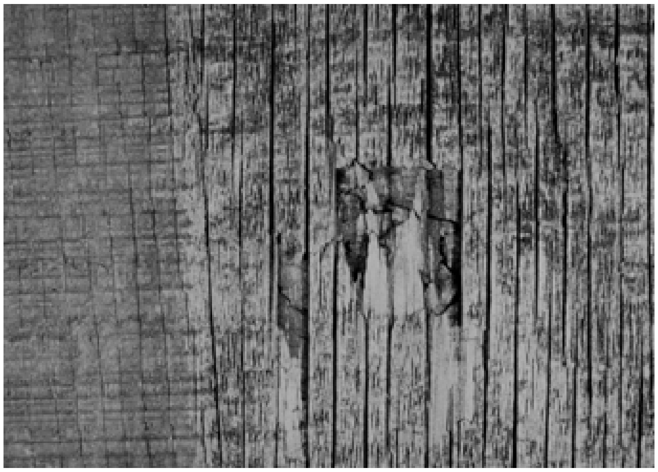

Figure 15–12. Front view of exterior grade of plywood siding after 10 years of exposure.

Weathered Wood as Natural Finish

The simplest finish for wood is that created by the weathering process. Without paint or treatment of any kind, wood surfaces gradually change in color and texture, and they may stay almost unaltered for a long time if the wood does not decay. Generally, dark-colored woods become lighter and light-colored woods become darker. As weathering continues, all woods become gray because of the loss of colored components from the wood surface and the growth of mildew. As the surface erodes, it becomes uneven because of the different erosion rates of earlywood and latewood. (Fig. 15–6).

Although leaving wood to weather to a natural finish may seem like an inexpensive low-maintenance alternative to finishing, there are many problems to this approach. To avoid decay, wood must be all heartwood from a decay-resistant species such as redwood or western redcedar. Wood should have vertical grain to decrease the potential for splitting, grain raising, and cupping. Composite wood products, such as plywood, must never be left unprotected to weather. The surface veneer of plywood can be completely destroyed within 10 years if not protected from weathering. Figure 15–12 shows weathering of unfinished plywood; the intact portion of the plywood (left) had been covered with a board to give a board-and-batten appearance.

To allow a wood structure to weather to a natural finish, the structure must be designed to keep the wood from getting wet from wind-driven rain (for example, wide roof overhangs). In most climates in the United States, exterior wood develops blotchy mildew growth and there is no protection against surface erosion or decay. It is very difficult to obtain the silvery-gray weathered patina that weathering can give. The climate along the coastal regions of New England and in some high mountains seems to encourage the development of this finish. Even when the climatic conditions favor the development of a weathered finish, it takes several years to achieve an even silvery-gray appearance.

Penetrating Wood Finishes

Penetrating finishes constitute a broad classification of natural wood finishes that do not form a film on the wood surface. Penetrating finishes are classified as (a) transparent or clear systems, (b) lightly colored systems, (c) pigmented or semi-transparent systems, and (d) oils.

Transparent or Clear Finishes

Penetrating transparent or clear finishes are generally a type of water repellent or water-repellent preservative. Water-repellent preservatives may be used as a natural finish. They differ from water repellents in that they contain a fungicide such as 3-iodo-2-propynyl butyl carbamate. As with water repellents, water-repellent preservatives contain a small amount of wax, a resin, or a drying oil. They were traditionally formulated using a solvent such as turpentine or mineral spirits, but they are presently available in a wide range of other solvent systems, including waterborne formulations.

Penetrating finishes that use paraffin oil as the solvent system are also available. These formulations penetrate wood like solventborne formulations do and the oil helps improve water repellency. Since penetrating finishes with paraffin oil are usually formulated without any volatile solvents, they meet air quality requirements. (See section on VOC-compliant finishes.) They are usually a good value because virtually all of what comes in the can ends up in the wood.

Water-repellent preservatives maintain the original appearance of the wood, but they are not very durable. Treating wood surfaces with a water-repellent preservative will protect wood exposed outdoors with little initial change in appearance. A bright, golden-tan color can be achieved with most wood species. The treatment decreases warping and cracking, prevents water staining at edges and ends of wood siding, and helps control mildew growth. The first application of a water-repellent preservative may protect exposed wood surfaces for only l to 2 years, but subsequent reapplications may last 2 to 4 years because the weathered boards absorb more finish. When a surface starts to show blotchy discoloration caused by extractives or mildew, it should be cleaned with a commercial cleaner or liquid household bleach and detergent solution, allowed to dry, and retreated.

> **Caution**: Because of the toxicity of some fungicides in water-repellent preservative solutions and some semitransparent stains, care should be exercised to avoid excessive contact with the solution or its vapor. Shrubs and plants should also be protected from accidental contamination.

Paintable water-repellent preservatives may also be used as a treatment for bare wood before priming and painting or in areas where old paint has peeled and the bare wood is exposed, particularly around butt joints or in corners. This treatment keeps rain or dew from penetrating into the wood, especially at joints and end grain, and thus decreases shrinking and swelling of the wood. As a result, less stress is placed on the paint film and its service life is extended

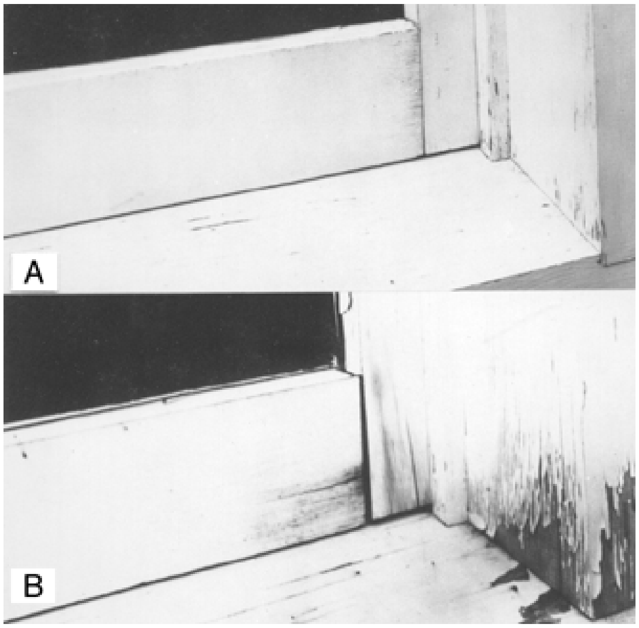

Figure 15–13. Effect of water-repellent preservative treatment. A, Window sash and frame treated with a water-repellent preservative and then painted; B, window sash and frame not treated before painting. Both window sash–frame sets were weathered for 5 years.

(Fig. 15–13). This stability is achieved by the small amount of wax present in water-repellent preservatives. The wax decreases the capillary movement or wicking of water up the back side of lap or drop siding. The fungicide inhibits decay.

A large number and variety of waterborne penetrating clear finishes are available for use on wood. The formulations of these finishes are generally proprietary, and it is difficult to determine the nature of these finishes. These formulations are usually water emulsions of synthetic polymers. The polymers do not penetrate the lateral surface of the wood very well, but they can change the surface properties. The polymer helps seal the surface and provides some water repellency. The formulations may include additional additives such as UV stabilizers, additional water repellents, mildewcides, and colorants.

Lightly Colored Finishes

Traditional solventborne formulations of water-repellent preservatives did not contain any coloring pigments. Therefore, the resulting finish varied little from the original color of the wood. Many of the newer formulations are slightly colored and have other additives such as UV stabilizers. As with traditional formulations, the preservative also prevents wood from darkening (graying) through mildew growth.

These lightly colored finishes may be water- or solventborne formulations. The color may be obtained from dyes or finely ground pigment. Although they are still classified as a penetrating finish or sealer for wood, many of the newer formulations form a slight film on the wood surface. This is particularly true for the waterborne formulations. As with the uncolored clear finishes, the durability of lightly colored finishes is somewhat limited. Although their durability is improved by the inclusion of UV stabilizers and finely ground pigment, lightly colored finishes still lack sufficient pigment to stop UV degradation of the wood.

Semitransparent Stains

Inorganic pigments can also be added to water-repellent preservative solutions to provide special color effects, and the mixture is then classified as a semitransparent stain. A semitransparent stain is a pigmented penetrating stain. Colors that match the natural color of the wood and extractives are usually preferred. The addition of pigment to the finish helps stabilize the color and increase the durability of the finish, but they give a less natural appearance because the pigment partially hides the original grain and color of the wood. Semitransparent stains are generally much more durable than are water-repellent preservatives and provide more protection against weathering. These stains slow weathering by retarding the alternate wetting and drying of wood, and the pigment particles on the wood surface minimize the degrading effects of sunlight. The amount of pigment in semitransparent stains can vary considerably, thus providing different degrees of protection against UV degradation and masking of the original wood surface. Higher pigment concentration yields greater protection against weathering, but it also hides the natural color of the wood.

Solventborne oil-based semitransparent penetrating stains penetrate the wood surface, are porous, and do not form a surface film like paints. As a result, they will not blister or peel even if moisture moves through the wood. Semitransparent penetrating stains are only moderately pigmented and do not totally hide the wood grain. Penetrating stains are alkyd or oil based, and some may contain a fungicide as well as a water repellent. Moderately pigmented latex-based (waterborne) stains are also available, but they do not penetrate the wood surface as well as the oil-based stains. Some latex-based formulations are oil modified. These formulations give better penetration than do the unmodified formulations.

Semitransparent stains are most effective on rough lumber or rough-sawn plywood surfaces. They may be used on smooth surfaces but have less than half the service life compared with that on rough surfaces. Stains are available in a variety of colors and are especially popular in the brown or red earth tones because these give a natural or rustic appearance to the wood. They are an excellent finish for weathered wood. Semitransparent stains are not effective when applied over a solid-color stain or old paint.

Many resin and paint manufacturers have tried to achieve the properties of solventborne semitransparent stains using waterborne formulations. Some of these finishes achieved a semitransparent appearance by the formation of a rather thin coating on the wood surface. The resins used in these formulations did not penetrate the wood surface. Therefore, these finishes were prone to fail within a few years through flaking of the thin coating from the surface. When the surfaces were refinished, the subsequent finish increased the film thickness and obscured the original appearance of the wood. Because the film buildup is not sufficient to give the good performance provided by a film-forming finish, waterborne semitransparent stains generally continue to fail by flaking. Many new formulations are modified with oil–alkyds. The oil penetrates the surface, thus improving the performance of the finish. Efforts are continuing to improve these formulations; it is advisable to check with a local paint supplier for the latest developments in this area.

Oils

Drying oils, such as linseed and tung, are sometimes used by themselves as natural finishes. Such oils are not recommended for exterior use unless they are formulated with a mildewcide. These oils are natural products and therefore provide food for mildew. When drying oils are used on highly colored woods such as redwood or the cedars, they tend to increase problems with mildew.

Film-Forming Finishes

Clear Varnish

Clear varnish is the primary transparent film-forming material used for a natural wood finish, and it greatly enhances the natural beauty and figure of wood. However, varnish lacks exterior permanence unless protected from direct exposure to sunlight, and varnish finishes on wood exposed outdoors without protection will generally require refinishing every l to 2 years. Thus, varnish is not generally recommended for exterior use on wood. Varnish coatings embrittle by exposure to sunlight and develop severe cracking and peeling. Varnish used in areas that are protected from direct sunlight by an overhang or used on the north side of the structure will last considerably longer. However, even in protected areas, a minimum of three coats of varnish is recommended, and the wood should be treated with a paintable water-repellent preservative before finishing. The use of pigmented stains and sealers as undercoats will also contribute to greater life of the clear finish. In marine exposures, up to six coats of varnish should be used for best performance.

