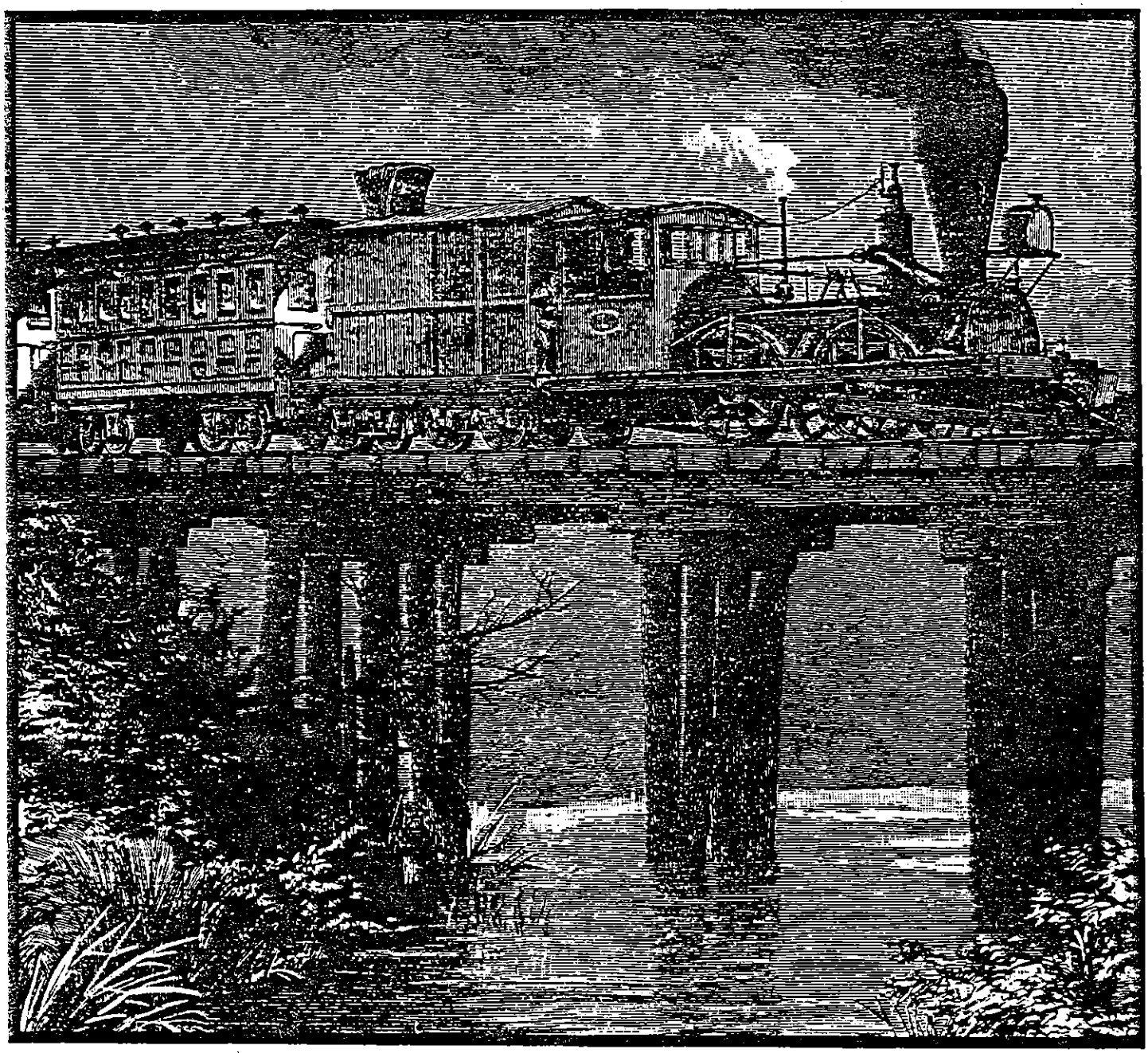
Wood Preservation and Wood Products Treatment



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PESTS THAT DAMAGE WOOD

Under proper use conditions, wood can give centuries of good service. But under unfavorable conditions, wood may readily be damaged and destroyed by fungi, insects, and marine borers. These pests can attack in many ways, using the wood for food or shelter. Consequently wood must be protected to insure maximum service life when used under conditions favorable to these pests (Fig. 1).

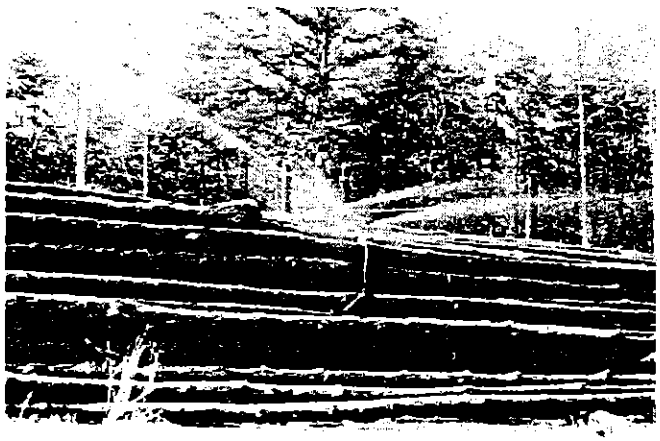

Figure 1
Sprinklers protect logs against mildew and rot by keeping wood saturated (photo courtesy of Dr. Terry Amburgey).

