CHAPTER 4

PRESERVATION AND PROTECTION OF TIMBER BRIDGES

4.1 INTRODUCTION

Wood has been successfully used as a bridge material for thousands of years, but before the early 1900's most structures were built of untreated timber. Protection from decay and deterioration was afforded by using the heartwood of naturally durable species or by covering the structure to protect it from weathering. Although many bridges constructed of untreated timber performed well (some lasting longer than 100 years), the use of untreated timber declined as naturally resistant North American wood species became unavailable in the quantities and sizes necessary for bridge construction. Additionally, it became economically and functionally impractical to cover timber bridges for protection. In spite of the attractiveness of using naturally durable wood, modem timber bridges must be preservatively treated to obtain adequate performance.

Wood will last for centuries if kept dry. However, if it is used in an unprotected environment, it becomes susceptible to attack by living and nonliving agents capable of degrading the wood structure. Nonliving or physical agents, including heat, abrasion, ultraviolet light, and strong chemicals, generally act slowly to decrease wood strength. Although these physical agents may be significant in some applications, the greatest hazard to timber bridges results from living or biotic agents, such as decay fungi, bacteria, insects, and marine borers. These agents can cause serious damage to untreated wood in a relatively short period in a variety of environments (see Chapter 13 for more detailed discussions on the agents and processes of deterioration).

Most of the biotic agents that enter and decay untreated wood require four basic conditions for survival: (1) moisture levels in the wood above the fiber saturation point, (2) free oxygen, (3) temperature in the range of 50 to 90°F, and (4) food, namely the wood. Although most biotic agents can be controlled by limiting moisture, oxygen, or temperature, it is often difficult or impractical to control these conditions. As a result, the most common method for controlling deterioration in adverse environments involves removing the food source by introducing toxic preservative chemicals into the wood cells using a pressure treatment process.

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Wood preservatives are toxic chemicals that penetrate and remain in the wood structure. They should not be confused with protective coatings, such as paints or stains, which do nothing to kill or prevent the spread of biotic agents. A wood preservative must have the ability to penetrate the wood and persist in sufficient quantities for long periods. The degree of protection depends on the type of preservative used, the treatment process, the species of wood, and the environment to which the structure will be exposed. Applied correctly, wood preservatives can increase the life of timber structures by as much as five times or more.

A complete approach to the preservation and protection of timber bridges involves many considerations related to materials, preservative treatments, design details, and construction practices. This chapter addresses design requirements and considerations related to preservative treatments, including types of preservatives, treatment processes, design specifications, and quality assurance. Additional information related to design details and construction practices is presented in subsequent chapters.

4.2 TYPES OF WOOD PRESERVATIVES

Wood preservatives are broadly classified as oil-type or waterborne preservatives. These classifications are based on the chemical composition of the preservative and the type of solvent or carrier employed in treating. Oil-type preservatives are generally used in petroleum solutions ranging from heavy oils to liquefied petroleum gas. Waterborne preservatives are water soluble and are applied in solutions with water. The advantages and disadvantages of each type of preservative/solvent system depend on the specific characteristics of the preservative and solvent and on the environmental conditions to which the treated wood will be exposed.

To adequately protect wood, conventional preservatives must be toxic to the intended targets, be they fungi, insects, or animals. Unfortunately, the same characteristics that make a preservative effective can, at higher levels, render it unsafe for humans. With the exception of one preservative, copper naphthenate, all the preservatives addressed in this section are restricted-use pesticides and can be obtained and used only by licensed applicators. Use of wood treated with these chemicals is not restricted, although it must be accompanied by a consumer information sheet that describes proper handling procedures and precautions (see Chapter 16). While current environmental concerns have stimulated the search for new, less toxic wood preservatives, most of these formulations are still in the evaluation process and are several years away from commercial service.

OIL-TYPE PRESERVATIVES

The three oil-type preservatives used in bridge applications are coal-tar creosote (creosote), pentachlorophenol (penta), and copper naphthenate. The characteristics of these preservatives vary significantly depending on the specific type of preservative and the carrier or solvent in which they are mixed. With the exception of some solutions of penta, oil-type preservatives generally leave the surface of the wood with an oily, unpaintable surface that may exude or bleed preservative. This bleeding can be minimized or eliminated when appropriate precautions are observed.

For bridge applications, oil-type preservatives are used almost exclusively for treating such structural components as beams and decks. They provide good protection from decay and other deterioration, are noncorrosive, and generally afford good physical protection of the wood surface from the effects of weathering. Because most oil-type preservatives can cause skin irritations, they should not be used for applications that require repeated human or animal contact, such as handrails.

Creosote

Creosote, which was first patented in 1831, ushered in the age of effective wood protection. It is a black or brownish oil consisting of a complex mixture of polynuclear aromatic hydrocarbons. Creosote is derived either from the destructive distillation of coal to produce coke (a byproduct of steel production) or by distillation of oil shale. Although creosote can be manufactured from other materials, such as wood or oil, all creosote used for commercial wood treatment is derived from coal tar. Because it is not a primary product, the composition of creosote has varied widely over the years. However, more restrictive requirements now ensure the availability of relatively uniform creosote. Because it is a complex mixture of nearly 300 compounds, the toxic mechanisms and migration of creosote from wood are still poorly understood more than 150 years after the chemical was patented.

Creosote has a long record of satisfactory use as a wood preservative, with many case histories documenting more than 50 years of proven performance in both railroad and highway use. This chemical has performed well in almost every environment except in areas where marine borer hazards are high because of attack by *Limnoria tripunctata* (this species of borer is capable of attacking creosoted wood in warmer marine saltwaters). Creosote provides the added advantages of protecting the wood from the effects of weathering and retarding the checking and splitting associated with changes in moisture content.

At one time, creosote was the most commonly used wood preservative for timber products, but an increased desire for clean surfaces, coupled with complaints about handling creosoted wood, has led to a gradual decline in the percentage of wood treated with this chemical. Today, creosote is frequently used to treat bridge components, utility poles, marine piling, and railroad ties. All these applications involve minimal human contact with the treated wood. Recently, a clean creosote with reduced surface deposits has been developed that leaves the wood a light brown color and has a reduced risk of preservative exudation on the wood surface.

As a wood preservative, creosote is commonly available in both its undiluted or straight form, and also as a blend in solvents. The following paragraphs discuss the various creosote preservatives and their use in timber bridge applications.

Coal-tar creosote in its straight or undiluted form is the most commonly used creosote preservative for sawn lumber, glulam, piling, and poles. This form of creosote preservative is preferred for bridge applications.

Creosote/coal-tar solutions are a blend of creosote and coal tar. There are four creosote/coal-tar solutions: Types A, B, C, and D. The percentage (by volume) of coal-tar distillate (creosote) in each type of solution is 80, 70, 60, and 50 percent, respectively. Creosote/coal-tar solutions have been used with some success for treating poles and piling in marine exposures. They are not commonly used in bridge applications because the high level of insolubles in the solutions can produce excessive bleeding of the treatment from the timber surface, contributing to environmental concerns. The number of creosote/coal-tar solutions available in the future is expected to decline because of the expense required to meet Environmental Protection Agency (EPA) requirements.

Creosote/petroleum-oil solutions consist of a blend of not less than 50 percent creosote (by volume) in a solution of petroleum oil. Although this type of preservative performs well in bridge applications when a minimum 50-percent volume of creosote is in the solution, there is currently no method of determining the percentage of creosote in the mixture after the creosote and oil are blended. There have been cases where treatments of this type contained insufficient quantities of creosote to adequately protect wood from deterioration. Until analytical or other methods are developed that ensure the level of creosote in oil solutions, this treatment is not recommended for bridge applications unless blending of the creosote and oil is observed and verified by the purchaser or a designated representative.

In addition to the preservatives mentioned already, creosote has been blended with naphthalene, penta, copper naphthenate, and sulfur. While some of these chemicals were effective in preventing wood deterioration, technical problems or costs have precluded their use.

Pentachlorophenol

First patented in 1935, penta was among the first of many synthetic pesticides that revolutionized the way people dealt with pests. Because penta could be easily synthesized by chlorinating phenol, there were few variations in the product, and the supply could meet demand. As a result, oilborne penta and the waterborne pentachlorophenate salt became two of our most important biocides. As a wood preservative, penta is a highly effective inhibitor of oxidative phosphorylation, which prevents the affected organism from obtaining energy. However, penta is not effective against marine borers and is not recommended for marine use.

Although penta is still widely used, the presence of trace contaminants known as dioxins has led to increased pressure to ban this preservative, and EPA has placed penta on its list of restricted-use chemicals (the dioxins present in penta are not the more highly toxic tetrachlorodioxins). Restricted-use chemicals can be used only by applicators who have passed a test on pesticide safety in their respective States; however, use of wood treated with this chemical is not restricted. In addition to these restrictions, EPA has placed limits on the permissible levels of dioxins present in penta. This combination of regulations should reduce the hazard of using penta. In spite of these restrictions, penta is used on approximately 30 percent of the wood treated each year, primarily for poles, posts, and timbers.

Penta is generally applied a solution of approximately 5 to 9 percent (by weight) in one of four hydrocarbon solvents, Type A, B, C, or D. The use of penta preservatives is characterized by the type of solvent.

Type A solvent is an oil solvent that is generally referred to as heavy oil. It is commonly used to treat sawn lumber, poles, and glulam after gluing. This is the preferred solvent for most bridge applications because the oil provides some protection from weathering, resulting in reduced checking and splitting in members. It is not paintable and should not be used in applications subject to human or animal contact.

Type B solvent is a liquefied petroleum gas (butane) that evaporates from the wood to leave a clean, paintable surface. It is used (with limited availability) to treat sawn lumber and lumber laminations for glulam, and may also be used to treat small glulam members after gluing. Penta in Type B solvent can be used in bridge applications for treating handrails and floors on pedestrian crossings. It is not recommended for main structural components or members subjected to ground contact because it provides no surface protection from weathering.

Type C solvent is a light petroleum solvent that gives the wood a light color that can be painted. For bridge applications, penta in Type C solvent is the preferred treatment for lumber laminations in glulam that must be treated before gluing. Although the light petroleum does provide some initial protection against weathering, its effectiveness diminishes with time.

Type D solvent is methylene chloride that provides a treatment similar to that produced by Type B solvent; however, the solvent recovery process for this treatment may result in raised grain and checking of the wood.

In addition to these oil-type solvents, efforts have been made to develop waterborne penta formulations (Type E solvents); however, these formulations are currently approved only for aboveground use. Stake tests are now underway to determine appropriate ground contact levels for waterborne penta formulations.

A considerable body of literature has accumulated to suggest that the solvent used to deliver penta to the wood has a significant impact on preservative performance. This effect is most notable with penta treatments using the gaseous solvents (Types B and D). Because penta must enter the target organism to be effective, the solvent must permit the preservative to come in contact with the target organism. Types B and D solvents apparently limit the ability of penta to move in this manner, and there are several reports of surface decay in poles treated with these formulations. Studies are now underway to better understand the nature of this effect.

