
A collaborative research project between the Philippine Forest Products Research and Development Institute and Oregon State University

J.J. Morrell
M.Y. Giron
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Introduction

Preservative-treated wood poles provide an efficient way of supporting overhead electric and telephone wires. In the Philippines, utilities purchase over 150,000 poles per year to expand service to rural communities and to replace poles lost to decay, insect attack, or other causes. The tropical conditions in the Philippines create an environment that is especially conducive to biodegradation. Due to a shortage of native timbers, many poles have to be imported, consuming valuable foreign exchange. The service life of a wood-pole system can be extended significantly by careful selection and preservative treatment, and by the development of a regular inspection and maintenance program.

In this manual, we address the basic properties of wood as they affect poles, the agents of deterioration, methods of preservation, and procedures for inspection and remedial treatment of poles in service. This booklet is intended as a guideline from which individual utilities can develop more detailed specifications for their service conditions.

Basic Properties of Wood

Trees are ideal for making utility poles because they have evolved to support high loads in tension and compression. The two basic groups of commercial trees are angiosperms, which mostly have broad leaves that are shed annually, and gymnosperms, with needle-like leaves that are often retained for several growing seasons. Tropical gymnosperms are rare, but other species of gymnosperms are often imported.

Viewing a tree in cross section, we see bark, sapwood, heartwood, and pith (Figure 1). The bark protects the tree from external damage. The lighter band of sapwood contains living cells that provide structural support and conduct liquids up and down the tree. Sapwood has no resistance to deterioration once the tree is cut. As sapwood ages, the inner cells die and form a core of heartwood, which varies greatly in thickness. In some species, such as molave (Vitex parviflora), yakal (Hopea basilanica), and guijo (Shorea guiso), heartwood contains compounds that are toxic to wood-degrading organisms, resulting in naturally durable wood. At the very center of the tree is the pith zone with little natural durability.

Wood consists of long tubes that are individually weak but have significant strength when combined into a single structure (Figure 2). Three complex polymers are present in the cell structure: cellulose, hemicellulose, and lignin. Cellulose is a long-chain polymer that provides strength to the cell, and hemicellulose is a branched polymer deposited around the cellulose. Lignin is the most complex polymer of the three. Within this matrix, extractives are deposited, some of which provide protection against fungi and insects. Highly organized polymers in the wood cell wall explain its strength properties.

Trees also contain large quantities of water, which is vital for translocating food manufactured in the leaves to the growing tissue immediately inside the bark. The moisture content (MC) of the unseasoned (green) wood of the outer sapwood and inner heartwood varies greatly in both conifers and hardwoods, ranging from as low as 30 percent to as high as 200 percent (oven-dry basis). To prepare green wood for preservative treatment, poles may be air seasoned or kiln dried.
Figure 2. Ultrastructure of softwood and hardwood showing (A) transverse, (B) tangential, and (C) radial faces.

and then pressure treated, or placed in the treating vessel, steam conditioned, and then pressure treated. Steam conditioning is used in warm, humid climates where the decay hazard precludes air seasoning.

Because large treated poles usually have a moisture gradient that is lowest near the surface and highest toward the center, they continue to season in service, and checks continue to widen and deepen, sometimes exposing untreated wood to attack by decay fungi and insects, especially in thin-sapwood species. Methods for preventing checking will be discussed later.

Native Hardwoods

Hardwoods are characterized by three basic cell types: ray cells, vessels, and fibers (Meniado et al. 1975, 1978a). Ray cells function in lateral transport and storage of nutrients. Vessels function in longitudinal transport of liquids and nutrients, and they vary in size depending on the time of year they are formed and the wood species.

These differences are important in species identification. Fibers are thick-walled cells that provide structural support to the living tree.

Tropical hardwoods are becoming scarce, with only limited supplies available locally. Meanwhile the thousands of tropical hardwood poles already in use must be maintained to maximize service life. Most of the hardwood poles in the Philippines are from the family Dipterocarpaceae, and are characterized by clear cylindrical trunks as large as 2 m in diameter.

- Apitong (*Dipterocarpus grandiflorus*) has excellent mechanical properties and is the most desirable species. Although difficult to dry, both the sapwood and heartwood are easily treated with preservatives, even when green. Apitong has been used extensively for utility poles, but declining supplies have forced the use of other hardwood species and of imported conifers.

- Red lauan (*Shorea negrosensis*) has a thin sapwood layer and moderately durable heartwood, which is difficult to treat with preservatives. As a result, poles of this species have shallow preservative protection that is easily damaged during installation or use.

- Tangile (*Shorea polysperma*) has thin sapwood, which is mostly used for furniture and other decorative purposes. The heartwood is moderately durable and is very difficult to treat.