Wood-Inhabition Fungi

Wood decay, mold and most sapwood stains, are caused by fungi. These fungi feed on living or dead wood. The many fungi that develop on or in wood can be divided into two major groups, depending on the damage they cause:

- o wood-destroying fungi (decay fungi),
- o wood-staining fungi (sapstaining fungi, mold fungi).

Both of these fungi groups produce spores (analogous to tiny seeds), which are distributed by wind and water. The spores can infect moist wood during storage, processing and use.

All fungi that grow on wood have certain basic requirements:

- o Favorable temperature-usually ranging between 50 degrees and 90 degrees F. The optimum is about 70 degrees to 85 degrees F. Wood is basically safe from decay at temperatures below 35 degrees F and above 100 degrees F.

- o Adequate moisture-Fungi will not attack dry wood (i.e. wood with a moisture content of 19 percent or less) 1/ Decay fungi require a wood moisture content (M.C.) of about 30 percent (the generally accepted **fiber saturation point** of wood)

Thus, air dried wood, usually with a M.C. not exceeding 19 percent and kiln dried wood with a M.C. of 15 percent or less can usually be considered safe from fungal damage.

- o Adequate oxygen - Fungi cannot live in water-saturated wood (Fig. 1).

- o Food source (wood itself).

1/ National Design Specifications

Wood Destroying Fungi

Both the sapwood and heartwood of most tree species are susceptible to decay. Decay fungi may grow in the interior of the wood or appear on wood surfaces as fan-shaped patches of fine, threadlike, cottony growths or as rootlike shapes (Fig. 2, 3).

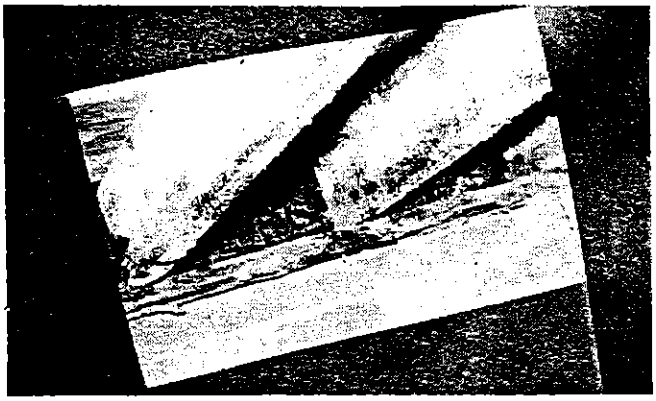

Figure 2
Mycelial fungus growth of wood-rooting fungus.

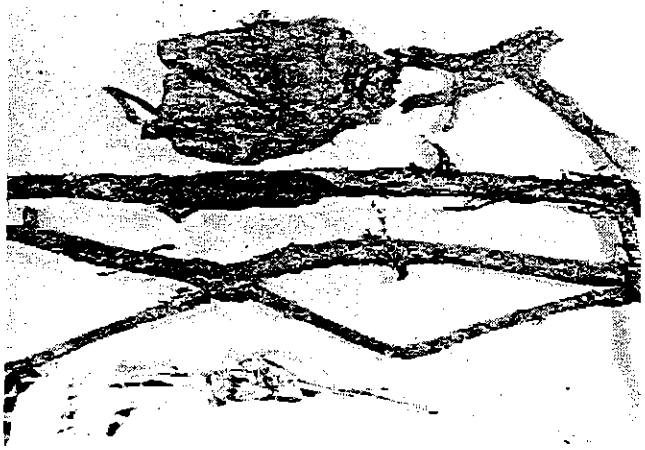

Figure 3
Root-like structures of a brown rot fungus.

The color of these growths may range from white through light brown, bright yellow, and dark brown. The spore-producing bodies may be mushrooms, shelf-like brackets, or structures with a flattened, crustlike appearance. Fine, threadlike fungal strands grow throughout the wood and digest parts of it as food. In time, the strength of the wood is destroyed.

Decay will stop when the temperature of the wood is either too low or too high or when the moisture content is drier than

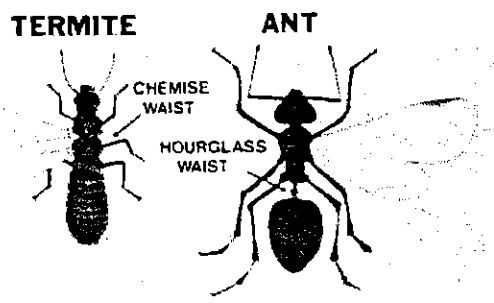

Figure 5
Differences between termite and ant.

Termites are divided into three major groups.

- o Subterranean or ground-inhabiting termites,
- o Drywood Termites,
- o Dampwood Termites.

Subterranean Termites- These termites attack wood products in buildings and other wood products throughout most of continental United States, but most damage occurs in the warm, southern coastal regions along the Atlantic Ocean and Gulf of Mexico.