Copper Naphthenate

In addition to creosote and penta, a third oil-type preservative, copper naphthenate, has received increased attention and use in the past few years. Originally developed in the 1940's, copper naphthenate is produced by complexing copper with napthenic acid derived from petroleum. As with penta, it can be blended with several types of oil solvents and has performed well in long-term stake tests. Its primary advantage is that it is considered an environmentally safe preservative and is not currently included on the EPA list of restricted-use pesticides. Although the use of copper naphthenate has been limited in the past because of its high cost relative to other preservatives, its future use will undoubtedly increase as environmental considerations become more restrictive for other oil-type preservatives.

WATERBORNE PRESERVATIVES

Waterborne preservatives include formulations of inorganic arsenical compounds in a water solution. These chemicals leave the wood surface relatively clean with a light green, gray-green, or brown color, depending on the type of chemical used. Unlike most oil-type preservatives, water-. borne formulations usually do not cause skin irritations and are suitable for use where limited human or animal contact is likely. After drying, wood surfaces treated with these preservatives can also be painted or stained.

The first waterborne preservatives were developed in the late 1800's; however, most of those formulations were susceptible to leaching from the wood and performed poorly in service. In the late 1930's, several waterborne formulations were developed that employed chromium along with copper and arsenic. The chromium bonds strongly with the wood to prevent leaching of the preservative system. The first of these formulations, chromated copper arsenate (CCA), was approved for wood use in the late 1940's, but did not receive extensive usage until the 1960's, when demand for clean and paintable wood increased. As CCA was being approved for use on wood, a second formulation, ammoniacal copper arsenate (ACA), was developed and approved for use on wood in 1953. Ammoniacal copper arsenate is the preferred waterborne preservative for difficult-to-treat species, such as Douglas-fir, because it penetrates the wood more effectively. A number of other waterborne formulations have also been developed, including acid copper chromate (ACC), ammoniacal copper zinc arsenate (ACZA), and chromated zinc chloride (CZC).

Of the numerous waterborne preservatives, CCA, ACA, and ACZA are most commonly used in bridge applications. Each of these preservatives is strongly bound to the wood, thereby reducing the risk of chemical leaching. Chromated copper arsenate is generally used to treat Southern Pine, ponderosa pine, and red pine, while ACA and ACZA are for refractory (difficult to treat) wood species, such as Douglas Fir-Larch; however, large quantities of western wood species, such as Hem-Fir, are treated with CCA. There are reports of incomplete penetration of Douglas-fir treated with CCA, and this matter is under study by the American Wood Preservers' Association. There are also reports that CCA and ACA are corrosive to galvanized hardware. However, the tendency for corrosion seems to vary with the wood species, preservative formulation, treatment conditions, and the service conditions to which the wood is exposed. Such corrosion has not been reported to be a problem for hot-dipped galvanized hardware commonly used for bridges.

While the treatment processes for ACA and ACZA use combinations of steam in higher temperature solutions to sterilize wood during the treatment process, CCA treatments are ambient temperature processes that do not result in wood sterilization. While this poses little problem in dimension lumber, failure to sterilize larger material during treatment can permit fungi already established in the central core to continue decaying the wood. Where CCA treatments are used on larger wood members with a high percentage of heartwood, the use of high-temperature kiln cycles to heat the center of the wood to at least 155 $^{\circ}$F for 75 minutes to eliminate established decay fungi is highly recommended.

Waterborne preservatives are used most frequently for railings and floors on pedestrian sidewalks or other areas that may receive human contact. In some situations, they are also used to treat laminations for glulam before gluing. Waterborne preservatives are also very effective in treating piling for marine exposures where borer hazards are high. Test results based on seawater exposure have shown that a dual treatment of waterborne preservatives followed by creosote is possibly the most effective method of protecting wood where marine borer hazards are extremely high. Waterborne preservatives are not recommended for large glulam members because the wetting and drying process associated with treatment can cause dimensional changes as well as warping, splitting, or cracking of members. Additionally, they provide little resistance to weathering, which may result in more pronounced checking and splitting from moisture changes than would occur with oil-type preservatives.

4.3 PRESERVATIVE TREATMENT

Preservative treatment of wood involves the introduction of chemical preservatives into the wood structure. To be effective, the treatment must provide sufficient preservative penetration (the depth to which the preservative enters the wood) and adequate retention (the amount of preservative chemicals remaining in the wood after treatment). In the direction parallel to grain, fluids flow relatively easily, and adequate penetration is usually not difficult to achieve. In the directions perpendicular to grain, however, movement is much more restrictive and pressure processes are normally required to force the preservatives into the wood structure. Even with effective wood preservatives, adequate performance cannot be achieved without sufficient preservative penetration and retention.

The degree of protection provided by preservative treatment depends not only on the protective value of the preservative chemicals but also on the material properties of the wood, the manner in which it is prepared, and the treating process used to apply the preservative. Each of these factors can have an effect on preservative penetration and retention, and thus on the service life of the component being treated.

MATERIAL FACTORS AFFECTING TREATMENT

There are several factors related to the material character of wood that can affect its ability to accept preservatives. The most significant of these factors are the wood species, geographic source, moisture content at the time of treatment, harvest-treatment interval, and storage conditions before treatment.

Wood Species and Source

Wood species vary considerably in their ability to accept preservative treatments. In general, the sapwood of any species is much more receptive to treatment than heartwood, which in many cases is nearly impenetrable (Figure 4-1). Unfortunately, not all commercial species have large quantities of sapwood. This poses a major challenge to treaters faced with treating species characterized by high percentages of difficult-to-treat heartwood (Table 4-1). Such species as Southern Pine, ponderosa pine, and red pine have a high percentage of sapwood and are relatively easy to

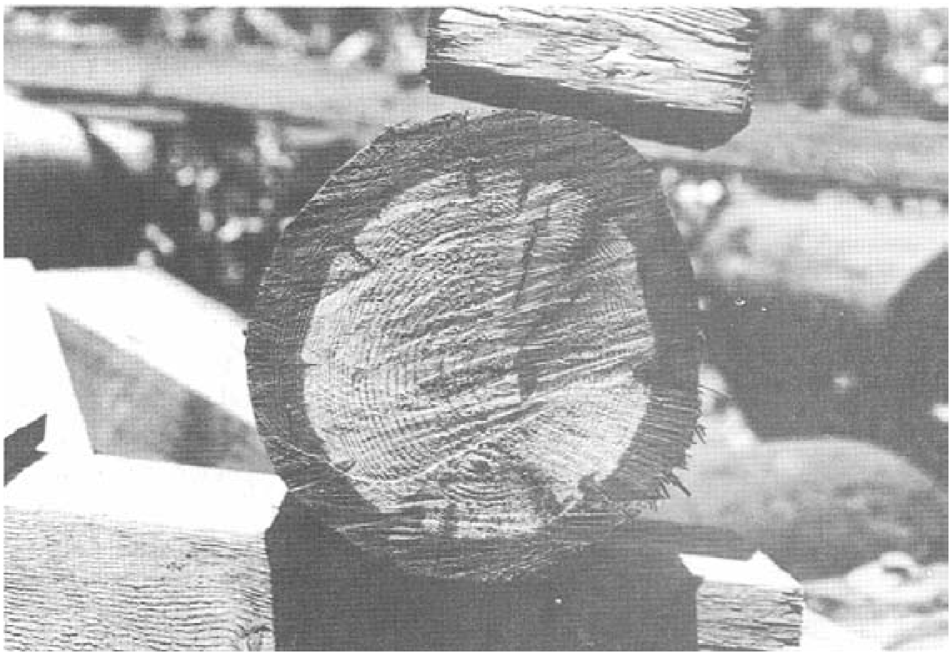


Figure 4-1.- Cross section of a coastal Douglas-fir pile treated with creosote. Note that the preservative treatment penetrates the outer sapwood ring but stops at the less permeable heartwood.

Table 4-1.- Relative treatabilitv of selected domestic species.

Heartwood least difficult to penetrate	Heartwood moderately difficult to penetrate	Heartwood difficult to penetrate	Heartwood very difficult to penetrate
Bristlecone pine	Baldcypress	Eastern hemlock	Alpine fir
Pinyon pine	California red fir	Engelmann spruce	Corkbark fir
Redwood	Douglas-fir (coast)	Grand fir	Douglas-fir (Rocky Mtn.)
	Eastern white pine	Lodgepole pine	Northern white-cedar
	Jack pine	Noble fir	Tamarack
	Loblolly pine	Sitka spruce	Western redcedar
	Longleaf pine	Western larch	
	Ponderosa pine	White fir	
	Red pine	White spruce	
	Shortleaf pine		
	Sugar pine		
	Western hemlock		

From Gjovik and Baechler.[9]

treat. Other species, such as Douglas-fir, have a low percentage of sapwood and are more difficult to treat. The amount of sapwood can also affect the rate at which wood must be processed after harvesting. Southern Pine has a high percentage of decay-susceptible sapwood and must be rapidly processed to prevent decay in the warm, humid southeastern climate. Conversely, such species as Douglas-fir have a lower percentage of sapwood and can be air-seasoned for long periods with relatively little degradation.

The effects of wood species and sapwood percentage on treatability differs for round material, such as piles and poles, and for sawn lumber. For round material, the sapwood of many species is treatable, resulting in a well-treated sapwood shell surrounding an untreated heartwood core. When some of the same species are sawn into lumber, however, many pieces contain little or no sapwood and are untreatable. Lodgepole pine, for example, has a treatable sapwood ring when used for piles or poles, but as sawn lumber, it may be totally untreatable.

Another species-related factor affecting treatment involves the elevation at which the wood is grown. Wood grown at higher elevations appears to be more difficult to treat than that grown at or near sea level. While this poses few problems in the eastern half of the country, a large percentage of western species are harvested from high-elevation stands. In one particular study,[11] it was found that treatability of Douglas-fir was highest in wood from the Oregon coastal range and steadily declined until the wood from trees grown east of the Cascade Mountains was classified as refractory, or untreatable (Figure 4-2). Although studied to a lesser extent, there are also reports that lodgepole pine, ponderosa pine, and many of the true firs *(Abies* sp.) are also affected in this manner. This variation in treatability places added importance on the need to adequately select the species and origin of wood to be treated and is recognized in national treating standards, which differentiate treatments for coastal Douglas-fir and intermountain Douglas-fir.

Moisture Content

In addition to wood species and source, moisture content at the time of treatment has a significant impact on preservative penetration and retention. Excessive moisture can result in incomplete penetration or areas totally void of treatment. It is generally accepted that wood must be below the fiber saturation point before treatment. Methods for reducing the moisture content of wood or conditioning before treatment are discussed under mechanical preparation.