- White lauan (*Pentaceme contorta*) also has thin sapwood, and a nondurable heartwood that can be readily treated with oil-borne preservatives, although field inspections suggest that preservative penetration often is shallow and incomplete, probably due to improper seasoning before treatment.

- Yemane (*Gmelina arborea*) is a plantation species with thick bands of sapwood. The heartwood is moderately durable and difficult to treat. Yemane is not yet widely used for wood poles, even though its mechanical properties are ideal for this purpose.

- Bagras (*Eucalyptus deglupta*) is extensively used for small-diameter poles in Australia, and may have a niche in the Philippines (Meniado et al. 1978b), where it is a plantation species. The thin sapwood surrounds a difficult-to-treat, nondurable heartwood core. This species has little natural durability and must be treated with preservatives to provide adequate service.
**Imported Conifers**

Conifers are characterized by the presence of three cell types: ray parenchymas that store food; ray tracheids that conduct materials laterally across the tree; and tracheids that conduct water and nutrients up and down the tree and provide structural support for the stem. Sapwood is light colored, whereas heartwood varies from light colored to dark red or brown. Four coniferous species are important in worldwide trade.

- Douglas-fir (*Pseudotsuga menziesii*) is widely used in the United States for both distribution and transmission lines. This species has excellent mechanical properties. Only a thin sapwood band surrounds a moderately durable heartwood core that is very difficult to treat with preservatives. For commercial purposes, two varieties of Douglas-fir are recognized. Pacific Coast Douglas-fir is easily treated along the grain and is commonly used for wood poles. Inland or Interior Douglas-fir is very difficult to treat and is not currently recommended for use in wood poles. Methods for improved treatment of this species are addressed in a later section (see page 7).

- Southern pines (*Pinus spp.*), a group of species from the southeastern United States, are characterized by thick bands of easily treated sapwood surrounding a difficult-to-treat heartwood core. Southern pines are most often used for distribution lines.

- Radiata pine (*Pinus radiata*), a species native to the United States, is intensively cultivated in Australia, New Zealand, South Africa, and South America. Like the southern pines, radiata pine is characterized by thick bands of easily treated sapwood surrounding a small, difficult-to-treat heartwood core.

**Tropical Monocots**

Although coconut (*Cocos nucifera*) does not have the high-strength properties of hardwoods or conifers, the use of poles from this wood to support small-voltage distribution lines in rural areas is increasing. Coconut has growth characteristics that differ radically from both hardwoods and conifers. In general, the center of a coconut pole is pithy and has little strength, whereas the outer shell is extremely dense and can carry small line loads. Coconut is highly susceptible to decay and must be treated soon after cutting. One problem with this species is the tendency for excessive treatment of the pith and incomplete treatment near the surface, where protection is needed most.

**Agents of Wood Deterioration**

Fungi and insects are the principal agents of wood degradation and are discussed separately. Other organisms that attack wood include bacteria, marine borers, and birds. Bacteria are small, single-celled organisms that decay wood very slowly. They are limited to very wet environments and are not covered here. Marine borers are economically important, but require salt water. Since most utility poles are on dry land or in fresh water, these organisms pose little threat. However, where utility lines cross salt-water estuaries, care must be taken to ensure that the poles used are treated for marine use.

All living organisms have four basic requirements: oxygen, water, a suitable temperature, and a food source. Maintaining wood in good condition involves removing one of these requirements to make it impossible for an organism to survive. For example, keeping wood dry by designing structures so that water is excluded prevents organisms from obtaining energy from the wood, and keeping the wood very wet excludes oxygen. When wood is used under conditions where oxygen, water, or temperature are not limiting, it must be either naturally durable or preservative-treated to ensure an adequate service life.

The potential for decay varies widely with region, climate, soil type, and a host of other factors. Attempts have been made to develop risk assessments or decay-hazard maps. One such index, the Scheffer Climate Index (Scheffer 1971), uses a combination of precipitation and average monthly temperature to arrive at a climate index for wood decay above the ground. The climate index can be calculated with the following formula:

\[
\text{Climate Index} = \sum_{\text{Jan}}^{\text{Dec}} \frac{(T - 2)(D - 3)}{16.7}
\]
where \( T \) = mean monthly temperature (C°) and \( D \) = mean number of days with 0.25 mm or greater of precipitation. The values are summed over 12 months and divided by 16.7.

In this system, indices below 35 have little or no risk of decay, those between 35 and 65 have a moderate risk, and those above 65 a high risk. The climate index for most of the Philippines exceeds 100, indicating a severe risk of decay.

Fungi

The fungi that attack wood are classified as white-, brown-, or soft-rot fungi (Figure 3). Each group differs in the way it attacks wood, but all proceed from sound wood to the incipient stage, when damage is not yet visible to the naked eye. At the intermediate stage, changes first become evident, and at the advanced stage, the damage is clearly visible. Incipient decay is usually detected by examining wood with a microscope or by culturing it for the presence of decay fungi (Figure 4). Intermediate decay can sometimes be detected by changes in color or texture, whereas advanced decay is easily seen.