At certain seasons of the year, winged males and females are produced by the termite colony. They swarm, mate, lose their wings, and attempt to begin a new colony in the soil (Fig. 6).

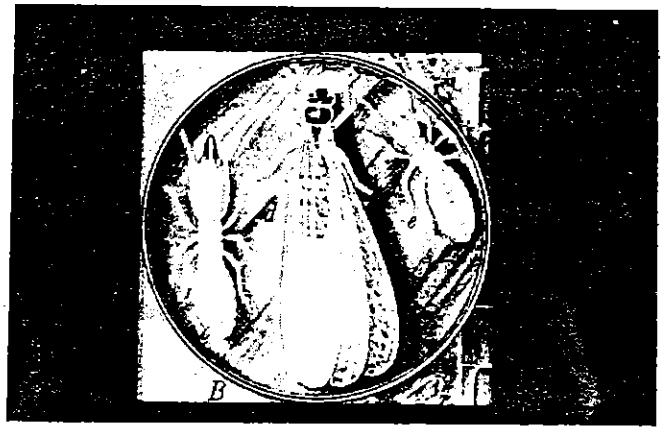

Figure 6
Subterranean termite - soldier, winged reproductive, and worker (1952 USDA Yearbook of Agriculture).

Termites build tunnels through earth and around obstructions to get to a source of food (either sound or decaying wood). They also require a constant source of moisture - usually obtained from the soil.

The presence of subterranean termites may be noted by:

- o the swarming of winged, ant-like insects and the discarded wings observed after swarming
- o earthen shelter tubes built over masonry or other foundations to a source of wood
- o the presence of white workers when termite shelter tubes are broken open
- o the hollowed-out condition of badly infested wood products

Drywood Termites- Drywood termites are found naturally only in Hawaii, Puerto Rico, and in a narrow strip of land extending from southern California and Texas to Florida and along the Atlantic coast to Virginia.

After swarming, drywood termites enter cracks and crevices in dry, sound wood. In excavating their galleries, they occasionally discharge oval-shaped fecal pellets through temporary openings in the wood surface. The ability of the drywood termite to live in dry wood without direct contact with the soil increases its menace. However, it reproduces slowly and does not destroy wood as quickly as the subterranean termite.

Dampwood Termites- Dampwood termites are a serious pest along the Pacific Coast. They do not require contact with the soil, but do need wood with a high moisture content.

Ants

Carpenter ants may be black or red. They usually live in stumps, trees, or logs, but often damage poles or structural timbers set in the ground. Elevated portions of buildings, such as windowsills and porch columns, are susceptible to damage. Carpenter ants use wood for shelter not for food (Fig. 7).

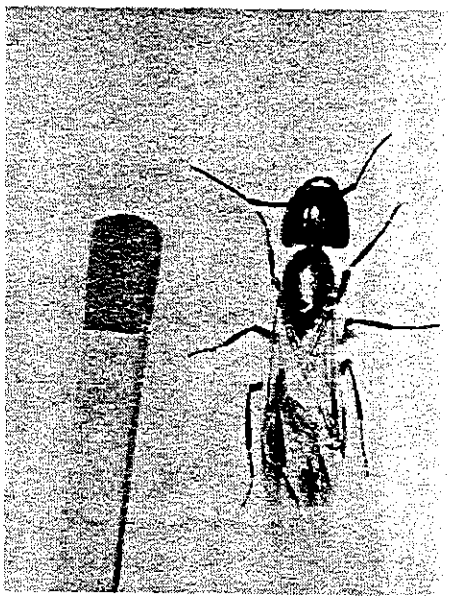

Figure 7

Winged carpenter ant by book match.

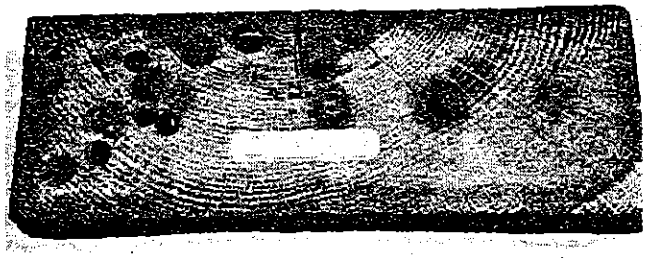

Figure 10
Shipworm damage.

Figure 11
Crustacean borer damage - severely weakened marine piling.

- Locate air-drying yards and sheds on well-drained sites with good air circulation, and keep the yards free of weeds.
- Practice good sanitation by removing debris or rotted wood which serves as a source of fungal infection and insects.
- Inspect stored wood products often. Termites, for example, may invade untreated stacked lumber if it remains undisturbed for long periods.
- Avoid rough handling of treated wood. Chipping, gouging, or splitting can expose unprotected interior wood and allow attack by decay fungi (Fig. 14).

