Preservative-Treated Wood and Alternative Products in the Forest Service

Types of Wood Preservatives

Wood preservatives have been used for more than a century. They are broadly classified as either waterborne or oil-type, based on the chemical composition of the preservative and the carrier used during the treating process. Some preservatives can be formulated for use with either water or oil solvents. Water-based preservatives often include some type of cosolvent, such as amine or ammonia to keep one or more of the active ingredients in solution. Each solvent has advantages and disadvantages that depend on the application.

Generally, wood preservatives also are classified or grouped by the type of application or exposure environment in which they are expected to provide long-term protection. Some preservatives have sufficient leach resistance and broad spectrum efficacy to protect wood that is exposed directly to soil and water. These preservatives will also protect wood exposed aboveground, and may be used in those applications at lower retentions (concentrations in the wood).

Other preservatives have intermediate toxicity or leach resistance that allows them to protect wood fully exposed to the weather, but not in contact with the ground. Some preservatives lack the permanence or toxicity to withstand continued exposure to precipitation, but may be effective with occasional wetting. Finally, there are formulations that are so readily leachable that they can only withstand very occasional, superficial wetting.

It is not possible to evaluate a preservative's long-term efficacy in all types of exposure environments and there is no set formula for predicting exactly how long a wood preservative will perform in a specific application. This is especially true for aboveground applications (figure 2) because preservatives are tested most extensively in ground contact. To compensate for this uncertainty, there is a tendency to be conservative in selecting a preservative for a particular application.

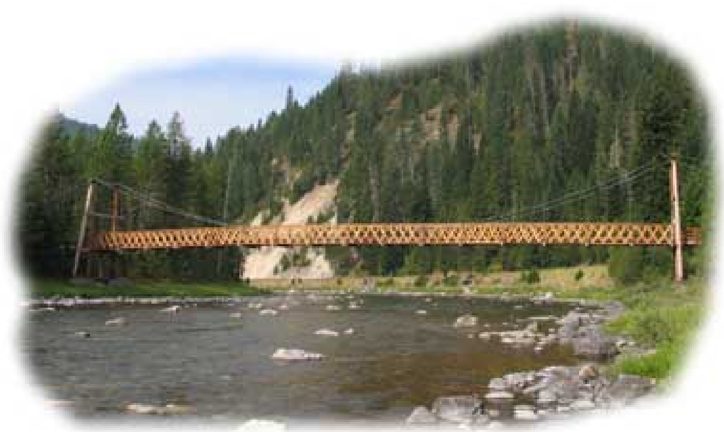

Figure 2—The Mocus Point Pack Bridge crosses the Lochsa River in the Clearwater National Forest, ID.

Oil-Type Preservatives

The most common oil-type preservatives are creosote, pentachlorophenol, and copper naphthenate. Occasionally, oxine copper and IPBC (3-iodo-2-propynyl butyl carbamate) also are used for aboveground applications. The conventional oil-type preservatives, such as creosote and pentachlorophenol solutions, have been confined largely to uses that do not involve frequent human contact. The exception is copper naphthenate, a preservative that was developed more recently and has been used less widely. Oil-type preservatives may be visually oily, or oily to the touch, and sometimes have a noticeable odor. However, the oil or solvent that is used as a carrier makes the wood less susceptible to cracks and checking. This type of preservative is suitable for treatment of glue-laminated stringers for bridges where cracks in the stringers could alter the bridges' structural integrity.

Creosote

Coal-tar creosote is effective when used in ground contact, water contact, or aboveground. It is the oldest wood preservative still in commercial use in the United States. It is made by distilling coal tar that is created when coal is carbonized at high temperatures (1,652 to 2,192 degrees Fahrenheit [900 to 1,200 degrees Celsius]). Unlike other oil-type preservatives, creosote usually is not dissolved in oil, but it does look and feel oily. Creosote contains a chemically complex mixture of organic molecules, most of which are polycyclic aromatic hydrocarbons. The composition of creosote varies because it depends on how the creosote is distilled. However, the small differences in composition in modern creosotes do not affect their performance as wood preservatives.