Characteristics of the fungal groups are below.

- White-rot fungi use all components of the wood cell wall, eventually causing as much as 96 percent loss of the original wood weight. These fungi are mostly a problem in hardwoods. Wood damaged by white-rot fungi becomes bleached white and, at the later stages of decay, individual wood fibers can be separated.

- Brown-rot fungi use the carbohydrate components of the cell wall, leaving a lignin residue and eventually causing 60 to 70 percent weight loss of wood. Brown-rot fungi are prevalent in conifers. A large loss of strength in the early stages of decay, eventually leaving the wood a brown, cracked mass, magnifies the impact of these fungi.

- Soft-rot fungi primarily use carbohydrates, but attack the wood in a completely different way from either white- or brown-rot fungi. The attack is in two stages, termed Type 1 or 2. Type 1 attack is characterized by the formation of cavities within the wood cell wall and is followed by Type 2 attack, involving a gradual erosion of the wood cell wall, from the lumen.

Figure 3. Wood decay fungi can be classified as (A) white-rot, (B) brown-rot, and (C) soft-rot fungi, depending on the appearance of the decayed wood.
The presence of decay fungi can be detected by culturing the wood. Both types of damage can be caused by the same fungi. Soft-rot fungi typically attack from the surface inward, gradually decreasing the residual circumference until the pole can no longer support its designed load. These fungi are more prevalent on hardwoods, probably reflecting treatment variations in the fibers of these species. They tend to be more important in wet agricultural soils.

**Insects**

**Beetles**

Wood-boring beetles generally lay their eggs on freshly fallen trees and can survive inferior preservative treatment to continue their growth in the finished product. Control is best achieved by rapid removal of the bark to reduce the moisture content. Alternatively, a long heating period during treatment can eliminate any insects that have invaded the wood between cutting and treatment.

One group that can be a problem in poles in the field is powderpost beetles or “bukbok” (Reyes 1989). They infest dry wood (12 to 20 percent MC) and can survive for many years before exiting. Powderpost beetle larvae bore numerous tunnels under the wood surface, leaving the wood a brown powdery mass (Figure 5). They are best controlled by using preservative-treated wood, although infestation is still possible through checks extending beyond the depth of the treated shell. Powderpost beetles are most often limited to the sapwood zone, where they feed on starches in the ray cells, so effective initial preservative treatment of the sapwood should prevent an infestation.

**Termites**

Termites pose a major threat to wood poles because of sheer numbers. They are social insects with a highly organized caste structure, consisting of workers, soldiers, and reproducitives (Figure 6). Colonies may approach two million members and their tunnels may cover an area up to 0.8 km in diameter. Termites exhibit a wide range of feeding habits and requirements. Fifty-four species of termites or “anay” occur in the Philippines, but only six of these cause significant wood damage—four subterranean species that require soil contact for survival and two that do not require soil contact.

Subterranean or soil-dwelling termites attack wood that is in direct contact with the soil or construct earthen tubes to reach wood not in ground contact (Figure 7). Wood damaged by these termites is generally darkened and the tun-
Figure 6. A termite worker (left) and winged reproductive.

Figure 7. Subterranean termites can attack wood out of ground contact by constructing earthen tubes that protect the insects from drying.

Figure 8. Wood damaged by subterranean termites has debris-filled tunnels concentrated in softer portions of the wood.

Figure 9. Mound-building termites construct large, easily detected mounds from which they then move out to attack other wood in the area.

...nals are filled with insect droppings (frass) and other debris (Figure 8). Tunnels tend to follow softer zones in the wood. Subterranean-termite damage can be limited by the application of soil insecticidal barriers in the soil, but applications must be made at regular intervals to be effective. Preservative treatment can limit termite attack, but any damage to the treated shell allows attack of interior, untreated wood.

Of the subterranean termites, the Philippine milk termite (Coptotermes vastator, Rhinotermitidae) is the most destructive. Soldiers of this species produce a milky secretion when disturbed, giving the species its name. Mound-building Los Banos termites (Microcerotermes los-banosensis) construct primary nests in soil and secondary or satellite nests above ground (Figure 9), moving between the two through earthen tubes.

Drywood termites or "unos" do not need soil contact and can attack wood that is quite dry (<10 percent MC). Cryptotermes cyanocephalus and...
C. dudleyi (Kalotermitidae) are found in the Philippines and infest furniture and wood in buildings. Wood damaged by drywood termites tends to have tunnels that are free of frass. Control of drywood termites is difficult because they can infest any dry wood and do not require soil contact for survival; however, an effective preservative-treated shell is an excellent barrier against attack.