Pigmented Varnish

Several finish manufacturers have formulated varnish with finely ground inorganic pigments that partially block UV radiation yet allow much of the visible light to pass through the finish. These products give much better performance than do traditional clear varnishes, and if a clear film is desired for exterior use, they may be a better choice. Pigmented varnish gives excellent performance on structures that are protected from sunlight by wide overhangs and wooded surroundings. The degradation of pigmented varnish initially occurs on the film surface as crazing and checking. These surface checks can be repaired by refinishing in a timely manner. Eventually, however, the buildup of coats will block much of the visible light and the wood will appear dark.

Solid-Color Stains

Solid-color stains are opaque finishes (also called hiding, heavy-bodied, or blocking) that come in a wide range of colors and are made with a much higher concentration of pigment than are semitransparent penetrating stains. As a result, solid-color stains totally obscure the natural color and grain of the wood. Solid-color stains (both oil- and latex-based) tend to form a film much like paint, and as a result they can also peel from the substrate. Both oil and latex solid-color stains are similar to paints and can usually be applied over old paint or to unfinished wood if adequately primed. As with any film-forming finish, good service life requires 4- to 5-mil dry film thickness.

Paint

Paints are highly pigmented film-forming coatings that give the most protection to wood. Paints are used for esthetic purposes, to protect the wood surface from weathering, and to conceal certain defects. They also provide a cleanable surface. Of all the finishes, paints provide the most protection for wood against surface erosion and offer the widest selection of colors. Paints are the only way to achieve a bright white finish. A nonporous paint film retards penetration of moisture and decreases discoloration by wood extractives as well as checking and warping of the wood. Paint is *not* a preservative. It will not prevent decay if conditions are favorable for fungal growth.

Paints do not penetrate the surface of the wood except to fill cut cells and vessels. They do not penetrate the cell wall of the wood as do some penetrating finishes. The wood grain is completely obscured as the surface film is formed. Paints perform best on vertical-grain lumber of species with low specific gravity. As with other film-forming finishes, paints can blister or peel if the wood is wetted or if inside water vapor moves through the house wall to the wood.

Latex paints are generally easier to use because water is used in cleanup. They are also porous and thus allow some moisture movement. In comparison, oil-based paints require organic solvents for cleanup, and some oil-based paints are resistant to moisture movement. Latex paints mainly formulated with acrylic resins are extremely resistant to weathering and maintain their gloss better than do oil-based paints. Such latex paints remain flexible throughout their service life. Oil-based paints tend to lose gloss within a year or two and are prone to embrittle over time.

The cost of finishes varies widely depending on the type of finish and quality (Table 15–4). Within a particular type of finish (for example, oil-based paint, all-acrylic latex paint, oil-based solid-color stain), cost usually correlates with quality. Better quality paints usually contain higher amounts of solids by weight. Paints with a lower percentage of solids may cost less by the unit but be more expensive per unit of solids, and more or heavier coats will have to be applied to achieve equal coverage. Comparing solids content and price can be the first criterion for selecting the better value because only the solids are left on the surface after the solvent evaporates. For example, if one paint is 50% solids and costs $20 and a second paint is 40% solids and costs $18, all other things being equal the $20 paint is a better value (25% more solids for about 11% more money). Another criterion is the amount and type of pigment because these determine the hiding power of the finish. Paint that contains primarily titanium dioxide pigment will have better hiding power than that with calcium carbonate filler. A paint with poor hiding power may require the application of more coats. Finally, the type and amount of binder affect the quality of the paint. For latex paints, all acrylic binders are more weather-resistant than are vinyl and vinyl–acrylic binders.

Fire-Retardant Coatings

Many commercial fire-retardant coating products are available to provide varying degrees of protection of wood against fire. These paint coatings generally have low surface flammability characteristics and "intumesce" to form an expanded low-density film upon exposure to fire, thus insulating the wood surface from heat and retarding pyrolysis reactions. The paints have added ingredients to restrict the flaming of any released combustible vapors. Chemicals may also be present in these paints to promote decomposition of the wood surface to charcoal and water rather than the formation of volatile flammable products. Most fire-retardant coatings are intended for interior use, but some are available for exterior application. Wood shakes and shingles are often impregnated with a fire retardant.

Compliance of VOC Finishes With Pollution Regulations

Volatile organic compounds (VOCs) are those organic materials in finishes that evaporate as the finish dries and/or cures. These materials are regarded as air pollutants, and the amount that can be released for a given amount of solids (for example, binder, pigments) in the paints is now regulated in many areas. Regulations that restrict the amount of VOCs in paints have been enacted in many states, including California, New York, Texas, Massachusetts, New Jersey, and Arizona, and legislation is pending in many others.

The result of such legislation is that all major paint companies have had to either change their paint formulation or market additional low-VOC formulations. Some smaller companies have been unaffected by VOC regulations because they market their products in limited geographic areas outside those affected by existing State and local legislation. This situation is slated to change soon. Under the 1990 New Clean Air Act, the U.S. Environmental Protection Agency (EPA) has been charged to enact a regulation that affects all of the United States. This regulation will take effect in 1999 and will regulate the amount of VOC in all types of architectural finishes, including paints, solid-color stains, and penetrating finishes, such as semitransparent stains and water-repellent preservatives.

Existing and pending regulations are a serious concern throughout the U.S. paint industry, particularly with regard to a national rule that will affect areas of the country that have not previously had to comply with VOC regulations. Many traditional wood finishes may no longer be acceptable, including oil-based semi-transparent stains, oil- and alkyd-based primers and top coats, solventborne water-repellents, and solventborne water-repellent preservatives. Many current wood finishes, including some latex-based materials, may be reformulated. These changes affect the properties of the finish, application, interaction with the wood (for example, adhesion, penetration, moisture-excluding effectiveness), and possibly durability.

Many penetrating finishes, such as semitransparent stains, have low solids content (pigment, oils, polymers) levels and are being reformulated to meet low-VOC regulations. To meet the VOC requirements, these reformulated finishes may contain higher solids content, reactive diluents, new types of solvents and/or cosolvents, or other nontraditional substituents. These low-VOC formulations are prone to form films rather than penetrate the wood surface. There is little information about the way these new penetrating finishes interact with the substrate to protect the wood or about the degradation mechanisms of these finishes when exposed to various outdoor conditions. Because such formulations may not interact with the wood in the same way as do traditional finishes, the effect of moisture may be different.

Application of Wood Finishes

Type of Finish

Water-Repellent Preservatives

The most effective method of applying a water repellent or water-repellent preservative is to dip the entire board into the solution. However, other application methods can be used if they are followed by back brushing. It is advantageous to treat the back side of the siding, particularly with highly colored wood species. (See section on back-priming.) 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 with end grain. Other areas especially vulnerable to moisture, such as the bottoms of doors and window frames, should also be treated. Coverage is about 6.1 m^2/L (250 ft^2/gal) on a smooth surface or 3.7 m^2/L (150 ft^2/gal) on a rough surface. Smooth wood will usually accept only a single coat; a second coat will not penetrate the wood. Water-repellent preservative treatment generally lasts longer on rough surfaces than on smooth surfaces because more finish penetrates the wood. As a natural finish, the life expectancy of a water-repellent preservative is only 1 to 2 years, depending upon the wood and exposure. However, reapplication is easy, particularly on decks and fences. Multiple coats brush-applied to the point of refusal (failure to penetrate) will enhance durability and performance of the wood.

Water-repellent-preservative-treated wood that is painted will not need retreatment unless the protective paint layer has peeled or weathered away. The water-repellent preservative should be applied only to the areas where the paint has peeled. The water-repellent preservative should be allowed

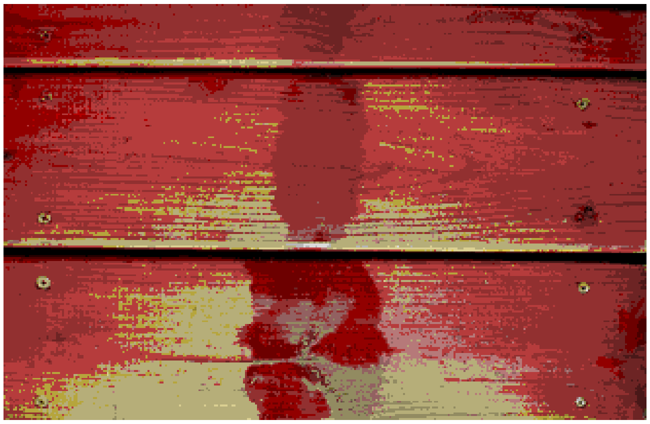

Figure 15–14. Lap marks on wood finished with semitransparent stain.

to dry for 3 days, and the peeled area should be reprimed before it is repainted.

Semitransparent Penetrating Stains

Semitransparent penetrating stains may be brushed, sprayed, or rolled on, but they must be back-brushed. Brushing works the finish into the wood and evens out the application so that there is less chance for lap marks. Semitransparent penetrating stains are generally thin and runny, so application can be messy. Lap marks may form if stains are improperly applied, but such marks can be prevented by staining only a small number of boards or one panel at a time (Fig. 15–14). 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. Coverage is usually about 4.9 to 9.8 m^2/L (200 to 400 ft^2/gal) on a smooth wood surface and from 2.4 to 4.9 m^2/L (100 to 200 ft^2/gal) on a rough or weathered surface. Stains perform much better on rough-sawn wood.

To give penetrating oil-based semitransparent stains a long life on rough-sawn or weathered lumber, use two coats and apply the second coat before the first is dry (wet on wet application). 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 min. 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 the wood. About an hour after applying the second coat, use a cloth, sponge, or dry brush lightly wetted with stain to wipe off excess stain that has not penetrated into the wood. Otherwise, areas of stain that did not penetrate may form an unsightly shiny surface film. Avoid intermixing different brands or batches of stain. Stir the stain occasionally and thoroughly during application to prevent settling and color change.

A two-coat system of semitransparent penetrating stain may last as long as 10 years on rough wood in certain exposures as a result of the large amount of stain absorbed. By comparison, the life expectancy of one coat of stain on new smooth wood is only 2 to 4 years; successive recoats last longer (Table 15–5).

> **Caution**: Sponges or cloths that are wet with oil-based stain are particularly susceptible to spontaneous combustion. To prevent fires, immerse such materials in water and seal in a water-filled air-tight metal container immediately after use.

Waterborne Semitransparent Stains

Waterborne semitransparent stains do not penetrate the wood surface as well as oilborne semitransparent stains, but they are easy to apply and less likely to form lap marks. These stains form a thin film, and a second coat will improve their durability. Apply the second coat any time after the first has dried.

Solid-Color Stains

Solid-color stains may be applied to a smooth wood surface by brush, spray, or roller; if the finish is applied by spray or roller, it is necessary to “back-brush” immediately after application. Solid-color stains act much like paint. One coat of solid-color stain is **not** considered adequate for siding. Some manufacturers recommend using the first coat as a primer, but a primer paint might be better, particularly if there is a possibility for extractives bleed. Two coats of solid-color stain applied over a quality latex or oil primer should give service life similar to that of a good paint system. Solid-color stains are not generally recommended for horizontal wood surfaces such as decks, roofs, and window sills.

Unlike paint, solid-color stain is subject to lap marks during application. Latex-based stains are particularly fast-drying and are more likely to show lap marks than are oil-based stains. To prevent lap marks, follow the procedures suggested in the section on application of semitransparent penetrating stains.

Paint

Wood and wood-based products should be protected from sunlight and water while stored prior to delivery to a construction site and while stored on the construction site. The finish should be applied as soon as possible after the wood is installed. Surface contamination from dirt, oil, and other foreign substances must be eliminated. The paint bond with the wood is greatly increased if the wood is painted within 1 week, weather permitting, after installation (see Weathering—Effect of weathering on paint adhesion). To achieve maximum paint life, do the following:

1. Treat wood siding and trim with a paintable water-repellent preservative or water repellent. Water repellents protect the wood against the absorption of rain and dew and thus help to minimize swelling and shrinking. Water repellents 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 these areas are prone to absorb

moisture, which leads to paint failure. Allow at least three 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 before painting.