Harvest-Treatment Interval

In the interim between harvesting and preservative treatment, wood is susceptible to attack by a variety of stain and decay organisms. Stain fungi generally attack the sapwood of freshly cut wood and cause discol-

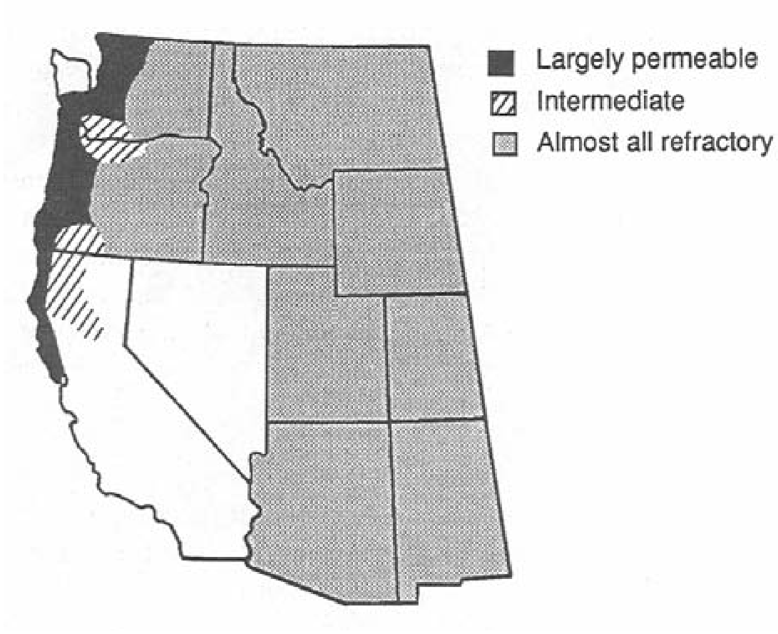


Figure 4-2.- Heartwood permeability of Douglas-fir varies with geographic source. Generally, coastal sources are permeable, Cascade Mountain sources are moderately impermeable, and intermountain sources are impermeable (refractory). From Morrell, Helsing, and Graham.[11]

oration, increased permeability to liquids, and reduced wood toughness (Chapter 13). Increased permeability can improve the treatability of difficult-to-treat species, but it can also result in bleeding of preservative from the wood after treatment. Stain prevention can be accomplished by drying the wood as quickly as possible or by dipping the freshly cut or peeled wood into fungicidal chemicals immediately after cutting. When wood is inspected before treatment, care should be taken to ensure the absence of stain, because this defect may indicate improper handling procedures. Where feasible, wood should be processed as soon as possible after cutting. Thick sapwood species should not be air seasoned for long periods, and care should be taken to ensure that all air-seasoned wood is sterilized during the treatment process. Species with thin sapwood are less susceptible to decay and stain fungi.

The length of time between harvest and treatment also seems to affect treatability. Although no detailed studies have been performed, treatability seems to decrease in Douglas-fir with increased length of air seasoning below the fiber saturation point.

MATERIAL PREPARATION

In addition to the need to choose treatable material that is free of defects, there are a number of mechanical processes that can substantially improve preservative treatment. These processes, which include debarking, prefabrication, incising, radial drilling, through-boring, kerfing, and pretreatment conditioning, are intended to enhance the penetration and retention of preservatives to provide maximum protection.

Debarking

One of the first processing steps in preservative treatment involves removal of the bark. This zone contains cells that are extremely resistant to fluid flow and can leave untreated, decay-susceptible sapwood pockets near the wood surface. In addition to the effect on treatability, many insects require the presence of bark to infest the log. Removing the bark before the insect larvae hatch and burrow into the wood can limit this type of damage.

Debarking of round logs is usually accomplished by mechanically rotating shavers, wheels, or drums (Figure 4-3). These devices also remove some sapwood, and care must be taken to ensure that thin sapwood species are not overpeeled. For most sawn timber products, bark is removed in this manner before sawing or is removed during the sawing process. Sawn lumber should be inspected before treatment for the presence of bark on the edges. When this material is present, it should be removed before treatment.

Prefabrication

One of the most damaging, yet common, practices in the construction of timber bridges is field fabrication of treated wood (for example, attaching connectors or other wood members). Preservative treatment creates an envelope of protection around the wood. Any field fabrication involving cutting or drilling after treatment breaks this envelope, exposing untreated wood to attack by decay fungi and insects (Figure 4-4). Decay potential in field-drilled holes and sawn surfaces can be reduced by field treatment of the cut surfaces during construction; however, wood treated by superficial field methods (Chapter 12) is less resistant to decay than wood treated by pressure processes. A more effective prevention method involves complete fabrication (cutting and boring) prior to preservative treatment. This practice results in thoroughly protected wood, reducing the risk of decay, minimizing potential maintenance costs, and reducing the time required for field erection. The latter benefit can reduce the cost of construction and make timber more competitive as a material. All timber members should be fabricated before preservative treatment.

Incising

The sapwood of most species is easily penetrated by liquids, but adequate penetration of species containing mostly heartwood can pose much difficulty. Because fluids move more easily through end-grain, one approach to improving the preservative penetration of these species is to increase the amount of cross-sectional area exposed to the fluid. This can be accomplished by cutting or boring a series of slits or holes into the wood. This practice, called incising, is required for the adequate treatment of many wood species and results in a deeper, more uniform treatment.

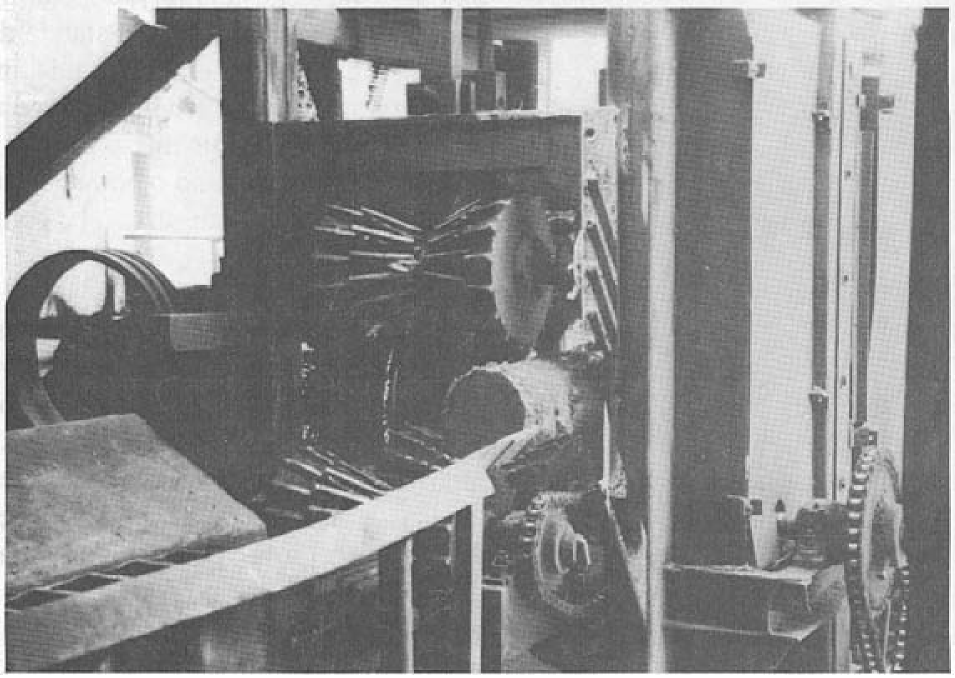


Figure 4-3.- Removing bark is an important part of the treating process. In this photo, logs are debarked by rotating wheels prior to being sawn (photo courtesy of Kevin Rockwell, Southern Pine Inspection Bureau).

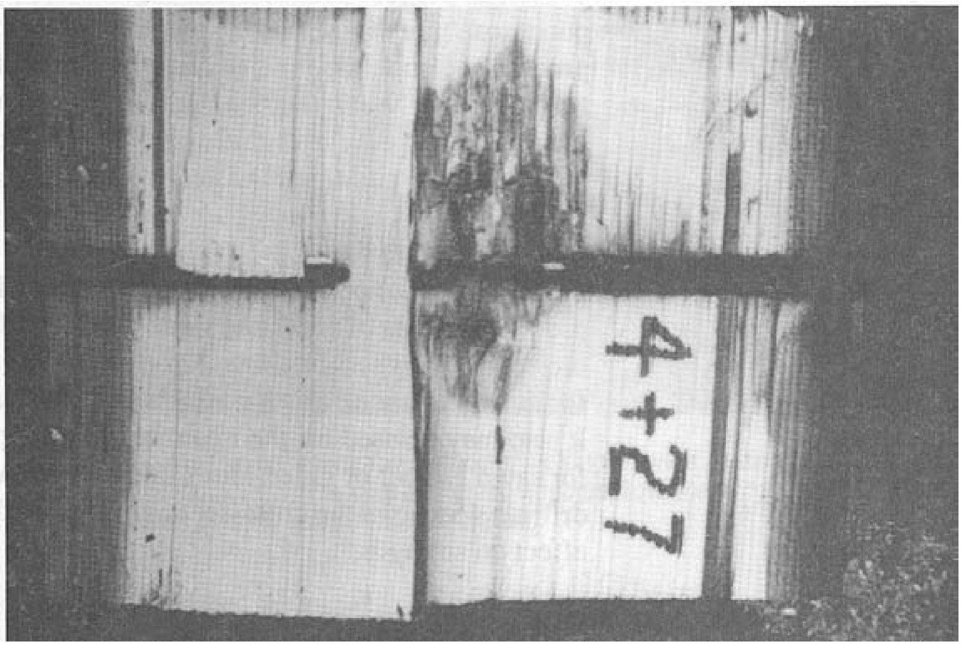


Figure 4-4.- Decay can originate in field-bored holes that are made after the wood is treated with preservatives. In this member, a hole drilled after treatment exposed untreated wood and eventually led to decay at the center of the member (the horizontal split across the bolt hole was made as the member was removed). Preboring holes prior to pressure treatment can prevent this damage.

Incising practices vary considerably, depending on the commodity being treated and the wood species. Current standards for preservative treatment of incised wood are results oriented. That is, incised material must meet preservative requirements for penetration and retention, but there is no standard incising pattern. While this approach poses little problem in large timbers used for railroad ties and other nonstructural applications, the effect of incising on wood strength can be considerable for smaller dimension lumber.[13]

Incising is most commonly performed by pressing teeth into the wood surface to a predetermined depth, generally 1/4 to 3/4 inch (Figure 4-5). The teeth are spaced to give the desired distribution of preservative with the minimum number of incisions. Studies are under way to develop other, less destructive incising methods. To date, needle incising, water-jet incising, and laser incising have been or are being explored. Although none of these has yet proven commercially feasible, the results of preliminary work in these areas is promising.

Incising improves preservative penetration and retention and is required for treating most species. It is not normally required for Southern Pine, ponderosa pine, or red pine. With some species, such as coastal Douglas-fir, western hemlock, eastern white pine, and many of the true firs grown at lower altitudes, incising can greatly improve preservative penetration and retention. With other more refractory species, such as western larch, intermountain Douglas-fir, and lodgepole pine, the effects of incising are beneficial but less pronounced. With the exception of Southern Pine, ponderosa pine, and red pine, incising is an important part of the treating process and should not be waived for a lack of incising equipment at a treating plant. When large, glued-laminated members exceed the size capacity of incising equipment, individual laminations should be edge incised before gluing, or the entire member manually incised after gluing.

