Wood Preservation

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Many commonly used wood species can deteriorate if exposed to conditions that support growth of wood-degrading organisms (see Chap. 14). Wood products can be protected from the attack of decay fungi, harmful insects, or marine borers by applying chemical preservatives. Preservative treatments greatly increase the life of wood structures, thus reducing replacement costs and allowing more efficient use of forest resources. The degree of protection achieved depends on the preservative used and the proper penetration and retention of the chemicals. Some preservatives are more effective than others, and some are more adaptable to certain use requirements. To obtain long-term effectiveness, adequate penetration and retention are needed for each wood species, chemical preservative, and treatment method. Not only are different methods of treating wood available, but treatability varies among wood species—particularly their heartwood, which generally resists preservative treatment more than does sapwood. Although some tree species possess naturally occurring resistance to decay and insects (see Chap. 14), many are in short supply or are not grown in ready proximity to markets.

In considering preservative treatment processes and wood species, the combination must provide the required protection for the conditions of exposure and life of the structure. All these factors are considered by the consensus technical committees in setting reference levels required by the American Wood Protection Association (AWPA, formerly American Wood-Preservers' Association)) and ASTM International (formerly American Society for Testing and Materials). Details are discussed later in this chapter. The characteristics, appropriate uses, and availability of preservative formulations may have changed after preparation of this chapter. For the most current information on preservative formulations, the reader is encouraged to contact the appropriate regulatory agencies, standardization organizations, or trade associations. ***Note that mention of a chemical in this chapter does not constitute a recommendation.***

Wood Preservatives

Wood preservatives must meet two broad criteria: (1) They must provide the desired wood protection in the intended end use, and (2) they must do so without presenting unreasonable risks to people or the environment. Because wood preservatives are considered to be a type of pesticide, the U.S. Environmental Protection Agency (EPA) is responsible for their regulation. Federal law requires that before selling or distributing a preservative in the United States,

Synopsis of EPA-approved consumer information sheets for wood treated with CCA, ACZA, creosote, or pentachlorophenol

NOTE: This is only a synopsis of information contained in consumer information sheets. For complete consumer information sheets, contact your treated wood supplier or the website of the Environmental Protection Agency.

Handling Precautions

Avoid frequent or prolonged inhalation of sawdust from treated wood. When sawing, sanding, and machining treated wood, wear a dust mask. Whenever possible, these operations should be performed outdoors to avoid indoor accumulations of airborne sawdust from treated wood. When power-sawing and machining, wear goggles to protect eyes from flying particles. Wear gloves when working with the wood. After working with the wood, and before eating, drinking, toileting, and use of tobacco products, wash exposed areas thoroughly. Avoid frequent or prolonged skin contact with creosote- or pentachlorophenol-treated wood. When handling creosote- or pentachlorophenol-treated wood, wear long-sleeved shirts and long pants and use gloves impervious to the chemicals (for example, gloves that are vinyl coated). Because preservatives or sawdust may accumulate on clothes, they should be laundered before reuse. Wash work clothes separately from other household clothing.

Treated wood should not be burned in open fires or in stoves, fireplaces, or residential boilers, because toxic chemicals may be produced as part of the smoke and ashes. Treated wood from commercial or industrial use (such as construction sites) may be burned only in commercial or industrial incinerators or boilers in accordance with state and Federal regulations. CCA-treated wood can be disposed of with regular municipal trash (municipal solid waste, not yard waste) in many areas. However, state or local laws may be stricter than federal requirements. For more information, please contact the waste management agency for your state.

Use Site Precautions

All sawdust and construction debris should be cleaned up and disposed of after construction. Do not use treated wood under circumstances where the preservative may become a component of food or animal feed. Examples of such sites would be use of mulch from recycled arsenic-treated wood, cutting boards, counter tops, animal bedding, and structures or containers for storing animal feed or human food. Only treated wood that is visibly clean and free of surface residue should be used for patios, decks, and walkways. Do not use treated wood for construction of those portions of beehives which may come into contact with honey. Treated wood should not be used where it may come into direct or indirect contact with drinking water, except for uses involving incidental contact such as docks and bridges.

Logs treated with pentachlorophenol should not be used for log homes. Wood treated with creosote or pentachlorophenol should not be used where it will be in frequent or prolonged contact with bare skin (for example, chairs and other outdoor furniture), unless an effective sealer has been applied. Creosote- and pentachlorophenol-treated wood should not be used in residential, industrial, or commercial interiors except for laminated beams or building components that are in ground contact and are subject to decay or insect infestation and where two coats of an appropriate sealer are applied. Do not use creosote- or pentachlorophenol-treated wood for farrowing or brooding facilities. Wood treated with pentachlorophenol or creosote should not be used in the interiors of farm buildings where there may be direct contact with domestic animals or livestock that may crib (bite) or lick the wood. In interiors of farm buildings where domestic animals or livestock are unlikely to crib (bite) or lick the wood, creosote- or pentachlorophenol-treated wood may be used for building components that are in ground contact and are subject to decay or insect infestation and where two coats of an appropriate sealer are applied. Sealers may be applied at the installation site. Urethane, shellac, latex epoxy enamel, and varnish are acceptable sealers for pentachlorophenol-treated wood. Coal-tar pitch and coal-tar pitch emulsion are effective sealers for creosote-treated wood-block flooring. Urethane, epoxy, and shellac are acceptable sealers for all creosote-treated wood.

a company must obtain registration from EPA. Before registering a new pesticide or new use for a registered preservative, EPA must first ensure that the preservative can be used with a reasonable certainty of no harm to human health and without posing unreasonable risks to the environment. To make such determinations, EPA requires more than 100 different scientific studies and tests from applicants. This chapter discusses only wood preservatives registered by the EPA.

Some preservatives are classified as “restricted use” by the EPA and these can be used only in certain applications and can be applied only by certified pesticide applicators. Restricted use refers to the chemical preservative and not to the treated wood product. The general consumer may buy and use wood products treated with restricted-use pesticides; EPA does not consider treated wood a toxic substance nor is it regulated as a pesticide. Although treated wood is not regulated as pesticide, there are limitations on how some types of treated wood should be used. Consumer Information Sheets (EPA-approved) are available from retailers of creosote-, pentachlorophenol-, and inorganic-arsenical-treated wood products. The sheets provide information about the preservative and the use and disposal of treated-wood products (see Synopsis of EPA-Approved Consumer Information Sheets for Wood Treated with CCA, ACZA, Creosote, or Pentachlorophenol). The commercial wood treater is bound by the EPA regulation and can treat wood only for an end use that is allowed for that preservative. Some preservatives that are not classified as restricted by EPA are available to the general consumer for nonpressure treatments. It is the responsibility of the end user to apply these preservatives in a manner that is consistent with the EPA-approved labeling. Registration of preservatives is under constant review by the EPA, and a responsible State or Federal agency should be consulted as to the current status of any preservative.

Before a wood preservative can be approved for pressure treatment of structural members, it must be evaluated to ensure that it provides the necessary durability and that it does not greatly reduce the strength properties of the wood. The EPA typically does not evaluate how well a wood preservative protects the wood. Traditionally this evaluation has been conducted through the standardization process of the AWPA. The AWPA Book of Standards lists a series of laboratory and field exposure tests that must be conducted when evaluating new wood preservatives. The durability of test products are compared with those of established durable products and nondurable controls. The results of those tests are then presented to the appropriate AWPA subcommittees for review. AWPA subcommittees are composed of representatives from industry, academia, and government agencies who have familiarity with conducting and interpreting durability evaluations. Preservative standardization by AWPA is a two-step process. If the performance of a new preservative is considered appropriate, it is first listed as a potential preservative. Secondary committee action is needed to have the new preservative listed for specific commodities and to set the required treatment level.

More recently the International Code Council–Evaluation Service (ICC–ES) has evolved as an additional route for gaining building code acceptance of new types of pressure-treated wood. In contrast to AWPA, the ICC–ES does not standardize preservatives. Instead, it issues Evaluation Reports that provide evidence that a building product complies with building codes. The data and other information needed to obtain an Evaluation Report are first established as Acceptance Criteria (AC). AC326, which sets the performance criteria used by ICC–ES to evaluate proprietary wood preservatives, requires submittal of documentation accredited third party agencies in accordance with AWPA , ASTM, and EN standard test methods. The results of those tests are then reviewed by an evaluation committee to determine if the preservative has met the appropriate acceptance criteria.

Wood preservatives have traditionally been divided into two general classes: (1) Oil-type or oil-borne preservatives, such as creosote and petroleum solutions of pentachlorophenol, and (2) waterborne preservatives that are applied as water solutions or with water as the carrier. Many different chemicals are in each of these classes, and each has different effectiveness in various exposure conditions. Some preservatives can be formulated so that they can be delivered with either water or oil-type carriers. In this chapter, both oil-borne and waterborne preservative chemicals are described as to their potential end uses. Tables 15–1 and 15–2 summarize preservatives and their treatment levels for various wood products.

Waterborne Preservatives

Waterborne preservatives are often used when cleanliness and paintability of the treated wood are required. Formulations intended for use outdoors have shown high resistance to leaching and very good performance in service. Waterborne preservatives are included in specifications for items such as lumber, timber, posts, building foundations, poles, and piling (Table 15–1). Because water is added to the wood in the treatment process, some drying and shrinkage will occur after installation unless the wood is kiln-dried after treatment.

Copper is the primary biocide in many wood preservative formulations used in ground contact because of its excellent fungicidal properties and low mammalian toxicity (Table 15–3). Because some types of fungi are copper tolerant, preservative formulations often include a co-biocide to provide further protection.

Inorganic arsenicals are a restricted-use pesticide. For use and handling precautions of pressure-treated wood containing inorganic arsenicals, refer to the EPA-approved Consumer Information Sheets.

Acid Copper Chromate (ACC)

Acid copper chromate (ACC) contains 31.8% copper oxide and 68.2% chromium trioxide (AWPA P5). The solid, paste, liquid concentrate, or treating solution can be made of copper sulfate, potassium dichromate, or sodium dichromate. Tests on stakes and posts exposed to decay and termite attack indicate that wood well impregnated with ACC generally provides acceptable service. However, some specimens placed in ground contact have shown vulnerability to attack by copper-tolerant fungi. ACC has often been used for treatment of wood in cooling towers. Its current uses are restricted to applications similar to those of chromated copper arsenate (CCA) (Table 15–4). ACC and CCA must be used at low treating temperatures (38 to 66 °C (100 to 150 °F)) because they are unstable at higher temperatures. This restriction may involve some difficulty when higher temperatures are needed to obtain good treating results in woods such as Douglas-fir.

Ammoniacal Copper Zinc Arsenate (ACZA)

Ammoniacal copper zinc arsenate (ACZA) is commonly used on the West Coast of North America for the treatment of Douglas-fir. The penetration of Douglas-fir heartwood is improved with ACZA because of the chemical composition and stability of treating at elevated temperatures. Wood treated with ACZA performs and has characteristics similar to those of wood treated with CCA (Table 15–1).

ACZA should contain approximately 50% copper oxide, 25% zinc oxide, and 25% arsenic pentoxide dissolved in a solution of ammonia in water (AWPA P5). The weight of ammonia is at least 1.38 times the weight of copper oxide. To aid in solution, ammonium bicarbonate is added (at least equal to 0.92 times the weight of copper oxide).

ACZA replaced an earlier formulation, ammoniacal copper arsenate (ACA) that was used for many years in the United States and Canada.

Table 15–1. Typical use categories and retentions for preservatives used in pressure treatment of Southern Pine species[a]

	Retentions (kg m^{-3})[b] for each type of exposure and AWPA use category designation						
		Exterior above-ground		Soil or fresh water			
	Interior, dry or damp	Vertical, coated	Horizontal	General	Severe/ critical	Very severe/ critical	
Preservative	1, 2	3A	3B	4A	4B	4C	4C (piles)
Waterborne: Listed by the AWPA							
ACC	NL[c]	NL[c]	4.0	8	—	—	—
ACZA	4.0	4.0	4.0	6.4	9.6	9.6	—
ACQ–B	4.0	4.0	4.0	6.4	9.6	9.6	—
ACQ–C	4.0	4.0	4.0	6.4	9.6	9.6	—
ACQ–D	2.4	2.4	2.4	6.4	9.6	9.6	—
CA–B	1.7	1.7	1.7	3.3	5.0	5.0	—
CA–C	1.0	1.0	1.0	2.4	5.0	5.0	—
CBA–A	3.3	3.3	3.3	6.5	9.8	9.8	—
CCA	NL[c]	NL[c]	4	6.4	9.6	9.6	12.8
CX–A	3.3	3.3	3.3	—	—	—	—
CuN (waterborne)	1.12	1.12	1.12	1.76	—	—	—
EL2	0.30	0.30	0.30	—	—	—	—
KDS	3.0	3.0	3.0	7.5	—	—	—
PTI	0.21	0.21	0.21/0.29[d]	—	—	—	—
SBX	2.8/4.5[e]	—	—	—	—	—	—
Oil-type: Listed by the AWPA							
Creosote	128/NR[f]	128.0	128.0	160	160	192	192
Penta P9 Type A Oil	6.4/NR[f]	6.4	6.4	8.0	8.0	8.0	9.6
Penta P9 Type C Oil	6.4/NR[f]	6.4	6.4	8.0	8.0	8.0	9.6
CuN (oilborne)	0.64/NR[f]	0.64	0.64	0.96	1.2	1.2	1.6
Cu8	0.32	0.32	0.32	—	—	—	—
Waterborne: Evaluation reports from ICC Evaluation Service, Inc.							
ESR–1721	0.8	0.8	0.8	2.2	3.6	5.3	5.3
ESR–1980	2.4	2.4	2.4	5.4	9.6	9.6	—
ESR–2067	0.3	0.3	0.3	—	—	—	—
ESR–2240	1.0	1.0	1.0	2.4	3.7		
ESR–2325	1.1	1.1	1.1	2.6	3.8	—	—
ESR–2711	2.1/2.7[g]	2.1/2.7[g]	2.1/2.7[g]	4.5	6.9	—	—

[a]Some exceptions exist for specific applications. See AWPA Standard U1 or ICC ES Evaluation Reports for details on specific applications. See Table 15–2 for seawater applications.
[b]To convert to retention expressed as lb ft^{-3}, divide these values by 16.0.
[c]NL, not labeled. EPA labeling does not currently permit use of wood newly treated with these preservatives in most applications within these use categories. See Table 15–4 for more details.
[d]Higher retention specified if the preservative is used without a stabilizer in the treatment solution.
[e]Higher retention for areas with Formosan subterranean termites.
[f]NR, not recommended for interior use in inhabited structures.
[g]2.1 kg m^{-3} retention limited to decking and specialty use items.