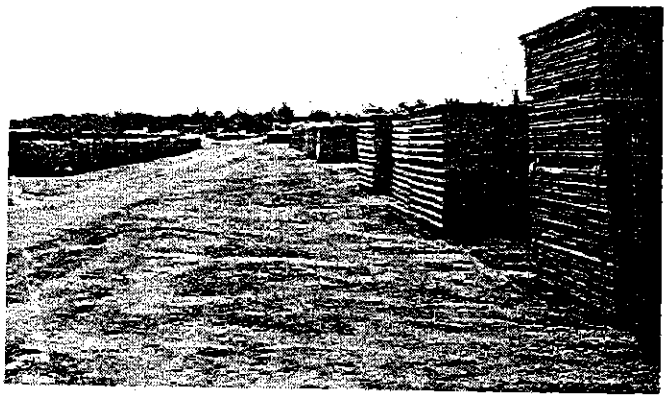

Figure 14
Storage yard free of weeds.

Use of Naturally Resistant Wood

The sapwood of all native tree species and the heartwood of most species have a low natural resistance to decay. However, the heartwood of some species is quite resistant. Examples are the heartwood of old- growth bald cypress (limited supply), cedar, redwood, and post oak. **They are resistant but definitely not immune to attack by decay fungi and insects.** Black locust and resinous southern pine heartwood, called 'fatwood' or 'lighterwood' is also highly resistant to decay.

Unfortunately, some naturally resistant woods are expensive or unavailable in commercial quantities (i.e. chestnut) or in dimensions needed. Because of high costs for labor and materials, the variable and undependable resistance of these species should preclude their use for most high hazard construction applications.

Chemical Control

The proper application of chemical preservatives can protect wood from decay and stain fungi, insects and marine borers, thus prolonging the service life of wood for many years.

The effectiveness of preservative treatment depends on the chemical formulation selected, method of application, proportion of sapwood to heartwood, moisture content of the wood, amount of preservative retained, depth of chemical penetration and distribution. Sapwood of most commercial species accepts preservatives much better than heartwood, and softwood species are generally more receptive to impregnation than the hardwoods. Preservative treatment by pressure is usually required for most wood products used for structural and other applications exposed to high risk of attack by fungi, insects or marine borers.

Type of Preservatives

Wood preservatives fall into three broad categories:

- creosote and creosote solutions,
- oilborne preservatives, and
- waterborne preservatives.

Creosote and Creosote Solutions- Creosote, an oily by-product of making coke from bituminous coal, is widely used as a preservative for such products as railroad ties, large timbers, fence posts, poles, and pilings (Fig. 15).

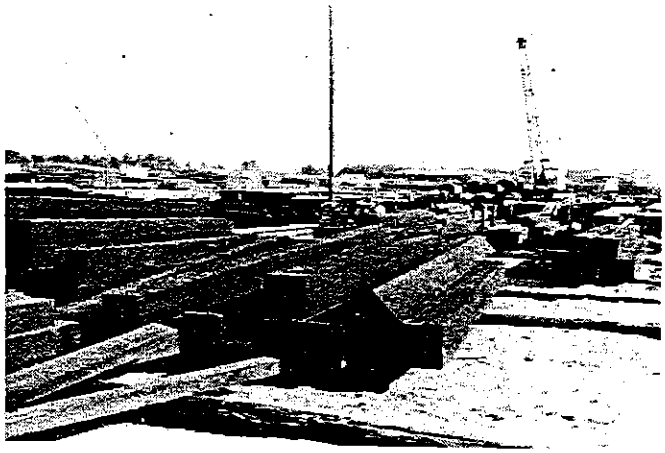

Figure 15
Creosoted railroad ties.

Advantages:
- toxic to wood-destroying fungi, insects, and some marine borers,
- low volatility,
- insolubility in water,
- ease of handling and application.

Disadvantages:
- dark color,
- strong odor,
- oily, unpaintable surface,
- tendency to bleed or exude from the wood surface,
- should not be used in homes or other living areas because of toxic fumes.

Oilborne Preservatives- These chemicals are generally insoluble in water. They are usually dissolved in petroleum or other organic solvents in order to penetrate wood. Research developments have recently made available oilborne preser-

APPLICATION OF WOOD PRESERVATIVES

Preparation of Wood for Treatment

For most of the commercial wood treatments in common use, wood must be prepared in some way before a preservative is applied. This preparation may include peeling, drying, conditioning, incising, cutting, and framing.

Peeling

The bark and cambium must be completely removed before treatment. This allows the preservative to penetrate into the wood. Bark obstructs penetration, resulting in exposed untreated wood (Fig. 18).

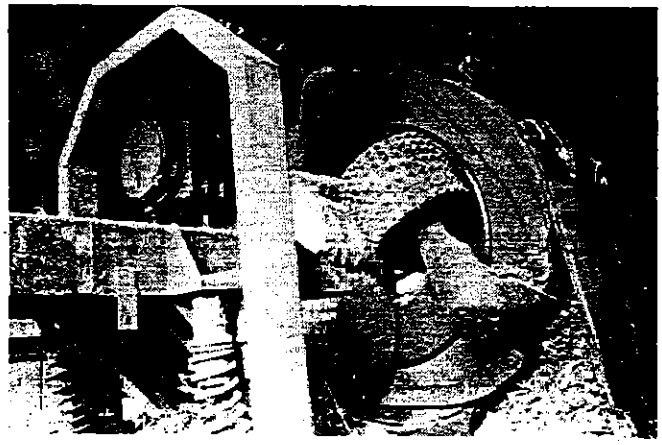

Figure 18
Debarking a log.