Preserving Poles

Preparation for Treatment

The goal of preservative treatment is to provide a barrier to fungi and insects in a system that will support the design load for a long period. In general, treated wood poles should have an average service life of 30 to 40 years. The ideal wood-pole specification should economically maximize average service life while minimizing early failures.

Preparation of poles for preservative treatment is an important step in assuring maximum service. They need to be handled carefully to prevent damage that can make a pole unmarketable. After logs are removed from the woods, they should either be peeled as soon as possible and seasoned to remove moisture prior to treatment, or stored under water to reduce the risk of fungal or insect attack. Studies show that freshly peeled wood is rapidly colonized by decay fungi and insects, causing significant strength loss if left untreated. Peeling should completely remove all bark, but should not remove an excess of easily treated sapwood.

Seasoning

Generally, removal of moisture from the wood before treatment is desirable. Seasoning can be accomplished by:

- air seasoning,
- kiln drying,
- steam conditioning, or
- Boulton seasoning.

The primary goal of seasoning is to remove enough moisture to permit adequate treatment of the wood. Although additional seasoning is desirable, it is often not economically practical. Many utilities include pretreatment or post-treatment moisture content in their wood-pole specifications. These standards normally range from 20 to 27 percent MC at 5 cm from the wood surface and can vary with the time of year, reflecting the difficulty of complete seasoning during rainy periods.

Air seasoning is by far the simplest and least expensive drying method, but poles continue to be susceptible to fungal and insect attack during this period. Air-seasoned poles must, therefore, be sterilized prior to or during the preservative treatment process to eliminate these organisms. In North America, the use of kiln drying is increasing but the process is energy intensive. Radiata pine and some tropical hardwoods are conditioned by steaming, followed by a vacuum period before treatment with waterborne salts. This method allows wood to be treated while the moisture content is still above the fiber saturation point, but is not suitable for all species and may cause considerable loss of strength. During Boulton seasoning, poles are placed in a treatment cylinder, which is filled with oil. The temperature is raised as a vacuum is drawn, lowering the boiling point of the water and accelerating drying of the wood. This energy-intensive process is widely used to season green Douglas-fir poles (Graham and Womack 1972).

Poles that are to be exposed to the elements should be sterilized during the treatment cycle. Sterilization requires that the center of a pole reach a minimum temperature of 67°C for at least 75 minutes. Poles less than 25 cm in diameter can be sterilized by heating in oil at 87.8°C for at least 1 hour per 2.5 cm of diameter. Longer periods are required for larger poles. Failure to sterilize poles increases the likelihood of incurring maintenance expenses later because of decay fungi already established in the wood.

Methods for Improving Treatment

After treatment or drilling, checking can expose untreated wood to fungal attack (Figure 10). A variety of methods have been developed to minimize the risk of exposing untreated wood
Figure 10. Preservative treatment produces a shell of protection around an untreated core that varies with wood species. Checks that form as the pole dries after treatment can extend beyond the treated shell, permitting the entry of decay fungi and insects.

(Figure 11) (Graham et al. 1969; Helsing and Graham 1976). These include:

- preboring,
- through-boring,
- radial drilling,
- incising, and
- kerfing.

Bolt holes for attachments can expose untreated wood. Either drilling bolt holes prior to preservative treatment or field treating holes drilled after treatment reduces the chance of fungal attack and, ultimately, of pole failure. Most utilities use standard attachment sites and clearances, so holes can be drilled to specification prior to treatment.

Critical groundline zones can be protected by through-boring or radial drilling, which improve the depth of preservative treatment. Through-boring involves drilling a series of parallel, small-diameter holes through the pole perpendicular to the longitudinal axis. These holes are spaced 7 cm to 10 cm apart and are confined to the zone 1 m below and 0.6 m above the groundline.

In radial drilling, 7- to 10-cm-long holes are drilled completely around the pole at 7- to 10-cm intervals above and below the groundline. In Pacific Coast Douglas-fir poles, both radial drilling and through-boring produce almost complete treatment of the drilled zone.

Incising is another way of increasing the depth of preservative treatment. Metal teeth are driven into the wood to depths ranging from 1.9 to 7.5 cm, either along the entire length or in the groundline zone. The teeth expose additional end-grain, which is more receptive to preservative, resulting in better treatment uniformity to the depth of the incision. Incising can only be used in species with heartwood that is receptive to preservative penetration along the grain.

Kerfing is a slightly different approach to the groundline decay problem (Helsing and Graham 1971). A kerf is sawn to the center of the untreated pole beginning at the butt and extending 2 m above the groundline. Kerfing controls checking by keeping the preservative-treated shell intact rather than by increasing treatment depth.