2. Prime the bare wood after the water-repellent preservative has dried (see section on back-priming). The primer coat forms a base for all succeeding paint coats. For woods with water-soluble extractives, such as redwood and cedar, primers block the bleed of extractives into the top coat. Use a primer that is labeled to "block extractives bleed," usually a quality alkyd-based paint. Many manufacturers are also formulating stain-blocking acrylic-latex-based paints. Allow a latex stain-blocking primer to dry for at least 24 to 48 h before applying the top coat. If the primer has not fully cured, extractives may bleed into the top coat. Apply a primer regardless of whether the top coat is an oil-based or latex-based paint. For species that are predominantly sapwood and free of extractives, such as pine, using a quality primer is still necessary to give a good base for the top coat. Apply enough primer to obscure the wood grain. Follow the application rates recommended by the manufacturer. Do not spread the primer too thinly. A primer coat that is uniform and of the proper thickness will distribute the swelling stresses that develop in wood and thus help to prevent premature paint failure.

3. Apply two coats of a good-quality acrylic latex house paint over the primer. Oil-based, alkyd-based, and vinyl–acrylic paints can also be used. If it is not practical to apply two top-coats to the entire house, consider two top-coats 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 top-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 top-coats can last 10 years (Table 15–5).

   Primer will cover about 6.1 to 7.4 m^2/L (250 to 300 ft^2/gal) on smooth bare wood; for repainting, coverage will be about 9.8 m^2/L (400 ft^2/gal). However, coverage can vary with different paints, surface characteristics, and application procedures. Research has indicated that the optimal thickness for the total dry paint coat (primer and two top-coats) is 0.10 to 0.13 mm (4 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.

4. To avoid peeling between paint coats, apply the first top-coat 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 that 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, use a mild detergent to remove all dirt and deteriorated paint. Then rinse the cleaned wood with water and allow all surfaces to dry before painting.

5. To avoid temperature blistering, do not apply oil-based paint on a cool surface that will be heated by the sun within a few hours. Temperature blistering is most common with thick coats of dark-colored paint 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.

6. Apply latex-based waterborne paints when the temperature is at least 10°C (50°F); oil-based paint may be applied when the temperature is at least 4°C (40°F). For proper curing of latex paint films, the temperature should not drop below 10°C (50°F) for at least 24 h after paint application. Low temperatures will result in poor coalescence of the paint film and early paint failure. Some new latex formulations are being developed for application at lower temperatures. Refer to application instructions on the label of the paint can.

7. To avoid wrinkling, fading, or loss of gloss of oil-based paints and streaking of latex paints, do not apply the paint during autumn days or cool spring evenings when heavy dews form during the night. Serious water absorption problems and major finish failure can occur with some paints when applied under these conditions.

Porches, Decks, and Fences

Exposed flooring on porches is usually painted. Since porches often get wet from windblown rain, it is particularly important to pretreat the wood surface with a water-repellent preservative prior to painting. Use primers and paints specially formulated for porches. These paints are 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. Decks finished with these finishes will need more frequent refinishing than do painted surfaces, but refinishing is easy because there is no need for the laborious surface preparation required for painted surfaces that have peeled. It is essential to limit the application of semitransparent stain to what the surface can absorb. Roller and spray application may put too much stain on the horizontal surfaces of decks. The best application method for such smooth surfaces is by brush. Unless specially formulated for use on decks, solid-color stains should not be used on any horizontal surface because they lack abrasion resistance, and because they form a film, they tend to fail by flaking.

Like decks, fences are fully exposed to the weather and at least some parts (such as posts) are in contact with the soil. As a result, wood decay and termite attack are potential problems. Often in the design of fences, little consideration is given to protecting exposed end-grain of various fence components or to avoiding trapped moisture. If a film-forming finish is to be used on a fence, it is extremely important to seal the end grain and protect exposed end-grain wherever possible. Use lumber pressure-treated with preservatives or naturally durable wood species for all posts and other fence components that are in ground contact.

In regard to the service life of naturally durable wood species compared with wood pressure-treated with preservatives, there are no absolute “rules.” In ground contact uses, pressure-treated wood species often outperform naturally durable species in warm wet climates, but less difference in service life often occurs in dry climates. The service life of naturally durable and preservative-treated woods is quite comparable in aboveground exposures, such as decking boards, railing, and fence boards. In selecting wood for porches, decks, and fences, whether preservative treated or a naturally durable species, consideration must be given to the exposure conditions, design of the structure, and properties of the wood, including its variability.

In aboveground uses, the weathering of wood can be as much a factor in long-term service life as is decay resistance. Whether naturally durable wood species or preservative-treated wood is used in full exposures to weather, it is necessary to protect the wood with a finish. Periodic treatment with a penetrating sealer, such as a water-repellent preservative, will decrease checking and splitting, and pigmented finishes will retard weathering.

Treated Wood

Treated wood is often used to construct porches, decks, and fences, particularly wood treated with chromated copper arsenate (CCA). Woods that have been pressure treated for decay sometimes have special finishing requirements. Wood pressure treated with waterborne chemicals, such as copper, chromium, and arsenic salts (CCA), that react with the wood or form an insoluble residue presents no major problem in finishing if the wood is properly redried and thoroughly cleaned after treating. The finishing characteristics are more controlled by species and grain orientation than by preservative treatment. Wood treated with solvent- or oilborne preservative chemicals, such as creosote or pentachlorophenol, is not considered paintable.

None of the common pressure preservative treatments (creosote, pentachlorophenol, water-repellent preservatives, and waterborne preservatives) will significantly change the weathering characteristics of woods. All preservative-treated wood will weather when exposed above ground and may develop severe checking and cracking. Finishing generally retards this weathering. However, there is one exception: waterborne treatments containing chromium decrease the degrading effects of weathering.

Creosote and pentachlorophenol are generally used only for industrial and commercial applications where applying a finish is not considered practical. Creosote is oily and therefore does not accept a finish very well. Pentachlorophenol is often formulated in heavy oil. In general, preservatives formulated in oil will not accept a finish. In some cases, oil-based semitransparent penetrating stains can be used on these products, but only after the preservative-treated wood has weathered for 1 to 2 years, depending on exposure.

The only preservative-treated woods that should be painted or stained immediately after treatment and without further exposure are the waterborne preservative treatments (such as CCA-treated wood). Since wood treated with these preservatives is often used for residential structures, it needs to be finished not only for esthetic reasons, but also to protect it from weathering. Many manufacturers of chemicals for treating wood with waterborne preservatives include a water-repellent treatment to give the treated wood better resistance to weathering, particularly checking and splitting. Even if the wood was treated with water repellent by the manufacturer, it should be maintained with a finish to extend its service life. Wood used in aboveground applications that has been properly treated with preservative is usually replaced because of weathering, not decay.

Marine Uses

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

For best protection, wood exposed to marine environments above water and above ground should be treated with a paintable water-repellent preservative, painted with a suitable paint primer, and top coated (at least two coats) with quality exterior marine products.

> **Note:** Any wood in contact with water or the ground should be pressure treated to specifications recommended for in-ground or marine use. Such treated woods are not always paintable. As indicated previously, CCA-treated woods are paintable when dry and clean.

Wood trim on boats is often varnished. When applied to boats, varnish is subjected to greater exposure to sunlight and water than when used on structures; therefore, it needs regular and frequent care and refinishing. Varnishes should be specially formulated for harsh exposure; three to six coats should be applied for best performance. The durability of the varnish can be extended by finishing the wood with a semitransparent stain prior to varnishing, but this obscures many natural characteristics of the wood. Keeping the appearance of varnished wood trim bright and new is labor intensive but often well worth the effort.

Refinishing

Exterior wood surfaces need to be refinished only when the old finish has worn thin and no longer protects the wood. In repainting, one coat may be adequate if the old paint surface is in good condition. Dirty paint can often be renewed and cleaned by washing with detergent. Too-frequent repainting with an oil-based system produces an excessively thick film that is likely to crack abnormally across the grain of the wood. Complete removal of the paint and repainting are the only cure for cross-grain cracking (see subsection on cross-grain cracking under Finish Failure or Discoloration). Latex paints seldom develop cross-grain cracking because they are more flexible than are oil-based paints. Since latex paints have replaced oil-based paints for most exterior application on residential structures, cross-grain cracking is rather rare unless the latex paint has been applied over many coats of oil-based paint. However, even with latex paints, excessive paint buildup should be avoided. Additional top-coats should be applied only when the primer begins to show.

Water-Repellent Preservatives

Water-repellent preservatives used as natural finishes can be renewed by simply brushing the old surface with a dry stiff-bristle brush to remove dirt and applying a new coat of finish. To determine if a water-repellent preservative has lost its effectiveness, splash a small quantity of water against the wood surface. If the water beads up and runs off the surface, the treatment is still effective. If the water soaks in, the wood needs to be refinished. Refinishing is also required when the wood surface shows signs of graying. Gray discoloration can be removed by washing the wood with a commercial mildew cleaner or liquid household bleach (see subsection on mildew under Finish Failure or Discoloration).

Semitransparent Penetrating Stains

Surfaces finished with semitransparent penetrating stains are relatively easy to refinish; heavy scraping and sanding are generally not required. Simply use a dry stiff-bristle brush to remove all surface dirt, dust, and loose wood fibers, and then apply a new coat of stain. The second coat of penetrating stain often lasts longer than the first because it penetrates into small surface checks that open as the wood weathers.

In refinishing surfaces originally finished with semitransparent stains, it is extremely important that the wood accept the stain. That is, the stain must penetrate the wood. Since the weathering rate of a stain varies with exposure, the stain may not penetrate well in some areas. For example, an area under the eaves, even on the south side of a structure, may be relatively unweathered. When applying stain to such an area, feather the new stain into the old. If the stain does not penetrate the wood within an hour, remove the excess. If the excess stain is not removed it will form shiny spots, which will flake from the surface as it weathers. The north side of a structure may not need to be restained nearly as often as the south side (northern hemisphere).

> **Note**: Steel wool and wire brushes should not be used to clean surfaces to be finished with semitransparent stain or water-repellent preservatives because small iron deposits may be left behind. These small iron deposits can react with certain water-soluble extractives in woods like western redcedar, redwood, Douglas-fir, and the oaks, to yield dark blue–black stains on the surface (see subsection on iron stain under Finish Failure or Discoloration).

Paint and Solid-Color Stains

In refinishing painted (or solid-color stained) surfaces, proper surface preparation is essential if the new coat is to have a long service life. First, scrape away all loose paint. Sand areas of exposed wood with 50- to 80-grit sandpaper to remove the weathered surface and to feather the abrupt paint edge. Then scrub any remaining old paint with a brush or sponge and water. Rinse the scrubbed surface with clean water, then wipe the surface with your hand or cloth (see subsection on chalking under Finish Failure or Discoloration). If the surface is still dirty or chalky, scrub it again using a detergent. Use a commercial cleaner or a dilute household bleach solution to remove mildew (see subsection on mildew under Finish Failure or Discoloration). Rinse the cleaned surface thoroughly with fresh water and allow it to dry before repainting. Treat bare wood with a water-repellent preservative and allow it to dry for at least 3 days before priming. Top coats can then be applied.

> **Note:** Special precautions are necessary if the old paint contains lead. See section on lead-based paint**.**

It is particularly important to clean areas that are protected from sun and rain, such as porches, soffits, and side walls protected by overhangs. These areas tend to collect dirt and water-soluble materials that interfere with the adhesion of new paint. It is probably adequate to repaint these protected areas every other time the house is painted.

Latex paint or solid-color stain can be applied over freshly primed surfaces and on weathered paint surfaces if the old paint is clean and sound (chalk-free). Before repainting surfaces with latex paint, conduct a simple test. After cleaning the surface, repaint a small, inconspicuous area with latex paint and allow it to dry at least overnight. Then, to test for adhesion, firmly press one end of an adhesive bandage onto the repainted surface. Remove the bandage with a snapping action. If the tape is free of paint, the fresh latex paint is well-bonded and the old surface does not need priming or additional cleaning. If the fresh latex paint adheres to the tape, the old surface is too chalky and needs more cleaning or priming with an oil-based primer. If both the fresh latex paint and the old paint coat adhere to the tape, the old paint is not well-bonded to the wood and must be removed before repainting.