Radial Drilling

In some applications, incising can be replaced by radial drilling. In this process, a series of small-diameter holes are drilled into the sapwood to the desired depth of treatment. Radial drilling is required by many utilities for the treatment of electric transmission poles in high-decay-hazard areas. It also may be used for the treatment of piling but is not commonly used for sawn lumber or glued-laminated timber. As with incising, radial drilling decreases the cross-sectional area of the wood and may have some effect on strength.

Through-Boring

In addition to incising and radial drilling, preservative penetration and retention can be greatly improved by through-boring. This process, which is used by some utilities to reduce the decay hazard in poles at the groundline, involves drilling a series of angled holes through the wood approximately 4 feet above and below the theoretical groundline

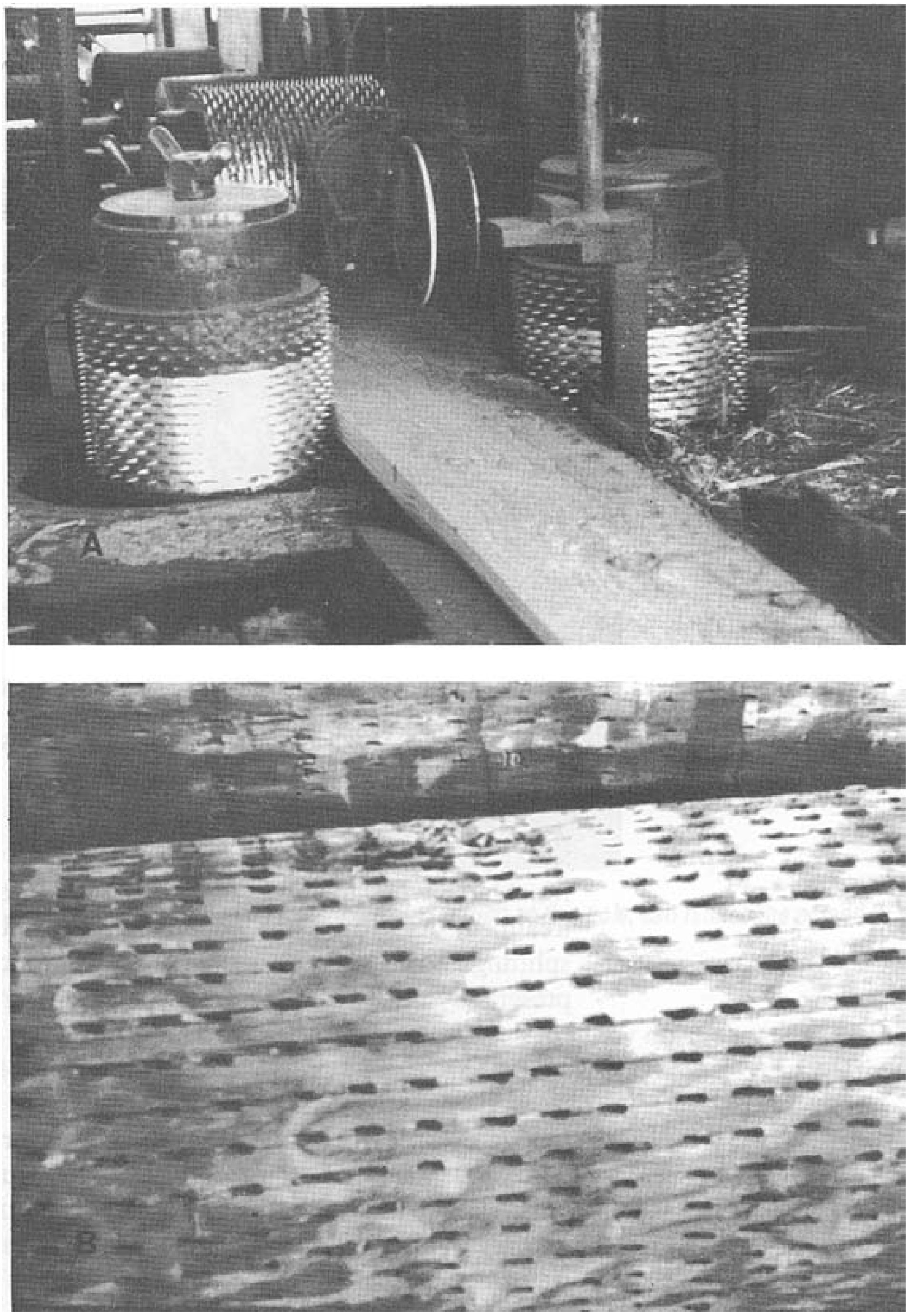


Figure 4-5.-(A) The most common method of incising involves pressing small metal teeth into the wood surface. (B) The openings in the wood improve the penetration and retention of preservatives in many difficult- to-treat species.

(Figure 4-6). When performed properly, through-boring results in nearly complete preservative penetration of the heartwood. Although there is a reduction in strength associated with through-boring (approximately 5 percent in bending strength in utility poles), it is a feasible method for providing maximum protection for poles and piling in areas of severe decay hazard.

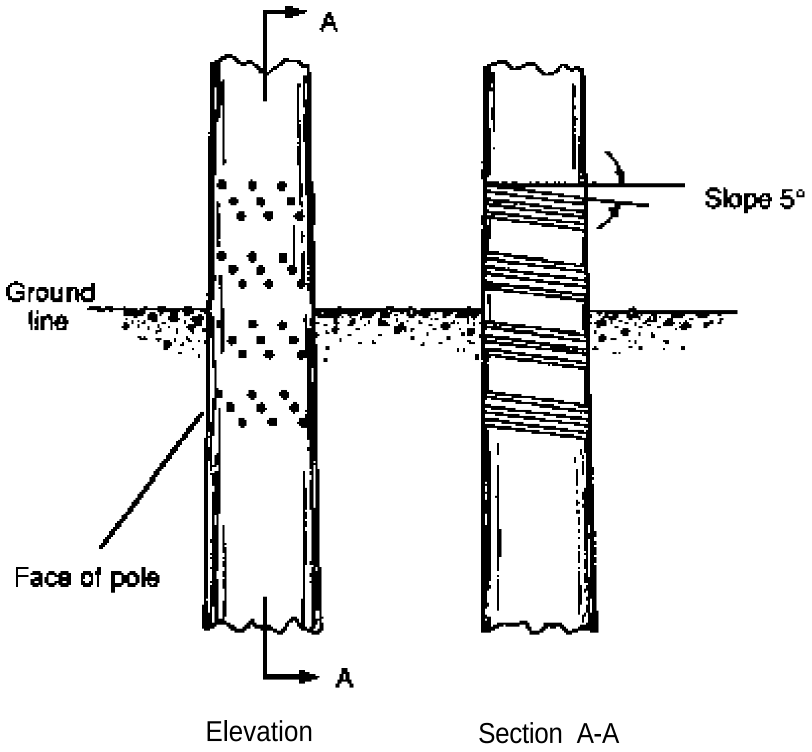


Figure 4-6.- Through-boring in areas of high decay hazard can result in nearly complete preservative penetration.

Kerfing

Most large wood members cannot be fully dried before preservative treatment. As a result, the wood continues to dry in service, resulting in splitting and checking from shrinkage. These checks penetrate beyond the preservative-treated shell of the wood member, providing avenues of entry for decay organisms. One method for limiting check development is to saw a narrow, longitudinal kerf to the center of the wood before preservative treatment (Figure 4-7). The kerf serves to allow some movement and relieve stresses from dimensional changes (shrinkage) that would otherwise cause the wood member to check. Although not commonly used in bridge applications, kerfing seems to work equally well in round or sawn timbers. While kerfing may reduce wood strength, the presence of a deep split has the same effect and, with kerfing, the location of the split can be controlled to minimize strength effects.

Conditioning

Conditioning is the process used to reduce the moisture content of wood before to preservative treatment. Although there are many methods of conditioning, the four most common methods are air drying, kiln drying, steaming, and Boulton drying. Air drying and kiln drying are often employed to process sawn lumber products for both treated and untreated uses. In contrast, steaming and Boulton drying are performed in a treating cylinder and are used exclusively as a method of conditioning wood before treatment. None of the conditioning methods completely dry large

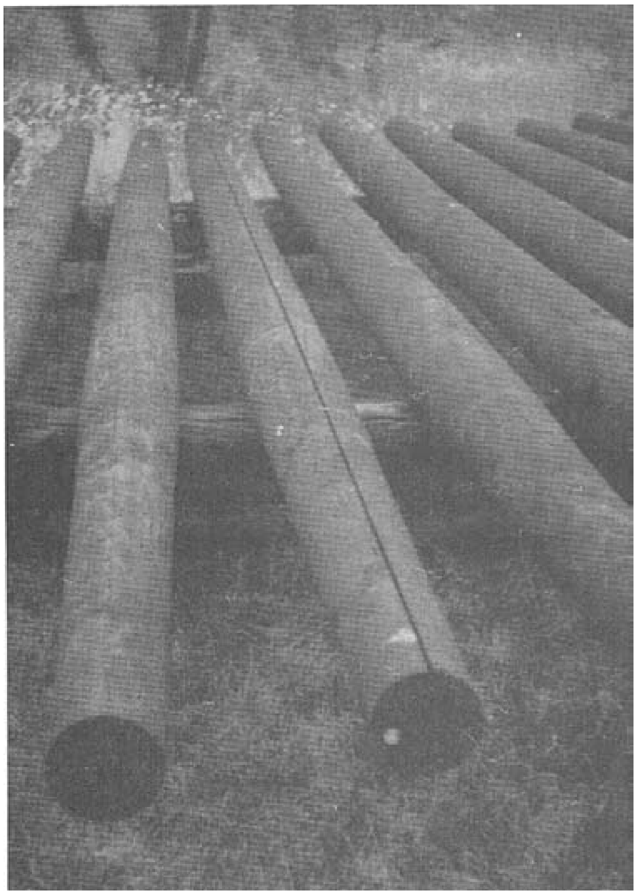


Figure 4-7.—Kerfing large wood members, such as this pole, can reduce the potential for checking in service.

members, which would be uneconomical, but they do adequately dry the zone to be treated. As a result, large sawn lumber members may continue to dry and check after they are placed in service.

Air Drying

Air drying is the least intensive drying method and is extensively used for large western conifers and eastern hardwoods (Figure 4-8). Generally, the species must exhibit some resistance to decay to prevent fungi from causing damage during the conditioning period. Air-drying periods vary, ranging from as short as 6 months to as long as 3 years or more, and in most cases the wood is colonized by decay fungi during the process. While these fungi do not seem to cause damage if the seasoning period is limited, their presence places added importance on the need to adequately sterilize the wood during the treatment process.