Figure 11. Diagrams of (A) incising, (B) radial drilling, (C) through-boring, and (D) kerfing to enhance treatment in high-hazard zones of the pole.
Each of these methods has some impact on wood strength. Through-boring and radial drilling decrease bending strength by about 10 percent, and kerfing reduces strength by about 5 percent. However, the gains in performance of the pole are well worth those small losses in strength.

Whitewood Inspection

Once a pole has been fabricated, pretreatment inspection can eliminate nonconforming poles. Inspectors should check for the presence of excessively large knots or knot clusters that might fail in service, fungal decay or insect attack, and breaks or large gouges due to poor handling (Figure 12). All of these defects decrease safety and service life of a system. Whitewood inspections can be performed by the treater, but it is worthwhile to perform spot checks with company personnel.

Figure 12. Whitewood inspection should detect (A) spike knots, (B) decay pockets, (C) mechanical damage, and (D) compression breaks.
Treatment Methods

Preservative treatment is designed to achieve a required amount of preservative retention at a specified depth or penetration in the wood. Most utility specifications are results oriented—delivery of the chemical into the wood is left to the discretion of the treater within specified limits. Three basic processes are used to deliver chemicals into wood poles in the Philippines:

- sap displacement (Boucherie) process,
- thermal treatment, and
- pressure treatment—full cell or empty cell.

The sap displacement and the high-pressure sap displacement processes are simple techniques for field treatment of poles. A rubber gasket is attached around the base of the intended tree. The gasket is connected to a reservoir of preservative maintained at atmospheric pressure or pumped to 30 to 50 pounds per square inch (psi), and held for 24 to 72 hours. The combination of the slight pressure on the fluid and the capillary stream of the still-living tree combine to move fluid upward in the sapwood. The sap displacement process has many variations and is used primarily for low-cost native trees far from conventional wood-treating plants. Field trials show that poles treated by these processes provide service lives extending 20 years or more.

Although thermal treatment is not widely used in the Philippines, poles that have been treated by this process (e.g., red cedar poles) are occasionally imported. Seasoned poles are immersed in an oil-borne preservative at temperatures ranging from 70° to 90°C for 16 to 24 hours, and then the oil is replaced by slightly cooler oil. The cool oil on the hot wood surface creates a slight vacuum, drawing additional chemical into the wood. This process works best with thin-sapwood species that have naturally durable heartwood. Where pressure treatment is not possible, thermal treatments provide a more uniform treatment than cold or hot soaking.

Pressure treatments, divided into full-cell and empty-cell processes, are carried out in pressure cylinders or retorts (Figure 13). Retorts are equipped with pressure and vacuum pumps and an array of gauges to control treatment conditions and measure preservative uptake by the wood. Treating plants can be controlled manually or by computer. Plants using oil-borne preservatives are also equipped with steam systems and often have steam coils in the retort to maintain solution temperature over the treatment cycle.

In the full-cell treatment, the wood is placed into a retort, the door closed, and a vacuum drawn to remove as much air as possible from the wood. Treating solution is added under vacuum and the pressure is slowly raised and held until the desired amount of chemical is forced into the wood. When the appropriate gross retention has been achieved, pressure is released and the solution is pumped out. The wood is then subjected to a series of steaming and vacuum cycles to recover excess solution, to reduce bleeding of preservative from the wood once the pole is in service, and to give the pole a better appearance. The full-cell process is designed to deliver a maximum amount of chemical into the treated zone and is often used for treatments with waterborne wood preservatives or for marine treatments with creosote solutions.

The initial vacuum phase is omitted in the empty-cell process which begins at, or slightly above, atmospheric pressure (30 psi). Preservative solution is added and the pressure is raised, compressing air as preservative is forced into the wood. The air expands rapidly after treatment, carrying excess preservative out of the wood by a process called "kickback". Variations on the empty-cell process affect the degree of kickback and therefore the retention. Empty-cell processes are most commonly used to treat wood with oil-borne chemicals and are designed to produce lower retentions of chemical for a given depth of treatment.
Wood Preservatives

Wood preservatives are, by their nature, toxic and must be handled carefully. In the Philippines, the Food and Drug Administration regulates preservatives and evaluates each chemical before deciding if its use is safe and warranted. Warning labels, developed to ensure safe handling, should always be read. Pesticides are under the authority of the Fertilizer and Pesticide Authority. Questions regarding application of a preservative or pesticide should be addressed to the appropriate agency.

Preservatives commonly employed for initial wood-pole treatments include: creosote; oil-borne pentachlorophenol and copper naphthenate; and waterborne formulations of arsenic, copper, zinc, and chrome. Each chemical has advantages and disadvantages for a given utility. In the Philippines, poles are specified under the Philippine Standards Association (PHILSA) (1974, 1975, 1976). Other preservative standards used on a world wide basis include those from the American National Standards Institute (ANSI) (1972); the American Wood Preservers' Association (AWPA) (1991); the British Standards Institution (BSI) (1991); and the Japan Standards Association (1982). Each of these standards establishes minimum preservative penetration and retention requirements for a given commodity (Table 1). Utilities may increase the rigor of a specification at their discretion, but each utility must weigh the cost of such changes against the anticipated increase in pole performance.