Drying

In most treating methods, a high moisture content prevents or slows the entrance of the preservative into the wood cells. Drying the wood allows better penetration of the preservative, reduces product weight and shrinkage with its potential for warping and checking after treatment.

Kiln drying is one method for accelerating drying under controlled drying conditions.

Conditioning

Operators of pressure treating plants can use several other methods besides conventional drying to condition wood for treatment. In the steaming and vacuum process, green wood is steamed in a treating cylinder or retort for several hours and then subjected to a vacuum. The vacuum reduces the boiling point of the water in the wood and speeds its removal. Then the evaporated water can be replaced by the preservative, applied under pressure.

Another method of conditioning green wood is boiling under vacuum (Boulton method). The wood is placed in a treating cylinder and submerged in hot oil. Then a vacuum is applied, removing water from the wood. With this method, wood can be conditioned at a lower temperature. Consequently, it can be used to avoid damage to a wood species (such as Douglas fir) which is sensitive to the higher temperatures of the steaming and vacuum process.

A third method of conditioning is known as vapor drying. In this process green wood is exposed to hot vapors of an organic compound, such as xylene, which gradually vaporizes and removes the water.

Incising

Incising consists of making a series of narrow holes or slits in the wood about 1/2- to 3/4-inch deep. This allows preservatives to better penetrate impregnation-resistant wood species (such as Douglas fir). Incising makes possible a more uniform penetration to at least the depth of holes.

Cutting and Framing

Cutting, shaping or drilling wood after treatment can expose untreated wood. This exposure can be avoided by cutting, shaping or boring the wood for its intended use before the preservative treatment. The treated wood then can be used without further machining (Fig. 19).

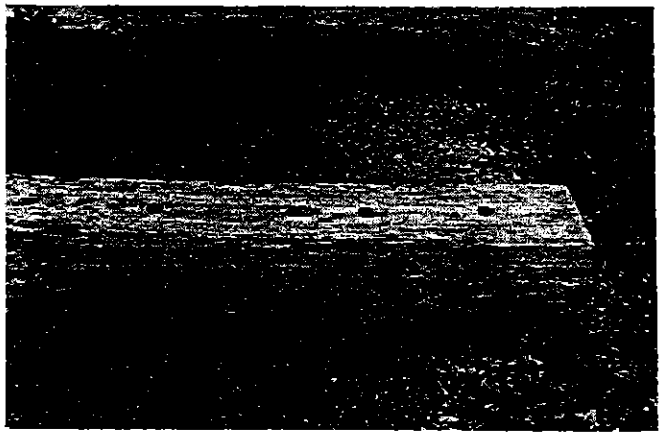

Figure 19
Boring prior to treatment.

Methods of Applying Wood Preservatives

There have been almost as many methods for applying wood preservatives as there are different preservatives. Only the ones in current use will be discussed. The treating method selected depends greatly on the ultimate use of the product. The two major types of treatment are pressure and nonpressure methods. Many variations of these methods are described in the standards and specifications of the American Wood Preservers Association (AWPA), the Federal Government, and other organizations.

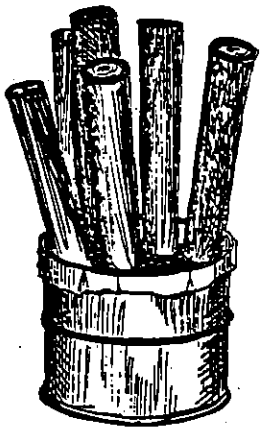

Figure 22

Cold soaking or steeping.

Steeping- The steeping process employs a **water-borne** salt preservative solution to either dry or green wood. It consists of submerging the wood in a tankful of the solution at atmospheric temperature for several days or weeks (heating the solution would speed-upenetration). Absorption is rapid the first 3 days then continues at a decreasing rate almost indefinitely. When treating flat-sawn, wood products space should be provided between and around each piece of wood to permit complete exposure to the preservative material.

Hot and Cold Bath (Thermal Process)- The hot and cold bath or thermal process, also called the boiling-and-cooling or open-tank treating method, is suitable with oil-based and water-borne preservatives. When used properly, the method provides a reasonably effective substitute for pressure impregnation. The process is quite simple involving the use of one or two tanks. With two tanks the wood product first is immersed into a hot solution usually of the preservative, itself, or even boiling water, followed by its immersion into a tank of cold solution (Fig. 23).