Back-Priming

Back-priming simply means the application of a primer or water-repellent preservative to the back side of wood (usually wood siding) before the wood is installed. Back-priming retards absorption of water, thus improving dimensional stability and extending the service life of the paint. It improves the appearance of the wood by decreasing extractives staining, particularly run-down extractives bleed. Treating the back side of siding with a water-repellent preservative is probably more effective than back-priming for improving dimensional stability and retarding extractives bleed. Water-repellent preservatives are particularly effective if used as a pretreatment before back-priming. However, back-priming with a stain-blocking primer alone has some benefit.

By slowing the absorption of water, the primer or water-repellent preservative improves dimensional stability of siding. Siding is less likely to cup, an important consideration for flat-grain wood. By decreasing shrinking and swelling, less stress is placed on the finish, thereby extending its service life. At the same time that the siding is back-primed, the end grain should be sealed with primer. This process has an even greater effect in stopping water absorption. Most paint failure near the end grain of siding can be eliminated by including end-grain priming along with the back-priming. When boards are cut during installation, the cut ends should be spot-primed.

Run-down extractives bleed occurs because water from wind-blown rain, leaks, and/or condensation of moisture wets the back of siding and absorbs extractives from the wood. If water from one course of siding runs down the front face of the course below it, the water may deposit the extractives on this surface, causing unsightly streaks (see subsection on extractives bleed under Finish Failure or Discoloration). Back-priming stops extractives bleed by forming a barrier between the water and the extractives. The primer should be stain-blocking, just as the primer used for the front (outside) surface of the siding. When finish is applied to siding in the factory, the back surface of the siding is routinely finished at the same time as the front surface.

Factory Finishing

Many siding, trim, and decking products are now available prefinished. Although it has been standard industry practice to preprime hardboard siding, factory finishing of solid wood products has rapidly grown during the last several years. The industry is currently growing at about 60% per year, and this growth is anticipated to continue into the early part of the next century. Coating suppliers for this industry predict that more than half of all wood siding materials will be factory finished by that time. In addition to siding, other wood products like interior trim and paneling are being prefinished. Much of this factory finishing has been made possible by the development of rapid-cure finish systems and the availability of efficient equipment to apply the finish.

Prefinishing wood at the factory rather than after installation results in overall cost savings as well as several other advantages. Weather and climate conditions during construction do not affect prefinished wood. This is a crucial consideration in northern climates where acceptable exterior finishing is impossible during the winter. In factory finishing, coverage can be controlled to give a consistent 100 to 127 µm (4 to 5 mil) dry film. The controlled conditions enable many factory finishers to guarantee their products against cracking, peeling, and blistering for 15 years. Another advantage of factory finishing is that siding is finished on all sides, including the end grain. When prefinished siding is installed, the end grain is sealed after any cross-cuts are made. This end-grain sealing is seldom done during installation of unfinished siding. The end-grain seal greatly increases resistance of siding to end-grain absorption of water, thus decreasing extractives bleed and other problems related to moisture.

Finish Failure or Discoloration

Paint is probably the most common exterior finish in use on wood today. It appears somewhere on practically every residential structure and on most commercial buildings. Even brick and aluminum-sided structures usually have some painted wood trim. When properly applied to the appropriate type of wood substrate, paint should have a service life of at least 10 years. If it does not, the selection of the paint, application, type of substrate, type of structure, and construction practices were not done properly or were not compatible.

Modern paint formulations based on acrylic polymers are extremely resistant to degradation by ultraviolet (UV) radiation. These paints degrade by a slow erosion process, which eventually exposes the primer. The erosion process depends on the exposure to the weather. Areas that deteriorate rapidly are those exposed to the greatest amount of sunshine and rain, usually on the west and south sides of a building (in the northern hemisphere). The normal deterioration process begins with soiling or a slight accumulation of dirt and then leads to gradual change and erosion of the coating. When the primer begins to show, that side of the structure should be repainted. It may not be necessary to paint all sides of the structure, since the erosion rate varies depending on exposure. This is particularly true for structures finished with white paint.

> **Note:** The most common cause of premature paint failure on wood is moisture.

Early paint failure may develop under certain conditions of service. Excessive moisture, flat grain, high coating porosity, and application of a new paint coat without proper preparation of the old surface can all contribute to early paint failure. Paint on the outside walls of residential structures is subject to wetting from rain, dew, and frost. Equally serious is “unseen” moisture that moves from inside the structure to the outside. This is particularly true for buildings in cold northern climates that do not have effective air and vapor barriers. Many moisture-related problems can be prevented by furring out the siding 9 to 19 mm (3/8 to 3/4 in.) prior to installation. For siding placed directly on insulation board or a wind barrier, placing wedges between the siding courses can reduce problems with moisture.

The next most common cause of paint failure is a poor bond between the substrate and the coating. Even in the absence of moisture, paint can peel if it does not bond well to the wood. If moisture is also present, paint failure is accelerated. The wide bands of latewood on flat-grain surfaces hold paint very poorly. If possible, flat-grain boards should be exposed “bark-side” out to minimize raising and separation of grain, and the boards should either be rough-sawn or scuff-sanded with 50-grit sandpaper prior to priming. Wood must be protected from the weather prior to installation and painted as soon as possible afterwards. Exposure to the weather for as little as 2 weeks will reduce the paint-holding properties of smooth wood. Scuff sanding prior to painting is necessary if the wood is exposed to the weather for more than 2 weeks. In fact, scuff sanding is always a good idea on planed lumber.

Moisture Blisters

Moisture blisters are bubble-like swellings of the paint film on the wood surface. As the name implies, these blisters usually contain moisture when they are formed. Moisture blisters may occur where outside moisture, such as rain, enters through joints and other end-grain areas of boards and siding. Moisture may also enter as a result of poor construction and maintenance practices. The blisters appear after spring rains and throughout the summer. Paint failure is most severe on the sides of buildings that face the prevailing winds and rain. Blisters may occur in both heated and unheated buildings.

Moisture blisters may also result from the movement of water from the inside of a structure to the outside. Plumbing leaks, humidifiers, overflow (sinks, bathtubs), and shower spray are sources of inside water, and improperly sealed walls can contribute to the problem. Such blisters are not seasonal and occur when the faulty condition develops.

Moisture blisters form between the wood substrate and the first coat of paint. After the blisters appear, they may dry out and collapse. Small blisters may disappear completely and fairly large ones may leave rough spots; in severe cases, the paint peels (Fig. 15–15). Thin coatings of new oil-based paint are the most likely to blister. Old, thick coats are usually too rigid to swell and form blisters; cracking and peeling usually result. Elimination of the moisture problem is the only practical way to prevent moisture blisters in paint. In addition, elimination of moisture problems can help prevent more serious problems such as decay (rot), warp, and splitting of the wood substrate.

To prevent moisture-related paint problems, follow good construction and painting practices. First, do whatever is possible to keep the wood dry. Provide an adequate roof overhang and properly maintain shingles, gutters, and downspouts. Window and door casings should slope away from the house, allowing water to drain away rapidly. Vent clothes dryers, showers, and cooking areas to the outside, not to the crawl space or attic. Avoid the use of humidifiers. If the house contains a crawl space, cover the soil with a vapor-retarding material to prevent migration of water vapor into the living quarters. In northern climates, use a vapor retarder on the interior side of all exterior walls and an air barrier to prevent condensation in the wall. In buildings in southern climates that are air conditioned a substantial part of the year, place the vapor retarder directly under the sheathing.

Mill Glaze

Since the mid-1980s, a condition known as "mill glaze" (also called planer's glaze) has occasionally occurred on smooth flat-grain western redcedar siding as well as other species. There is controversy over the exact cause of this condition, but it seems to occur as a result of planing and/or drying of the lumber. The condition seems to be caused by dull planer blades and is exacerbated on flat-grain surfaces, which are more difficult to plane. The problem is most severe on flat-grain boards because of the orientation of latewood to earlywood. Dull blades tend to burnish the surface and crush the less dense earlywood bands that lie directly beneath the more dense latewood bands at the surface. Later, when these boards are exposed to weather, particularly cyclic moisture conditions, the crushed earlywood absorbs moisture and rebounds, which causes the surface latewood bands to raise. In vertical-grain wood, the earlywood–latewood bands are perpendicular to the surface and the lumber is easier to plane, even with dull tooling.

Figure 15–15. Paint can peel from wood when excessive moisture moves through house wall. Some cross-grain cracking is also evident on this older home.

During the planing or milling process, overheating may bring more water-soluble extractives to the surface, creating a hard, varnish-like glaze. Excess water-soluble extractives can also form (bleed) on the surface during kiln drying. As these extractives age, particularly in direct sunlight, they become insoluble and are difficult to remove. If extractives bleed to the surface prior to final planing or sanding of the lumber, this final surface preparation usually removes them.

Sanding may remove some extractives buildup, but it is not likely to remove all the crushed wood. Subsequent wetting may still cause the surface to deform. One or more wetting and drying cycles are necessary to remove these planer-induced stresses in the wood, but the wood should not be exposed to sunlight for more than 2 weeks before application of a film-forming finish because exposure decreases the adhesion of the coating (see Weathering, Effects on Paint Adhesion).

Mill glaze can cause failure of the finish. Failure is most common on flat-grain siding finished with one or two thin coats of oil-based solid-color stain (also called opaque or full-bodied stain). These low-solids coatings provide only 25 to 50 µm (1 to 2 mil) of dry-film thickness, whereas a brush-applied three-coat paint system (primer and two top-coats) provides 100 to 127 µm (4 to 5 mil) of dry-film thickness. Thin coatings of solid-color stain do not build up enough film to withstand the stresses caused by raised grain, particularly if the coating–wood bond is weakened by extractives buildup on the wood surface.

When using flat-grain bevel siding, the simplest and best solution to the problem of mill glaze and finish failure is to install the siding rough-side out. The rough side is the side of choice for application of penetrating semi-transparent stains, and although solid-color stains form films, they also will provide much better service life when applied to the rough-sawn side. In addition to the lack of mill glaze, the rough side gives two additional advantages. The film buildup on the rough side will be greater and the film will have greater mechanical adhesion or "bite." The best film buildup is obtained by brush application. If the finish is applied by roller or spray, it is advisable to back-brush immediately after application to even out the finish and to work it into the wood surface, thus avoiding bridging, gaps, and lap marks.

If the flat-grain siding must be installed smooth-side out, remove the planing stresses by wetting the surface, then allow 2 to 3 days for the surface to dry before applying the finish. Scratch-sanding the surface with 50- to 80-grit sandpaper also improves paint adhesion. Use either a top quality three-coat paint system or apply a stain-blocking primer prior to applying solid-color stain. In selecting finishes for highly colored wood such as western redcedar or redwood, choose a primer that is impervious to bleed of water-soluble extractives. Although many waterborne primers are being marketed for use on western redcedar and redwood, many paint manufacturers still recommend an oil-based, stain-blocking primer followed by two coats of high quality, acrylic latex top coat. Solid-color stains, particularly the latex formulations, do not block water-soluble extractives very well, especially when only one coat is applied.

Mill glaze has not been common in recent years because paint companies are recommending the use of a primer prior to the application of a solid-color stain, and painting contractors are generally following these recommendations.

Intercoat Peeling

Intercoat peeling is the separation of the new paint film from the old paint coat, which indicates a weak bond between the two (Fig. 15–16). Intercoat peeling usually results from inadequate cleaning of weathered paint and usually occurs within 1 year of repainting. This type of paint peeling can be prevented by following good painting practices. Intercoat peeling can also result from allowing too much time between applying the primer coat and top coat in a new paint job. If more than 2 weeks elapse between applying an oil-based primer and a top coat, soap-like materials may form on the surface and interfere with bonding of the next coat of paint. When the period between applications exceeds 2 weeks, scrub the surface before applying the second coat. Do not apply a primer coat in the fall and wait until spring to finish with the top coat.