### Creosote

Creosote, patented in 1836, is our oldest wood preservative and is a by-product of the destructive distillation of coal to produce coke for

<table>
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<tr>
<th>Species</th>
<th>Sapwood thickness (cm)</th>
<th>Penetration (%)</th>
<th>Assay zone (cm)</th>
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<th>Penta&lt;sup&gt;c&lt;/sup&gt;</th>
<th>Creosote (As Cu)</th>
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<sup>a</sup> Sources include the Philippine Standards Association (1975), and the American Wood Preservers' Association (1991).

<sup>b</sup> CCA = chromated copper arsenate; ACZA = ammoniacal copper zinc arsenate.

<sup>c</sup> Pentachlorophenol in the Philippine standards is specified as a 5 percent solution, and 192 kg/m<sup>3</sup> of this solution must be in the assay zone.

<sup>d</sup> Philippine hardwoods include apitong, bagtikan, tangile, white lauan, red lauan, coconut, and Eucalyptus. These woods are not segregated for treatment.

<sup>e</sup> For tropical exposures, the use of radial drilling or through boring to improve the depth of preservative treatment is strongly advised. Where used, penetration should be required to the depth of drilling, and the inner assay zone should contain 4.8, 4.8, 1.2, or 96 kg/m<sup>3</sup> of CCA/ACZA, pentachlorophenol, copper naphthenate, or creosote, respectively.
steel production. It is a complex mixture of over 300 components, including many polynuclear aromatic hydrocarbons, but its toxicity is poorly understood. Although creosote-treated poles provide excellent service—in one instance for over 80 years—their use has declined with the development of cleaner and equally effective preservatives. Skin burns caused by creosote can be minimized through application of commercially available sunscreens.

**Oil-borne Preservatives**

- Pentachlorophenol (penta) was among the first of the synthetic wood preservatives and was once the most widely used. Penta is easily synthesized by chlorinating phenol to produce a compound with broad-spectrum toxicity to fungi and insects. This process produces trace amounts of dioxins, a class of compounds containing a number of potent carcinogens. Although these carcinogens have not been found in the dioxins in penta, many countries have banned or severely restricted penta use.

- Copper naphthenate was developed in the 1940’s as a replacement for penta. Its high cost limited its use, but with penta under increasing environmental scrutiny, interest in copper naphthenate is reviving. It is produced by complexing naphthenic acids, derived from the refining of petroleum, with copper. In field trials, copper naphthenate has provided slightly less protection than comparable amounts of penta, but its toxicity to humans is far lower, and it has no dioxins. As utilities experiment with test lines of poles treated with this chemical, its acceptance is increasing.

A factor to be considered with oil-borne treatments is the role of the oil carrier. In general, heavier oils containing higher levels of aromatic components provide greater protection against fungal attack. Wood treated with preservatives in light solvents tends to be more susceptible to surface decay by soft-rot fungi. This effect was clearly borne out by the soft-rot damage found when penta was used in liquified petroleum gas instead of in heavy oils. While the treatment was attractive, the lack of residual solvent allowed soft-rot attack to proceed rapidly. This solvent effect is even more critical under the extreme decay hazards prevalent in the Philippines.

**Waterborne Preservatives**

Many utilities have actively explored the use of waterborne preservatives because the solvent is inexpensive and treated wood is clean, dry, and paintable. Waterborne preservatives currently employed for treating wood poles include chromated copper arsenate (CCA), chromated copper borate (CCB), and ammoniacal copper zinc arsenate (ACZA).

- Chromated copper arsenate was developed in India in the 1930’s, and its use has grown dramatically since 1970. Each component of CCA serves a different function. Copper is an excellent fungicide, arsenic provides insect protection as well as protection against copper-tolerant fungi, and chromium is a fixative. Once CCA contacts the wood, it undergoes a series of complex reactions to fix to the wood and resist leaching. Service tests for over 50 years attest to the excellent performance of this preservative. Disadvantages include a tendency to make the pole hard (and therefore difficult to climb) and its susceptibility to slow, glowing combustion. The heat of a grass fire around a pole can ignite the chromium, which continues to burn slowly until the pole fails. Despite these drawbacks, CCA treatments are widely used for wood poles. Some utilities use aluminum wraps to protect poles in fire-prone areas, but these shields may trap moisture, increasing the risk of fungal attack.

- Chromated copper borate, developed as an arsenic-free alternative to CCA, is used in Europe and India. CCB appears to be slightly less effective than CCA for ground contact.