Creosote-treated wood is dark brown to black and has a distinct odor, which some people consider unpleasant. Creosote-treated wood is very difficult to paint. Workers sometimes object to creosote-treated wood because it soils their clothes and makes their skin sensitive to the sun. The treated wood sometimes has an oily surface.

Patches of creosote sometimes accumulate, creating a hazard when it contacts the skin. Because of these concerns, creosote-treated wood often is not the first choice for applications such as bridge members or handrails, where there is a high probability of human contact.

However, creosote-treated wood has advantages to offset concerns with its appearance and odor. It has a lengthy record of satisfactory use in a wide range of applications and is relatively inexpensive. Creosote is effective in protecting both hardwoods and softwoods and improving the dimensional stability of the treated wood.

Creosote is listed in American Wood-Preservers' Association (AWPA) Standards for a wide range of wood products created from many different species of trees. The minimum creosote retentions required by the standards are in the range of 5 to 8 pounds per cubic foot (80 to 128 kilograms per cubic meter) for aboveground applications, 10 pounds per cubic foot (160 kilograms per cubic meter) for wood used in ground contact, and 12 pounds per cubic foot (192 kilograms per cubic meter) for wood used in critical structural applications, such as highway construction. With heated solutions and lengthy pressure periods, creosote can penetrate wood that is fairly difficult to treat. Creosote is suitable for treatment of glue-laminated members. Creosote treatment does not accelerate, and may even inhibit, the corrosion of metal fasteners.

Treatment facilities that use creosote are found throughout the United States, so this wood preservative is readily available. Creosote is classified as a Restricted Use Pesticide (RUP) by the U. S. Environmental Protection Agency (EPA). Producers of treated wood, in cooperation with the EPA , have created Consumer Information Sheets with guidance on appropriate handling and site precautions when using wood treated with creosote (appendix A). These sheets should be available for all persons who handle creosote-treated wood.

Pentachlorophenol

Pentachlorophenol has been widely used as a pressure-treatment preservative in the United States since the 1940s. The active ingredients, chlorinated phenols, are crystalline solids that can be dissolved in different types of organic solvents. A performance of pentachlorophenol and the properties of the treated wood are influenced by the properties of the solvent.

Pentachlorophenol is effective when used in ground contact, freshwater, or aboveground. It is not as effective when used in seawater. A heavy oil solvent (specified as Type A in AWPA Standard P9) is preferable when the treated wood is to be used in ground contact. Wood treated with lighter solvents may not be as durable.

Wood treated with pentachlorophenol in heavy oil typically has a brown color, and may have a slightly oily surface that is difficult to paint. It also has some odor, which is associated with the solvent. Pentachlorophenol in heavy oil should not be used when frequent contact with skin is likely (handrails, for instance). Pentachlorophenol in heavy oil has long been a popular choice for treating utility poles, bridge timbers, glue-laminated beams, and foundation pilings. The effectiveness of pentachlorophenol is similar to that of creosote in protecting both hardwoods and softwoods, and pentachlorophenol often is thought to improve the dimensional stability of the treated wood.

Pentachlorophenol is listed in the AWPA standards for a wide range of wood products and wood species. The minimum softwood retentions are 0.4 pounds per cubic foot (6.4 kilograms per cubic meter) for wood used aboveground, and 0.5 pounds per cubic foot (8 kilograms per cubic meter) for wood used in critical structural applications or in ground contact.

With heated solutions and extended pressure periods, pentachlorophenol can penetrate woods that are difficult to treat. Pentachlorophenol does not accelerate the corrosion of metal fasteners relative to untreated wood. The heavy oil solvent imparts some water repellency to the treated wood. Treatment facilities in many areas of the United States use pentachlorophenol in heavy oil, making it another readily available wood preservative.

Pentachlorophenol is most effective when applied with a heavy solvent, but it performs well in lighter solvents for aboveground applications. Lighter solvents also provide the advantage of a less oily surface appearance, lighter color, and improved paintability. The standards for aboveground minimum retentions for pentachlorophenol vary from 0.25 to 0.3 pounds per cubic foot (4 to 4.8 kilograms per cubic meter) for treatment of red oak to 0.4 pounds per cubic foot (6.4 kilograms per cubic meter) for softwood species.