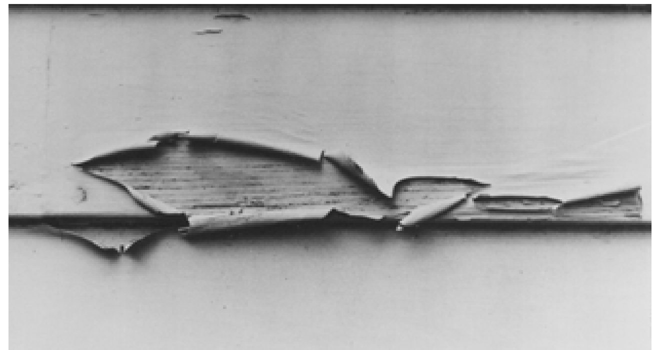

Figure 15–16. Intercoat peeling of paint, usually caused by poor preparation of old paint surface.

Cross-Grain Cracking

Cross-grain cracking occurs when oil-based or alkyd paint coatings become too thick (Fig. 15–17). This problem often occurs on older homes that have been painted many times. Paint usually cracks parallel to the wood grain; cross-grain cracks run across the grain. Once cross-grain cracking has occurred, the only solution is to completely remove the old paint and apply a new finishing system to the bare wood. To prevent cross-grain cracking, follow the paint manufacturer's recommendations for spreading rates. Do not repaint unweathered, protected areas such as porch ceilings and roof overhangs as often as the rest of the house. If possible, repaint these areas only as they weather and require new paint.

Chalking

Chalking results from weathering of the paint's surface, which releases pigment and degraded resin particles. These particles form a fine powder on the paint surface. Most paints chalk to some extent. This phenomenon is desirable because it allows the paint surface to self-clean, and it is the most desirable mechanism for removing degraded paint. However, chalking is objectionable when the paint pigment washes down a surface with a different color or when it causes premature paint failure through excessive erosion.

The paint formulation determines how fast the paint chalks; discoloration from chalking can be decreased by selecting a paint with a slow chalking rate. Therefore, if chalking is likely to be a problem, select a paint that the manufacturer has indicated will chalk slowly. Latex paints, particularly those based on acrylic polymers, chalk very slowly.

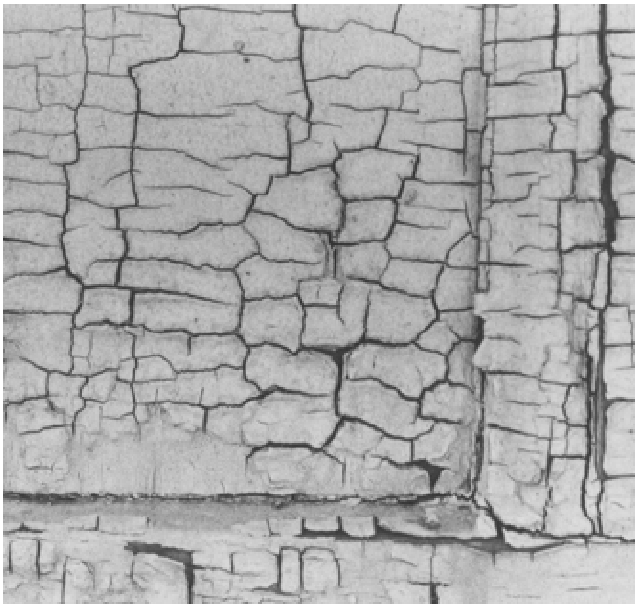

Figure 15–17. Cross-grain cracking from excessive buildup of paint.

When repainting surfaces that have chalked excessively, proper preparation of the old surface is essential to prevent premature paint peeling. Scrub the old surface thoroughly with a detergent solution to remove all old deposits and dirt. Rinse thoroughly with clean water before repainting. To check for excessive chalking, lightly rub the paint surface with a dark (for light-colored paint) or white (for dark-colored paint) cloth. The amount of pigment removed by the cloth is a good indication of the chalking. If the surface is still chalky after cleaning, it may need to be primed prior to repainting. Otherwise, the new paint coat may peel. Discoloration or chalk that has run down a lower surface may be removed by vigorous scrubbing with a good detergent. This discoloration will gradually weather away if chalking on the painted surface above the discolored surface is corrected.

Mildew

Mildew is probably the most common cause of house paint discoloration and gray discoloration of unfinished wood (Fig. 15–18). Mildew is a form of microscopic stain fungi. The most common fungal species are black, but some are red, green, or other colors. Mildew grows most extensively in warm, humid climates, but it is also found in cold northern climates. Mildew may be found anywhere on a building, although it is most common on walls behind trees or shrubs where air movement is restricted. Mildew may also be associated with the dew pattern of the house. Dew will form on those parts of the house that are not heated and tend to cool rapidly, such as eaves and ceilings of carports and porches. The dew then provides a source of moisture for mildew fungi.

Mildew fungi can be distinguished from dirt by examination under a high-power magnifying glass. In the growing stage,

Figure 15–18. Mildew is most common in shaded, moist, or protected areas.

when the surface is damp or wet, the fungus is characterized by its threadlike growth. In the dormant stage, when the surface is dry, the fungus has numerous egg-shaped spores; by contrast, granular particles of dirt appear irregular in size and shape. A simple test for the presence of mildew on wood or paint is to apply a drop or two of liquid household bleach solution (5% sodium hypochlorite) to the discolored surface. The dark color of mildew will usually bleach out in 1 or 2 min. A surface discoloration that does not bleach is probably dirt. It is important to use fresh bleach solution because bleach deteriorates upon aging and loses its potency.

In warm, damp climates where mildew occurs frequently, use a paint containing zinc oxide and a mildewcide for both the primer and top coats. Before repainting mildew-infected wood or painted wood, the mildew must be killed or it will grow through the new paint coat. To kill mildew on wood or on paint, and to clean an area for general appearance or for repainting, use a bristle brush or sponge to scrub the painted surface with a commercial cleaner formulated for mildew removal. Mildew can also be removed using a dilute solution of household bleach with detergent:

- 1 part household detergent
- 10 parts (5%) sodium hypochlorite (household bleach)
- 30 parts warm water

> **Warning:** Do not mix bleach with ammonia or with any detergents or cleansers that contain ammonia. Mixed together, bleach and ammonia form a lethal combination, similar to mustard gas. Many household cleaners contain ammonia, so be extremely careful in selecting the type of cleaner to mix with bleach. Avoid splashing the cleaning solution on yourself or on shrubbery or grass.

Rinse the cleaned surface thoroughly with fresh water. Before the cleaned surface can become contaminated, repaint it with a paint containing a mildewcide. When finishing new wood or refinishing areas that have peeled, pretreatment of wood surfaces with a water-repellent preservative prior to priming can also help deter mildew growth, even after the wood has been painted. Oil-based paints are somewhat more prone to mildew than are latex paints because the oils may be a food source for mildew.

Discoloration From Water-Soluble Extractives

In some wood species, the heartwood contains water-soluble extractives. (Sapwood does not contain extractives.) These extractives can occur in both hardwoods and softwoods. Western redcedar and redwood are two common softwood species that contain large quantities of extractives. The extractives give these species their attractive color, good stability, and natural decay resistance, but they can also discolor paint. Extractive staining problems can occur occasionally with such woods as Douglas-fir and southern yellow pine.

When extractives discolor paint, moisture is usually the culprit. The extractives are dissolved and leached from the wood by water. The water then moves to the paint surface, evaporates, and leaves the extractives behind as a reddish brown stain (Fig. 15–19). Diffused discoloration from wood extractives is caused by water from rain and dew that penetrates a porous or thin paint coat. It may also be caused by rain and dew that penetrates joints in the siding or by water from faulty roof drainage and gutters.

Diffused discoloration is best prevented by following good painting practices. Apply a water-repellent preservative or water repellent to the bare wood before priming. Use an oil-based, stain-resistant primer or a latex primer especially formulated for use over woods likely to discolor from extractives. Do not use porous paints such as flat alkyds and latex directly over these extractive-rich woods. If the wood is already painted, clean the surface, apply an oil-based or latex stain-resistant primer and then the top coat. Be sure to allow sufficient time for the primer to cure so that it blocks the extractives stain. Before priming and repainting, apply a water-repellent preservative or water repellent to any wood exposed by peeled paint.

Water-soluble extractives can also cause a run-down or streaked type of discoloration. This discoloration results when the back of siding is wetted, the extractives are dissolved, and the colored water then runs down the face of the adjacent painted board below the lap joint.

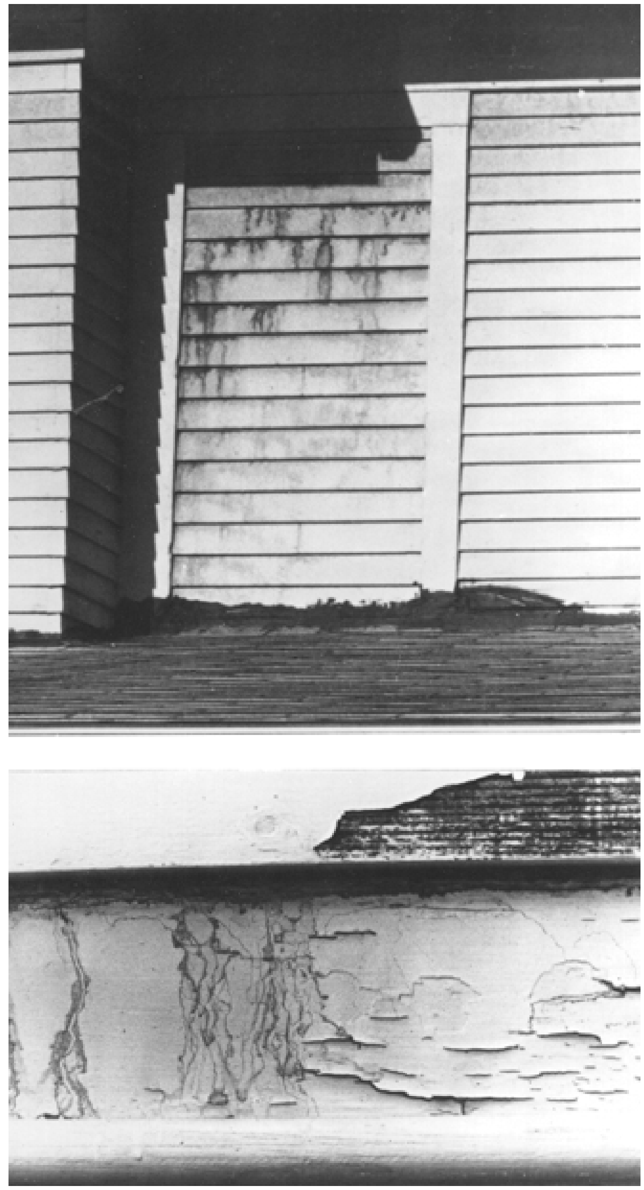

Figure 15–19. Water-soluble extractive discoloration can result from water wetting the back of the siding and then running down the front (top). Water causing discoloration also leads to paint failure (bottom).

Water that produces a run-down discoloration can result from the movement of water vapor within the house to the exterior walls and condensation during cold weather. Major sources of water vapor are humidifiers, unvented clothes dryers, showers, and moisture from cooking and dishwashing. Run-down discoloration may also be caused by draining of water into exterior walls from roof leaks, faulty gutters, ice dams, and wind-driven rain blown beneath the siding.

Run-down discoloration can be prevented by decreasing condensation or the accumulation of moisture in the wall. The same precautions to avoid moisture buildup in walls as described in the section on moisture blisters will also prevent extractives bleed. Water from rain and snow can be prevented from entering the walls by proper maintenance of the gutters and roof. The formation of ice dams can be prevented by installing adequate insulation in the attic and by providing adequate ventilation. If discoloration is to be stopped, moisture problems must be eliminated.