Chromated Copper Arsenate (CCA)

Wood treated with CCA (commonly called green treated) dominated the treated-wood market from the late 1970s until 2004. However, as the result of the voluntary label changes submitted by the CCA registrants, the EPA labeling of CCA currently permits the product to be used for primarily industrial applications (Table 15–4), and CCA-treated products are generally not available at retail lumber yards. CCA can no longer be used for treatment of lumber intended for use in residential decks or playground equipment. It is important to note that existing structures are not affected by this labeling change and that the EPA has not recommended removing structures built with CCA-treated lumber. These changes were made as part of the ongoing CCA re-registration process, and in light of the current and anticipated market demand for alternative preservatives for nonindustrial applications. Allowable uses for CCA are based on specific commodity standards listed in the 2001 edition of the AWPA standards. The most important of these allowable uses are based on the standards for poles, piles, and wood used in highway construction. A list of the most common allowable uses is shown in Table 15–4.

Although several formulations of CCA have been used in the past, CCA Type C has been the primary formulation and is currently the only formulation listed in AWPA standards. CCA–C was found to have the optimum combination of efficacy and resistance to leaching, but the earlier formulations (CCA–A and CCA–B) have also provided long-term protection for treated stakes exposed in Mississippi (Table 15–5). CCA–C has an actives composition of 47.5% chromium trioxide, 34.0% arsenic pentoxide, and 18.5% copper oxide. AWPA Standard P5 permits substitution of potassium or sodium dichromate for chromium trioxide; copper sulfate, basic copper carbonate, or copper hydroxide for copper oxide; and arsenic acid, sodium arsenate, or pyroarsenate for arsenic pentoxide.

Table 15–2. Preservative treatment and retention necessary to protect round timber piles from severe marine borer attack[a]

Marine borers and preservatives	Retention ($kg\ m^{-3}$)[b] Round piles	Sawn materials
Limnoria tripunctata only		
Ammoniacal copper zinc arsenate	40, 24[c]	40
Chromated copper arsenate	40, 24[c]	
Creosote	320, 256[c]	400
Limnoria tripunctata and Pholads (dual treatment)		
First treatment		
Ammoniacal copper zinc arsenate	16, (1.0)	24
Chromated copper arsenate	16, (1.0)	24
Second treatment		
Creosote	320, (20.0)	320
Creosote solution	320, (20.0)	320

[a]See AWPA Commodity Specification G for more information.
[b]To convert to retention expressed as $lb\ ft^{-3}$, divide these values by 16.0.
[c]Lower retention levels are for marine piling used in areas from New Jersey northward on the East Coast and north of San Francisco on the West Coast in the United States.

High retention levels (40 $kg\ m^{-3}$ (2.5 $lb\ ft^{-3}$)) of CCA preservative provide good resistance to attack by the marine borers *Limnoria* and *Teredo* (Table 15–2).

Alkaline Copper Quat (ACQ)

Alkaline copper quat (ACQ) has an actives composition of 67% copper oxide and 33% quaternary ammonium compound (quat). Multiple variations of ACQ have been standardized. ACQ type B (ACQ–B) is an ammoniacal copper formulation, ACQ type D (ACQ–D) is an amine copper formulation, and ACQ type C (ACQ–C) is a combined ammoniacal-amine formulation with a slightly different quat compound. The multiple formulations of ACQ allow some flexibility in achieving compatibility with a specific wood species and application. When ammonia is used as the carrier, ACQ has improved ability to penetrate difficult-to-treat wood species. However, if the wood species is readily treatable, such as Southern Pine sapwood, an amine carrier can be used to provide a more uniform surface appearance. Recently ACQ has been formulated using small particles of copper rather than copper solubilized in ethanolamine. These formulations are discussed in more detail in the Preservatives with ICC–ES Evaluation Reports section. Use of particulate copper formulations of ACQ is currently limited to permeable woods (such as species of pine with a high proportion of sapwood), but efforts continue to adapt the treatment to a broader range of wood species.

Alkaline Copper DCOI (ACD)

Alkaline copper DCOI (ACD) is a recently proposed formulation of alkaline copper ethanolamine that utilizes 4,5-dichloro-2-N-octyl-4-isothiazolin-3-one (DCOI) as co-biocide

Table 15–3. Active ingredients in waterborne preservatives used for pressure treatments

Active ingredient	Preservative
Inorganic actives	
Arsenic	ACZA, CCA
Boron	CBA–A, CX–A, SBX, KDS
Chromium	ACC, CCA
Copper	ACC, ACZA, ACQ–B, ACQ–C, ACQ–D, CA–B, CA–C, CBA–A, CCA, CXA, ESR–1721, ESR–1980, ESR–2240, ESR–2325, KDS, KDS–B, ESR–2711
Zinc	ACZA
Organic actives	
Alkylbenzyldimethyl ammonium compound	ACQ–C
DCOI	EL2, ESR–2711
Didecyldimethyl ammonium compound	ACQ–B, ACQ–D
HDO: Bis-(N-cyclo-hexyldiazeniumdioxy)Cu	CX–A
Imdiacloprid	EL2, PTI, ESR–2067
Propiconazole	CA–C, PTI, ESR–1721
Polymeric betaine	KDS, KDS–B
Tebuconazole	PTI, ESR–1721, ESR–2067, ESR–2325

Table 15–4. Generalized examples of products that may still be treated with CCA under conditions of current label language[a]

Type of end use still allowed	2001 AWPA standard
Lumber and timbers used in seawater	C2
Land, fresh-water, and marine piles	C3
Utility poles	C4
Plywood	C9
Wood for highway construction	C14
Round, half-round, and quarter-round fence posts	C16
Poles, piles, and posts used as structural members on farms	C16
Members immersed in or frequently splashed by seawater	C18
Lumber and plywood for permanent wood foundations	C22
Round poles and posts used in building construction	C23
Sawn timbers (at least 5 in. thick) used to support residential and commercial structures	C24
Sawn cross-arms	C25
Structural glued-laminated members	C28
Structural composite lumber (parallel strand or laminated veneer lumber)	C33
Shakes and shingles	C34

[a]Refer to the EPA or a treated-wood supplier for the most recent definition of allowable uses.

to provide protection against copper-tolerant fungi. The ratio of alkaline copper to DCOI in the formulation ranges from 20:1 to 25:1. The ACD formulation is listed as a preservative in AWPA standards. It has been proposed for both above-ground and ground-contact applications, but at the time this chapter was finalized it had not yet been standardized for treatment of any commodities.

Copper bis(dimethyldithiocarbamate) (CDDC)

Copper bis(dimethyldithiocarbamate) (CDDC) is a reaction product formed in wood as a result of the dual treatment of two separate treating solutions. The first treating solution contains a maximum of 5% bivalent copper–ethanolamine (2-aminoethanol), and the second treating solution contains a minimum of 2.5% sodium dimethyldithiocarbamate (AWPA P5). Although this preservative is not currently commercially available, CDDC-treated wood products are included in the AWPA Commodity Standards for uses such as residential construction.

Copper Azole (CA–B, CA–C and CBA–A)

Copper azole (CA–B) is a formulation composed of amine copper (96%) and tebuconazole (4%). Copper azole (CA–C) is very similar to CA–B, but half the tebuconazole is replaced with propiconazole. The active ingredients in CA–C are in the ratio of 96% amine copper, 2% tebuconazole, and 2% propiconazole. An earlier formulation (CBA–A) also contained boric acid. Although listed as an amine formulation, copper azole may also be formulated with an amine–ammonia formulation. The ammonia may be included when the copper azole formulations are used to treat refractory species, and the ability of such a formulation to adequately treat Douglas-fir has been demonstrated. Inclusion of ammonia, however, is likely to have slight affects on the surface appearance and initial odor of the treated wood.

Copper HDO (CXA)

Copper HDO (CXA) is an amine copper water-based preservative that has been used in Europe and was recently standardized in the United States. The active ingredients are copper oxide, boric acid, and copper–HDO (bis-(N-cyclohexyldiazeniumdioxy copper). The appearance and handling characteristics of wood treated with copper HDO are similar to those of the other amine copper-based treatments. It is also referred to as copper xyligen. Currently, copper HDO is standardized only for applications that are not in direct contact with soil or water.

Copper Naphthenate (Waterborne)

Waterborne copper naphthenate (CuN–W) has an actives composition similar to oil-borne copper naphthenate, but the actives are carried in a solution of ethanolamine and water instead of petroleum solvent. Wood treated with the waterborne formulation has a drier surface and less odor than the oil-borne formulation. The waterborne formulation has been standardized for above-ground and some ground-contact applications (Table 15–1).

Inorganic Boron (Borax–Boric Acid)

Borate preservatives are readily soluble in water and highly leachable and should be used only above ground where the wood is protected from wetting. When used above ground and protected from wetting, this preservative is very effective against decay, termites, beetles, and carpenter ants. Inorganic boron (SBX) is listed in AWPA standards for protected applications such as framing lumber. The solid or treating solution for borate preservatives (borates) should be greater than 98% pure, on an anhydrous basis (AWPA P5). Acceptable borate compounds are sodium octaborate, sodium tetraborate, sodium pentaborate, and boric acid. These compounds are derived from the mineral sodium borate, which is the same material used in laundry additives.

Table 15–5. Results of Forest Products Laboratory studies on 38- by 89- by 457-mm (nominal 2- by 4- by 18-in.) Southern Pine sapwood stakes, pressure-treated with commonly used wood preservatives, installed at Harrison Experimental Forest, Mississippi

Preservative	Average retention (kg m^{-3} (lb ft^{-3}))[a]	Average life or condition at last inspection
Controls (untreated stakes)		1.8 to 3.6 years
Acid copper chromate	2.08 (0.13)	11.6 years
	2.24 (0.14)	6.1 years
	4.01 (0.25)	80% failed after 40 years
	4.17 (0.26)	80% failed after 60 years
	4.65 (0.29)	4.6 years
	5.93 (0.37)	60% failed after 60 years
	8.01 (0.50)	50% failed after 40 years
	12.18 (0.76)	22% failed after 40 years
Ammoniacal copper arsenate	2.56 (0.16)	16.6 years
	3.52 (0.22)	80% failed after 30 years
	3.84 (0.24)	38.7 years
	4.01 (0.25)	60% failed after 40 years
	7.37 (0.45)	20% failed after 40 years
	8.17 (0.51)	10% failed after 60 years
	15.54 (0.97)	No failures after 60 years
	20.02 (1.25)	No failures after 60 years
Chromated copper arsenate	2.40 (0.15)	28.7 years
Type I (Type A)	3.52 (0.22)	45% failed after 40 years
	4.65 (0.29)	30% failed after 60 years
	7.05 (0.44)	10% failed after 40 years
	7.05 (0.44)	20% failed after 60 years
Type II (Type B)	3.68 (0.23)	30% failed after 40 years
	4.17 (0.26)	No failures after 46 years
	5.93 (0.37)	No failures after 46 years
	8.33 (0.52)	No failures after 46 years
	12.66 (0.79)	No failures after 46 years
	16.66 (1.04)	No failures after 46 years
Type III (Type C)	2.24 (0.14)	No failures after 25 years
	3.20 (0.20)	No failures after 35 years
	4.00 (0.25)	20% failed after 20 years
	4.33 (0.27)	10% failed after 25 years
	6.41 (0.40)	No failures after 35 years
	6.41 (0.40)	No failures after 25 years
	9.61 (0.60)	No failures after 35 years
	9.93 (0.62)	No failures after 25 years
	12.66 (0.79)	No failures after 25 years
Oxine copper	0.22 (0.014)	26.9 years
(Copper-8-quinolinolate)	0.48 (0.03)	27.3 years
AWPA P9 heavy petroleum	0.95 (0.059)	31.3 years
	1.99 (0.124)	No failures after 45 years
Copper naphthenate		
0.11% copper in No. 2 fuel oil	0.19 (0.012)	15.9 years
0.29% copper in No. 2 fuel oil	0.46 (0.029)	21.8 years
0.57% copper in No. 2 fuel oil	0.98 (0.061)	27.1 years
0.86% copper in No. 2 fuel oil	1.31 (0.082)	29.6 years
Creosote, coal-tar	52.87 (3.3)	24.9 years
	65.68 (4.1)	14.2 years
	67.28 (4.2)	17.8 years
	73.69 (4.6)	21.3 years
	124.96 (7.8)	70% failed after 54-1/2 years
	128.24 (8.0)	90% failed after 60 years
	132.97 (8.3)	50% failed after 46 years
	160.20 (10.0)	90% failed after 55 years
	189.04 (11.8)	50% failed after 60 years

Table 15–5. Results of Forest Products Laboratory studies on 38- by 89- by 457-mm (nominal 2- by 4- by 18-in.) Southern Pine sapwood stakes, pressure-treated with commonly used wood preservatives, installed at Harrison Experimental Forest, Mississippi—con.