Pentachlorophenol in light oil has some similarities to pentachlorophenol in heavy oil. It can be used to treat species of wood that are difficult to treat and it does not accelerate corrosion. Wood treated with pentachlorophenol in light oil may be used in recreational structures and in applications where human contact is likely, such as handrails, if a sealer such as urethane, shellac, latex, epoxy enamel, or varnish is applied. Wood treated with pentachlorophenol in light oil may be painted or stained after it dries. One disadvantage of the lighter oil is that the treated wood has less water repellency. Treatment facilities that use pentachlorophenol in light oil are not as numerous as those that use heavy oil.

Pentachlorophenol is classified as an RUP by the EPA. Producers of treated wood, in cooperation with the EPA, have created consumer information sheets with guidance on appropriate handling and site precautions for wood treated with pentachlorophenol (appendix A). These sheets should be available for all persons who handle wood treated with pentachlorophenol.

Copper Naphthenate

Copper naphthenate is effective when used in ground contact, water contact, or aboveground. It is not standardized for use in saltwater applications. Copper naphthenate's effectiveness as a preservative has been known since the early 1900s, and various formulations have been used commercially since the 1940s. It is an organometallic compound formed as a reaction product of copper salts and naphthenic acids derived from petroleum. Unlike other commercially applied wood preservatives, small quantities of copper naphthenate can be purchased at retail hardware stores and lumberyards. Cuts or holes in treated wood can be treated in the field with copper naphthenate.

Wood treated with copper naphthenate has a distinctive bright green color that weathers to light brown. The treated wood also has an odor that dissipates somewhat over time. Depending on the solvent used and treatment procedures, it may be possible to paint wood treated with copper naphthenate after it has been allowed to weather for a few weeks.

Copper naphthenate can be dissolved in a variety of solvents. The heavy oil solvent (specified in AWPA Standard P9, Type A) or the lighter solvent (AWPA Standard P9, Type C) are the most commonly used. Copper naphthenate is listed in AWPA standards for treatment of major softwood species that are used for a variety of wood products. It is not listed for treatment of any hardwood species, except when the wood is used for railroad ties. The minimum copper naphthenate retentions (as elemental copper) range from 0.04 pounds per cubic foot (0.6 kilograms per cubic meter) for wood used aboveground, to 0.06 pounds per cubic foot (1 kilograms per cubic meter) for wood that will contact the ground and 0.075 pounds per cubic foot (1.2 kilograms per cubic meter) for wood used in critical structural applications.

When dissolved in No. 2 fuel oil, copper naphthenate can penetrate wood that is difficult to treat. Copper naphthenate loses some of its ability to penetrate wood when it is dissolved in heavier oils. Copper naphthenate treatments do not significantly increase the corrosion of metal fasteners relative to untreated wood.

Copper naphthenate is commonly used to treat utility poles, although fewer facilities treat utility poles with copper naphthenate than with creosote or pentachlorophenol. Unlike creosote and pentachlorophenol, copper naphthenate is not listed as an RUP by the EPA. Even though human health concerns do not require copper naphthenate to be listed as an RUP, precautions such as the use of dust masks and gloves should be used when working with wood treated with copper naphthenate.

Oxine Copper (Copper-8-Quinolinolate)

Oxine copper is effective when used aboveground. Its efficacy is reduced when it is used in direct contact with the ground or with water. It has not been standardized for those applications. Oxine copper (copper-8-quinolinolate) is an organometallic compound. The formulation consists of at least 10-percent copper-8-quinolinolate, 10-percent nickel-2-ethylhexanoate, and 80-percent inert ingredients. It is accepted as a standalone preservative for aboveground use to control sapstain fungi and mold and also is used to pressure-treat wood.

Oxine copper solutions are greenish brown, odorless, toxic to both wood decay fungi and insects, and have a low toxicity to humans and animals. Oxine copper can be dissolved in a range of hydrocarbon solvents, but provides protection much longer when it is delivered in heavy oil. Oxine copper is listed in the AWPA standards for treating several softwood species used in exposed, aboveground applications. The minimum specified retention for these applications is 0.02 pounds per cubic foot (0.32 kilograms per cubic meter, as elemental copper).