- In ammoniacal copper zinc arsenate, ammonia maintains solubility of the metal components. Once the ammonia evaporates, the chemicals precipitate in the wood, leaving a clean, paintable surface. ACZA is used primarily along the West Coast of the United States for treatment of Douglas-fir poles. The ammonia and a slightly warmer solution temperature combine to improve treatment of difficult-to-treat species. Like CCA, ACZA tends to make the poles harder to climb than do oil-borne treatments. This problem can be overcome by changes in gaff design and by keeping hooks sharp.

Various new preservatives are under development. Unfortunately, preservative development
Post-treatment Inspection

After a pole has been treated, the next phase in quality control is a thorough inspection. The pole is examined for defects that either have been overlooked or have developed since the earlier inspections. Increment cores are removed to determine the depth of preservative penetration (Figure 14). Cores from a given treatment charge should be combined and analyzed to ensure that the desired preservative retention has been achieved. While many standards call for inspection of a limited number of poles per charge, the cost of the pole is so small compared with cost of installation that inspecting every pole for penetration is recommended and pays off in system reliability. Poles that fail to meet the penetration requirements should be retreated, providing the treatment conditions do not exceed the process limitations for that wood species or product. Some utilities restrict the number of times a pole may be retreated. All poles in charges that fail to meet the retention requirements should likewise be treated again.

Pole Maintenance Program

Despite the creation and implementation of rigorous standards, a certain percentage of wood poles eventually deteriorate. Ignoring these poles threatens the safety and reliability of the entire system. Effective maintenance programs, in which physical inspections are made at regular intervals to detect damaged poles before they fail, are far less expensive than emergency replacement plus the loss of revenue while power is out.

The purpose of inspection is to identify damaged or deteriorating poles and to assess their residual strength to determine if they should be replaced. Many utilities use relative guides to residual wood strength based on the thickness of the remaining sound wood shell. Although not completely accurate, such guides do help in deciding whether to save or reject a pole.

Inspection for decay is a combination of art and science, and should be performed by someone familiar with wood. The best training method is to identify poles that are going to be removed from service and then have trainees perform inspections using standard techniques. Once they have made their decisions, poles are cut at points where defects were identified to determine the accuracy of the assessments. This activity permits inspectors to learn from the process and is useful for gauging the reliability of the inspection methods.

A number of tools are available for detecting advanced decay, but none is uniformly reliable (Graham and Helsing 1979, Rural Electrification Administration 1974), so a combination should be used to detect the various possible decay patterns (Figure 15).

Tools can be classified as mechanical, electrical, or acoustic. Mechanical devices are the most commonly used and include hammers, drills, increment borers, and shell-depth indicators. Tools can be further divided by their ability to detect external or internal defects. None of those currently available can detect incipient or early decay and most cannot detect intermediate damage.
External Defect Detection

External decay is more easily detected than is internal, although some probing may be necessary to fully delineate the extent of damage. The inspector should look for beetle exit holes, nearby termite mounds, and the presence of surface wood with cross-breaks suggesting decay. Surface damage usually occurs below the groundline, making it necessary to excavate, generally to a depth of 45 cm. The surface can then be probed for soft spots with either a pointed pick or a small paint scraper. Inspectors must be careful to distinguish decaying wood from soft and wet, but sound, wood. In the pick test, a pointed awl is driven a short distance into the wood and then a piece is snapped out (Figure 16). Clean, brashy breaks suggest decay, while more fibrous breaks reflect sound wood. Alternatively, the surface can be scraped and examined for evidence of softened wood.

Surface decay can also be assessed with a spring-driven pin-penetration device called a Pilodyn (Figure 17), which was developed to estimate specific gravity of trees. A steel pin is driven into the wood at a known force. The depth of penetration can be related to soundness of the wood after corrections for wood moisture content. Pilodys have been widely used in Europe for detecting and assessing surface damage. An advantage over scraping and picking is that the Pilodyn gives a base measurement against which later measurements can be compared to determine if decay is advancing.

Internal Defect Detection

Sounding

The most basic method of detecting internal defects is by sounding a pole with a hammer at regular intervals from the groundline to as high as the inspector can reach (Figure 18). A dull thud indicates the presence of an internal de-
Drilling

If sounding indicates a defect, three or four holes are drilled at a steep downward angle beginning at groundline and spiraling around the pole at 120° intervals and upward at 15- to 30-cm intervals (Figure 19). Drill bits of about 1.9-cm diameter are employed. The resulting hole can be used for adding supplemental treatments after inspection. The angled hole increases the likelihood of detecting voids and permits examination of the wood zone below groundline. It may be necessary to excavate the pole prior to drilling to evaluate zones deeper in the ground. As the drill enters the wood, inspectors should listen for increased drill speed or torque release, which indicates softer, potentially decaying wood. They should also examine drill shavings for evidence of decay. Shavings from sound wood are generally larger than those from decaying wood and are not easily broken.