Preservative	Average retention (kg m^{-3} (lb ft^{-3}))[a]	Average life or condition at last inspection
Creosote, coal-tar (con.)	211.46 (13.2)	20% failed after 54-1/2 years
	232.29 (14.5)	No failures after 55 years
	264.33 (16.5)	10% failed after 60 years
Pentachlorophenol		
Stoddard solvent	2.24 (0.14)	13.7 years
(mineral spirits)	2.88 (0.18)	15.9 years
	3.20 (0.20)	9.5 years
	3.20 (0.20)	13.7 years
	6.09 (0.38)	80% failed after 39 years
	6.41 (0.40)	15.5 years
	10.73 (0.67)	No failures after 39 years
Heavy gas oil	3.20 (0.20)	89% failed after 50 years
(Mid-United States)	6.41 (0.40)	80% failed after 50 years
	9.61 (0.60)	20% failed after 50 years
No. 4 aromatic oil	3.36 (0.21)	21.0 years
(West Coast)	6.57 (0.41)	70% failed after 50 years
AWPA P9 (heavy petroleum)	1.76 (0.11)	90% failed after 39 years
	3.04 (0.19)	60% failed after 39 years
	4.65 (0.29)	No failures after 39 years
	8.49 (0.53)	No failures after 35 years
	10.73 (0.67)	No failures after 39 years
Petroleum solvent controls	64.08 (4.0)	7.6 years
	65.68 (4.1)	4.4 years
	75.29 (4.7)	12.9 years
	123.35 (7.7)	14.6 years
	126.56 (7.9)	90% failed after 50 years
	128.16 (8.0)	19.7 years
	128.16 (8.0)	23.3 years
	128.16 (8.0)	14.6 years
	129.76 (8.1)	3.4 years
	136.17 (8.5)	20.9 years
	157.00 (9.8)	6.3 years
	192.24 (12.0)	17.1 years
	193.84 (12.1)	80% failed after 50 years
	310.79 (19.4)	9.1 years

[a]Retention of active ingredients for preservatives and total solvent for petroleum solvent controls.

In addition to pressure treatments, borates are commonly sprayed, brushed, or injected to treat wood in existing structures. They will diffuse into wood that is wet, so these preservatives are often used as a remedial treatment. Borates are widely used for log homes, natural wood finishes, and hardwood pallets.

EL2

EL2 is a waterborne preservative composed of the fungicide 4,5-dichloro-2-N-octyl-4-isothiazolin-3-one (DCOI), the insecticide imidacloprid, and a moisture control stabilizer (MCS). The ratio of actives is 98% DCOI and 2% imidacloprid, but the MCS is also considered to be a necessary component to ensure preservative efficacy. EL2 is currently listed in AWPA standards for above-ground applications only (Table 15–1).

KDS

KDS and KDS Type B (KDS–B) utilize copper and polymeric betaine as the primary active ingredients. The KDS formulation also contains boron, and has an actives composition of 41% copper oxide, 33% polymeric betaine, and 26% boric acid. KDS–B does not contain boron and has an actives composition of 56% copper oxide and 44% polymeric betaine. KDS is listed for treatment of commodities used above ground and for general use in contact with soil or fresh water. It is not listed for soil or fresh water contact in severe exposures. The listing includes treatment of common pine species as well as Douglas-fir and western hemlock. KDS–B is currently in the process of obtaining listings for specific commodities. The appearance of KDS-treated wood is similar to that of wood treated with other alkaline copper formulations (light green–brown). It has some odor initially after treatment, but this odor dissipates as the wood dries.

Oligomeric Alkylphenol Polysulfide (PXTS)

PXTS is a recently developed and somewhat unusual preservative system. It is an oligomer formed by the reaction of cresylic acid and sulfur chlorides in the presence of excess sulfur. PXTS is a solid at room temperature but becomes a liquid when heated to above approximately 58 °C. It can also be dissolved and diluted in some aromatic and organic chlorinated solvents. PXTS is not currently listed for treatment of any commodities and is currently not commercially available.

Propiconazole and Tebuconazole

Propiconazole and tebuconazole are organic triazole biocides that are effective against wood decay fungi but not against insects (AWPA P5, P8). They are soluble in some organic solvents but have low solubility in water and are stable and leach resistant in wood. Propiconazole and tebuconazole are currently components of waterborne preservative treatments used for pressure-treatment of wood in the United States, Europe, and Canada. They are also used as components of formulations used to provide mold and sapstain protection. Propiconazole is also standardized for use with AWPA P9 Type C or Type F organic solvents.

Propiconazole–Tebuconazole–Imidacloprid (PTI)

PTI is a waterborne preservative solution composed of two fungicides (propiconazole and tebuconazole) and the insecticide imidacloprid. It is currently listed in AWPA standards for above-ground applications only. The efficacy of PTI is enhanced by the incorporation of a water-repellent stabilizer in the treatment solutions, and lower retentions are allowed with the stabilizer (Table 15–1).

Preservatives with ICC–ES Evaluation Reports

Some commercially available waterborne wood preservatives are not standardized by the AWPA. Instead, they have obtained ICC–ES evaluation reports. In this chapter we refer to these preservatives by their Evaluation Report number (Table 15–1).

ESR–1721

ESR–1721 recognizes three preservative formulations. Two are the same formulations of copper azole (CA–B and CA–C) also listed in AWPA standards. The other (referred to here as ESR–1721) uses particulate copper that is ground to sub-micron dimensions and dispersed in the treatment solution. Wood treated with ESR–1721 has a lighter green color than the CA–B or CA–C formulations because the copper is not dissolved in the treatment solution. All three formulations are listed for treatment of commodities used in a range of applications, including contact with soil or freshwater. Use of ESR–1721 (dispersed copper) is currently limited to easily treated pine species.

ESR–1980

ESR–1980 includes a listing for both the AWPA standardized formulation of ACQ–D and a waterborne, micronized copper version of alkaline copper quat (referred to here as ESR–1980). The formulation is similar to ACQ in that the active ingredients are 67% copper oxide and 33% quaternary ammonium compound. However, in ESR–1980 the copper is ground to sub-micron dimensions and suspended in the treatment solution instead of being dissolved in ethanolamine. The treated wood has little green color because the copper is not dissolved in the treatment solution. The use of the particulate form of copper is currently limited to the more easily penetrated pine species, but efforts are underway to adapt the formulation for treatment of a broader range of wood species. ESR–1980 is listed for treatment of commodities used in both above-ground and ground-contact applications.

ESR–2067

ESR–2067 is an organic waterborne preservative with an actives composition of 98% tebuconazole (fungicide) and 2% imidacloprid (insecticide). The treatment does not impart any color to the wood. It is currently listed only for treatment of commodities that are not in direct contact with soil or standing water.

ESR–2240

ESR–2240 is a waterborne formulation that utilizes finely ground (micronized) copper in combination with tebuconazole in an actives ratio of 25:1. It is listed for above-ground and ground-contact applications. In addition to wood products cut from pine species, ESR–2240 can be used for treatment of hem–fir lumber and Douglas-fir plywood.

ESR–2325

ESR–2325 is another waterborne preservative that utilizes finely ground copper particles and tebuconazole as actives. The ratio of copper to tebuconazole in the treatment solution is 25:1. Its use is currently limited to more readily treated species such as the Southern Pine species group, but Douglas-fir plywood is also listed. ESR–2315 is listed for treatment of wood used above-ground and in contact with soil or fresh water.

ESR–2711

ESR–2711 combines copper solubilized in ethanolamine with the fungicide 4,5-dichloro-2-N-octyl-4-isothiazolin-3-one (DCOI). The ratio of copper (as CuO) to DCOIT ranges from 10:1 to 25:1. The ESR listing provides for both above-ground and ground-contact applications. The appearance of the treated wood is similar to that of wood treated with other formulations utilizing soluble copper, such as ACQ. It is currently only listed for treatment of pine species.

Oil-Borne or Oil-Type Preservatives

Oil-type wood preservatives are some of the oldest preservatives, and their use continues in many applications. Wood does not swell from treatment with preservative oils, but it may shrink if it loses moisture during the treating process. Creosote and solutions with heavy, less volatile petroleum oils often help protect wood from weathering but may adversely influence its cleanliness, odor, color, paintability, and fire performance. Volatile oils or solvents with oil-borne preservatives, if removed after treatment, leave the wood cleaner than do the heavy oils but may not provide as much protection. Wood treated with some preservative oils can be glued satisfactorily, although special processing or cleaning may be required to remove surplus oils from surfaces before spreading the adhesive.

Coal-Tar Creosote and Creosote Solutions

Coal-tar creosote (creosote) is a black or brownish oil made by distilling coal tar that is obtained after high-temperature carbonization of coal. Advantages of creosote are (a) high toxicity to wood-destroying organisms; (b) relative insolubility in water and low volatility, which impart to it a great degree of permanence under the most varied use conditions; (c) ease of application; (d) ease with which its depth of penetration can be determined; (e) relative low cost (when purchased in wholesale quantities); and (f) lengthy record of satisfactory use. Creosote is commonly used for heavy timbers, poles, piles, and railroad ties.

AWPA Standard P1/P13 provides specifications for coal-tar creosote used for preservative treatment of piles, poles, and timber for marine, land, and freshwater use. The character of the tar used, the method of distillation, and the temperature range in which the creosote fraction is collected all influence the composition of the creosote, and the composition may vary within the requirements of standard specifications. Under normal conditions, requirements of these standards can be met without difficulty by most creosote producers.

Coal tar or petroleum oil may also be mixed with coal-tar creosote, in various proportions, to lower preservative costs. AWPA Standard P2 provides specifications for coal-tar solutions. AWPA Standard P3 stipulates that creosote–petroleum oil solution shall consist solely of specified proportions of 50% coal-tar creosote by volume (which meets AWPA standard P1/P13) and 50% petroleum oil by volume (which meets AWPA standard P4). However, because no analytical standards exist to verify the compliance of P3 solutions after they have been mixed, the consumer assumes the risk of using these solutions. These creosote solutions have a satisfactory record of performance, particularly for railroad ties and posts where surface appearance of the treated wood is of minor importance. Compared with straight creosote, creosote solutions tend to reduce weathering and checking of the treated wood. These solutions have a greater tendency to accumulate on the surface of the treated wood (bleed) and penetrate the wood with greater difficulty because they are generally more viscous than is straight creosote. High temperatures and pressures during treatment, when they can be safely used, will often improve penetration of high-viscosity solutions.

Although coal-tar creosote or creosote solutions are well suited for general outdoor service in structural timbers, creosote has properties that are undesirable for some purposes. The color of creosote and the fact that creosote-treated wood usually cannot be painted satisfactorily make this preservative unsuitable where appearance and paintability are important.

The odor of creosote-treated wood is unpleasant to some people. Also, creosote vapors are harmful to growing plants, and foodstuffs that are sensitive to odors should not be stored where creosote odors are present. Workers sometimes object to creosote-treated wood because it soils their clothes, and creosote vapor photosensitizes exposed skin. With precautions to avoid direct skin contact with creosote, there appears to be minimal danger to the health of workers handling or working near the treated wood. The EPA or the wood treater should be contacted for specific information on this subject.

In 1986, creosote became a restricted-use pesticide, and its use is currently restricted to pressure-treatment facilities. For use and handling of creosote-treated wood, refer to the EPA-approved Consumer Information Sheet.

Freshly creosoted timber can be ignited and burns readily, producing a dense smoke. However, after the timber has seasoned for some months, the more volatile parts of the oil disappear from near the surface and the creosoted wood usually is little, if any, easier to ignite than untreated wood. Until this volatile oil has evaporated, ordinary precautions should be taken to prevent fires. Creosote adds fuel value, but it does not sustain ignition.

Other Creosotes

Creosotes distilled from tars other than coal tar have been used to some extent for wood preservation, although they are not included in current AWPA specifications. These include wood-tar creosote, oil-tar creosote, and water–gas-tar creosote. These creosotes provide some protection from decay and insect attack but are generally less effective than coal-tar creosote.

Pentachlorophenol Solutions

Water-repellent solutions containing chlorinated phenols, principally pentachlorophenol (penta), in solvents of the mineral spirits type, were first used in commercial dip treatments of wood by the millwork industry in about 1931. Commercial pressure treatment with pentachlorophenol in heavy petroleum oils on poles started in about 1941, and considerable quantities of various products soon were pressure treated. AWPA Standard P8 defines the properties of pentachlorophenol preservative, stating that pentachlorophenol solutions for wood preservation shall contain not less than 95% chlorinated phenols, as determined by titration of hydroxyl and calculated as pentachlorophenol.

AWPA standard P9 defines solvents and formulations for organic preservative systems. The performance of pentachlorophenol and the properties of the treated wood are influenced by the properties of the solvent used. A commercial process using pentachlorophenol dissolved in liquid petroleum gas (LPG) was introduced in 1961, but later research showed that field performance of penta–LPG systems was inferior to penta–P9 systems. Thus, penta–LPG systems are no longer used. The heavy petroleum solvent included in AWPA P9 Type A is preferable for maximum protection, particularly when wood treated with pentachlorophenol is used in contact with the ground. The heavy oils remain in the wood for a long time and do not usually provide a clean or paintable surface.