Oxine copper solutions are somewhat heat sensitive, which limits the use of heat to increase penetration of the preservative. However, oxine copper can penetrate difficult-to-treat species, and is sometimes used to treat Douglas-fir used aboveground in wooden bridges and deck railings. Oilborne oxine copper does not accelerate corrosion of metal fasteners relative to untreated wood. A water-soluble form can be made with dodecylbenzene sulfonic acid, but the solution corrodes metals. Oxine copper is not widely used by pressure-treatment facilities, but is available from at least one plant on the West Coast.

Wood treated with oxine copper presents fewer toxicity or safety and handling concerns than oilborne preservatives that can be used in ground contact. Sometimes, it is used as a preservative to control sapstain fungi or incorporated into retail stains for siding, shingles, and cabin logs. Oxine copper is listed by the U.S. Food and Drug Administration (FDA) as an indirect additive that can be used in packaging that may come in direct contact with food.

Precautions such as wearing gloves and dust masks should be used when working with wood treated with oxine copper. Because of its somewhat limited use and low mammalian toxicity, there has been little research to assess the environmental impact of wood treated with oxine copper.

IPBC and Insecticides

IPBC (3-iodo-2-propynyl butyl carbamate) is not intended for use in ground contact or for horizontal surfaces that are fully exposed to the weather. It does provide protection for wood that is aboveground and partially protected from the weather. IPBC contains 97-percent 3-iodo-2-propynyl butyl carbamate that includes a minimum of 43.4-percent iodine. IPBC industrial fungicides are broad-spectrum fungicidal additives used in architectural coatings and construction applications (such as paints, stains, adhesives, caulks, and sealants), textiles, and plastic products to prevent dry film fungal growth. The IPBC preservative is included as the primary fungicide in several water-repellent-preservative formulations under the trade name *Polyphase* and sold at retail stores. Although oil-soluble formulations are discussed in this report, water-based formulations also may be used.

IPBC is colorless. Depending on the solvent and formulation, it may be possible to paint treated wood. Some formulations may have noticeable odor, but others may have little or no odor. IPBC is not an effective insecticide and is not used as a stand-alone treatment for critical structural members.

IPBC is listed as a preservative in AWPA standards, but no pressure-treated wood products have been standardized for IPBC. Dip-treating (a nonpressure process) with IPBC was standardized recently for ponderosa-pine mill-work at a minimum retention of 950 parts per million (about 0.023 pounds per cubic foot [0.37 kilograms per cubic meter]). Soil block tests indicate that IPBC can prevent fungal attack of hardwoods and softwoods when it is used at a retention of 0.022 pounds per cubic foot (0.35 kilograms per cubic meter) or higher. After 9 years of aboveground exposure tests with pressure-treated Douglas-fir, ponderosa pine, and western hemlock results indicate that mixtures of IPBC and chloropyrifos can protect wood from decay at IPBC retentions as low as 0.05 pounds per cubic foot (0.8 kilograms per cubic meter).

Some pressure-treating facilities use a mixture of IPBC and an insecticide, such as permethrin or chloropyrifos, to treat structural members used aboveground that will be largely protected from the weather, although this practice is not a standardized treatment. These facilities are using IPBC retentions of 0.035 pounds per cubic foot (0.56 kilograms per cubic meter) or higher, with mineral spirits as the solvent. The advantage of this treatment is that it is colorless and allows the wood to maintain its natural appearance. This treatment is being used on Western species that are difficult to treat. Very few facilities are conducting pressure treatments with IPBC.

IPBC has relatively low acute toxicity for mammals and is not classified as an EPA RUP. However, workers should follow standard precautions, such as wearing gloves and dust masks, when working with wood treated with IPBC. Because IPBC typically has not been used for pressure treatment, there has been little evaluation of the environmental impact of wood treated with IPBC. It appears that IPBC degrades rapidly in soil and aquatic environments. It has low toxicity for birds, but is highly toxic to fish and aquatic invertebrates. The relatively low IPBC concentrations used in the wood and its rapid degradation in the environment would be expected to limit any environmental accumulations caused by leaching. Because IPBC usually is used with a light solvent, the preservative is not likely to bleed or ooze out of wood.