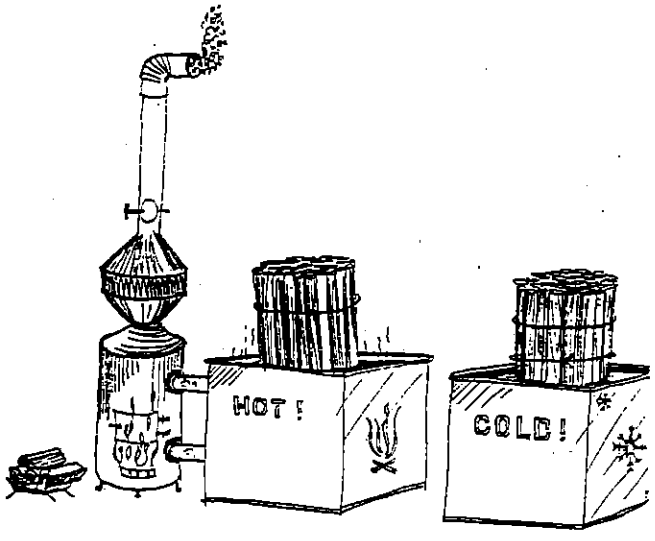

Figure 23
Hot and cold bath.

Most preservative absorption and penetration takes place during the cold bath. When one tank is used, heating can be discontinued, allowing the wood and preservative to cool together.

Double Diffusion- Treatment by double diffusion is a two-stage dispersion of a preservative liquid into a piece of wood. An example of the process would be to first soak a green wood product, such as a post, in a solution of copper sulfate. When a sufficient amount of the chemical has diffused into the wood, it is then immersed in a second solution consisting of sodium arsenate and sodium chromate. The purpose of double diffusion is to convert very leachable, chemical salt solutions into fixed and stable preservatives within the wood.

Vacuum Process- In the vacuum process wood products are enclosed in an airtight container from which air is removed with a vacuum pump. The container then is filled with the preservative without additional pressure and without the air re-entering. The partial removal of air from the wood, by the vacuum, followed by addition of the preservative creates a slight pressure that drives the preservative into the wood. Vacuum treatment works well with penta and easily treatable woods and products like pine, window stock.

Preservative Pads or Bandages (Treatment on Site) - There are several variations of employing this treating concept: The preservative can be applied to the surfaces of the wood, can be injected into the wood or placed into holes drilled in the wood. The preservative used can be water-borne, solvent in oil or have a consistency of grease or mayonnaise.

This method is most often used to extend the life of standing poles that had previously been treated. Since treated poles are costly, consideration must be given to replacement costs, including treatment and installation, so a 5-year increase of service life would be a very worthwhile expenditure for preservative bandage treatment.

The major task of this treating process involves removal of soil from around the pole for a depth of about 18'. This part of the pole, below ground, and the part 12' above ground is the portion most vulnerable to decay and failure. All decayed wood and soil must be removed from the pole and the preservative should be applied thoroughly to the 'cleaned' portion of the pole. This treated area should then be wrapped with a heavy duty, water resistant paper or plastic film to confine the preservative to the pole.

Sapstain (Blue Stain) Prevention- Sapstain fungi do not decay their wood host, but they degrade lumber and other wood products and lower their value. Also, sapstain fungi often precede the decay fungi because conditions favorable for attack (high temperatures and humidity) are comparable for both types of fungi.

To protect green logs, poles and other round timbers, they should be processed soon after trees are felled. If they cannot be processed promptly, the timbers should be stored submerged in water or be subjected to a continuous spray of water. When these storage methods are not feasible, protection for several months can be afforded by application of a chemical spray containing a solution of benzene hexachloride and penta in fuel oil. The entire log and especially the ends must be

For example, pilings treated to meet specifications for fresh water should not be used in marine waters.

Some end-uses will place a greater physical stress on treated wood than other uses and will result in a shorter service live. The cost of replacement for some end-uses may justify periodic retreatment of wood, on site, to prolong its service life.

taminated with arsenic or who breathed air containing arsenic.

4. pentachlorophenol has produced defects to the offspring of laboratory animals; and

5. a dioxin contaminate (HxCDD) in pentachlorophenol has been shown to cause cancer in laboratory animals.

Because of the potential hazard of these preservatives, there are new EPA label requirements for their handling and end use. In addition to the potential hazards of chronic toxicity, a single or short term exposure can cause the following acute health effects:

Creosote:

- can cause skin irritation; vapors and fumes are irritating to the eyes and respiratory tract; and prolonged and repeated exposure may lead to dermatitis.

Pentachlorophenol:

- Irritating to eyes, skin and respiratory tract.
- Ingestion of penta solutions, inhalation of concentrated vapors or excessive skin contact may lead to fever, headache, weakness, dizziness, nausea, and profuse sweating. In extreme cases, coordination loss and convulsion may occur: high levels of exposure can be fatal.
- Prolonged exposure can lead to an acne-like skin condition or other skin disorders, and may cause damage to the liver, kidneys or nervous system.

Inorganic arsenicals:

- exposure to high concentrations of arsenical compounds can cause nausea, headache, diarrhea and abdominal pain (if material was swallowed); extreme symptoms can progress to dizziness, muscle spasms, delirium and convulsion.
- prolonged exposure can produce chronic, persistent symptoms of headache, abdominal distress, salivation, low-grade fever, and upper respiratory irritation.
- long term effects can include liver damage, loss of hair and fingernails, anemia and skin disorders.