Because of the toxicity of pentachlorophenol, care is necessary when handling and using it to avoid excessive personal contact with the solution or vapor. Do not use indoors or where human, plant, or animal contact is likely. Pentachlorophenol became a restricted-use pesticide in November 1986 and is currently only available for use in pressure treatment. For use and handling precautions, refer to the EPA-approved Consumer Information Sheet.

The results of pole service and field tests on wood treated with 5% pentachlorophenol in a heavy petroleum oil are similar to those with coal-tar creosote. This similarity has been recognized in the preservative retention requirements of treatment specifications. Pentachlorophenol is effective against many organisms, such as decay fungi, molds, stains, and insects. Because pentachlorophenol is ineffective against marine borers, it is not recommended for the treatment of marine piles or timbers used in coastal waters.

Copper Naphthenate

Copper naphthenate is an organometalic compound formed as a reaction product of copper salts and naphthenic acids that are usually obtained as byproducts in petroleum refining. It is a dark green liquid and imparts this color to the wood. Weathering turns the color of the treated wood to light brown after several months of exposure. The wood may vary from light brown to chocolate brown if heat is used in the treating process. AWPA P8 standard defines the properties of copper naphthenate, and AWPA P9 covers the solvents and formulations for organic preservative systems.

Copper naphthenate is effective against wood-destroying fungi and insects. It has been used commercially since the 1940s and is currently standardized for a broad range of applications (Table 15–1). Copper naphthenate is not a restricted-use pesticide but should be handled as an industrial pesticide. It may be used for superficial treatment, such as by brushing with solutions with a copper content of 1% to 2% (approximately 10% to 20% copper naphthenate). Water-based formulations of copper naphthenate may also be available.

Oxine Copper (copper-8-quinolinolate)

Oxine copper (copper-8-quinolinolate) is an organometalic compound, and the formulation consists of at least 10% copper-8-quinolinolate, 10% nickel-2-ethylhexanoate, and 80% inert ingredients (AWPA P8). It is accepted as a stand-alone preservative for aboveground use for sapstain and mold control and is also used for pressure treating (Table 15–1). A water-soluble form can be made with dodecylbenzene sulfonic acid, but the solution is corrosive to metals.

Oxine copper solutions are greenish brown, odorless, toxic to both wood decay fungi and insects, and have a low toxicity to humans and animals. Because of its low toxicity to humans and animals, oxine copper is the only EPA-registered preservative permitted by the U.S. Food and Drug Administration for treatment of wood used in direct contact with food. Some examples of its uses in wood are commercial refrigeration units, fruit and vegetable baskets and boxes, and water tanks. Oxine copper solutions have also been used on nonwood materials, such as webbing, cordage, cloth, leather, and plastics.

Zinc Naphthenate

Zinc naphthenate is similar to copper naphthenate but is less effective in preventing decay from wood-destroying fungi and mildew. It is light colored and does not impart the characteristic greenish color of copper naphthenate, but it does impart an odor. Waterborne and solventborne formulations are available. Zinc naphthenate is not widely used for pressure treating.

3-Iodo-2-Propynyl Butyl Carbamate

3-Iodo-2-propynyl butyl carbamate (IPBC) is a fungicide that is used as a component of sapstain and millwork preservatives. It is also included as a fungicide in several surface-applied water-repellent-preservative formulations. Waterborne and solvent-borne formulations are available. Some formulations yield an odorless, treated product that can be painted if dried after treatment. It is listed as a pressure-treatment preservative in the AWPA standards but is not currently standardized for pressure treatment of any wood products. IPBC also may be combined with other fungicides, such as didecyldimethylammonium chloride in formulations used to prevent mold and sapstain.

IPBC/Permethrin

IPBC is not an effective insecticide and has recently been standardized for use in combination with the insecticide permethrin (3-phenoxybenzyl-(1R,S)-cis, trans-2, 2-dimethyl-3-(2,2-dichlorovinyl) cycloproanecarboxylate) under the designation IPBC/PER. Permethrin is a synthetic pyrethroid widely used for insect control in agricultural and structural applications. The ratio of IPBC to permethrin in the IPBC/PER varies between 1.5:1 and 2.5:1. The formulation is carried in a light solvent such as mineral spirits, making it compatible with composite wood products that might be negatively affected by the swelling associated with water-based pressure treatments. The IPBC/PER formulation is intended only for use in above-ground applications. The formulation is listed as a preservative in AWPA standards, but at the time this chapter was finalized it had not yet been standardized for treatment of any commodities.

Alkyl Ammonium Compounds

Alkyl ammonium compounds such as didecyldimethylammonium chloride (DDAC) or didecyldimethylammonium carbonate (DDAC)/bicarbonate (DDABC) have some efficacy against both wood decay fungi and insects. They are soluble in both organic solvents and water and are stable in wood as a result of chemical fixation reactions. DDAC and DDABC are currently being used as a component of alkaline copper quat (ACQ) (see section on Waterborne Preservatives) for above-ground and ground-contact applications and as a component of formulations used for sapstain and mold control.

4,5-Dichloro-2-N-Octyl-4-Isothiazolin-3-One (DCOI)

4,5-dichloro-2-N-octyl-4-isothiazolin-3-one (DCOI) is a biocide that is primarily effective against wood decay fungi. It is soluble in organic solvents but not in water, and it is stable and leach resistant in wood. The solvent used in the formulation of the preservative is specified in AWPA P9 Type C. DCOI can be formulated to be carried in a waterborne system, and it is currently used as a component in the waterborne preservative EL2. It has also recently been proposed for use as co-biocide in a copper ethanolamine formulation referred to as ACD.

Chlorpyrifos

Chlorpyrifos (CPF) is an organophosphate insecticide that has been widely used for agricultural purposes. It has been standardized by the AWPA as a preservative but is not currently used as a component of commercial pressure treatments. Chloropyrifos is not effective in preventing fungal attack and should be combined with an appropriate fungicidal preservative for most applications.

Treatments for Wood Composites

Many structural composite wood products, such as glued-laminated beams, plywood, and parallel strand and laminated veneer lumber, can be pressure-treated with wood preservatives in a manner similar to lumber. However, flake- or fiber-based composites are often protected by adding preservative during manufacture. A commonly used preservative for these types of composites is zinc borate. Zinc borate is a white, odorless powder with low water solubility that is added directly to the furnish or wax during panel manufacture. Zinc borate has greater leach resistance than the more soluble forms of borate used for pressure treatment and thus can be used to treat composite siding products that are exposed outdoors but partially protected from the weather. Zinc borate is currently listed in AWPA Commodity Standard J for nonpressure treatment of laminated strand lumber, oriented strandboard, and engineered wood siding. The standard requires that these products have an exterior coating or laminate when used as siding. Another preservative that has been used to protect composites is ammoniacal copper acetate, which is applied by spraying the preservative onto the OSB flakes before drying.

Water-Repellent and Nonpressure Treatments

Effective water-repellent preservatives will retard the ingress of water when wood is exposed above ground. These preservatives help reduce dimensional changes in the wood as a result of moisture changes when the wood is exposed to rainwater or dampness for short periods. As with any wood preservative, the effectiveness in protecting wood against decay and insects depends upon the retention and penetration obtained in application. These preservatives are most often applied using nonpressure treatments such as vacuum impregnation, brushing, soaking, or dipping. Preservative systems containing water-repellent components are sold under various trade names, principally for the dip or equivalent treatment of window sash and other millwork. The National Wood Window and Door Association (NWWDA) standard, WDMA I.S. 4–07A, *Water Repellent Preservative Treatment for Millwork*, lists preservative formulations that have met certain requirements, including EPA registration and efficacy against decay fungi.

The AWPA Commodity Specification I for nonpressure treatment of millwork and other wood products provides requirements for these nonpressure preservatives but does not currently list any formulations. The preservative must also meet the *Guidelines for Evaluating New Wood Preservatives for Consideration by the AWPA* for nonpressure treatment.

Water-repellent preservatives containing oxine copper are used in nonpressure treatment of wood containers, pallets, and other products for use in contact with foods. When combined with volatile solvents, oxine copper is used to pressure-treat lumber intended for use in decking of trucks and cars or related uses involving harvesting, storage, and transportation of foods (AWPA P8).

Nonpressure preservatives sold to consumers for household and farm use typically contain copper naphthentate, zinc naphthenate, or oxine copper. Their formulations may also incorporate water repellents.

Selecting Preservatives

The type of preservative applied is often dependent on the requirements of the specific application. For example, direct contact with soil or water is considered a severe deterioration hazard, and preservatives used in these applications must have a high degree of leach resistance and efficacy against a broad spectrum of organisms. These same

Figure 15–1. Field stake test plot at Harrison Experimental Forest in southern Mississippi.

preservatives may also be used at lower retentions to protect wood exposed in lower deterioration hazards, such as above the ground. The exposure is less severe for wood that is partially protected from the weather, and preservatives that lack the permanence or toxicity to withstand continued exposure to precipitation may be effective in those applications. Other formulations may be so readily leachable that they can be used only indoors.

To guide selection of the types of preservatives and loadings appropriate to a specific end use, the AWPA recently developed use category system (UCS) standards. The UCS standards simplify the process of finding appropriate preservatives and preservative retentions for specific end uses. They categorize treated wood applications by the severity of the deterioration hazard (Table 15–6). The lowest category, Use Category 1 (UC1), is for wood that is used in interior construction and kept dry; UC2 is for interior wood completely protected from the weather but occasionally damp. UC3 is for exterior wood used above ground; UC4 is for wood used in ground contact in exterior applications. UC5 includes applications that place treated wood in contact with seawater and marine borers. Individual commodity specifications then list all the preservatives that are standardized for a specific use category along with the appropriate preservative retention.

Although some preservatives are effective in almost all environments, they may not be well-suited for applications involving frequent human contact or for exposures that present only low to moderate biodeterioration hazards. Additional considerations include cost, potential odor, surface dryness, adhesive bonding, and ease of finish application.

Evaluating New Preservatives

Wood preservatives often need to provide protection from a wide range of wood-attacking organisms (fungi, insects, marine borers, and bacteria). Because they must protect wood in so many ways, and protect wood for a long time period, evaluating wood treatments requires numerous tests. Some of the most important tests are mentioned here, but they should be considered only as a minimum, and other tests are useful as well. Appendix A of the AWPA Standards provides detailed guidelines on the types of tests that may be needed to evaluate new wood preservatives.

The ***laboratory leaching test*** helps to evaluate how rapidly the treatment will be depleted. A treatment needs leach resistance to provide long-term protection. In this test small cubes of wood are immersed in water for 2 weeks.

The ***laboratory decay test*** is used to challenge the treated wood with certain fungal isolates that are known to aggressively degrade wood. It should be conducted with specimens that have been through the leaching test. The extent of decay in wood treated with the test preservative is compared to that of untreated wood and wood treated with an established preservative. This test can help to determine the treatment level needed to prevent decay.

Field stake evaluations are some of the most informative tests because they challenge the treated wood with a wide range of natural organisms under severe conditions (Fig. 15–1). Stakes are placed into the soil in regions with a warm, wet climate (usually either the southeastern United States or Hawaii). At least two different sites are used to account for differences in soil properties and types of organisms present. The extent of deterioration in wood treated with the test preservative is compared to that of untreated wood and wood treated with an established preservative.

Above-ground field exposures are useful for treatments that will be used to protect wood above ground. Although not as severe as field stake tests, above-ground tests do provide useful information on above-ground durability. Specimens are exposed to the weather in an area with a warm, wet climate (usually either the southeastern United States or Hawaii). The specimens are designed to trap moisture and create ideal conditions for above-ground decay. The extent of deterioration in wood treated with the test preservative is compared to that of untreated wood and wood treated with an established preservative.

Corrosion testing is used to determine the compatibility of the treatment with metal fasteners.

Treatability testing is used to evaluate the ability of a treatment to penetrate deeply into the wood. Shallow surface treatments rarely provide long-term protection because degrading organisms can still attack the interior of the wood.

Strength testing compares the mechanical properties of treated wood with matched, untreated specimens. Treatment chemicals or processes have the potential to damage the wood, making it weak or brittle.