Waterborne Preservatives

Waterborne preservatives react with or precipitate in treated wood, becoming "fixed." They resist leaching. Because waterborne preservatives leave a dry, paintable surface, they are commonly used to treat wood for residential applications, such as decks and fences. Waterborne preservatives are used primarily to treat softwoods, because they may not fully protect hardwoods from soft-rot attack. Most hardwood species are difficult to treat with waterborne preservatives.

These preservatives can increase the risk of corrosion when metals contact treated wood used in wet locations. Metal fasteners, connectors, and flashing should be made from hot-dipped galvanized steel, copper, silicon bronze, or stainless steel if they are used with wood treated with waterborne preservatives containing copper. Aluminum should not be used in direct contact with wood treated with waterborne preservatives containing copper. Borates are another type of waterborne preservative. However, they do not fix in the wood and leach readily if they are exposed to rain or wet soil. Borate treatment does not increase the risk of corrosion when metals contact preservative-treated wood.

Chromated Copper Arsenate (CCA)

CCA protects wood used aboveground, in contact with the ground, or in contact with freshwater or seawater. Wood treated with CCA (commonly called *green treated)* dominated the treated wood market from the late 1970s until 2004. Chromated copper arsenate has been phased out voluntarily for most applications around residential areas and where human contact is prevalent. The allowable uses for CCA are discussed in more detail in the Recommended Guidelines section.

The three standardized formulations are: CCA Type A, CCA Type B, and CCA Type C. CCA Type C (CCA-C) is the formulation used by nearly all treatment facilities because of its resistance to leaching and its demonstrated effectiveness. CCA-C is comprised of 47.5 percent chromium trioxide, 18.5 percent copper oxide, and 34.0 percent arsenic pentoxide dissolved in water.

CCA-C has decades of proven performance. It is the reference preservative used to evaluate the performance of other waterborne wood preservatives during accelerated testing. Because it has been widely used for so many years, CCA-C is listed in AWPA standards for a wide range of wood products and applications. The minimum retention of CCA-C in wood ranges from 0.25 pounds per cubic foot (4 kilograms per cubic meter) in aboveground applications to 2.5 pounds per cubic foot (40 kilograms per cubic meter) in marine applications. Most ground-contact applications require minimum retentions of 0.4 pounds per cubic foot (6.4 kilograms per cubic meter). Critical structural applications require minimum retentions of 0.6 pounds per cubic foot (9.6 kilograms per cubic meter). It may be difficult to obtain adequate penetration of CCA in some difficult-to-treat species. The chromium serves as a corrosion inhibitor. Corrosion of fasteners in wood treated with CCA is not as much of a concern as in wood treated with other waterborne preservatives that contain copper but do not contain chromium.

CCA contains inorganic arsenic and is classified as an RUP by the EPA. Producers of treated wood, in cooperation with the EPA, created the Consumer Information Sheet which has been replaced with the Consumer Safety Information Sheet that gives guidance on handling and site precautions at sites where wood treated with inorganic arsenic is used (appendix B). The consumer safety information sheet should be available to all persons who handle wood treated with CCA.

Ammoniacal Copper Zinc Arsenate (ACZA)

Ammoniacal copper zinc arsenate (ACZA) contains copper oxide (50 percent), zinc oxide (25 percent), and arsenic pentoxide (25 percent). ACZA is a refinement of an earlier formulation, ACA, which is no longer available in the United States. The color of the treated wood varies from olive to bluish green. The wood may have a slight ammonia odor until it has dried thoroughly. ACZA is an established preservative that is used to protect wood from decay and insect attack in a wide range of exposures and applications. Exposure tests showed that it protected stakes and posts that contacted the ground.