Kiln Drying

In kiln drying, sawn lumber or timbers are placed in an enclosed structure and subjected to elevated temperatures and forced ventilation until the desired moisture content is achieved (Figure 4-9). The process increases

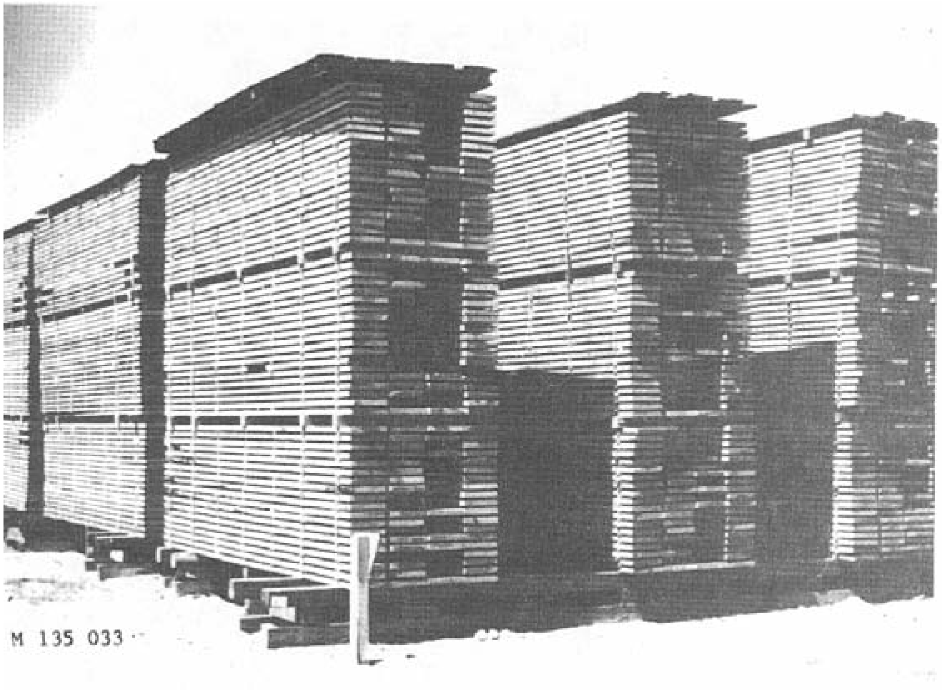


Figure 4-8.- Sawn lumber stacked for air drying. Note the thin wood strips or "stickers" placed between the lumber to permit free air circulation.

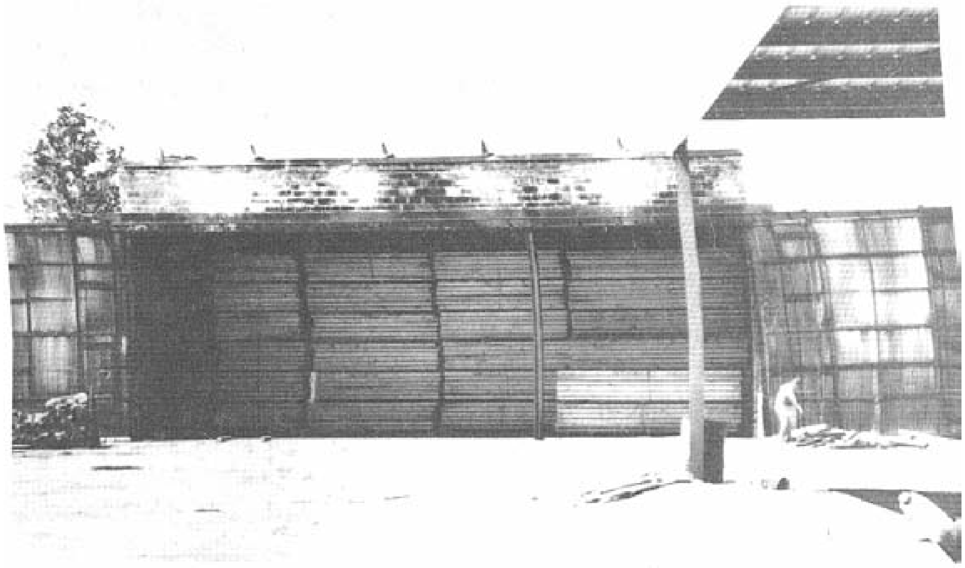


Figure 4-9.- Sawn lumber stacked for drying in a dry kiln (photo courtesy of Kevin Rockwell, Southern Pine Inspection Bureau).

the drying rate considerably over air drying and is commonly used for dimension lumber. The temperatures for conventional kiln drying typically range from 110 to 180°F, although high-temperature drying may reach temperatures in excess of 212°F. Drying time depends on the wood species, initial moisture content, lumber size, and the temperature maintained in the kiln. For 2-inch material dried to 19-percent moisture content at conventional temperatures, average times vary from approximately

41 hours for Southern Pine to approximately 72 hours for Douglas-fir. In the South and, at an increasing level, the West, kiln drying is the preferred method for reducing moisture content of dimension lumber before treating.

Steaming

In steam conditioning, green wood is placed in a treating cylinder and heated by steam to temperatures up to 245°F for several hours. After the steaming process is complete, a vacuum is applied to the cylinder, reducing the boiling point of water and causing the moisture in the outer zone of the wood to evaporate. The steaming and vacuum generally reduce the moisture content of the wood slightly, and the elevated temperature of the wood significantly facilitates preservative penetration. A sufficient steaming period also will sterilize the wood and exterminate decay fungi. Steaming is used primarily for conditioning wood that will be treated with waterborne preservatives, but steaming is not used when the planned treatment will be with CCA.

Boulton Drying

Boulton drying is a process developed in the 1870's that involves heating wood in oil under vacuum. Boulton drying is extensively used in western species, especially Douglas-fir, to condition green or partially air-seasoned timber before pressure treatment with oil-type preservatives. The Boulton drying period lasts from 24 to 48 hours and employs temperatures of 180 to 220°F. It permits seasoning of green, freshly cut, or peeled material to treatable moisture levels, with a minimal impact on wood strength. Although the Boulton process is still extensively used, it is under increasing scrutiny because the moisture removed from the wood is contaminated by trace amounts of wood preservative. Because of this, the wastewater, which can approach 5,000 gallons from a single charge, must be used to make up new solution or be disposed of. This adds to the expense of using this energy-intensive process and may ultimately preclude its use.

METHODS OF APPLYING PRESERVATIVES

There are two basic types of methods for applying preservative treatment to wood, nonpressure methods and pressure methods. Nonpressure methods include brushing, soaking, dipping, and the thermal process. With the exception of the thermal treatment of western redcedar and lodgepole pine, nonpressure processes are not used to any significant extent to initially treat wood used in bridge construction. Brushing and soaking are used to protect field cuts and bore holes made after pressure treatment (Chapter 12).

Wood used in bridges and other exposed environments is treated by using processes involving combinations of vacuum and pressure in a confined cylinder (retort) to deliver a specified amount of chemical into the wood (Figure 4-10). These pressure processes date back to 1836, and with few exceptions, the basic processes used today were patented before 1904.

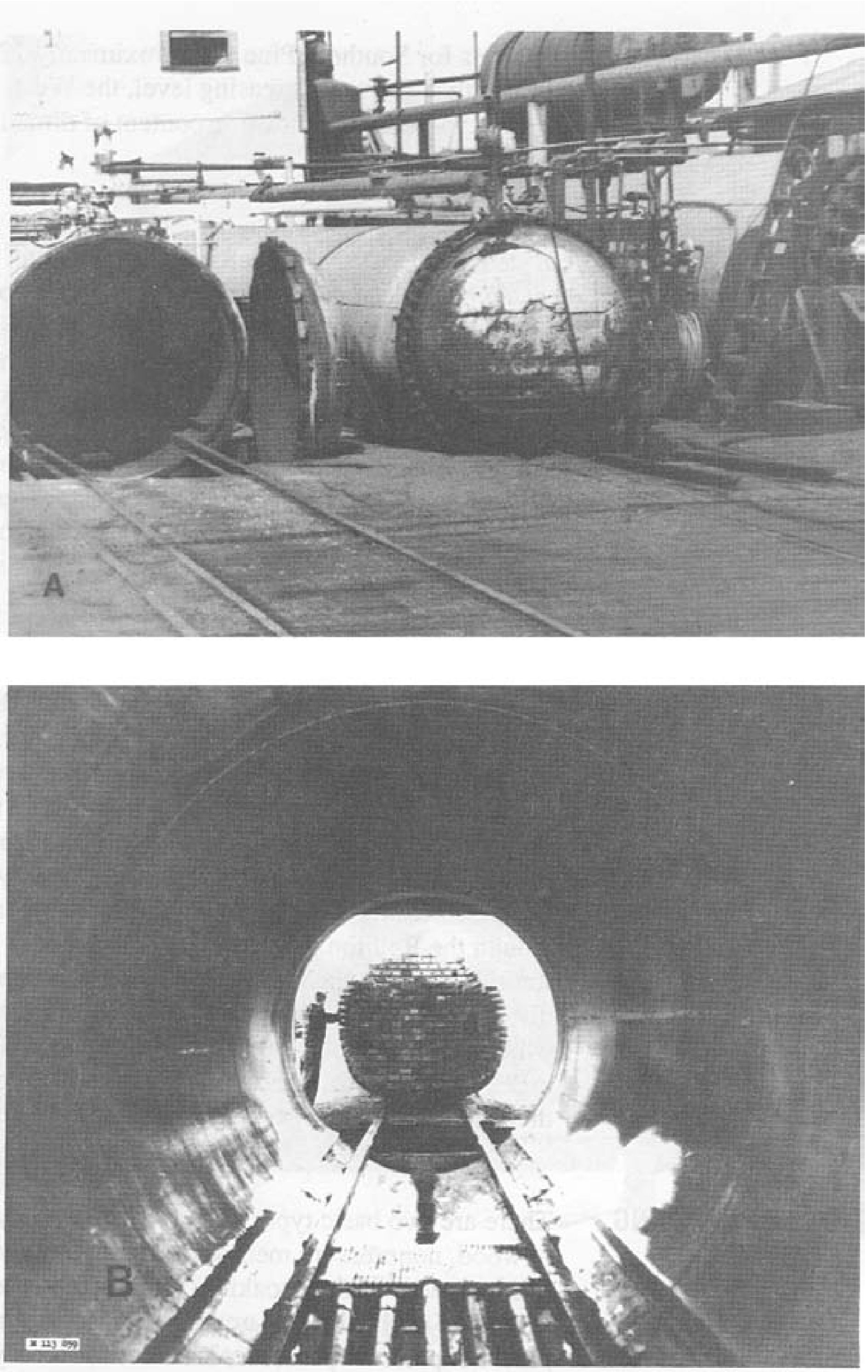


Figure 4-10.-(A) Treatment cylinders (retorts) for pressure-treating wood. (B) As viewed from the inside of a cylinder, wood ready for treating is loaded on carts that are rolled into the cylinder on steel tracks.

Although there have been many process variations to improve chemical penetration and fixation, or to reduce exudation of chemical from the wood, the overall treatment processes have remained fairly stable since the 1950's.

The objectives of the pressure processes are to kill any fungi that may be growing in the wood and ensure that a sufficient amount of preservative is delivered to the proper depth in the wood. The two types of pressure processes are the full-cell process and the empty-cell processes. The names *full-cell* and *empty-cell* are somewhat representative of the results of the respective treating processes. In the full-cell process, wood preservative coats the wood cell walls and, to various degrees, fills the empty-cell cavities. In the empty-cell processes, the cell walls also are penetrated, but the cell cavities are left relatively empty of preservative.