First Aid

Since accidents do happen, first aid information on the chemical(s) in use must be readily available. The product label gives basic first aid directions, as do Material Safety Data sheets supplied by chemical manufacturers. The following general steps are applicable for accidental exposure to wood preservatives.

- In cases of skin contact, first remove contaminated clothing that's in contact with the skin, immediately wash the affected areas with mild soap and water. Don't irritate the skin with vigorous scrubbing. Later, if you notice inflammed skin, redness or itching in the affected area, consult a doctor.
- In cases of eye contact, immediately flush the eyes with running water. Lift the upper and lower eyelids for complete irrigation and continue for fifteen minutes, then see a doctor.
- If accidental inhalation has occurred, move the victim to fresh air and apply artificial respiration as needed. Get medical help immediately.

If chemical preservative has been swallowed, call medical help immediately:

* If creosote or penta was swallowed, first give one or two glasses of water, induce vomiting, then administer two tablespoons of 'USP Drug Grade' activated charcoal inwater.

* If an arsenical chemical has been swallowed, drink large quantities of water, or milk if available. Get professional medical help immediately.

- Never attempt to give anything by mouth to an unconscious person.
- Never induce vomiting in an unconscious person.

Protecting the Applicator[1/]

General

- Good work habits are reflected in the general precautions included on all wood preservative labels. These basic, common-sense hygiene rules can significantly reduce risks of chronic exposure to wood preservative chemicals. For example:
- Don't eat, drink or smoke in the work area - a worker's hands can transmit residues to whatever they touch.
- Wash hands often, especially **before** using the restroom, smoking or eating.
- Remove gloves to handle paper work, phones or equipment which others may handle with unprotected hands.
- At commercial treatment plants, protective clothing must be left at the plant. If work clothes must be laundered at home, wash them separately from other laundry.
- **Protective clothing** requirements will be specified on the label. These will include use of **impermable gloves** for applying the preservatives and in all situations where dermal (skin) contact is expected (e.g., handling freshly

1/ Adapted in part from: Federal Register, Friday, Jan. 10, 1986, Part III, Environmental Protection Agency, pp. 1334-1348, Vol. 51, No. 7.

vatives. The CIS will serve as the main vehicle for conveying information about treated wood to consumers. The focus of the CAP will be on ensuring the dissemination of the CIS at the time of sale or delivery to end users.

The individual wood treater's CIS will, at a minimum, contain the language agreed to by AWPI, SAWP, NFPA, and EPA on the model CIS, to the extent it applies to the wood preserver's product.

Wood treaters will be free to add other information to their CIS's such as the member's name, address, and logo; but in all cases, the use site precautions and the safe handling practices information will be separate, legible, and prominent.

The primary responsibility for ensuring that the CIS is disseminated to the consuming public will reside with the wood treaters. This voluntary program may be modified by EPA at a later date.

Inorganic Arsenical Pressure-Treated Wood

The following wording will appear on the Consumer Information Sheet (CIS) for inorganic arsenical pressure-treated wood:

Consumer Information - 'This wood has been preserved by pressure- treatment with an EPA-registered pesticide containing inorganic arsenic to protect it from insect attack and decay. Wood treated with inorganic arsenic should be used only where such protection is important.

Inorganic arsenic penetrates deeply into and remains in the pressure-treated wood for a long time. Exposure to inorganic arsenic may present certain hazards. Therefore, the following precautions should be taken both when handling the treated wood and in determining where to use or dispose of the treated wood'.

Use Site Precautions for Inorganic Arsenical Pressure-Treated Wood - 'Wood, pressure-treated with waterborne arsenical preservatives, may be used inside residences as long as all sawdust and construction debris are cleaned up and disposed of after construction.

Do not use treated wood under circumstances where the preservatives may become a component of food or animal feed. Examples of such sites would be structures or containers for storing silage or food.

Do not use treated wood for cutting-boards or countertops.

Only treated wood that is visibly clean and free of surface residue should be used in patios, decks and walkways.

Do not use treated wood for construction of those portions of beehives which may come into contact with the honey.

Treated wood should not be used where it may come into direct or indirect contact with public drinking water, except for uses involving incidental contact such as docks and bridges'.

Handling Precautions for Inorganic Arsenical Pressure-Treated Wood - 'Dispose of treated wood by ordinary trash collection or burial. 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 (e.g., construction sites) may be burned only in commercial or industrial incinerators or boilers in accordance with State and Federal regulations.

Avoid frequent or prolonged inhalation of sawdust from treated wood. When sawing 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.

After working with the wood, and before eating, drinking, and use of tobacco products, wash exposed areas thoroughly.

If preservatives or sawdust accumulate on clothes, launder before reuse. Wash work clothes separately from other household clothing'.

Creosote Pressure-Treated Wood

The following wording will appear on the Consumer Information Sheets (CIS) for creosote pressure-treated wood:

Consumer Information - 'This wood has been preserved by pressure treatment with an EPA-registered pesticide containing creosote to protect it from insect attack and decay. Wood treated with creosote should be used only where such protection is important.

Creosote penetrates deeply into and remains in the pressure- treated wood for a long time. Exposure to creosote may present certain hazards. Therefore the following precautions should be taken both when handling the treated wood and in determining where to use the treated wood'.