ACZA is listed in the AWPA standards for treatment of a range of softwood and hardwood species and wood products. The minimum ACZA retention is 0.25 pounds per cubic foot (4 kilograms per cubic meter) for above-ground applications and 0.4 pounds per cubic foot (6.4 kilograms per cubic meter) for wood that contacts the ground. A slightly higher retention, 0.6 pounds per cubic foot (9.6 kilograms per cubic meter), is required for wood used in highway construction and for critical structural components that are exposed to high decay hazard. The ammonia in the treating solution, in combination with processing techniques such as steaming and extended pressure periods at elevated temperatures, allow ACZA do a better job of penetrating difficult-to-treat species of wood than many other water-based wood preservatives.

ACZA is used frequently in the Western United States to treat Douglas-fir lumber and timbers used to construct secondary highway bridges, trail bridges, and boardwalks. The ACZA treatment can accelerate corrosion in comparison to untreated wood, requiring the use of hot-dipped galvanized or stainless steel fasteners. Treatment facilities using ACZA are located in Western States, where many native tree species are difficult to treat with CCA.

ACZA contains inorganic arsenic and is classified as an RUP by the EPA. Producers of treated wood, in cooperation with the EPA, have created consumer information sheets that suggest appropriate handling precautions and precautions at sites where wood treated with inorganic arsenic (appendix B) will be used. These sheets should be available to all personnel who handle wood treated with ACZA.

Alkaline Copper Quaternary (ACQ) Compounds

Alkaline copper quat (ACQ) is one of several wood preservatives that have been developed in recent years to meet market demands for alternatives to CCA. The fungicides and insecticides in ACQ are copper oxide (67 percent) and a quaternary ammonium compound (quat). Many variations of

ACQ have been standardized or are being 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.

Wood treated with ACQ-B is dark greenish brown and fades to a lighter brown. It may have a slight ammonia odor until the wood dries. Wood treated with ACQ-D has a lighter greenish-brown color and has little noticeable odor; wood treated with ACQ-C varies between the color of ACQ-B and that of ACQ-D, depending on the formulation. Stakes treated with these three formulations have demonstrated their effectiveness against decay fungi and insects when the stakes contacted the ground.

The ACQ formulations are listed in the AWPA standards for a range of applications and many softwood species. The listings for ACQ-C are limited because it is the most recently standardized. The minimum ACQ retentions are 0.25 pounds per cubic foot (4 kilograms per cubic meter) for aboveground applications, 0.4 pounds per cubic foot (6.4 kilograms per cubic meter) for applications involving ground contact, and 0.6 pounds per cubic foot (9.6 kilo-grams per cubic meter) for highway construction. The different formulations of ACQ allow some flexibility in achieving compatibility with a specific wood species and application. An ammonia carrier improves the ability of ACQ to penetrate into wood that is difficult to treat. For wood species that are easier to treat, such as southern pine, an amine carrier will provide a more uniform surface appearance.

All ACQ treatments accelerate corrosion of metal fasteners relative to untreated wood. Hot-dipped galvanized copper or stainless steel fasteners must be used. The number of pressure-treatment facilities using ACQ is increasing.

In the Western United States, the ACQ-B formulation is used because it will penetrate difficult-to-treat Western species better than other waterborne preservatives. Treatment plants elsewhere generally use the ACQ-D formulation. Researchers at the USDA Forest Service's Forest Products Laboratory in Madison, WI, are evaluating the performance of a secondary highway bridge constructed using Southern pine lumber treated with ACQ-D (Ritter and Duwadi 1998).

Copper Azoles (CBA-A and CA-B)

Copper azole is another recently developed preservative formulation that relies primarily on amine copper, but with additional biocides, to protect wood from decay and insect attack (figure 3). The first copper azole formulation developed was the copper azole type A (CBA-A), which contains 49-percent copper, 49-percent boric acid, and 2-percent tebuconazole. Type A is no longer used in the United States. The copper azole type B (CA-B) formulation was standardized recently. CA-B does not contain boric acid. It is comprised of 96-percent copper and 4-percent tebuconazole. Wood treated with either copper azole formulation has a greenish-brown color and little or no odor.