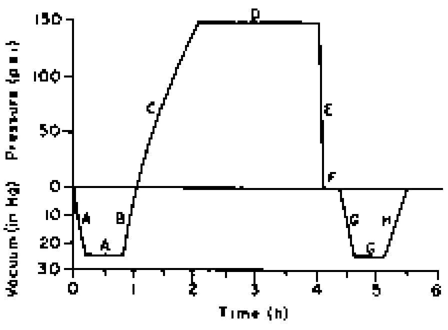
Full-Cell Process

The full-cell (or Bethell) process uses an initial vacuum in the treating cylinder for 30 minutes or longer to remove as much air as possible from the wood. Following this vacuum, preservative is added to the cylinder and pressure is applied up to 150 lb/in^2. Once a sufficient amount of chemical has been forced into the wood, the pressure is released and the preservative is withdrawn (Figure 4-11 A). At this point, a vacuum may be introduced in the cylinder, or the wood may be steamed to hasten recovery of excess preservative and to clean the wood surface.

The full-cell process produces the maximum solution retention for a given depth of penetration and is most often used for treatments with waterborne preservatives and for treating marine piling with creosote. For waterborne preservatives, solution strength can be varied to achieve the desired retention. With the exception of wood members in ground contact in areas of high decay hazard, the full-cell process is not recommended for wood bridge members treated with creosote or other preservatives in oil carriers (unless the required retention cannot be provided by empty-cell processes discussed below). High retentions of oil-type preservative in cell cavities can result in excessive bleeding of preservatives on the wood surface.

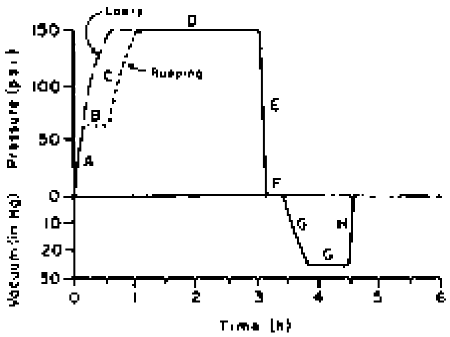
Empty-Cell Processes

The empty-cell processes, which include the Lowry and Rueping processes, do not use the initial vacuum treatment employed in the full-cell process (Figure 4-11 B). In the Lowry process, the preservative solution is admitted into the cylinder containing the wood, and the pressure on the solution is gradually increased. This pressure is held until a sufficient amount of solution is forced into the wood. As the pressure is released, air that was compressed into the wood forces out excessive preservative in a process termed *kickback*, resulting in a lower preservative retention for a given depth of penetration. At the end of the pressure period, the cylinder is drained, and a final vacuum is generally applied to remove any surplus preservative from the wood.



A. Preliminary vacuum
B. Filling cylinder with preservative
C. Pressure rising to maximum
D. Maximum pressure maintained
E. Pressure released
F. Preservative withdrawn
G. Final Vacuum
H. Vacuum released

A. Full-cell treatment cycle



A. Preliminary air pressure applied
B. Filling cylinder with preservative
C. Pressure rising to maximum
D. Maximum pressure maintained
E. Pressure released
F. Preservative withdrawn
G. Final Vacuum
H. Vacuum released

B. Empty-cell treatment cycle

Figure 4-11- Diagrammatic representations of the full-cell and empty-cell processes for pressure-treating wood.

In the Rueping process, the cylinder containing the wood is initially pressurized at 25 to 100 lb/in^2 for 30 to 60 minutes before the preservative solution is added. After this period, preservative is forced into the cylinder, causing air in the cylinder to escape into an equalizing or Rueping tank at a rate that keeps the pressure constant in the cylinder. When the treating cylinder is filled with preservative, additional pressure is applied, and the treating process is completed in the same manner as the Lowry process.

Both the Lowry and Rueping processes are widely and successfully used in the treating industry. One advantage of the Lowry process is that it uses the same treating equipment used for the full-cell process. The Rueping process requires an equalizing tank and additional equipment to force the preservative into the pressurized cylinder.

Empty-cell processes are used for oil-type treatment of sawn lumber, glulam, piling, and poles. The objective of the processes is to achieve deep penetration with a relatively low net retention. As a result, the potential for substantial surface bleeding of preservative is less than with a full-cell process. It is recommended that empty-cell processes be used for all bridge treatments involving oil-type preservatives, provided retention requirements can be met.

Modified Pressure Processes

One variation in the pressure processes is the use of solvents that carry the preservative into the wood but vaporize after the pressure is released, leaving dry chemical deposited in the wood cell wall. Two such processes, the Dow and Cellon processes, use methylene chloride and butane, respectively, to dissolve penta. Because the solvents have a high vapor pressure, they rapidly volatilize from the wood, leaving the penta behind. The main advantage of these processes is the absence of surface oils that make painting difficult or mar the appearance. One disadvantage seems to be an increased susceptibility to the development of surface decay when the wood is used in ground contact.

POSTTREATMENT CLEANING

At the conclusion of the pressure period, some treaters heat wood in oil-type preservatives for several hours to force out excess preservative. Steaming also can be used to clean the wood surface after the pressure process. These heating or steaming periods reduce the amount of excessive preservative and decrease the potential for unsightly bleeding in service.

4.4 SPECIFYING TREATED TIMBER FOR BRIDGES

Although properly used preservative treatments will provide a long service life for wood products, the manner in which a commodity is specified can have a significant impact on its performance. Factors related to treatment preparation, processes, and results must all be carefully considered and specified, not only to ensure performance, but also to protect the buyer against inferior products. This section discusses treatment specifications, standards, and design considerations related to timber bridge applications. Methods of specifying treated timber, including typical specifications, also are addressed.

SPECIFICATIONS AND STANDARDS

Specifications and standards for the preservative treatment of wood are maintained by the American Wood Preservers' Association (AWPA), the American Association of State Highway and Transportation Officials (AASHTO), the American Institute of Timber Construction (AITC), and the Federal Government. The AWPA standards[6] the most widely used and most comprehensive standards and are the recommended source of specifications and treating process procedures for sawn lumber, glulam, piling, and poles used for timber bridges. The AASHTO (M133), AITC (AITC 109), and Federal standards directly reference or closely parallel the AWPA standards.

The AWPA standards are prepared by technical groups that consist of wood treaters, users, and general interest parties who assemble technical information to develop recommendations for the use of treated wood in specific environments. They contain requirements for the composition of preservatives and solvents, penetration and retention for various species and uses, and analytical procedures to ensure that treatment requirements are met. Also included are limits for pressures, temperatures, and exposure times during conditioning and treatment to avoid conditions that adversely affect strength or other wood properties. The standards are results oriented and are generally stated as minimums or acceptable levels over a designated range of values. This flexibility is intended to permit the purchaser and treater some latitude in meeting treatment requirements for specific applications without damaging the wood.

A book of AWPA standards is published annually and is available at nominal cost from AWPA (see Table 16-10 for address). The book is divided into five basic categories consisting of (1) preservative standards (P-standards), (2) commodity standards (C-standards), (3) analytical methods (A-standards), (4) miscellaneous standards (M-standards), and (5) conversion factors and correction tables (F-standards). The standards in these five groups are cross referenced and address a wide variety of timber products, many of which are not related to bridge applications. A list of those most applicable to timber bridges is given in Table 4-2. Although the standards may seem confusing at first glance, they contain a wealth of information and, with experience, are relatively simple to use. It is important that the designer obtain a current copy of these standards and become familiar with the contents prior to specifying treated timber.

DESIGN CONSIDERATIONS

Many of the design and performance considerations required for specifying treated timber for bridge applications were discussed in the preceding sections of this chapter. There are, however, several topics that continue to cause concern and deserve further emphasis before discussing treatment specifications. These topics include dimensional stability, surface appearance, and some special considerations for glulam.

Dimensional Stability

The primary purpose of wood preservatives is to protect timber members from decay and other deterioration. In addition to providing this protection, several of the oil-type preservatives, including creosote, creosote in petroleum oil, and penta or copper naphthenate in oil (Type A), provide added protection against the effects of weathering. Unlike waterborne preservatives or oil-type preservatives in volatile solvents, which afford little or no protection from moisture penetration, these heavier oil-type preservatives provide a water-resistant barrier on the wood surface.[10] Although they will not prevent splitting in members because of initial drying, they do reduce the susceptibility of the member to fluctuating moisture contents and associated dimensional changes and can reduce splitting and checking in service. This is an important consideration in timber bridges because checks provide avenues of entry for decay fungi and insects that would substantially reduce the service life of the structure.

The benefits of heavy oil preservatives are most pronounced in glulam members because of their large size. Glulam members are generally

Table 4-2. -Summary of AWPA Commodity Standards most applicable to bridges.

Preservative (P) Standards	
Creosote	P1
Creosote and Creosote Solutions	P2
Creosote-Petroleum Oil Solution	P3
Petroleum Oil for Blending with Creosote	P4
Waterborne Preservatives	P5
Creosote for Brush or Spray Treatment for Field Cuts	P7
Oil-Borne Preservatives	P8
Standard for Solvents for Organic Preservative Systems	P9
Creosote-Pentachlorophenol Wood Preservative Solution	P11
Creosote/Coal-Tar Solution for Use in Treatment of Marine (Coastal Waters) Piles and Timbers	P12
Coal-Tar Creosote for Use in Treatment of Marine (Coastal Waters) Piles and Timbers	P13
Commodity (C) Standards	
All Timber Products, Pressure Treatment (General Requirements)	C1
Lumber, Timbers, Bridge Ties, and Mine Ties, Pressure Treatment	C2
Piles, Pressure Treatment	C3
Poles, Pressure Treatment	C4
Posts, Pressure Treatment	C5
Wood for Highway Construction, Pressure Treatment	C14
Material in Marine Construction, Pressure Treatment	C18
Structural Glued-Laminated Members and Laminations Before Gluing, Pressure Treatment	C28
Analysis Methods (A Standards)	
Analysis of Creosote and Oil-Type Preservatives	A1
Analyses of Waterborne Preservatives and Fire Retardant Formulations	A2
Determining Penetration of Preservatives	A3
Sampling Wood Preservatives	A4
Analyses of Oil-Borne Preservatives	A5
Determination of Water and Oil-Type Preservatives in Wood	A6
Wet Ashing Procedure for Preparing Wood for Chemical Analysis	A7
Qualitative Recovery of Creosote or Creosote/Coal-Tar Solution from Freshly Treated Piles, Poles, or Timber (Squeeze Method)	A8
Analysis of Treated Wood and Treating Solutions by X-Ray Emission Spectroscopy	A9
Analysis of CCA Treating Solutions and CCA Treated Wood by Colorimetry	A10
Analysis of Treated Wood and Treating Solutions by Atomic Absorption Spectroscopy	A11
Miscellaneous (M) Standards	
Purchase of Treated Wood Products	M1
Inspection of Treated Timber Products	M2
Care of Pressure-Treated Wood Products	M4
Glossary of Terms Used in Wood Preservation	M5
Brands Used on Forest Products	M6
Guideline for the Physical Inspection of Poles in Service	M13
Miscellaneous Methods, Procedures and Information	M17

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installed at a relatively low moisture content (less than 16 percent), and splitting and checking of the member because of initial moisture losses are minimal. However, without some protection to retard moisture absorption into the wood, members may split and check in service. Treatment with waterborne preservatives or penta in volatile solvents can lead to significant performance problems in glulam, as shown in Figure 4-12. With the exception of handrails or other components that may be subject to human or animal contact, or wood members that must be treated before they are glued, it is recommended that all bridge components be treated with creosote, creosote in petroleum oil, or penta or copper naphthenate in heavy oil (Type A) for best performance.