Use Site Precautions for Creosote Pressure-Treated Wood - 'Wood treated with creosote 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-treated wood should not be used in residential interiors. Creosote-treated wood in interiors of industrial buildings should be used only for industrial building components which are in ground contact and are subject to decay or insect infestation, and for wood block flooring. For such uses, two coats of an appropriate sealer must be applied. Sealers may be applied at the installation site.

Wood treated with creosote should not be used in the interiors of farm buildings where there may be in direct contact with domestic animals or livestock which 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-treated wood may be used for building components which are in ground contact and are subject to decay or insect infestation, if two coats of an effective sealer are applied. Sealers may be applied at the installation site.

Do not use creosote treated wood for farrowing or brooding facilities.

Do not use treated wood under circumstances where the preservative may become a component of food or animal feed. Examples of such use would be structures or containers for storing silage or food.

Do not use treated wood for cutting-boards or countertops.

Only treated wood that is visibly clean and free of surface residues should be used for patios, decks and walkways.

Do not use treated wood for construction of those portions

vinyl-coated).

When power-sawing and machining, wear goggles to protect eyes from flying particles.

After working with the wood, and before eating, drinking and uses of tobacco products, wash exposed areas thoroughly.

If oily preservatives or sawdust accumulate on clothes, launder before reuse. Wash work clothes separately from other household clothing.

Urethane, shellac, latex epoxy enamel and varnish are acceptable sealers for pentachlorophenol-treated wood'.

Penta is moderately persistent in the aquatic environment. It was reportedly detected in lake water and fish 6 months after an accidental spill. The prevailing use patterns of penta, primarily as a wood preservative, should preclude significant contamination of water as long as spills and industrial accidents are avoided.

Penta is moderately persistent in the soil. Published data report that persistence ranges from 21 days to 5 years. Under most conditions, penta will seldom persist in the soil for periods exceeding 9 months and its half-life will frequently be far less than this. Numerous studies have identified soil microorganisms capable of degrading penta, but the extent of their distribution is unknown. Since the major use of penta (wood preservative) does not involve application to the soil, the likeliest source of soil contamination is the leaching or bleeding of the preservative from treated wood. Such phenomena may result in low levels of penta contamination in the immediate vicinity (within several inches) of the treated wood.

Available data indicate that penta is not readily translocated by plants and that the compound in rapidly eliminated by mammals following exposure. Significant accumulation in plants and mammals is not likely to occur.

Arsenicals

No problems have been found in the literature as to the effects of arsenical wood preservatives on the environment. Arsenate, the form present in aerobic soils, is bound tightly to the soil components and becomes unavailable for plant uptake or leaching.

Creosote

There are no recorded reports of wild or domestic animals being injured by creosote.

The amount of creosote as a liquid that enters the environment is relatively small. The fate of creosote in the environment is not known, but most of its components are quickly biodegraded.

SOURCES OF INFORMATION

This manual is intended to provide basic information essential to safe handling of pesticides and to prepare treaters for certification. Changing of pesticide registration and use requires continuing study to keep up-to-date.

Proceedings, standards, and other publications of the American Wood Preservers Association provide current information of wood preservers. Other trade publications will also prove helpful.

Following are several references recommended for further study.

Handling Precautions for Penta and Santobrite. Technical Bulletin No. 0/PS-3, Monsanto Co., Organic Chemical Division, St. Louis, Missouri 63166.

Utilization of the Southern Pines. Peter Koch, USDA Agriculture Handbook No. 420, Aug. 1972. Provides information on wood- destroying organisms and the treating process.

Selection, Production, Procurement and Use of Preservative - Treated Wood, Supplementing Federal Specification TT-W-571. Lee R. Gjovik and Roy B. Baechler, USDA Forest Service, General Technical Report FPL-15, 1977.

Safe Handling Guide to Sapstain Control Chemicals, Western Wood Products Assoc., Portland, Oregon 1982. 14pp.

Preservative Treatment of Wood by Pressure Methods. J.D. Maclean, USDA Agriculture Handbook No. 40, Dec. 1952. Reprinted with corrections Sept. 1960.

Wood as an Engineering Material. Wood Handbook, Chapters 17-19, USDA Agriculture Handbook No. 72, Revised 1974.

Wood Deterioration and Its Prevention by Preservative Treatment. Darrel D. Nicholas, editor, with assistance of Wesley E. Loos, Syracuse University Press, 1973 (two volumes).

Wood Preservation. George M. Hunt and George A. Garratt, McGraw Hill Book Co., Inc., Third Edition, 1953.

The Analysis of Existing Wood Preserving Techniques and Possible Alternatives. B. Fuller et al. Metrek Division/The Mitre Corporation. Developed under contract with the U.S. Environmental Protection Agency, June, 1977.

Chlorophenate Wood Protection. British Columbia Ministry of Environment. 1983. D.E. Konasewich et al., Wood Protection Task Force, 90 pp.

The Preservation of Wood. Ian Stalker and Milton Applefield, Extension Entomology, University of Georgia,A correspondence course for wood treaters, 150 pp., 1986.