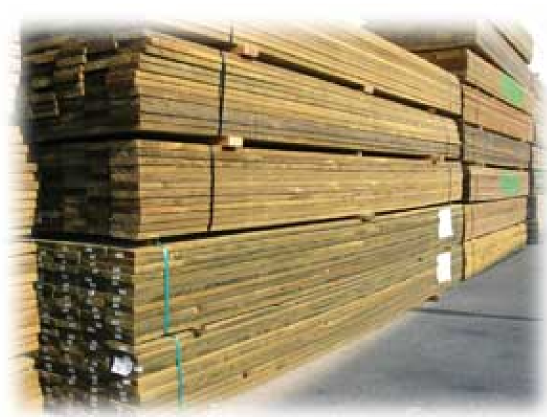

Figure 3—Pressure-treated lumber stockpiled at a lumberyard. Lumber treated with ACQ-D and CA-B has become widely available.

Tests showed that the copper azole formulations protected stakes in the ground from attack by decay fungi and insects. The formulations are listed in the AWPA standards for treatment of a range of softwood species. Minimum CA-B retentions in the wood are 0.10, 0.21, or 0.31 pounds per cubic foot (1.6, 3.4, or 5 kilograms per cubic meter) for wood used aboveground, contacting the ground, or in critical structural components, respectively.

Copper azole is an amine formulation. Ammonia may be added at the treating plant when the copper azole is used on Western species that are difficult to treat. This formulation is often used to treat Douglas-fir. Formulations with ammonia slightly darken the surface appearance and initially affect the odor of the treated wood.

Copper azole treatments increase the rate of corrosion of metal fasteners relative to untreated wood. Appropriate hot-dipped galvanized steel, copper or stainless steel fasteners, connectors, and flashing are recommended. Although copper azole was introduced to North America recently, almost 100 treating facilities now use this preservative.

Borates

Borate compounds are the most commonly used unfixed waterborne preservatives. Unfixed preservatives can leach from treated wood. They are used for pressure treatment of framing lumber used in areas with high termite hazard, and as surface treatments for a wide range of wood products, such as cabin logs and the interiors of wood structures. They are also applied as internal treatments using rods or pastes. At higher rates of retention, borates also are used as fire-retardant treatments for wood.

Boron has some exceptional performance characteristics, including activity against fungi and insects, but low mammalian toxicity. It is relatively inexpensive. Another advantage of boron is its ability to diffuse with water into wood that normally resists traditional pressure treatment. Wood treated with borates has no added color, no odor, and can be finished (primed and painted).

While boron has many potential applications in framing, it probably is not suitable for many Forest Service applications because the chemical will leach from the wood under wet conditions. It may be a useful treatment for insect protection in areas continually protected from water.

Inorganic boron is listed as a wood preservative in the AWPA standards, which include formulations prepared from sodium octaborate, sodium tetraborate, sodium pentaborate, and boric acid. Inorganic boron is also standardized as a pressure treatment for a variety of species of softwood lumber used out of contact with the ground and continuously protected from water. The minimum borate (B2O3) retention is 0.17 pounds per cubic foot (2.7 kilograms per cubic meter). A retention of 0.28 pounds per cubic foot (4.5 kilograms per cubic meter) is specified for areas with Formosan subterranean termites.

Borate preservatives are available in several forms, but the most common is disodium octaborate tetrahydrate (DOT). DOT has higher water solubility than many other forms of borate, allowing more concentrated solutions to be used and increasing the mobility of the borate through the wood. With the use of heated solutions, extended pressure periods, and diffusion periods after treatment, DOT can penetrate species that are relatively difficult to treat, such as spruce. Several pressure treatment facilities in the United States use borate solutions.

Although borates have low mammalian toxicity, workers handling borate-treated wood should use standard precautions, such as wearing gloves and dust masks. The environmental impact of borate-treated wood for construction projects in sensitive areas has not been evaluated. Because borate-treated wood is used in areas protected from precipitation or water, little or no borate should leach into the environment. Borates have low toxicity to birds, aquatic invertebrates, and fish. Boron occurs naturally at relatively high levels in the environment. Because borates leach readily, extra care should be taken to protect borate-treated wood from precipitation when it is stored at the jobsite. Precipitation could deplete levels of boron in the wood to ineffective levels and harm vegetation directly below the stored wood.