When waterborne treated members are used, the moisture content of the member after treating can also have an effect on dimensional stability. When timber is treated with waterborne preservatives, the wood becomes saturated with water, increasing the probability that seasoning checks and splits will develop as the member dries. It is recommended that all mem-

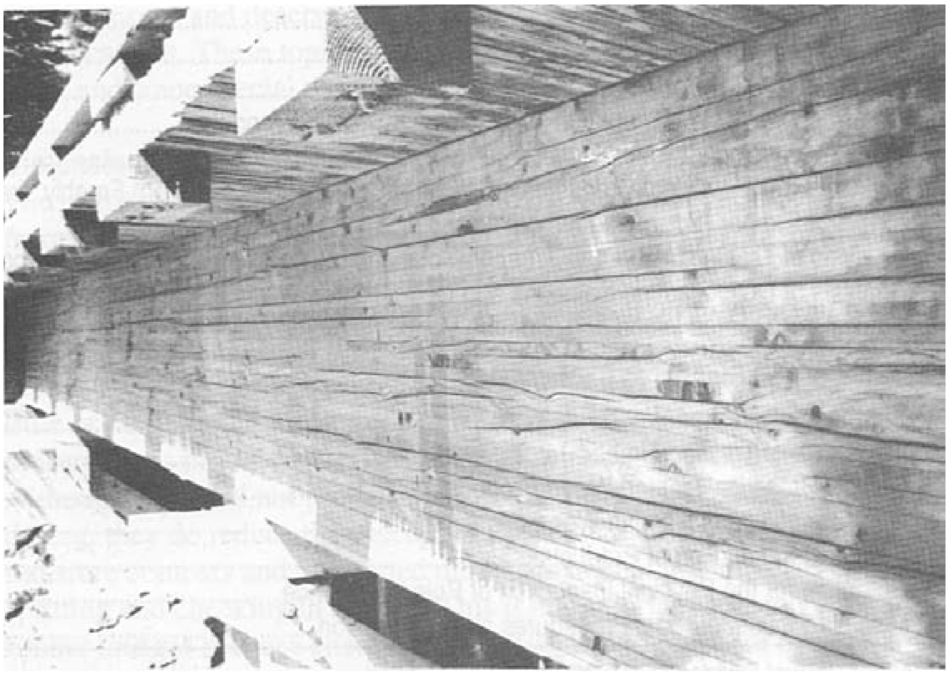

Figure 4-12.- Large glulam bridge members treated with waterborne preservatives (before or after gluing frequently check and split in service. With the exception of members that are subject to human or animal contact, all glulam used in bridge applications should be treated with oil-type preservatives.

bers treated with waterborne preservatives be dried after treatment. In most cases, drying to a moisture content of 19 percent is sufficient, but in very arid regions, lower moisture contents may be desirable. A number of recent studies have shown a significant posttreatment effect to be a direct result of the redrying after treatment. While stiffness has not been shown to be affected, some strength properties have been reduced. Recent modifications to the AWA standards for sawn lumber have restricted the posttreatment redrying temperature to no more than 190°F to minimize this potential problem.

Surface Appearance

In the past, users of treated wood were most concerned with performance, and there was less concern for such amenities as surface appearance. The recent environmental emphasis has changed this perspective, and the surface appearance and exudation or bleeding of oil-type preservatives have become important environmental issues. The most severe bleeding of treated wood members generally occurs along exterior beams or other components that are subjected to direct sunlight. The heating effect on these members can cause bleeding of preservatives that would otherwise not occur in shaded locations.

In most cases, the bleeding of oil-type preservatives in small quantities poses no harmful effects; however, bleeding should be minimized or eliminated whenever possible. Following are suggestions for improving the cleanliness of oil-type preservatives.

1. Specify the correct preservative retentions recommended in the appropriate AWPA standard for the type of material, use condition, and preservative. Retentions in excess of these levels increase the level of preservative in the wood, which may cause bleeding, and do not increase service life.

2. Use of empty-cell processes rather than the full-cell treating process for oil-type preservatives results in a lower level of preservative in the wood cell cavities and should be specified whenever possible. Empty-cell processes may not be feasible in situations when retentions greater than or equal to 20 lb/ft^3 for creosote are required.

3. When using creosote, use of clean creosote containing lower levels of xylene insolubles can reduce surface deposits.

4. Expansion baths (heating in preservative) at the conclusion of the treatment cycle and combinations of vacuum/steaming periods can reduce surface deposits and decrease bleeding once the wood is placed in service.

In addition to the above considerations, surface cleanliness also is related in some degree to the quality control and cleanliness of the treater. When the treating plant cylinder and pipes are kept free of sludges, surface residues and potential bleeding are reduced.

Special Considerations for Glulam

In most bridge applications, glulam is pressure treated after it is has been laminated (glued). In some cases, large members, such as arches, will not fit into treating cylinders after manufacture, and the individual laminations must be treated before gluing. Glulam can be manufactured from treated laminations when certain preservatives are used, specifically the waterborne preservatives or penta in light petroleum or volatile solvents (Type B, C, or D). When bridge members are treated before gluing, penta in light petroleum (Type C solvent) is recommended. Although penta in light petroleum is not as effective in protecting the member from moisture as the heavy oil preservatives, it does give limited surface protection and generally produces the best final results.

There recently has been some concern regarding glulam manufacture from treated laminations. In a December 1986 statement issued by the AITC, a policy was adopted by western laminators not to glue preservative-treated western species. Although this policy does not involve all laminators and does not affect Southern Pine species, the designer should verify industry capabilities before issuing designs or specifications that require preservative treatment before gluing.

SPECIFICATIONS FOR TREATED TIMBER

Treated timber must be properly and completely specified to obtain the required treatment for the intended application. For all types of treatments, specifications must include a preservative according to an AWPA P-standard and a treatment requirement (including preservative retention and penetration) in accordance with an AWPA C-standard. In addition, requirements for mechanical preparation and treating conditions may be desirable to ensure optimum preservative performance. These requirements vary for different component types and preservatives and generally include such items as pretreatment and posttreatment moisture contents, incising, prefabrication, treating procedures, and posttreatment steaming or cleaning.

The AWPA standards for treated timber in bridge applications are found in Standard C14, Wood for Highway Construction-Preservative Treatment by Pressure Process, and also in Standard C28, Standard for Preservative Treatment of Structural Glued Laminated Members and Laminations Before Gluing of Southern Pine, Pacific Coast Douglas Fir, Hemfir and Western Hemlock by Pressure Process. Both of these standards contain information related to treating requirements and preservative penetration and retention for various types of components, use conditions, and preservatives. Standard C14 gives specific requirements for sawn lumber, posts, poles, and piling but relies mainly on other AWPA standards for specific process requirements. Minimum preservative retentions from Standard C14 are shown in Table 4-3. Note that the retention for each preservative is specified for different components, such as sawn lumber, piles, and posts. The right column of the table specifies AWPA standard that gives additional treatment requirements for that type of component. For glulam, AWPA Standard C28 gives treating requirements for members treated before or after gluing. Retention requirements for glulam treated after gluing are shown in Table 4-4. Note that preservative retentions are based on the species of the laminations, not the type of component.

In most AWPA standards, minimum requirements for preservative retention are based on the type of material and the conditions where it will be used: aboveground, in ground contact, or in marine environments with exposure to borers. For wood used in bridges and other highway applications, aboveground conditions are generally not used and all components other than those subject to marine borers are treated to ground contact retentions. In Standard C14, one retention is specified regardless of whether the component is in ground contact or not (these retentions are approximately equal to ground contact requirements for sawn lumber specified in AWPA Standard C2). In Standard C28, retentions are specified for aboveground and ground contact; however, for bridge applications, the retentions specified for ground contact are normally used to provide retention levels comparable to those specified in Standard C14 for sawn lumber. Although much of a bridge will be out of ground or marine contact, it is important to recognize that some aboveground locations also are high-decay hazard environments. This is particularly true in the critical joint areas where moisture can collect and where decay is most likely to develop.

AWPA Standards C14 and C28 are designed to achieve 50 or more years of service life in most environments; however, additional requirements can be imposed when warranted by the needs of severe service. When additional retention or penetration requirements are considered, it is best to consult with specialists from a national treating organization, a university, or the USDA Forest Service, Forest Products Laboratory to ensure that such treatments are practical, safe, and worth the added costs. A listing of national treated timber organizations that provide assistance to users is given in Chapter 16.

Typical Treatment Specifications for Bridges

All information required to properly specify treated wood is found in the applicable AWPA standards. Additionally, the standards indicate which types of treatment are appropriate for various wood species and component types. The following sample specifications illustrate the information required to specify treated timber for several preservatives and commodity products. Additional requirements are included for treatment procedures,

Table 4-3.- Minimum preservative retentions for lumber, poles, and piling used for highway construction.