Preservative Effectiveness

Preservative effectiveness is influenced not only by the protective value of the preservative chemical, but also by the

Table 15–6. Summary of use category system developed by the American Wood Protection Association

Use category	Service conditions	Use environment	Common agents of deterioration	Typical applications
UC1	Interior construction Above ground Dry	Continuously protected from weather or other sources of moisture	Insects only	Interior construction and furnishings
UC2	Interior construction Above ground Damp	Protected from weather, but may be subject to sources of moisture	Decay fungi and insects	Interior construction
UC3A	Exterior construction Above ground Coated and rapid water runoff	Exposed to all weather cycles, not exposed to prolonged wetting	Decay fungi and insects	Coated millwork, siding, and trim
UC3B	Ground contact or fresh water Non-critical components	Exposed to all weather cycles, normal exposure conditions	Decay fungi and insects	Fence, deck, and guardrail posts, crossties and utility poles (low decay areas)
UC4A	Ground contact or fresh water Non-critical components	Exposed to all weather cycles, normal exposure conditions	Decay fungi and insects	Fence, deck, and guardrail posts, crossties and utility poles (low decay areas)
UC4B	Ground contact or fresh water Critical components or difficult replacement	Exposed to all weather cycles, high decay potential includes salt-water splash	Decay fungi and insects with increased potential for biodeterioration	Permanent wood foundations, building poles, horticultural posts, crossties and utility poles (high decay areas)
UC4C	Ground contact or fresh water Critical structural components	Exposed to all weather cycles, severe environments, extreme decay potential	Decay fungi and insects with extreme potential for biodeterioration	Land and fresh-water piling, foundation piling, crossties and utility poles (severe decay areas)
UC5A	Salt or brackish water and adjacent mud zone Northern waters	Continuous marine exposure (salt water)	Salt-water organisms	Piling, bulkheads, bracing
UC5B	Salt or brackish water and adjacent mud zone NJ to GA, south of San Francisco	Continuous marine exposure (salt water)	Salt-water organisms, including creosote-tolerant *Limnoria tripunctata*	Piling, bulkheads, bracing
UC5C	Salt or brackish water and adjacent mud zone South of GA, Gulf Coast, Hawaii, and Puerto Rico	Continuous marine exposure (salt water)	Salt-water organisms, including Martesia, Sphaeroma	Piling, bulkheads, bracing

method of application and extent of penetration and retention of the preservative in the treated wood. Even with an effective preservative, good protection cannot be expected with poor penetration or substandard retention levels. The species of wood, proportion of heartwood and sapwood, heartwood penetrability, and moisture content are among the important variables that influence the results of treatment. For various wood products, the preservatives and retention levels listed in the AWPA Commodity Standards or ICC–ES evaluation reports are given in Table 15–1.

Determining whether one preservative is more effective than another within a given use category is often difficult. Few service tests include a variety of preservatives under comparable conditions of exposure. Furthermore, service tests may not show a good comparison between different preservatives as a result of the difficulty in controlling for differences in treatment quality. Comparative data under similar exposure conditions, with various preservatives and retention levels, are included in the U.S. Forest Service, Forest Products Laboratory, stake test studies. A summary of these test results is included in Table 15–5. Note, however, that because the stakes used in these studies are treated under carefully controlled conditions, their performance may not reflect variability in performance exhibited by a broad range of commercially treated material.

Figure 15–2. During pressure treatment, preservative typically penetrates only the sapwood. Round members have a uniform treated sapwood shell, but sawn members may have less penetration on one or more faces.

Similar comparisons have been conducted for preservative treatments of small wood panels in marine exposure (Key West, Florida). These preservatives and treatments include creosotes with and without supplements, waterborne preservatives, waterborne preservative and creosote dual treatments, chemical modifications of wood, and various chemically modified polymers. In this study, untreated panels were badly damaged by marine borers after 6 to 18 months of exposure, whereas some treated panels have remained free of attack after 19 years in the sea.

Test results based on seawater exposure have shown that dual treatment (waterborne copper-containing preservatives followed by creosote) is possibly the most effective method of protecting wood against all types of marine borers. The AWPA standards have recognized this process as well as the treatment of marine piles with high retention levels of ammoniacal copper zinc arsenate (ACZA) or chromated copper arsenate (CCA). The recommended treatment and retention in kilograms per cubic meter (pounds per cubic foot) for round timber piles exposed to severe marine borer hazard are given in Table 15–2. Poorly treated or untreated heartwood faces of wood species containing "high sapwood" that do not require heartwood penetration (for example, southern pines, ponderosa pine, and red pine) have been found to perform inadequately in marine exposure. In marine applications, only sapwood faces should be allowed for waterborne-preservative-treated pine in direct seawater exposure.

Effect of Species on Penetration

The effectiveness of preservative treatment is influenced by the penetration and distribution of the preservative in the wood. For maximum protection, it is desirable to select species for which good penetration is assured.

In general, the sapwood of most softwood species is not difficult to treat under pressure (Fig. 15–2). Examples of species with sapwood that is easily penetrated when it is well dried and pressure treated are the pines, coastal Douglas-fir, western larch, Sitka spruce, western hemlock, western redcedar, northern white-cedar, and white fir (*A. concolor*). Examples of species with sapwood and heartwood somewhat resistant to penetration are the red and white spruces and Rocky Mountain Douglas-fir. Cedar poles are commonly incised to obtain satisfactory preservative penetration. With round members, such as poles, posts, and piles, the penetration of the sapwood is important in achieving a protective outer zone around the heartwood.

The proportion of sapwood varies greatly with wood species, and this becomes an important factor in obtaining adequate penetration. Species within the Southern Pine group are characterized by a large sapwood zone that is readily penetrated by most types of preservatives. In part because of their large proportion of treatable sapwood, these pine species are used for the vast majority of treated products in the United States. Other important lumber species, such as Douglas-fir, have a narrower sapwood band in the living tree, and as a result products manufactured from Douglas-fir have a lower proportion of treatable sapwood.

The heartwood of most species is difficult to treat. There may be variations in the resistance to preservative penetration of different wood species. Table 15–7 gives the relative resistance of the heartwood to treatment of various softwood and hardwood species. Although less treatable than sapwood, well-dried white fir, western hemlock, northern red oak, the ashes, and tupelo are examples of species with heartwood that is reasonably easy to penetrate. The southern pines, ponderosa pine, redwood, Sitka spruce, coastal Douglas-fir, beech, maples, and birches are examples of species with heartwood that is moderately resistant to penetration.

Preparation of Wood for Treatment

For satisfactory treatment and good performance, the wood product must be sound and suitably prepared. Except in specialized treating methods involving unpeeled or green material, the wood should be well peeled and either seasoned or conditioned in the cylinder before treatment. It is also highly desirable that all machining be completed before treatment, including incising (to improve the preservative penetration in woods that are resistant to treatment) and the operations of cutting or boring of holes.

Peeling

Peeling round or slabbed products is necessary to enable the wood to dry quickly enough to avoid decay and insect damage and to permit the preservative to penetrate satisfactorily. Even strips of the thin inner bark may prevent penetration. Patches of bark left on during treatment usually fall off in time and expose untreated wood, thus permitting decay to reach the interior of the member.

Careful peeling is especially important for wood that is to be treated by a nonpressure method. In the more thorough

Table 15–7. Penetration of the heartwood of various softwood and hardwood species[a]

Ease of treatment	Softwoods	Hardwoods
Least difficult	Bristlecone pine (*Pinus aristata*) Pinyon (*P. edulis*) Pondersosa pine (*P. pondersosa*) Redwood (*Sequoia sempervirens*)	American basswood (*Tilia americana*) Beech (white heartwood) (*Fagus grandifolia*) Black tupelo (blackgum) (*Nyssa sylvatica*) Green ash (*Fraxinus pennsylvanica* var. *lanceolata*) Pin cherry (*Prunus pennsylvanica*) River birch (*Betula nigra*) Red oak (*Quercus* spp.) Slippery elm (*Ulmus fulva*) Sweet birch (*Betula lenia*) Water tupelo (*Nyssa aquatica*) White ash (*Fraxinus americana*)
Moderately difficult	Baldcypress (*Taxodium distichum*) California red fir (*Abies magnifica*) Douglas-fir (coast) *(Pseudotsuga taxifolia)*) Eastern white pine (*Pinus strobus*) Jack pine (*P. banksiana*) Loblolly pine (*P. taeda*) Longleaf pine (*P. palustris*) Red pine (*P. resinosa*) Shortleaf pine (*P. echinata*) Sugar pine (*P. lambertiana*) Western hemlock (*Tsuga heterophylla*)	Black willow (*Salix nigra*) Chestnut oak (*Quercus montana*) Cottonwood (*Populus* sp.) Bigtooth aspen (*P. grandidentata*) Mockernut hickory (*Carya tomentosa*) Silver maple (*Acer saccharinum*) Sugar maple (*A. saccharum*) Yellow birch (*Betula lutea*)
Difficult	Eastern hemlock (*Tsuga canadensis*) Engelmann spruce (*Picea engelmanni*) Grand fir (*Abies grandis*) Lodgepole pine (*Pinus contorta* var. *latifolia*) Noble fir (*Abies procera*) Sitka spruce (*Picea sitchensis*) Western larch (*Larix occidentalis*) White fir (*Abies concolor*) White spruce (*Picea glauca*)	American sycamore (*Platanus occidentalis*) Hackberry (*Celtis occidentalis*) Rock elm (*Ulmus thomoasi*) Yellow-poplar (*Liriodendron tulipifera*)
Very difficult	Alpine fir (*Abies lasiocarpa*) Corkbark fir (*A. lasiocarpa* var. *arizonica*) Douglas-fir (Rocky Mountain) (*Pseudotsuga taxifolia*) Northern white-cedar (*Thuja occidentalis*) Tamarack (*Larix laricina*) Western redcedar (*Thuja plicata*)	American beech (red heartwood) (*Fagus grandifolia*) American chestnut (*Castanea dentata*) Black locust (*Robinia pseudoacacia*) Blackjack oak (*Quercus marilandica*) Sweetgum (redgum) (*Liquidambar styraciflua*) White oak (*Quercus* spp.)

[a]As covered in MacLean (1952).

processes, some penetration may take place both longitudinally and tangentially in the wood; consequently, small strips of bark are tolerated in some specifications. Processes in which a preservative is forced or permitted to diffuse through green wood lengthwise do not require peeling of the timber. Machines of various types have been developed for peeling round timbers, such as poles, piles, and posts (Fig. 15–3).

Drying

Drying of wood before treatment is necessary to prevent decay and stain and to obtain preservative penetration. However, for treatment with waterborne preservatives by certain diffusion methods, high moisture content levels may be permitted. For treatment by other methods, however, drying before treatment is essential. Drying before treatment opens up the checks before the preservative is applied, thus increasing penetration, and reduces the risk of checks opening after treatment and exposing unpenetrated wood. Good penetration of heated organic-based preservatives may be possible in wood with a moisture content as high as 40% to 60%, but severe checking while drying after treatment can expose untreated wood.

For large timbers and railroad ties, air drying is a widely used method of conditioning. Despite the increased time, labor, and storage space required, air drying is generally the most inexpensive and effective method, even for pressure treatment. However, wet, warm climatic conditions make it difficult to air dry wood adequately without objectionable infection by stain, mold, and decay fungi. Such infected wood is often highly permeable; in rainy weather, infected wood can absorb a large quantity of water, which prevents satisfactory treatment.

How long the timber must be air dried before treatment depends on the climate, location, and condition of the

Figure 15–3. Machine peeling of poles. The outer bark has been removed by hand, and the inner bark is being peeled by machine. Frequently, all the bark is removed by machine.

Figure 15–4. Deep incising permits better penetration of preservative.

seasoning yard, methods of piling, season of the year, timber size, and species. The most satisfactory seasoning practice for any specific case will depend on the individual drying conditions and the preservative treatment to be used. Therefore, treating specifications are not always specific as to moisture content requirements.

To prevent decay and other forms of fungal infection during air drying, the wood should be cut and dried when conditions are less favorable for fungus development (Chap. 14). If this is impossible, chances for infection can be minimized by prompt conditioning of the green material, careful piling and roofing during air drying, and pretreating the green wood with preservatives to protect it during air drying.

Lumber of all species, including Southern Pine poles, is often kiln dried before treatment, particularly in the southern United States where proper air seasoning is difficult. Kiln drying has the important added advantage of quickly reducing moisture content, thereby reducing transportation charges on poles.

Conditioning of Green Products

Plants that treat wood by pressure processes can condition green material by means other than air and kiln drying. Thus, they avoid a long delay and possible deterioration of the timber before treatment.

When green wood is to be treated under pressure, one of several methods for conditioning may be selected. The steaming-and-vacuum process is used mainly for southern pines, and the Boulton or boiling-under-vacuum process is used for Douglas-fir and sometimes hardwoods.

In the steaming process, the green wood is steamed in the treating cylinder for several hours, usually at a maximum of 118 °C (245 °F). When steaming is completed, a vacuum is immediately applied. During the steaming period, the outer part of the wood is heated to a temperature approaching that of the steam; the subsequent vacuum lowers the boiling point so that part of the water is evaporated or forced out of the wood by the steam produced when the vacuum is applied. The steaming and vacuum periods used depend upon the wood size, species, and moisture content. Steaming and vacuum usually reduce the moisture content of green wood slightly, and the heating assists greatly in getting the preservative to penetrate. A sufficiently long steaming period will also sterilize the wood.

In the Boulton or boiling-under-vacuum method of partial seasoning, the wood is heated in the oil preservative under vacuum, usually at about 82 to 104 °C (180 to 220 °F). This temperature range, lower than that of the steaming process, is a considerable advantage in treating woods that are especially susceptible to injury from high temperatures. The Boulton method removes much less moisture from heartwood than from sapwood.

Incising

Wood that is resistant to penetration by preservatives may be incised before treatment to permit deeper and more uniform penetration. To incise, lumber and timbers are passed through rollers equipped with teeth that sink into the wood to a predetermined depth, usually 13 to 19 mm (1/2 to 3/4 in.). The teeth are spaced to give the desired distribution of preservative with the minimum number of incisions. A machine of different design is required for deeply incising the butts of poles, usually to a depth of 64 mm (2.5 in.) (Fig. 15–4).

Incising is effective because preservatives usually penetrate the wood much farther along the grain than across the grain. The incisions open cell lumens along the grain, which greatly enhances penetration. Incising is especially effective in improving penetration in the heartwood areas of sawn surfaces.

Incising is practiced primarily on Douglas-fir, western hemlock, and western larch ties and timbers for pressure treatment and on cedar and Douglas-fir poles. Incising can result in significant reductions in strength (Chap. 5).