Borate-treated wood should be used only in applications where the wood is kept free from rainwater, standing water, and ground contact.

Other Waterborne Preservatives

Other waterborne preservatives have been introduced recently on the commercial market. They have not been on the market long enough to have long-term performance studies completed.

Their effectiveness or performance has not been established. This publication only describes preservatives that have been evaluated and standardized by the American Wood-Preservers′ Association (AWPA), the primary standard-setting body for pressure-treated wood. To become standardized by the AWPA, preservative-treated wood must undergo a series of rigorous tests to ensure its durability. These tests include several years of outdoor exposure in a climate with severe biodeterioration hazards. The results of these tests are reviewed by AWPA members who represent government agencies, universities, commercial chemical suppliers, and treatment companies. Be wary of purchasing wood that has been treated with a preservative that has not been standardized for that application by either the AWPA or another major standard-setting body, such as the American Society for Testing and Materials (ASTM).

Preservatives That Are No Longer Available Commercially

Several preservative formulations that have been used in the past were not available commercially in 2005. The wood preservative industry has become more dynamic because of economic factors and regulations. The following preservative formulations are included in this report because they may become available in the future and because they have been used to treat existing structures.

Ammoniacal Copper Arsenate (ACA)

ACA was an older formulation of ACZA that didn't contain zinc. It has not been available in the United States for many years and is not likely to be produced in the future. ACA should be replaced with ACZA in older guidelines and specifications.

Acid Copper Chromate (ACC)

Acid copper chromate (ACC) has been used as a wood preservative in Europe and the United States since the 1920s. ACC contains 31.8-percent copper oxide and 68.2-percent chromium trioxide. The treated wood has a light greenish-brown color and little noticeable odor. During tests, stakes and posts that were impregnated with ACC held up well when exposed to decay and termite attack, although they may have been susceptible to attack by some species of copper-tolerant fungi.

ACC is listed in the AWPA standards for a wide range of softwoods and hardwoods, with a minimum retention of 0.25 pounds per cubic foot (4 kilograms per cubic meter) for wood used aboveground and 0.5 pounds per cubic foot (8 kilograms per cubic meter) for wood that contacts the ground. In critical structural applications, such as highway construction, AWPA listings for ACC are limited to signposts, handrails and guardrails, and glue-laminated beams used aboveground. It may be difficult to obtain adequate penetration of ACC in some of the wood species that are difficult to treat, such as white oak or Douglas-fir. The high chromium content of ACC prevents much of the corrosion that might otherwise occur with an acidic copper preservative.

ACC does not contain arsenic, but the treatment solution does use hexavalent chromium. The chromium is converted to the more benign trivalent state during treatment and storage of the wood. This process of chromium reduction is the basis for fixation in ACC, and depends on time, temperature, and moisture. Fixation standards or BMPs (best management practices) have not been developed for ACC, because of its relatively low usage. As a general guide, the fixation considerations discussed for CCA can be applied to ACC, but the fixation times must be extended because of ACC's higher chromium content. In 2005, only one manufacturer had a registration for ACC, and it was not being marketed.

Ammoniacal Copper Citrate (CC)

Ammoniacal copper citrate (CC) uses copper oxide (62 percent) as the fungicide and insecticide, and citric acid (38 percent) to help distribute copper within the wood structure. In 2004, CC was withdrawn from the AWPA standards because it was not being used.

Copper Dimethyldithiocarbamate (CDDC)

Copper dimethyldithiocarbamate is a reaction product formed in wood that has been treated with two different solutions. It contains copper and sulfur compounds. CDDC protects against decay fungi and insects. It has not been standardized for use in seawater. CDDC is standardized for treatment of southern pine and some other pine species at copper retentions of 0.1 pound per cubic foot (1.6 kilograms per cubic meter) for wood used aboveground or 0.2 pound per cubic foot (3.2 kilograms per cubic meter) for wood that contacts the ground. CDDC-treated wood has a light brown color and little or no odor. CDDC was introduced several years ago, but because of the expense of converting plants for its use and of the two-step treatment process, CDDC-treated wood was not available commercially in 2005.

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Last Modified: 06/28/2006 19:16:15