Extractives discoloration will usually weather away in a few months once the cause of the extractives bleed is eliminated. However, discoloration in protected areas can become darker and more difficult to remove with time. In these cases, wash the discolored areas with a mild detergent soon after the problem develops. Paint cleaners are effective on darker stains.

Highly colored woods such as redwood and the cedars benefit from back-priming or treatment with a water-repellent preservative. Although such methods will not completely eliminate extractives staining, they will help reduce staining, particularly from wind-driven rain blown underneath siding (see subsection on back-priming in Application of Wood Finishes).

Blue Stain

Blue stain is caused by microscopic fungi that commonly infect only the sapwood of trees. In some species, these fungi are prone to develop a blue–black discoloration of the wood. Blue stain does not weaken wood structurally, but conditions that favor blue stain are also ideal for wood decay and paint failure.

Wood in service may contain blue stain, and no detrimental effects will result as long as the moisture content is kept below 20%. (Wood in properly designed and well-maintained structures usually has a moisture content of 8% to 13%.) However, if the wood is exposed to moisture from sources such as rain, condensation, or leaky plumbing, the moisture content will increase and the blue-stain fungi may develop and become visible.

A commercial mildew cleaner or a 5% sodium hypochlorite solution (ordinary liquid household bleach) with detergent may remove some blue discoloration, but it is not a permanent cure. The bleach removes the stain from the surface only. To prevent blue stain, the lumber must be cut and dried as soon as possible after harvesting the logs. The lumber must then be kept dry until used and while it is in service. With some wood species that are prone to develop blue stain, the logs are often treated with a fungicide while in storage before the lumber is cut.

Iron Stain

Iron stains on wood can occur through rusting of fasteners or by the reaction of iron with tannins in the wood. When standard steel nails are used on exterior siding and then painted, a reddish brown discoloration may occur through the paint in the immediate vicinity of the nailhead. This reddish brown discoloration is rust, and it can be prevented by using corrosion-resistant nails, which include high-quality galvanized, stainless steel, and aluminum nails. Poor quality galvanized nails can corrode easily and, like steel nails, can cause unsightly staining of the wood and paint. The galvanizing on nailheads should not "chip loose" as the nails are driven into the wood.

Unsightly rust stains may also occur when standard steel nails are used in association with finishing systems such as solid-color or opaque stains, semitransparent penetrating stains, and water-repellent preservatives. Rust stains can also result from screens and other steel objects or fasteners, which corrode and/or release iron compounds.

A chemical reaction of iron with tannins in wood results in an unsightly blue–black discoloration of wood. In this case, discoloration results from the reaction of iron with certain wood extractives. Steel nails are the most common source of iron for such discoloration, but problems have also been associated with traces of iron left from cleaning the wood surface with steel wool or wire brushes. The discoloration can sometimes become sealed beneath a new finishing system. When this happens, the problem is extremely difficult to fix. The coating must be stripped before the iron stain can be removed.

Oxalic acid will remove the blue–black discoloration from iron. Apply a saturated solution containing about 0.5 kg (1 lb) of oxalic acid per 4 L (1 gal) of hot water to the stained surface. Many commercial brighteners contain oxalic acid, and these are usually effective for removing iron stains. A saturated solution of sodium bifluoride ($NaHF_2$) works as well but it may be more difficult to obtain than oxalic acid. After removing the stain, wash the surface thoroughly with warm fresh water to remove the oxalic acid. If all sources of iron are not removed or the wood is not protected from corrosion, the discoloration will recur.

> **Caution**: Use extreme care when using oxalic acid, which is toxic.

If iron stain is a serious problem on a painted surface, the nails can be countersunk and caulked, and the area spot primed and top coated. This is a costly and time-consuming process that is only possible with opaque finishes. Little can be done to give a permanent fix to iron stains on natural finishes other than removing the fasteners, cleaning the affected areas with oxalic acid solution, and replacing the fasteners. It is best to use corrosion-resistant fasteners such as stainless steel rather than risk iron stain, particularly when using natural finishes on wood containing high amounts of tannin, such as western redcedar, redwood, and oak.

Brown Stain Over Knots

The knots in many softwood species, particularly pine, contain an abundance of resins and other highly colored compounds. These compounds can sometimes cause paint to peel or turn brown. The resins that compose pitch can be "set" or hardened by the high temperatures used in kiln drying construction lumber if the proper kiln schedule is used. Some of the other compounds are not affected by kiln drying.

The elimination of staining of paint by colored resins and water-soluble extractives in knots is often difficult because the resins are soluble in oil-based primers and diffuse through them. Latex-based formulations are also not very effective in this regard. It is generally necessary to treat the knot with a specially formulated knot sealer or shellac. Do not use ordinary shellac or varnish to seal knots because such finishes are not formulated for this use; they can cause early paint failure in outdoor exposure. After sealing the knots, apply primer, followed by two top-coats.

Finishing of Interior Wood

Interior finishing differs from exterior finishing primarily in that interior woodwork usually requires much less protection against moisture but more exacting standards of appearance and cleanability. A much wider range of finishes and finish methods are possible indoors because weathering does not occur. Good finishes used indoors should last much longer than paint or other coatings on exterior surfaces. The finishing of veneered panels and plywood may still require extra care because of the tendency of these wood composites to surface check.

Much of the variation in finishing methods for wood used indoors is caused by the wide latitude in the uses of wood—from wood floors to cutting boards. There is a wide range of finishing methods for just furniture. Factory finishing of furniture is often proprietary and may involve more than a dozen steps. Methods for furniture finishing will not be included in this publication; however, most public libraries contain books on furniture finishing. In addition, product literature often contains recommendations for application methods. This section will include general information on wood properties, some products for use in interior finishing, and brief subsections on finishing of wood floors and kitchen utensils.

Color change of wood can sometimes cause concern when using wood in interiors, particularly if the wood is finished to enhance its natural appearance. This color change is a natural aging of the newly cut wood, and nothing can be done to prevent it, except, of course, to keep the wood in the dark. The color change is caused by visible light, not the UV radiation associated with weathering. It is best to keep all paintings and other wall coverings off paneling until most of the color change has occurred. Most of this change occurs within 2 to 3 months, depending on the light intensity. If a picture is removed from paneling and there is a color difference caused by shadowing by the picture, it can be corrected by leaving the wood exposed to light. The color will even out within several months.

To avoid knots, the use of fingerjointed lumber has become common for interior trim. As with exterior wood, the quality of the lumber is determined by the poorest board. Pieces of wood for fingerjointed lumber often come from many different trees that have different amounts of extractives and resins. These extractives and resins can discolor the finish, particularly in humid environments such as bathrooms and kitchens. When finishing fingerjointed lumber, it is prudent to use a high-quality stain-blocking primer to minimize discoloration.

Types of Finish and Wood Fillers

Opaque Finishes

The procedures used to paint interior wood surfaces are similar to those used for exterior surfaces. However, interior woodwork, especially wood trim, requires smoother surfaces, better color, and a more lasting sheen. Therefore, enamels or semigloss enamels are preferable to flat paints. Imperfections such as planer marks, hammer marks, and raised grain are accentuated by high-gloss finishes. Raised grain is especially troublesome on flat-grain surfaces of the denser softwoods because the hard bands of latewood are sometimes crushed into the soft earlywood in planing, and later expand when the wood moisture content changes. To obtain the smoothest wood surface, it is helpful to sponge it with water, allow to dry thoroughly, and sand before finishing. Remove surface dust with a tack cloth. In new buildings, allow woodwork adequate time to come to equilibrium moisture content in the completed building before finishing the woodwork.

To effectively paint hardwoods with large pores, such as oak and ash, the pores must be filled with wood filler (see subsection on wood fillers). The pores are first filled and sanded, then interior primer/sealer, undercoat, and top coat are applied. Knots, particularly in the pines, should be sealed with shellac or a special knot-sealer before priming to retard discoloration of light-colored finishes by colored resins in the heartwood of these species. One or two coats of undercoat are next applied, which should completely hide the wood and also provide a surface that can be easily sanded smooth. For best results, the surface should be sanded just before applying the coats of finish. After the final coat has been applied, the finish may be left as is, with its natural gloss, or rubbed to a soft sheen.

Transparent Finishes

Transparent finishes are often used on hardwoods and some softwood trim and paneling. Most finish processes consist of some combination of the fundamental operations of sanding, staining, filling, sealing, surface coating, and sometimes waxing. Before finishing, planer marks and other blemishes on the wood surface that would be accentuated by the finish must be removed.

Stains

Some softwoods and hardwoods are often finished without staining, especially if the wood has an attractive color. When stain is used, however, it often accentuates color differences in the wood surface because of unequal absorption into different parts of the grain pattern. With hardwoods, such emphasis of the grain is usually desirable; the best stains for this purpose are dyes dissolved in either water or solvent. The water-soluble stains give the most pleasing results, but they raise the grain of the wood and require extra sanding after they dry.

The most commonly used stains are those that do not raise grain and are dissolved in solvents that dry quickly. These stains often approach the water-soluble stains in clearness and uniformity of color. Stains on softwoods color the earlywood more strongly than the latewood, reversing the natural gradation in color unless the wood has been initially sealed. To give more nearly uniform color, softwoods may be coated with penetrating clear sealer before applying any type of stain. This sealer is often called a “wash coat.”

If stain absorbs into wood unevenly causing a blotchy appearance, the tree was probably infected with bacteria and/or blue-stain fungi prior to being cut for lumber. Once the log is cut into lumber, the infection occurs across grain boundaries and makes infected areas more porous than normal wood. When such areas are stained, they absorb excessive amounts of stain very quickly, giving the wood an uneven blotchy appearance. Although this problem is not very common, should it occur it can be difficult to fix. Blue stain on lumber can easily be seen; the infected pieces can either be discarded or sealed before staining. However, bacteria-infected areas cannot be detected prior to staining. If the wood is to be used for furniture or fine woodwork, it might be a good idea to check the lumber, before planing, by applying a stain. Pieces on which the stain appears blotchy should not be used. Sealing the lumber with varnish diluted 50/50 with mineral spirits prior to staining may help; commercial sealers are also available. Bacteria or blue-stain infection may occur in the sapwood of any species, but it seems to be more problematic with the hardwoods because these species tend to be used for furniture, cabinets, and fine woodwork.

Fillers

In hardwoods with large pores, the pores must be filled, usually after staining and before varnish or lacquer is applied, if a smooth coating is desired. The filler may be transparent and not affect the color of the finish, or it may be colored to either match or contrast with the surrounding wood. For finishing purposes, hardwoods may be classified as shown in Table 15–6. Hardwoods with small pores may be finished with paints, enamels, and varnishes in exactly the same manner as softwoods. A filler may be a paste or liquid, natural or colored. Apply the filler by brushing it first across and then with the grain. Remove surplus filler immediately after the glossy wet appearance disappears. First, wipe across the grain of the wood to pack the filler into the pores; then, wipe with a few light strokes along the grain. Allow the filler to dry thoroughly and lightly sand it before finishing the wood.

Sealers

Sealers are thinned varnish, shellac, or lacquer that are used to prevent absorption of surface coatings and to prevent the bleeding of some stains and fillers into surface coatings, especially lacquer coatings. Lacquer and shellac sealers have the advantage of drying very quickly.

Table 15–6. Classification of hardwoods by size of pores[a]

Large pores	Small pores
Ash	Aspen
Butternut	Basswood
Chestnut	Beech
Elm	Cherry
Hackberry	Cottonwood
Hickory	Gum
Lauan	Magnolia
Mahogany	Maple
Mahogany, African	Red alder
Oak	Sycamore
Sugarberry	Yellow-poplar
Walnut	

[a]Birch has pores large enough to take wood filler effectively, but small enough to be finished satisfactorily without filling.