Cutting and Framing

All cutting and boring of holes should be done prior to preservative treatment. Cutting into the wood in any way after treatment will frequently expose the untreated interior of the timber and permit ready access to decay fungi or insects.

In some cases, wood structures can be designed so that all cutting and framing is done before treatment. Railroad companies have followed this practice and have found it not only practical but economical. Many wood-preserving plants are equipped to carry on such operations as the adzing and boring of crossties; gaining, roofing, and boring of poles; and framing of material for bridges and specialized structures, such as water tanks and barges.

Treatment of the wood with preservative oils results in little or no dimensional change. With waterborne preservatives, however, some change in the size and shape of the wood may occur even though the wood is redried to the moisture content it had before treatment. If precision fitting is necessary, the wood is cut and framed before treatment to its approximate final dimensions to allow for slight surfacing, trimming, and reaming of bolt holes. Grooves and bolt holes for timber connectors are cut before treatment and can be reamed out if necessary after treatment.

Application of Preservatives

Wood-preserving methods are of two general types: (a) pressure processes, in which the wood is impregnated in closed vessels under pressures considerably above atmospheric, and (b) nonpressure processes, which vary widely in the procedures and equipment used.

Pressure Processes

In commercial practice, wood is most often treated by immersing it in a preservative in a high-pressure apparatus and applying pressure to drive the preservative into the wood. Pressure processes differ in details, but the general principle is the same. The wood, on cars or trams, is run into a long steel cylinder, which is then closed and filled with preservative (Fig. 15–5). Pressure forces the preservative into the wood until the desired amount has been absorbed. Considerable preservative is absorbed, with relatively deep penetration. Three pressure processes are commonly used: full cell, modified full cell, and empty cell.

Full Cell

The full-cell (Bethel) process is used when the retention of a maximum quantity of preservative is desired. It is a standard procedure for timbers to be treated with creosote when protection against marine borers is required. Waterborne preservatives may be applied by the full-cell process if uniformity of penetration and retention is the primary concern. With waterborne preservatives, control over preservative retention is obtained by regulating the concentration of the treating solution.

Steps in the full-cell process are essentially the following:

1. The charge of wood is sealed in the treating cylinder, and a preliminary vacuum is applied for a half-hour or more to remove the air from the cylinder and as much as possible from the wood.
2. The preservative, at ambient or elevated temperature depending on the system, is admitted to the cylinder without breaking the vacuum.
3. After the cylinder is filled, pressure is applied until the wood will take no more preservative or until the required retention of preservative is obtained.
4. When the pressure period is completed, the preservative is withdrawn from the cylinder.
5. A short final vacuum may be applied to free the charge from dripping preservative.

When the wood is steamed before treatment, the preservative is admitted at the end of the vacuum period that follows steaming. When the timber has received preliminary conditioning by the Boulton or boiling-under-vacuum process, the cylinder can be filled and the pressure applied as soon as the conditioning period is completed.

Modified Full Cell

The modified full-cell process is basically the same as the full-cell process except for the amount of initial vacuum and the occasional use of an extended final vacuum. The modified full-cell process uses lower levels of initial vacuum; the actual amount is determined by the wood species, material size, and final retention desired. The modified full-cell process is commonly used for treatment of lumber with waterborne preservatives.

Empty Cell

The objective of the empty-cell process is to obtain deep penetration with a relatively low net retention of preservative. For treatment with oil preservatives, the empty-cell process should always be used if it will provide the desired retention. Two empty-cell processes, the Rueping and the Lowry, are commonly employed; both use the expansive force of compressed air to drive out part of the preservative absorbed during the pressure period.

The Rueping empty-cell process, often called the empty-cell process with initial air, has been widely used for many years in Europe and the United States. The following general procedure is employed:

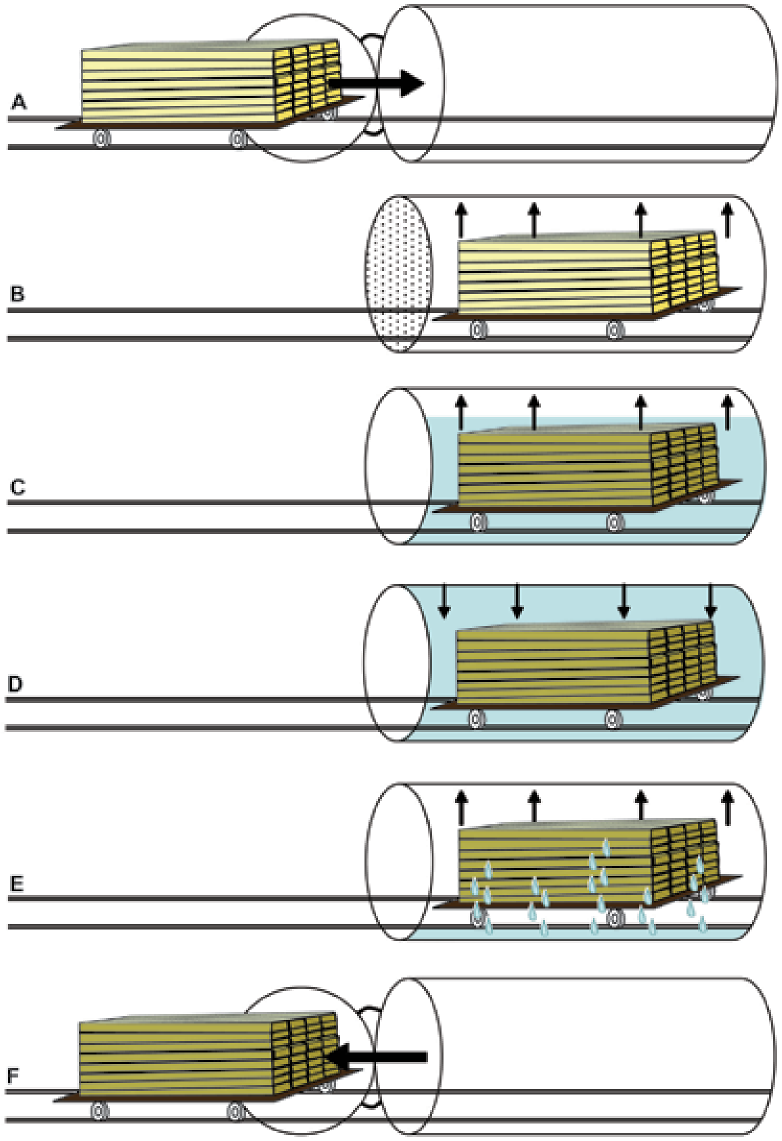

Figure 15–5. Typical steps in pressure treating process: A, untreated wood is placed in cylinder; B, a vacuum is applied to pull air out of the wood; C, the wood is immersed in solution while still under vacuum; D, pressure is applied to force the preservative into the wood; E, preservative is pumped out, and a final vacuum is pulled to remove excess preservative; F, excess preservative is pumped away, and the wood is removed from the cylinder.

1. Air under pressure is forced into the treating cylinder, which contains the charge of wood. The air penetrates some species easily, requiring but a few minutes application of pressure. In treating the more resistant species, common practice is to maintain air pressure from 1/2 to 1 h before admitting the preservative, but the necessity for lengthy air-pressure periods does not seem fully established. The air pressures employed generally range from 172 to 689 kPa (25 to 100 lb in^{-2}), depending on the net retention of preservative desired and the resistance of the wood.
2. After the period of preliminary air pressure, preservative is forced into the cylinder. As the preservative is pumped in, the air escapes from the treating cylinder into an equalizing or Rueping tank, at a rate that keeps the pressure constant within the cylinder. When the treating cylinder is filled with preservative, the treating pressure is increased above that of the initial air and is maintained until the wood will absorb no more preservative, or until enough has been absorbed to leave the required retention of preservative in the wood after the treatment.

3. At the end of the pressure period, the preservative is drained from the cylinder, and surplus preservative is removed from the wood with a final vacuum. The amount of preservative recovered can be from 20% to 60% of the gross amount injected.

The Lowry is often called the empty-cell process without initial air pressure. Preservative is admitted to the cylinder without either an initial air pressure or a vacuum, and the air originally in the wood at atmospheric pressure is imprisoned during the filling period. After the cylinder is filled with the preservative, pressure is applied, and the remainder of the treatment is the same as described for the Rueping treatment.

The Lowry process has the advantage that equipment for the full-cell process can be used without other accessories that the Rueping process usually requires, such as an air compressor, an extra cylinder or Rueping tank for the preservative, or a suitable pump to force the preservative into the cylinder against the air pressure. However, both processes have advantages and are widely and successfully used.

With poles and other products where bleeding of preservative oil is objectionable, the empty-cell process is followed by either heating in the preservative (expansion bath) at a maximum of 104 °C (220 °F) or a final steaming for a specified time limit at a maximum of 116 °C (240 °F) prior to the final vacuum.

Treating Pressures and Preservative Temperatures

The pressures used in treatments vary from about 345 to 1,723 kPa (50 to 250 lb in^{-2}), depending on the species and the ease with which the wood takes the treatment. Most commonly, pressures range from about 862 to 1,207 kPa (125 to 175 lb in^{-2}). Many woods are sensitive to high treating pressures, especially when hot. For example, AWPA standards permit a maximum pressure of 1,050 kPa (150 lb in^{-2}) in the treatment of redwood, eastern hemlock, and eastern white pine, while the limitation for oak is 1,723 kPa (250 lb in^{-2}).

AWPA T1 standard requires that the temperature of creosote and creosote solutions, as well as that of the oil-type preservatives, during the pressure period not be greater than 100 °C (212 °F). For the waterborne preservatives that contain chromium (ACC and CCA), the maximum solution temperature is limited to 50 °C (120 °F) to avoid premature precipitation of the preservative. For most other waterborne preservatives, the maximum solution temperature is 65 °C (150 °F), although a higher limit 93 °C (200 °F) is permitted for inorganic boron solutions.

Effect on Mechanical Properties

Coal-tar creosote, creosote solutions, and pentachlorophenol dissolved in petroleum oils are practically inert to wood and have no chemical influence that would affect its strength. Chemicals commonly used in waterborne salt preservatives, including chromium, copper, arsenic, and ammonia, are reactive with wood. Thus, these chemicals are potentially damaging to mechanical properties and may also promote corrosion of mechanical fasteners.

Significant reductions in mechanical properties may be observed if the treating and subsequent drying processes are not controlled within acceptable limits. Factors that influence the effect of the treating process on strength include (a) species of wood, (b) size and moisture content of the timbers treated, (c) type and temperature of heating medium, (d) length of the heating period in conditioning the wood for treatment and time the wood is in the hot preservative, (e) post-treatment drying temperatures, and (f) amount of pressure used. Most important of those factors are the severity and duration of the in-retort heating or post-treatment redrying conditions used. The effect of wood preservatives on the mechanical properties of wood is covered in Chapter 5.

Nonpressure Processes

The numerous nonpressure processes differ widely in the penetration and retention levels of preservative attained, and consequently in the degree of protection they provide to the treated wood. When similar retention and penetration levels are achieved, wood treated by a nonpressure method should have a service life comparable to that of wood treated by pressure. Nevertheless, results of nonpressure treatments, particularly those involving surface applications, are not generally as satisfactory as those of pressure treatment. The superficial processes do serve a useful purpose when more thorough treatments are impractical or exposure conditions are such that little preservative protection is required.

Nonpressure methods, in general, consist of (a) surface application of preservatives by brief dipping, (b) soaking in preservative oils or steeping in solutions of waterborne preservatives, (c) diffusion processes with waterborne preservatives, (d) vacuum treatment, and (e) a variety of miscellaneous processes.

Brief Dipping

It is a common practice to treat window sash, frames, and other millwork, either before or after assembly, by dipping the item in a water-repellent preservative.

In some cases, preservative oil penetrates the end surfaces of ponderosa pine sapwood as much as 25 to 76 mm (1 to 3 in.). However, end penetration in such woods as the heartwood of southern pines and Douglas-fir is much less. Transverse penetration of the preservative applied by brief dipping is very shallow, usually less than a millimeter (a few hundredths of an inch). The exposed end surfaces at joints are the most vulnerable to decay in millwork products; therefore, good end penetration is especially advantageous. Dip applications provide very limited protection to wood used in contact with the ground or under very moist conditions, and they provide very limited protection against attack by termites. However, they do have value for exterior woodwork and millwork that is painted, not in contact with the ground, and exposed to moisture only for brief periods.

Cold Soaking and Steeping

The methods of cold soaking well-seasoned wood for several hours or days in low-viscosity preservative oils or steeping green or seasoned wood for several days in waterborne preservatives have provided a range of success on fence posts, lumber, and timbers.

Pine posts treated by cold soaking for 24 to 48 h or longer in a solution containing 5% of pentachlorophenol in No. 2 fuel oil have shown an average life of 16 to 20 years or longer. The sapwood in these posts was well penetrated, and preservative solution retention levels ranged from 32 to 96 kg m^{-3} (2 to 6 lb in^{-3}). Most species do not treat as satisfactorily as do the pines by cold soaking, and test posts of such woods as birch, aspen, and sweetgum treated by this method have failed in much shorter times.

Preservative penetration and retention levels obtained by cold soaking lumber for several hours are considerably better than those obtained by brief dipping of similar species. However, preservative retention levels seldom equal those obtained in pressure treatment except in cases such as sapwood of pines that has become highly absorptive through mold and stain infection.