Material and Usage	Creosote[1]	Creosote-Coal Tar[1]	Creosote-Petroleum	Pentachlorophenol[2]	Pentachlorophenol, P9 Type E solvent	ACC	ACA	ACZA	CCA	PAS	AWPA standards
Lumber for Bridges, Structural Members, Decking, Cribbing, and Culverts											
Southern Pine, Coastal Douglas-fir, Western Hemlock, and Western Larch	12.0	12.0	12.0	0.60	NR[5]	NR	0.60	0.60	0.60	NR	C2
Structural Lumber in Salt Water											
Southern Pine	25.0	25.0	NR	NR	NR	NR	2.50	2.50	2.50	NR	C2
Coastal Douglas-fir, Hemlock	25.0	NR	NR	NR	NR	NR	2.50	2.50	2.50	NR	C2
Structural Lumber in Saltwater-Dual Treatment											
Southern Pine											
First treatment	NR	NR	NR	NR	NR	NR	1.50	1.50	1.50	NR	C2
Second treatment	20.0	20.0	NR	NR	NR	NR	NR	NR	NR	NR	C2
Coastal Douglas-fir, Western Hemlock											
First treatment	NR	NR	NR	NR	NR	NR	1.50	1.50	1.50	NR	C2
Second treatment	20.0	20.0	NR	NR	NR	NR	NR	NR	NR	NR	C2
Piles for Foundation, Land, or Fresh-Water Use											
Southern Pine, Ponderosa Pine, Jack Pine and Red Pine	12.0	12.0	12.0	0.60	NR	NR	0.80	0.80	0.80	NR	C3
Coastal Douglas-fir, Western Larch, Intermountain Douglas-fir, and Lodgepole Pine	17.0	17.0	17.0	0.85	NR	NR	1.00	1.00	1.00	NR	C3
Oak	6.0	6.0	6.0	0.30	NR	NR	NR	NR	NR	NR	C3
Posts, Fence, Guide, Sign, and Sight											
All Softwood Species											
Round, Half-Round, and Quarter Round[3]	8.0	8.0	8.0	0.40	NR	0.50	0.40	0.40	0.40	NR	C5
Sawn Four Sides	10.0	10.0	10.0	0.50	NR	0.62	0.50	0.50	0.50	NR	C2
Posts, Guardrail, Spacer Blocks[4]											
All Softwood Species											
Round	10.0	10.0	10.0	0.50	NR	NR	0.50	0.50	0.50	NR	C5
Sawn Four Sides	12.0	12.0	12.0	0.60	NR	NR	0.60	0.60	0.60	NR	C2
Poles, Lighting:											
Southern Pine, Ponderosa Pine	7.5	NR	NR	0.38	NR	NR	0.60	0.60	0.60	NR	C4
Red Pine	10.5	NR	NR	0.53	NR	NR	0.60	0.60	0.60	NR	C4
Coastal Douglas-fir	9.0	NR	NR	0.45	NR	NR	0.60	0.60	0.60	NR	C4
Jack Pine, Lodgepole Pine	12.0	NR	NR	0.60	NR	NR	0.60	0.60	0.60	NR	C4
Western Red Cedar, Western Larch, Intermountain Douglas-fir	16.0	NR	NR	0.80	NR	NR	0.60	0.60	0.60	NR	C4
Handrails and Guardrails (not in contact with ground or water)											
All Softwood Species	8.0	NR	NR	0.40	0.40	0.25	0.25	0.25	0.25	0.40	C2

[1] When these preservatives are specified for materials to be used in salt water, the creosote-coal tar shall conform to AWPA Standard P12, and the creosote shall conform to AWPA Standard P13.

[2] Retention by lime ignition method. When copper pyridine method is used, multiply the results by 1.1 to convert to the lime ignition result.

[3] Where permitted in AWPA Standard C5.

[4] If spacer blocks are treated with other sawn material, the retention of the charge shall be determined by assay of borings taken from the other sawn material, unless each is sampled and assayed as an individual commodity.

[5] NR-Not recommended. Waterborne preservatives or pentachlorophenol in suitable solvents should be used where a dry surface is required or the material is to be painted.

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Table 4-4. Minimum preservative retentions for glued-laminated timber treated after manufacture.

Treatment	Retention by assay (lb/ft^3), minimum — Southern Pine: Above-ground	Southern Pine: Ground contact	Pacific coast Douglas-fir, hemfir, or western hemlock: Above-ground	Pacific coast Douglas-fir, hemfir, or western hemlock: Ground contact
Creosote	6.0	12.0	6.0	12.0
Creosote/Coal-Tar Solution	6.0	12.0	6.0	12.0
Creosote Petroleum	NR	NR	6.0	12.0
Pentachlorophenol	0.30	0.60	0.30	0.60

NR = Not recommended.
Refer to AWPA Standard C28 for table footnotes and requirements related to assay and penetration requirements.
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surface cleanliness, and moisture content for waterborne preservatives. These additional requirements are recommended but may be changed to meet specific design applications. For materials or use conditions other than those noted, sample specifications should be modified in accordance with AWPA Standards C14 and C28, and the applicable P-standards (preservative) listed in Table 4-2. For additional information on specifying treated timber, refer to AWPA Standard M1, Standard for the Purchase of Treated Wood Products.[6]

Creosote Treatment for Sawn Lumber

Sawn lumber shall be pressure treated using an empty-cell process with creosote conforming to AWPA Standard P1 to a minimum net retention of 12 lb/ft^3 in accordance with AWPA Standard C14. All members shall be fabricated before treatment and shall be free of excess preservative and solvent at the conclusion of the treating process.

Note: The same specification applies to glulam treated after gluing when AWPA Standard C14 is replaced by AWPA Standard C28.

Creosote Treatment for Douglas-Fir Foundation Piling in Land or Freshwater Use

Timber piling shall be incised and pressure-treated with creosote conforming to AWPA Standard P1 to a minimum net retention of 17 lb/ft^3 in the assay zone in accordance with AWPA Standard C14.

Note: Refer to AWPA Standard C14 for treating retentions for other species and piling used in salt water.

Creosote/Petroleum-Oil Treatment for Sawn Lumber

Sawn lumber shall be pressure treated using an empty-cell process with creosote/petroleum-oil solution conforming to AWPA Standard P3 to a minimum net retention of 12 lb/ft^3 in accordance with AWPA Standard

C14. All members shall be fabricated before treatment and shall be free of excess preservative and solvent at the conclusion of the treating process.

Note: The same specification applies to glulam treated after gluing when AWPA Standard C14 is replaced by AWPA Standard C28.

Penta in Petroleum-Oil (Type A) Treatment for Glulam Treated After Gluing

Glulam shall be pressure treated using an empty-cell process with pentachlorophenol conforming to AWPA Standard P8 in hydrocarbon solvent, Type A, conforming to AWPA Standard P9 to a minimum net retention of 0.60 lb/ft^3 in accordance with AWPA Standard C28. All members shall be fabricated before treatment and shall be free of excess preservative and solvent at the conclusion of the treating process.

Penta in Petroleum-Oil (Type C) Treatment for Laminations for Glulam Treated Before Gluing

Lumber laminations for glulam shall be pressure treated with pentachlorophenol conforming to AWPA Standard P8 in hydrocarbon solvent, Type C, conforming to AWPA Standard P9 to a minimum net retention of 0.60 lb/ft^3 in accordance with AWPA Standard C28.

CCA Treatment for Southern Pine Sawn Lumber Deck Planks

Sawn lumber planks shall be pressure treated with CCA conforming to AWPA Standard P5 to a minimum net retention of 0.60 lb/ft^3 in accordance with AWPA Standard C14. All members shall be fabricated before treatment and dried to a moisture content of 19 percent or less after treatment.

Note: CCA is used extensively for Southern Pine but is not recommended for Douglas-fir and other refractory species. These species are normally treated with ACA or ACZA.

ACZA Treatment for Douglas-Fir Sawn Lumber Guardrail Posts

Sawn lumber for guardrail posts shall be pressure treated with ACZA conforming to AWPA Standard P5 to a minimum net retention of 0.60 lb/ft^3 in the assay zone in accordance with AWPA Standard C14. All members shall be incised and fabricated before treatment and dried to a moisture content of 19 percent or less after treatment.

ACA Treatment for Western Hemlock Sawn Lumber Handrails

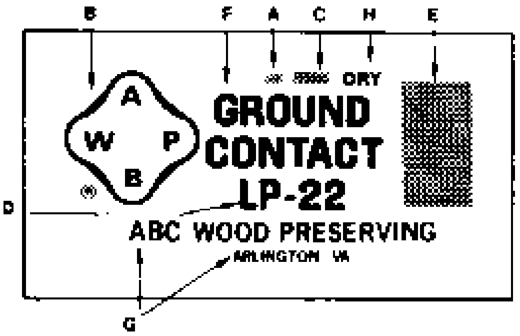
Sawn lumber for handrails shall be pressure treated with ACA conforming to AWPA Standard P5 to a minimum net retention of 0.25 lb/ft^3 in accordance with AWPA Standard C14. All members shall be incised and fabricated before treatment and dried to a moisture content of 19 percent or less after treatment.

4.5 QUALITY CONTROL AND CERTIFICATION

While proper specifications help ensure proper treatment, wood is a variable material that does not always treat evenly. Inspection and quality control before, during, and after the treating process ensure that the material is suitable for the intended application. This inspection generally begins before treatment, when the untreated or white wood is inspected for grade, moisture content, stain or decay, and proper manufacture (cutting, boring, incising). Pieces with defects are rejected by the inspector based on end-use specifications. This point in the inspection is one of the most important because many defects are more easily seen in the white wood.

During the treatment procedure, the treater routinely removes samples of the treating solution for analysis to ensure adequate solution strength. In addition, the treating process is monitored by gauges to ensure compliance with the applicable AWPA standard. Following treatment, the material is again visually inspected to ensure that inadequate material did not slip through the white wood inspection. The inspector then removes a series of increment cores, at selected locations (depending on the commodity), from pieces in the charge. The depth of preservative penetration is measured either visually or by using chemical indicators to ensure that penetration requirements are met. Generally, a percentage of cores in each charge (usually 90 percent) must meet the requirements. If this does not occur, then all pieces in the charge are bored, and pieces not meeting the requirement must be retreated or rejected. The increment cores also are collected and returned to the laboratory where they are analyzed for preservative retention. Once again, failure to meet the retention requirement will lead to rejection of the charge.

Inspection of treated timber can be performed internally through a regular inspection staff or by contract through a third party. Many government bodies that purchase large quantities of treated wood maintain inspection staffs; however, the quantity of timber purchased by most users is usually not sufficient to justify a full-time staff. In these cases, the use of independent third-party inspection can provide reliable quality control at a reasonable cost. The treating industry has developed a quality control and certification program for treated products to assist users in obtaining properly treated material. The program is administered by the American Wood Preservers Bureau (AWPB), which acts as an independent third-party organization that licenses a number of inspection agencies to provide in-plant and field inspections of wood treaters and their products. Agency inspectors are highly qualified technicians who qualify individual treating plants for participation in the program. They train personnel for internal quality control programs and independently collect samples of pressure-treated wood; samples are sent to the agency or bureau laboratory for analysis of preservative retention and penetration. Treaters participating in the program who maintain their product quality are authorized to certify



A Year of treatment
B American Wood Preservers Bureau trademark or trademark of the AWPB certified agency
C The preservative used for treatment
D The applicable American Wood Preservers Bureau quality standard
E Trademark of the AWPB certified agency
F Proper exposure conditions
G Treating company and plant location
H Dry or KDAT if applicable

Figure 4-13.- Typical quality mark and nomenclature for wood treated in accordance with AWPB quality standards (courtesy of the American Wood Preservers Bureau). Used by permission.

their products with an AWPB quality mark (stamp or tag), which indicates that the product meets the specified standard (Figure 4-13). Additional information, including participating treaters and certified inspectors, may be obtained from AWPB at the address given in Table 16-10.

Although the AWPB is the largest nationwide organization for inspecting and certifying treated material, there are other qualified organizations and individuals that perform this service. For example, the Southern Pine Inspection Bureau administers an inspection and certification program for Southern Pine dimension lumber treated with waterborne preservatives. Regardless of the inspection organization or individual used, the user should always require that each piece of treated material be legibly ink stamped (waterborne preservatives only), branded, or tagged as evidence of inspection to certify compliance with treating standards. Examples of brands used for this purpose are given in AWPA Standard M6, Brands Used on Forest Products.[6]

4.6 SELECTED REFERENCES

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