Surface Coats

Transparent surface coatings over the sealer may be gloss varnish, semigloss varnish, shellac, nitrocellulose lacquer, or wax. Wax provides protection without forming a thick coating and without greatly enhancing the natural luster of the wood. Other coatings are more resinous, especially lacquer and varnish; they accentuate the natural luster of some hardwoods and seem to give the surface more “depth.” Shellac applied by the laborious process of French polishing probably achieves this impression of depth most fully, but the coating is expensive and easily marred by water. Rubbing varnishes made with resins of high refractive index for light (ability to bend light rays) are nearly as effective as shellac. Lacquers have the advantages of drying rapidly and forming a hard surface, but more applications of lacquer than varnish are required to build up a lustrous coating. If sufficient film buildup is not obtained and the surface is cleaned often, such as the surface of kitchen cabinets, these thin films can fail.

Varnish and lacquer usually dry to a high gloss. To decrease the gloss, surfaces may be rubbed with pumice stone and water or polishing oil. Waterproof sandpaper and water may be used instead of pumice stone. The final sheen varies with the fineness of the powdered pumice stone; coarse powders make a dull surface and fine powders produce a bright sheen. For very smooth surfaces with high polish, the final rubbing is done with rottenstone and oil. Varnish and lacquer made to produce a semigloss or satin finish are also available.

Flat oil finishes commonly called Danish oils are also very popular. This type of finish penetrates the wood and does not form a noticeable film on the surface. Two or more coats of oil are usually applied; the oil may be followed by a paste wax. Such finishes are easily applied and maintained but they are more subject to soiling than is a film-forming type of finish. Simple boiled linseed oil or tung oil are also used extensively as wood finishes.

Finishes for Floors

Wood possesses a variety of properties that make it a highly desirable flooring material for homes, factories, and public buildings. A variety of wood flooring products are available, both unfinished and prefinished, in many wood species, grain characteristics, flooring types, and flooring patterns.

The natural color and grain of wood floors accentuate many architectural styles. Floor finishes enhance the natural beauty of wood, protect it from excessive wear and abrasion, and make the floor easier to clean. The finishing process consists of four steps: sanding the surface, applying a filler (for open-grain woods), staining to achieve a desired color effect, and finishing. Detailed procedures and specified materials depend to a great extent on the species of wood used and finish preference.

Careful sanding to provide a smooth surface is essential for a good finish because any irregularities or roughness in the surface will be accentuated by the finish. Development of a top-quality surface requires sanding in several steps with progressively finer sandpaper, usually with a machine unless the area is small. When sanding is complete, all dust must be removed with a vacuum cleaner and then a tack cloth. Steel wool should not be used on floors unprotected by finish because minute steel particles left in the wood later cause iron stains. A filler is required for wood with large pores, such as oak and walnut, if a smooth, glossy varnish finish is desired (Table 15–6).

Stains are sometimes used to obtain a more nearly uniform color when individual boards vary too much in their natural color. However, stains may also be used to accent the grain pattern. The stain should be an oil-based or non-grain-raising type. Stains penetrate wood only slightly; therefore, the finish should be carefully maintained to prevent wearing through to the wood surface; the clear top-coats must be replaced as they wear. It is difficult to renew the stain at worn spots in a way that will match the color of the surrounding area.

Finishes commonly used for wood floors are classified as sealers or varnishes. Sealers, which are usually thinned varnishes, are widely used for residential flooring. They penetrate the wood just enough to avoid formation of a surface coating of appreciable thickness. Wax is usually applied over the sealer; however, if greater gloss is desired, the sealed floor makes an excellent base for varnish. The thin surface coat of sealer and wax needs more frequent attention than do varnished surfaces. However, rewaxing or resealing and waxing of high traffic areas is a relatively simple maintenance procedure, as long as the stained surface of the wood hasn't been worn.

Varnish may be based on phenolic, alkyd, epoxy, or polyurethane resins. Varnish forms a distinct coating over the wood and gives a lustrous finish. The kind of service expected usually determines the type of varnish. Varnishes especially designed for homes, schools, gymnasiums, or other public buildings are available. Information on types of floor finishes can be obtained from flooring associations or individual flooring manufacturers.

The durability of floor finishes can be improved by keeping them waxed. Paste waxes generally provide the best appearance and durability. Two coats are recommended, and if a liquid wax is used, additional coats may be necessary to get an adequate film for good performance.

Finishes for Items Used for Food

The durability and beauty of wood make it an attractive material for bowls, butcher blocks, and other items used to serve or prepare food. A finish also helps keep the wood dry, which makes it less prone to harbor bacteria and less likely to crack. When wood soaks up water, it swells; when it dries out, it shrinks. If the wood dries out rapidly, its surface dries faster than the inside, resulting in cracks and checks. Finishes that repel water will decrease the effects of brief periods of moisture (washing), making the wood easier to clean.

Finishes that form a film on wood, such as varnish or lacquer, may be used but they may eventually chip, crack, and peel. Penetrating finishes, either drying or nondrying, are often a better choice for some products.

Types of Finish

Sealers and Drying Oils

Sealers and drying oils penetrate the wood surface, then solidify to form a barrier to liquid water. Many commercial sealers are similar to thinned varnish. These finishes can include a wide range of formulations including polyurethane, alkyds, and modified oils. Unmodified oils such as tung, linseed, and walnut oil can also be used as sealers if they are thinned to penetrate the wood.

Nondrying Oils

Nondrying oils simply penetrate the wood. They include both vegetable and mineral oils. Vegetable oils (such as olive, corn, peanut, and safflower) are edible and are sometimes used to finish wood utensils. Mineral (or paraffin) oil is a nondrying oil from petroleum. Since it is not a natural product, it is not prone to mildew or to harbor bacteria.

Paraffin Wax

Paraffin wax is similar to paraffin oil but is solid at room temperature. Paraffin wax is one of the simplest ways to finish wood utensils, especially countertops, butcher blocks, and cutting boards.

Eating Utensils

Wood salad bowls, spoons, and forks used for food service need a finish that is resistant to abrasion, water, acids, and stains and a surface that is easy to clean when soiled.

Appropriate finishes are varnishes and lacquers, penetrating wood sealers and drying oils, and nondrying vegetable oils.

Many varnishes and lacquers are available, and some of these are specifically formulated for use on wood utensils, bowls, and/or cutting boards. These film-forming finishes resist staining and provide a surface that is easy to keep clean; however, they may eventually chip, peel, alligator, or crack. These film-forming finishes should perform well if care is taken to minimize their exposure to water. Utensils finished with such finishes should never be placed in a dishwasher.

Penetrating wood sealers and drying oils may also be used for eating utensils. Some of these may be formulated for use on utensils. Wood sealers and oils absorb into the pores of the wood and fill the cavities of the wood cells. This decreases the absorption of water and makes the surface easy to clean and more resistant to scratching compared with unfinished wood. Penetrating wood sealers are easy to apply and dry quickly. Worn places in the finish may be easily refinished. Some of these finishes, particularly drying oils, should be allowed to dry thoroughly for several weeks before use.

Nondrying vegetable oils are edible and are sometimes used to finish wood utensils. They penetrate the wood surface, improve its resistance to water, and can be refurbished easily. However, such finishes can become rancid and can sometimes impart undesirable odors and/or flavors to food.

Of these finish types, the impermeable varnishes and lacquers may be the best option for bowls and eating utensils; this kind of finish is easiest to keep clean and most resistant to absorption of stains.

> **Note**: Whatever finish is chosen for wood utensils used to store, handle, or eat food, it is important to be sure that the finish is safe and not toxic (poisonous). Also be sure that the finish you select is recommended for use with food or is described as food grade. For information on the safety and toxicity of any finish, check the label, contact the manufacturer and/or the Food and Drug Administration, or check with your local extension home economics expert or county agent.

Butcher Blocks and Cutting Boards

One of the simplest treatments for wood butcher blocks and cutting boards is the application of melted paraffin wax (the type used for home canning). The wax is melted in a double-boiler over hot water and liberally brushed on the wood surface. Excess wax, which has solidified on the surface, can be melted with an iron to absorb it into the wood, or it may be scraped off. Refinishing is simple and easy. Other penetrating finishes (sealers, drying and nondrying oils) may also be used for butcher blocks and cutting boards. As mentioned in the subsection on eating utensils, vegetable oils may become rancid. If a nondrying oil is desired, mineral oil may be used. Film-forming finishes are not recommended for butcher blocks or cutting boards.

Wood Cleaners and Brighteners

The popularity of wood decks and the desire to keep them looking bright and new has led to a proliferation of commercial cleaners and brighteners. The removal of mildew from wood was discussed in an earlier section of this chapter (see Finish Failure or Discoloration). Mildew growth on unpainted and painted wood continues to be the primary cause of discoloration. Although it can be removed with a dilute solution of household bleach and detergent, many commercial products are available that can both remove mildew and brighten the wood surface.

The active ingredient in many of these products is sodium percarbonate (disodium peroxypercarbonate). This chemical is an oxidizing agent as is bleach, and it is an effective mildew cleaner. It also helps brighten the wood surface. Some cleaners and brighteners are reported to restore color to wood. It is not possible to add color to wood by cleaning it. Removing the discoloration reveals the original color. Brightening the wood may make it appear as if it has more color. Once all the colored components of the wood surface have been removed through the weathering process, the surface will be a silvery gray. If color is desired after weathering occurs, it must be added to the wood by staining.

In addition to sodium percarbonate, other oxidizing products may contain hydrogen peroxide by itself or in combination with sodium hydroxide. If sodium hydroxide is used without a brightener, it will darken the wood. Commercial products are also formulated with sodium hypochlorite and/or calcium hypochlorite (household bleach is a solution of sodium hypochlorite). These products usually contain a surfactant or detergent to enhance the cleansing action of the oxidizing agent. Other types of brighteners contain oxalic acid. This chemical removes stains caused by extractives bleed and iron stains and also brightens the wood, but it is not very effective for removing mildew.

Paint Strippers

Removing paint and other film-forming finishes from wood is a time-consuming and often difficult process. It is generally not done unless absolutely necessary to refinish the wood. Removing the finish is necessary if the old finish has extensive cross-grain cracking caused by buildup of many layers of paint, particularly oil-based paint. If cracking and peeling are extensive, it is usually best to remove all the paint from the affected area. Total removal of paint is also necessary if the paint has failed by intercoat peeling. It may be necessary to remove paint containing lead; however, if the paint is still sound and it is not illegal to leave it on the structure, it is best to repaint the surface without removing the old paint (see Lead-Based Paint).

This discussion of paint strippers is limited to film-forming finishes on wood used in structures. Removing paint from furniture can be done using the same methods as described here. Companies that specialize in stripping furniture usually immerse the furniture in a vat of paint stripper and then clean and brighten the wood. This procedure removes the paint very efficiently.

Some of the same methods can be used for the removal of interior and exterior paint. Because of the dust caused by mechanical methods or the fumes given off by chemical strippers, it is extremely important to use effective safety equipment, particularly when working indoors. A good respirator is essential, even if the paint does not contain lead (see Lead-Based Paint).

> **Note:** The dust masks sold in hardware stores do not block chemical fumes and are not very effective against dust.

Two general types of stripping methods are discussed here: mechanical and chemical. The processes are discussed in general terms primarily in regard to their effect on wood; some attention is given to their ease of use and safety requirements. Consult product literature for additional information on appropriate uses and safety precautions.

Mechanical Methods

Finishes can be removed by scraping, sanding, wet or dry sandblasting, spraying with pressurized water (power washing), and using electrically heated pads, hot air guns, and blow torches. Scraping is effective only in removing loosely bonded paint or paint that has already partially peeled from the wood. It is generally used when paint needs to be removed only from small areas of the structure, and it is generally combined with sanding to feather the edge of the paint still bonded to the wood (see Lead-Based Paint).