Steeping with waterborne preservatives has very limited use in the United States but it has been used for many years in Europe. In treating seasoned wood, both the water and the preservative salt in the solution soak into the wood. With green wood, the preservative enters the water-saturated wood by diffusion. Preservative retention and penetration levels vary over a wide range, and the process is not generally recommended when more reliable treatments are practical.

Diffusion Processes

In addition to the steeping process, diffusion processes are used with green or wet wood. These processes employ waterborne preservatives that will diffuse out of the water of the treating solution or paste into the water of the wood.

The double-diffusion process developed by the Forest Products Laboratory has shown very good results in fence post tests and standard 38- by 89-mm (nominal 2- by 4-in.) stake tests, particularly for full-length immersion treatments. This process consists of steeping green or partially seasoned wood first in one chemical solution, then in another. The two chemicals then react in the wood to form a precipitate with low solubility. However, the preservatives evaluated in this process do not currently have EPA registration for use in nonpressure treatments.

Vacuum Process

The vacuum process, or "VAC–VAC" as referred to in Europe, has been used to treat millwork with water-repellent preservatives and construction lumber with waterborne and water-repellent preservatives.

In treating millwork, the objective is to use a limited quantity of water-repellent preservative and obtain retention and penetration levels similar to those obtained by dipping for 3 min. In this treatment, a quick, low initial vacuum is followed by filling the cylinder under vacuum, releasing the vacuum and soaking, followed by a final vacuum. This treatment provides better penetration and retention than the 3-min dip treatment, and the surface of the wood is quickly dried, thus expediting glazing, priming, and painting. The vacuum treatment is also reported to be less likely than dip treatment to leave objectionably high retention levels in bacteria-infected wood referred to as "sinker stock."

Lumber intended for buildings has been treated by the vacuum process, either with a waterborne preservative or a water-repellent/preservative solution, with preservative retention levels usually less than those required for pressure treatment. The process differs from that used in treating millwork in employing a higher initial vacuum and a longer immersion or soaking period.

In a study by the Forest Products Laboratory, an initial vacuum of –93 kPa (27.5 inHg) was applied for 30 min, followed by a soaking for 8 h, and a final or recovery vacuum of –93 kPa (27.5 inHg) for 2 h. Results of the study showed good penetration of preservative in the sapwood of dry lumber of easily penetrated species such as the pines. However, in heartwood and unseasoned sapwood of pine and heartwood of seasoned and unseasoned coastal Douglas-fir, penetration was much less than that obtained by pressure treatment. Preservative retention was less controllable in vacuum than in empty-cell pressure treatment. Good control over retention levels is possible in vacuum treatment with a waterborne preservative by adjusting concentration of the treating solution.

Miscellaneous Nonpressure Processes

Several other nonpressure methods of various types have been used to a limited extent. Many of these involve the application of waterborne preservatives to living trees. The Boucherie process for the treatment of green, unpeeled poles has been used for many years in Europe. This process involves attaching liquid-tight caps to the butt ends of the poles. Then, through a pipeline or hose leading to the cap, a waterborne preservative is forced under hydrostatic pressure into the pole.

A tire-tube process is a simple adaptation of the Boucherie process used for treating green, unpeeled fence posts. In this treatment, a section of used inner tube is fastened tight around the butt end of the post to make a bag that holds a solution of waterborne preservative. There are now limitations for application of these processes because of the potential loss of preservative to the soil around the treatment site.

In-Place and Remedial Treatments

In-place treatments may be beneficial both during construction and as part of an inspection and maintenance program. Although cutting or drilling pressure-treated wood during construction is undesirable, it cannot always be avoided. When cutting is necessary, the damage can be partly overcome by a thorough application of copper naphthenate (1% to 2% copper) to the cut surface. This provides a protective coating of preservative on the surface that may slowly migrate into the end grain of the wood. The exposed end-grain in joints, which is more susceptible to moisture absorption, and the immediate area around all fasteners, including drill holes, will require supplemental on-site treatment. A special device is available for pressure-treating bolt holes that are bored after treatment. For treating the end surfaces of piles where they are cut off after driving, at least two generous coats of copper naphthenate should be applied. A coat of asphalt or similar material may be thoroughly applied over the copper naphthenate, followed by some protective sheet material, such as metal, roofing felt, or saturated fabric, fitted over the pile head and brought down the sides far enough to protect against damage to the treatment and against the entrance of storm water. AWPA Standard M4 contains instructions for the care of pressure-treated wood after treatment.

Surface Applications

The simplest treatment is to apply the preservative to the wood with a brush or by spraying. Preservatives that are thoroughly liquid when cold should be selected, unless it is possible to heat the preservative. When practical, the preservative should be flooded over the wood rather than merely painted. Every check and depression in the wood should be thoroughly filled with the preservative, because any untreated wood left exposed provides ready access for fungi. Rough lumber may require as much as 40 L of preservative per 100 m^2 (10 gallons per 1,000 ft^2) of surface, but surfaced lumber requires considerably less. The transverse penetration obtained will usually be less than 2.5 mm (0.1 in.), although in easily penetrated species, end-grain (longitudinal) penetration is considerably greater. The additional life obtained by such treatments over that of untreated wood will be affected greatly by the conditions of service. For wood in contact with the ground, service life may be from 1 to 5 years.

For brush or spray applications, copper naphthenate in oil is the preservative that is most often used. The solution should contain 1% to 2% elemental copper. Copper naphthenate is available as a concentrate or in a ready-to-use solution in gallon and drum containers. Borate solutions can also be sprayed or brushed into checks or splits. However, because they are not fixed to the wood they can be leached during subsequent precipitation. Borates are sold either as concentrated liquids (typically formulated with glycol) or as powders that can be diluted with water.

Another type of surface treatment is the application of water-soluble pastes containing combinations of copper naphthenate, copper quinolinolate, copper hydroxide, or borates. The theory with these treatments is that the diffusible components (such as boron) will move through the wood, while the copper component remains near the surface of a void or check. These pastes are most commonly used to help protect the ground-line area of poles. After the paste is applied, it is a covered with a wrap to hold the paste against the pole and prevent loss into the soil. In bridge piles this type of paste application should be limited to terrestrial piles that will not be continually or frequently exposed to standing water. These pastes may also be effective if used under cap beams or covers to protect exposed end-grain. Reapplication schedules will vary based on the manufacturers recommendations as well as the method and area of application.

Internal Diffusible Treatments

Surface-applied treatments often do not penetrate deeply enough to protect the inner portions of large wooden members. An alternative to surface-applied treatments is installation of internal diffusible chemicals. These diffusible treatments are available in liquid, solid, or paste form and are applied into treatment holes that are drilled deeply into the wood. They are similar (and in some cases identical) to the surface-applied treatments or pastes. Boron is the most common active ingredient, but fluoride and copper have also been used. In timbers, deep holes are drilled perpendicular to the upper face on either side of checks. In round piles, steeply sloping holes are drilled across the grain to maximize the chemical diffusion and minimize the number of holes needed. The treatment holes are plugged with tight fitting treated wooden plugs or removable plastic plugs. Plugs with grease fittings are also available so that the paste can be reapplied without removing the plug.

Solid rod treatments have advantages in environmentally sensitive areas or in applications where the treatment hole can only be drilled at an upward angle. However, the chemical may not diffuse as rapidly or for as great a distance as compared to a liquid form. Solid forms may be less mobile because diffusible treatments require moisture to move through wood. Concentrated liquid borates may also be poured into treatment holes and are sometimes used in conjunction with the rods to provide an initial supply of moisture. When the moisture content falls below 20%, little chemical movement occurs, but fortunately growth of decay fungi is substantially arrested below 30% moisture. Because there is some risk that rods installed in a dry section of a timber would not diffuse to an adjacent wet section, some experience in proper placement of the treatment holes is necessary. The diffusible treatments do not move as far in the wood as do fumigants, and thus the treatment holes must be spaced more closely. A study of borate diffusion in timbers of several wood species reported that diffusion along the grain was generally less than 12 cm (5 in.), and diffusion across the grain was typically less than 5 cm (2 in.).

Internal Fumigant Treatments

As with diffusibles, fumigants are applied in liquid or solid form in predrilled holes. However, they then volatilize into a gas that moves through the wood. To be most effective, a fumigant should be applied at locations where it will not readily volatilize out of the wood to the atmosphere. When fumigants are applied, the timbers should be inspected thoroughly to determine an optimal drilling pattern that avoids metal fasteners, seasoning checks, and severely rotted wood. In vertical members such as piles, holes to receive liquid fumigant should be drilled at a steep angle (45° to 60°) downward toward the center of the member, avoiding seasoning checks. The holes should be no more than 1.2 m (4 ft) apart and arranged in a spiral pattern. With horizontal timbers, the holes can be drilled straight down or slanted. As a rule, the holes should be extended to within about 5 cm (2 in.) of the bottom of the timber. If strength is not jeopardized, holes can be drilled in a cluster or in pairs to accommodate the required amount of preservative. If large seasoning checks are present, the holes should be drilled on each side of the member to provide better distribution. As soon as the fumigant is injected, the hole should be plugged with a tight-fitting treated wood dowel or removable plastic plug. For liquid fumigants, sufficient room must remain in the treating hole so the plug can be driven without displacing the chemical out of the hole. The amount of fumigant needed and the size and number of treating holes required depends upon the timber size. Fumigants will eventually diffuse out of the wood, allowing decay fungi to recolonize. Fortunately, additional fumigant can be applied to the same treatment hole. Fumigant treatments are generally more toxic and more difficult to handle than are diffusible treatments. Some are classified as restricted-use pesticides by the U.S. EPA.

One of the oldest and most effective fumigants is chloropicrin (trichloronitromethane). Chloropicrin is a liquid and has been found to remain in wood for up to 20 years; however, a 10-year retreatment cycle is recommended, with regular inspection. Chloropicrin is a strong eye irritant and has high volatility. Due to chloropicrin's hazardous nature, it should be used in areas away from buildings permanently inhabited by humans or animals. During application, workers must wear protective gear, including a full face respirator. Methylisothiocyante (MITC) is the active ingredient in several fumigants, but is also available in a solid-melt form that is 97% actives. The solid-melt MITC is supplied in aluminum tubes. After the treatment hole is drilled the cap is removed from the tube, and the entire tube is placed into the whole. This formulation provides ease of handling and application to upward drilled sloping treatment holes. Metham sodium (sodium N-methldithiocarbamate) is a widely used liquid fumigant that decomposes in the wood to form the active ingredient MITC. Granular dazomet (tetrahydro-3, 5-dimethyl-2-H-1,3,5, thiodazine-6-thione) is applied in a solid granular form that decomposes to a MITC content of approximately 45%. Dazomet is easy to handle but slower to decompose and release MITC than the solid-melt MITC or liquid fumigants. Some suppliers recommend the addition of a catalyst such as copper naphthenate to accelerate the breakdown process.

Best Management Practices

The active ingredients of various waterborne wood preservatives (copper, chromium, arsenic, and zinc) are water soluble in the treating solution but resist leaching when placed into the wood. This resistance to leaching is a result of chemical stabilization (or fixation) reactions that render the toxic ingredients insoluble in water. The mechanism and requirements for the stabilization reactions differ, depending on the type of wood preservative.

For each type of preservative, some reactions occur very rapidly during pressure treatment, while others may take days or even weeks, depending on storage and processing after treatment. If the treated wood is placed in service before these fixation reactions have been completed, the initial release of preservative into the environment may be much greater than if the wood has been conditioned properly.

With oil-type preservatives, preservative bleeding or oozing out of the treated wood is a particular concern. This problem may be apparent immediately after treatment. Such members should not be used in bridges over water or other aquatic applications. In other cases, the problem may not become obvious until after the product has been exposed to heating by direct sunlight. This problem can be minimized by using treatment practices that remove excess preservative from the wood.

Best management practice (BMP) standards have been developed to ensure that treated wood is produced in a way that will minimize environmental concerns. The Western Wood Preservers Institute (WWPI) has developed guidelines for treated wood used in aquatic environments. Although these practices have not yet been adopted by the industry in all areas of the United States, purchasers can require that these practices be followed. Commercial wood treatment firms are responsible for meeting conditions that ensure stabilization and minimize bleeding of preservatives, but persons buying treated wood should make sure that the firms have done so.

Consumers can take steps to ensure that wood will be treated according to the BMPs. Proper stabilization may take time, and material should be ordered well before it is needed so that the treater can hold the wood while it stabilizes. If consumers order wood in advance, they may also be able to store it under cover, allowing further drying and fixation. In general, allowing the material to air dry before it is used is a good practice for ensuring fixation, minimizing leaching, and reducing risk to construction personnel. With all preservatives, the wood should be inspected for surface residue, and wood with excessive residue should not be placed in service.

CCA

The risk of chemical exposure from wood treated with CCA is minimized after chemical fixation reactions lock the chemical in the wood. The treating solution contains hexavalent chromium, but the chromium reduces to the less toxic trivalent state within the wood. This process of chromium reduction also is critical in fixing the arsenic and copper in the wood. Wood treated with CCA should not be immersed or exposed to prolonged wetting until the fixation process is complete or nearly complete. The rate of fixation depends on temperature, taking only a few hours at 66 °C (150 °F) but weeks or even months at temperatures below 16 °C (60 °F). Some treatment facilities use kilns, steam, or hot-water baths to accelerate fixation.

The BMP guideline for CCA stipulates that the wood should be air seasoned, kiln dried, steamed, or subjected to a hot-water bath after treatment. It can be evaluated with the AWPA chromotropic acid test to determine whether fixation is complete.