When the paint is peeling and partially debonded on large areas of a structure, the finish is usually removed by power washing or wet sandblasting. These methods work well for paint that is loosely bonded to the wood. If the paint is well bonded, complete removal can be difficult without severely damaging the wood surface. The pressure necessary to debond paint from the wood can easily cause deep erosion of the wood. The less dense earlywood erodes more than the dense latewood, leaving behind a surface consisting of latewood, which is more difficult to repaint. Power washing is less damaging to the wood than is wet or dry sandblasting, particularly if low pressure is used. If high pressure is necessary to remove the paint, it is probably bonded well enough that it does not need to be removed for normal refinishing. If more aggressive mechanical methods are required, wet sandblasting can remove even well-bonded paint, but it causes more damage to the wood than does water blasting. Dry sandblasting is not very suitable for removing paint from wood because it can quickly erode the wood surface along with the paint, and it tends to glaze the surface.

A number of power sanders and similar devices are available for complete paint removal. Many of these devices are suitable for removing paint that contains lead; they have attachments for containing the dust. Equipment that has a series of blades similar to a power hand-planer is less likely to "gum up" with paint than equipment that merely sands the surface. Some of this equipment is advertised in the *Old House Journal* and the *Journal of Light Construction*. Please consult the manufacturers' technical data sheets for detailed information to determine the suitability of their equipment for your needs and to meet government regulations on lead-containing paint.

Paint can be removed by heating then scraping it from the wood, but this method must not be used for paint that contains lead. Paint can be softened by using electrically heated pads, hot air guns, or blow torches. Heated pads and hot air guns are slow methods, but they cause little damage to the wood. Sanding is still necessary, but the wood should be sound after the paint is removed. Blow torches have been used to remove paint and, if carefully used, do not damage the wood. Blow torches are extremely hazardous; the flames can easily ignite flammable materials beneath the siding through gaps in the siding. These materials may smolder, undetected, for hours before bursting into flame and causing loss of the structure.

> **Note:** Removing paint with a blow torch is not recommended.

Chemical Methods

If all the paint needs to be removed, then mechanical methods should be used in concert with other methods, such as chemical paint strippers. For all chemical paint strippers, the process involves applying paint stripper, waiting, scraping off the softened paint, washing the wood (and possibly neutralizing the stripper), and sanding the surface to remove the wood damaged by the stripper and/or the raised grain caused by washing. Chemical paint strippers, although tedious to use, are sometimes the most reasonable choice. A range of paint strippers are available. Some are extremely strong chemicals that quickly remove paint but are dangerous to use. Others remove the paint slowly but are safer. With the exception of alkali paint stripper (discussed below), there appears to be an inverse correlation between how safe a product is and how fast it removes the paint.

Solvent-Based Strippers

Fast-working paint strippers usually contain methylene chloride, a possible carcinogen that can burn eyes and skin. Eye and skin protection and a supplied-air respirator are essential when using this paint stripper. Paint strippers having methylene chloride can remove paint in as little as 10 min. Because of concerns with methylene chloride, some paint strippers are being formulated using other strong solvents; the same safety precautions should be used with these formulations as with those containing methylene chloride. To remain effective in removing paint, a paint stripper must remain liquid or semiliquid; slow-acting paint stripers are often covered to keep them active. Solvent-type strippers contain a wax that floats to the surface to slow the evaporation of the solvent. Covering the paint stripper with plastic wrap also helps to contain the solvent.

Alkali-Based Strippers

As an alternative to strong solvents, some paint strippers contain strong bases (alkali). Like solvent-based paint strippers, alkali-based strippers require eye and skin protection. Follow the manufacturer's recommendations about whether a respirator is necessary as well. Although alkali-based paint strippers soften the paint rather slowly, they are strong chemicals and can severely damage the wood substrate. Because they degrade the paint slowly, these strippers are often left on the painted wood a full day or overnight. They are usually covered with a cloth, which helps in peeling the weakened paint from the surface.

These cloth-covered types of products have the advantage of containing the paint stripper and paint extremely well, an important consideration when removing paint containing lead. They have the disadvantage of severely degrading the wood substrate. Strong alkali actually pulps the wood surface. Once the paint is removed, it is essential to neutralize the surface with acid. Oxalic acid is frequently used for this process. Unfortunately, it is extremely difficult to balance the acid and base concentrations. If excess alkali is left in the wood, it will continue to degrade it and to degrade the subsequent paint coating. Excess oxalic acid can also damage the wood. The neutralization procedure leaves behind reaction products of the acid and base (water and a salt). Often, the salt is hygroscopic (absorbs moisture from the air) and causes the wood to get wet. Wet wood does not hold paint very well.

> **Note:** Alkali-based strippers require extra care to ensure that the wood is neutralized and that residual salts are washed from the wood. The surface must be sanded before repainting.

Since the surface must be sanded before repainting, paint performance might be improved by letting the wood weather for an extended period (possibly as long as a year) before repainting to let rain leach unwanted chemicals from the wood. In addition, rinse the siding periodically using a hose, particularly areas that rain does not reach, such as siding under eaves and porches. Once all the residue has been removed, the surface can be sanded (50-grit sandpaper) and painted.

Although alkali paint strippers can cause burns on unprotected skin, the fumes are not nearly as toxic as those in solvent-type strippers. Alkali paint strippers are an excellent choice for indoor use such as door and window trim and fireplace mantles. Indoors, the weakened wood surface may not be as much of a concern because less stress is placed on the wood–paint interface; the wood is not exposed to weather extremes.

"Safe" Paint Strippers

Several paint strippers are being marketed under the "safe" caveat. These strippers work much slower than those having strong chemical solvents. The active ingredient in such paint strippers is usually proprietary. In regard to safety, follow the manufacturer's recommendations.

Avoidance of Problems

Failure of the finish on wood that has been stripped can be avoided by using methods that do not damage the wood surface. The best way to remove paint may involve a combination of methods. For example, use power washing to remove as much paint as possible. Then, use a solvent-based chemical paint stripper on paint that could not be removed by power washing. Avoid using excessive amounts of chemical stripper. Applying too much stripper or leaving it on the painted wood for too long can damage the wood. It is better to use less stripper and reapply it, if necessary, than to try to remove all the paint with one application, leaving the stripper on the paint for an extended period.

The problem of paint removal is complicated by the wide range of paint types and wood species. Companies that make paint strippers may optimize the formulations without considering their effects on the wood. Removing the paint from the wood is only half the task. Getting a paintable surface is the other half. Companies that formulate paint strippers must consider this other half. Those who use paint strippers need to understand the added burden of surface preparation.

Disposal of Old Paint

No matter what method you use to remove paint, be careful in disposing of the old paint, particularly paint that contains lead. Lead is considered hazardous waste, and there are regulations that restrict the handling and disposal of this material. Be sure to follow all regulations, both national and local, during the removal, storage, and disposal of paint, especially paint containing lead (see Lead-Based Paint).

Lead-Based Paint

The information in this section is taken from material prepared by the National Association of Home Builders (NAHB) and is contained in *Rehabilitation of Wood-Frame Houses* (USDA 1998). Lead-based paint was widely used in residential applications in the United States until the early 1940s, and its use was continued to some extent, particularly for the exterior of dwellings, until 1976. In 1971, Congress passed the Lead-Based Paint Poisoning Prevention Act, and in 1976, the Consumer Product Safety Commission (CPSC) issued a ruling under this Act that limited the lead content of paint used in residential dwellings, toys, and furniture to 0.06%.

Lead-based paint is still manufactured today for applications not covered by the CPSC ruling, such as paint for metal products, particularly those made of steel. Occasionally, such lead-based paint (for example, surplus paint from a shipyard) inadvertently gets into retail stores and the hands of consumers. A study conducted for the Environmental Protection Agency in 1986 indicated that about 42 million U.S. homes still contain interior and/or exterior lead-based paint. As rehabilitation of these homes increases, how to abate the toxicity of lead-based paint has become the subject of increased public and official concern.

Studies have shown that ingestion of even minute amounts of lead can have serious effects on health, including hypertension, fetal injury, and damage to the brain, kidneys, and red blood cells. Low levels of ingestion can also cause partial loss of hearing, impairment of mental development and IQ, growth retardation, inhibited metabolism of vitamin D, and disturbances in blood formation. The American Academy of Pediatrics regards lead as one of the foremost toxicological dangers to children.

Lead-based paint applied to the exterior of homes disintegrates into chalk and powder as a result of the effects of moisture and ultraviolet radiation. This extremely fine lead dust can accumulate in the soil near the house and can ultimately enter the house. Poor quality lead-based paint used on interior surfaces can also produce dust. Lead dust can be generated when coatings on surfaces are broken through aging or as a result of rehabilitation. The dust cannot be completely removed by conventional house-cleaning methods.

Methods used to abate the toxicity of lead-based paint or to remove the paint can themselves generate lead dust. This is particularly true when unacceptable methods and work practices are used. Poorly performed abatement can be worse than no abatement. The micron-sized lead dust particles can remain airborne for substantial periods and cannot be fully removed by standard cleaning methods from the surfaces on which they have settled. When working on old painted surfaces, the worker should assume that one or more of the paint coats contain lead. Proper precautions should be taken accordingly.

Paint coats may be checked for lead content. A portable x-ray fluorescence (XRF) analyzer is commonly used to determine the level of lead in paint. Because this device has the potential for giving very inaccurate results if used by an inexperienced person, the analysis should be done by a qualified professional. Chemical spot testing, using a solution of 6% to 8% sodium sulfide in water, is sometimes used to screen painted surfaces for the presence of lead. Be certain to check all paint coats, because the older ones are more likely to be lead based. Test kits for detecting lead-based paint are available in most paint and hardware stores.

Removal of lead-based paints can present some serious health problems. The U.S. Department of Health and Urban Development (HUD) has taken a leading role in developing guidelines for the removal of lead-based paints. At this time, HUD has approved three approaches to abating the toxicity of lead-based paint:

1. Covering the painted surface with wallboard, a fiberglass cloth barrier, or permanently attached wallpaper
2. Removing the paint
3. Replacing the entire surface to which lead-based paint has been applied

Certain practices are prohibited in residential structures owned and operated by HUD: machine sanding without an attached high-efficiency particulate air (HEPA) vacuum filtration apparatus, use of propane torches, contained water blasting, washing, and repainting.

Removal of lead-based paint by scraping or application of heat does not solve the problem of lead-particulate dust. Scraping should be accompanied by misting. Dry scraping is prohibited by Maryland abatement regulations. Sanding without a HEPA-filtered vacuum should not be used as a finishing method after scraping or any other method of toxicity abatement. The HEPA sanders are recommended for limited surface areas only; they are most appropriate for flat surfaces such as door jambs and stair risers. Open abrasive blasting is also prohibited by some regulations.

High levels of airborne lead can be produced by heat guns, and the use of a respirator is essential. Some lead is likely to be volatilized at the operating temperatures of most heat guns. Lead fumes are released at about 371°C (700°F). Heat guns capable of reaching or exceeding this temperature should not be operated in that range.

Chemical methods for removing lead-based paint may require multiple applications, depending on the number of paint coats. Caustic and solvent-based chemicals should not be allowed to dry on the lead-painted surface. If drying occurs, paint removal will not be satisfactory and the potential for creating lead dust will be increased.

Chemical substances used for paint removal are usually hazardous and should be used with great care. Some solvent-based chemical strippers are flammable and require ventilation. They may contain methylene chloride, which is a central nervous system depressant that at high concentrations can cause kidney and liver damage and is a possible carcinogen. Supplied-air respirators should be used when working with strippers containing this substance. If the solvent-based strippers do not contain methylene chloride, organic vapor filters must be added to respirators. Caustic chemical strippers also have a very high pH (alkaline content), which can cause severe skin and eye injuries.

Caution: Remodeling or refinishing projects that require disturbing, removing, or demolishing portions of the structure that are coated with lead-based paint pose serious problems. The consumer should seek information, advice, and perhaps professional assistance for addressing these problems. Contact HUD for the latest information on the removal of lead-based paints. Debris coated with lead-based paint is regarded as hazardous waste.

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