ACZA and ACQ–B

The key to achieving stabilization with ACZA and ACQ–B is to allow ammonia to volatilize. This can be accomplished by air or kiln drying. The BMPs require a minimum of 3 weeks of air drying at temperatures higher than 16 °C (60 °F). Drying time can be reduced to 1 week if the material is conditioned in the treatment cylinder. At lower temperatures, kiln drying or heat is required to complete fixation. There is no commonly used method to determine the degree of stabilization in wood treated with ACZA or ACQ–B, although wood that has been thoroughly dried is acceptable. If the wood has a strong ammonia odor, fixation is not complete.

ACQ–C, ACQ–D, and Copper Azole

Proper handling and conditioning of the wood after treatment helps minimize leaching and potential environmental impacts for these preservatives. Amine (and ammonia in some cases) keeps copper soluble in these treatment solutions. The mechanism of copper's reaction in the wood is not completely understood but appears to be strongly influenced by time, temperature, and retention levels. As a general rule, wood that has been thoroughly dried after treatment is properly stabilized.

Copper stabilization in the copper azole CA–B formulation is extremely rapid (within 24 h) at the UC3B retention of 1.7 kg m^{-3} (0.10 lb ft^{-3}) but slows considerably at higher retentions unless the material is heated to accelerate fixation.

Pentachlorophenol, Creosote, and Copper Naphthenate

For creosote, the BMPs stipulate use of an expansion bath and final steaming period at the end of the charge.

Expansion Bath—Following the pressure period, the creosote should be heated to a temperature 6 to 12 °C (10 to 20 °F) above the press temperatures for at least 1 h. Creosote should be pumped back to storage and a minimum gauge vacuum of –81 kPa (24 inHg) should be applied for at least 2 h.

Steaming—After the pressure period and once the creosote has been pumped back to the storage tank, a vacuum of not less than –74 kPa (22 inHg) is applied for at least 2 h to recover excess preservative. The vacuum is then released back to atmospheric pressure and the charge is steamed for 2 to 3 h. The maximum temperature during this process should not exceed 116 °C (240 °F). A second vacuum of not less than –74 kPa (22 inHg) is then applied for a minimum of 4 h.

The BMPs for copper naphthenate are similar to those for creosote and pentachlorophenol. The recommended treatment practices for treatment in heavy oil include using an expansion bath, or final steaming, or both, similar to that described for creosote. When No. 2 fuel oil is used as the solvent, the BMPs recommend using a final vacuum for at least 1 h.

Handling and Seasoning of Timber after Treatment

Treated timber should be handled with sufficient care to avoid breaking through the treated shell. The use of pikes, cant hooks, picks, tongs, or other pointed tools that dig deeply into the wood should be prohibited. Handling heavy loads of lumber or sawn timber in rope or cable slings can crush the corners or edges of the outside pieces. Breakage or deep abrasions can also result from throwing or dropping the lumber. If damage results, the exposed areas should be retreated, if possible.

Wood treated with preservative oils should generally be installed as soon as practicable after treatment to minimize lateral movement of the preservative, but sometimes cleanliness of the surface can be improved by exposing the treated wood to the weather for a limited time before installation. Lengthy, unsheltered exterior storage of treated wood before installation should be avoided. Treated wood that must be stored before use should be covered for protection from the sun and weather.

With waterborne preservatives, seasoning after treatment is important for wood that will be used in buildings or other places where shrinkage after placement in the structure would be undesirable. Injecting waterborne preservatives puts large amounts of water into the wood, and considerable shrinkage is to be expected as subsequent seasoning takes place. For best results, the wood should be dried to approximately the moisture content it will ultimately reach in service. During drying, the wood should be carefully piled and, whenever possible, restrained by sufficient weight on the top of the pile to prevent warping.

Quality Assurance for Treated Wood

Treating Conditions and Specifications

Specifications on the treatment of various wood products by pressure processes have been developed by AWPA. These specifications limit pressures, temperatures, and time of conditioning and treatment to avoid conditions that will cause serious injury to the wood. The specifications also contain minimum requirements for preservative penetration and retention levels and recommendations for handling wood after treatment to provide a quality product. Specifications are broad in some respects, allowing the purchaser some latitude in specifying the details of individual requirements. However, the purchaser should exercise great care so as not to hinder the treating plant operator from doing a good treating job and not to require treating conditions so severe that they will damage the wood.

Penetration and Retention

Penetration and retention requirements are equally important in determining the quality of preservative treatment. Penetration levels vary widely, even in pressure-treated material. In most species, heartwood is more difficult to penetrate than sapwood. In addition, species differ greatly in the degree to which their heartwood may be penetrated. Incising tends to improve penetration of preservative in many refractory species, but those highly resistant to penetration will not have deep or uniform penetration even when incised. Penetration in unincised heartwood faces of these species may occasionally be as deep as 6 mm (1/4 in.) but is often not more than 1.6 mm (1/16 in.).

Experience has shown that even slight penetration has some value, although deeper penetration is highly desirable to avoid exposing untreated wood when checks occur, particularly for important members that are costly to replace. The heartwood of coastal Douglas-fir, southern pines, and various hardwoods, although resistant, will frequently show transverse penetrations of 6 to 12 mm (1/4 to 1/2 in.) and sometimes considerably more.

Complete penetration of the sapwood should be the goal in all pressure treatments. It can often be accomplished in small-size timbers of various commercial woods, and with skillful treatment, it may often be obtained in piles, ties, and structural timbers. Practically, however, the operator cannot always ensure complete penetration of sapwood in every piece when treating large pieces of round material with thick sapwood (such as poles and piles). Therefore, specifications permit some tolerance. For instance, AWPA Processing and Treatment Standard T1 for Southern Pine poles requires that 89 mm (3.5 in.) or 90% of the sapwood thickness be penetrated for waterborne preservatives. The requirements vary, depending on the species, size, class, and specified retention levels.

Preservative retentions are typically expressed on the basis of the mass of preservative per unit volume of wood within a prescribed assay zone. The retention calculation is not based on the volume of the entire pole or piece of lumber. For example, the assay zone for Southern Pine poles is between 13 and 51 mm (0.5 and 2.0 in.) from the surface. To determine the retention, a boring is removed from the assay zone and analyzed for preservative concentration. The preservatives and retention levels listed in the AWPA Commodity Standards and ICC–ES evaluation reports are shown in Table 15–1. The current issues of these specifications should be referenced for up-to-date recommendations and other details. In many cases, the retention level is different depending on species and assay zone. Higher preservative retention levels are specified for products to be installed under severe climatic or exposure conditions. Heavy-duty transmission poles and items with a high replacement cost, such as structural timbers and house foundations, are required to be treated to higher retention levels. Correspondingly, deeper penetration or heartwood limitations are also necessary for the same reasons. It may be necessary to increase retention levels to ensure satisfactory penetration, particularly when the sapwood is either unusually thick or is somewhat resistant to treatment. To reduce bleeding of the preservative, however, it may be desirable to use preservative-oil retention levels less than the stipulated minimum. Older specifications based on treatment to refusal do not ensure adequate penetration or retention of preservative, should be avoided, and must not be considered as a substitute for results-type specification in treatment.

Inspection of Treatment Quality

AWPA standards specify how charges of treated wood should be inspected to ensure conformance to treatment standards. Inspections are conducted by the treating company and also should be routinely conducted by independent third-party inspection agencies. These third-party agencies verify for customers that the wood was properly treated in accordance with AWPA standards. The U.S. Department of Commerce American Lumber Standard Committee (ALSC) accredits third-party inspection agencies for treated-wood products. Quality control overview by ALSC-accredited agencies is preferable to simple treating plant certificates or other claims of conformance made by the producer without inspection by an independent agency. Updated lists of accredited agencies can be obtained from the ALSC website at www.alsc.org. Each piece of treated wood should be marked with brand, ink stamp, or end-tag that shows the logo of an accredited inspection agency and other information required by AWPA standards (Fig. 15–6). Other important information that should be shown includes the type of preservative, preservative retention, and the intended use category

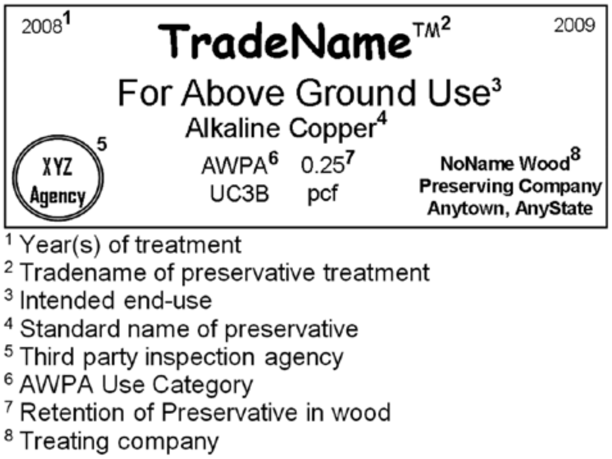

Figure 15–6. Typical end tag for preservative-treated lumber conforming to the ALSC accreditation program.

(exposure condition). Purchasers may also elect to have an independent inspector inspect and analyze treated products to ensure compliance with the specifications—recommended for treated-wood products used for critical structures. Railroad companies, utilities, and other entities that purchase large quantities of treated timber usually maintain their own inspection services.

Effects on the Environment

Preservatives intended for use outdoors have mechanisms that are intended to keep the active ingredients in the wood and minimize leaching. Past studies indicate that a small percentage of the active ingredients of all types of wood preservatives leach out of the wood. The amount of leaching depends on factors such as fixation conditions, preservative retention in the wood, product size and shape, type of exposure, and years in service. Ingredients in all preservatives are potentially toxic to a variety of organisms at high concentrations, but laboratory studies indicate that the levels of preservatives leached from treated wood generally are too low to create a biological hazard.

In recent years, several studies have been conducted on preservative releases from structures and on the environmental consequences of those releases. These recent studies of the environmental impact of treated wood reveal several key points. All types of treated wood evaluated release small amounts of preservative components into the environment. These components can sometimes be detected in soil or sediment samples. Shortly after construction, elevated levels of preservative components can sometimes be detected in the water column. Detectable increases in soil and sediment concentrations of preservative components generally are limited to areas close to the structure. Leached preservative components either have low water solubility or react with components of the soil or sediment, limiting their mobility and limiting the range of environmental contamination. Levels of these components in the soil immediately adjacent to treated structures can increase gradually over the years, whereas levels in sediments tended to decline over time. Research indicates that environmental releases from treated wood do not cause measurable impacts on the abundance or diversity of aquatic invertebrates adjacent to the structures. In most cases, levels of preservative components were below concentrations that might be expected to affect aquatic life. Samples with elevated levels of preservative components tended to be limited to fine sediments beneath stagnant or slow-moving water where the invertebrate community is not particularly intolerant to pollutants.

Conditions with a high potential for leaching and a high potential for metals to accumulate are the most likely to affect the environment (Fig. 15–7). These conditions are most likely to be found in boggy or marshy areas with little water exchange. Water at these sites has low pH and high organic acid content, increasing the likelihood that preservatives will be leached from the wood. In addition, the stagnant water prevents dispersal of any leached components of preservatives, allowing them to accumulate in soil, sediments, and organisms near the treated wood. Note that all construction materials, including alternatives to treated wood, have some type of environmental impact. In addition to environmental releases from leaching and maintenance activities, the alternatives may have greater impacts and require greater energy consumption during production.

Recycling and Disposal of Treated Wood

Treated wood is not listed as a hazardous waste under Federal law, and it can be disposed of in any waste management facility authorized under State and local law to manage such material. State and local jurisdictions may have additional regulations that impact the use, reuse, and disposal of treated wood and treated-wood construction waste, and users should check with State and local authorities for any special regulations relating to treated wood. Treated wood must not be burned in open fires or in stoves, fireplaces, or residential boilers, because the smoke and ashes may contain toxic chemicals.

Treated wood from commercial and industrial uses (construction sites, for example) may be burned only in commercial or industrial incinerators or boilers in accordance with State and Federal regulations. Spent railroad ties treated with creosote and utility poles treated with pentachlorophenol can be burned in properly equipped facilities to generate electricity (cogeneration). As fuel costs and energy demands increase, disposal of treated wood in this manner becomes more attractive. Cogeneration poses more challenges for wood treated with heavy metals, and particularly for wood treated with arsenic. In addition to concerns with emissions, the concentration of metals in the ash requires further processing.

Figure 15–7. Wood preservative leaching, environmental mobility, and effects on aquatic insects were evaluated at this wetland boardwalk in western Oregon.

As with many materials, reuse of treated wood may be a viable alternative to disposal. In many situations treated wood removed from its original application retains sufficient durability and structural integrity to be reused in a similar application. Generally, regulatory agencies also recognize that treated wood can be reused in a manner that is consistent with its original intended end use.

The potential for recycling preservative-treated wood depends on several factors, including the type of preservative treatment and the original use. Researchers have demonstrated that wood treated with heavy metals can be chipped or flaked and reused to form durable panel products or wood–cement composites. However, this type of reuse has not yet gained commercial acceptance. Techniques for extraction and reuse of the metals from treated wood have also been proposed. These include acid extraction, fungal degradation, bacterial degradation, digestion, steam explosion, or some combination of these techniques. All these approaches show some potential, but none is currently economical. In most situations landfill disposal remains the least expensive option. For treated wood used in residential construction, one of the greatest obstacles is the lack of an efficient process for collecting and sorting treated wood. This is less of a problem for products such as railroad ties and utility poles.

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