Taking Increment Bores

Increment borers are hollow steel bits that extract a solid wood core from the pole (Figure 20). The core can be examined to determine depth of preservative treatment, examined for the presence of advanced decay, analyzed for preservative content, or cultured on nutrient media for the presence of decay fungi. When a utility is first
beginning a program, performing some inspections with an increment borer can help inspectors locate sites of typical defects. The presence or absence of fungi provides a guide to the condition of the wood-pole system.

**Measuring Shell Depth**

Measuring the depth of solid wood in inspection holes helps to determine if a pole can support the load it was intended to carry. Shell-depth indicators are long metal rods inscribed along their length and hooked at the end (Figure 21). The rod is inserted to the bottom of the treatment hole and then slowly withdrawn along the side of the hole until sound wood is reached. As long as care is taken to ensure that the wood being measured is sound, the shell-depth indicator provides a good estimate of residual shell depth.
Figure 21. A shell-depth indicator can be used to measure the depth of the residual shell.

Electrical inspection

Several devices use changes in electrical properties of decaying wood to detect defects. Some are claimed to detect incipient decay, but comparative tests have not substantiated this. The simplest of these devices is the electrical-resistance moisture meter (Salamon 1971, James 1975) which measures electrical resistance between two plastic coated metal pins driven into the wood (Figure 22A). Moisture meters are generally reliable between 7 and 22 percent MC. The device does not detect decay, but only suggests where it might occur. Generally, readings above 20 to 25 percent suggest that moisture conditions favor decay development. Electrical devices are unreliable when inspecting wood treated with CCA or ACZA, since metal ions affect electrical resistance (James 1976). The moisture meter cannot be used with pins longer than 7.5 cm, which limits its inspection depth.

A second electrical inspection device employed by some utilities is the Shigometer (Shigo et al. 1977), which also measures electrical resistance but uses a twisted wire probe inserted into a hole drilled into the wood (Figure 22B). The Shigometer is based on the principle that decay fungi release ions as they degrade wood, thereby decreasing electrical resistance. Drops in electrical resistance shown by the meter indicate zones of decay that can then be subjected to a more detailed drilling inspection. The device has worked well in living trees, but it is not widely used for poles because differentiation between decay and moisture-content variation along a pole is difficult.

Figure 22. Electrical decay-assessment devices include the (A) electrical-resistance moisture meter, and (B) the Shigometer.

Acoustic Inspection

Increasingly sophisticated acoustic devices are being used for wood pole inspection. The simplest example of acoustic decay detection is sounding the pole with a hammer. In principle, as sound moves through wood, the characteristics of the wood alters the sound wave (Figure 23). The changes to this wave can be used to detect defects or to estimate residual strength. Large defects can be detected because as the sound wave travels through the wood, it must pass around the void. As a result, the time it takes to reach the other side of the wood will increase and this change can be detected by measuring time of flight of the sound wave. This only determines that some type of defect is present and further physical inspection is
required to identify the nature of the defect more fully. For example, these devices cannot distinguish between decay pockets and other defects that create voids, such as ring shakes.

Measuring how long a sound wave takes to cross a pole is better than simple sounding. Time-of-flight acoustic inspection devices have been used for many years with mixed success. A sound wave transducer is attached to one side of the pole and a receiver to the other near the groundline (Figure 24). The signal is sent and the time of flight is compared with that for a sound pole of the same diameter and species. Multiple tests around the pole are usually required.

Recently, inspection devices have been developed to measure modulus of elasticity by taking into account both the time of flight of a sound wave and the degree to which it is altered as it moves through the wood. Wood contains many features that alter sound waves, including growth rings, knots, shakes, and, of course, fungal and insect damage. Each of these conditions alters the

Figure 23. Examples of acoustic signals from sound and decayed wood. Sound waves moving across a wood cross section are affected by a number of wood properties that slow and alter the sound wave.

Figure 24. A number of sonic inspection devices are available for wood poles including (A) Pole Test and (B) the De-K-Tector.
their accuracy has been challenged, but they do illustrate increasing sophistication in wood-pole inspection systems.

Pole-system Inspection

The timing and extent of an inspection depends on how well the inspector knows the wood-pole system, including geographic and climatic features of the region, species and ages of the poles, types of preservative treatments, and prior inspection records (Goodell and Graham 1983). Inspection before failures occur is critical because remedial treatments are more effective on sound wood. In temperate climates, inspection cycles normally range from 8 to 15 years. In tropical regions, where fungal and insect hazards are more severe, inspections should be made more often. Initially, it may be advisable to inspect a representative portion of the system every 3 to 5 years to develop data on the rate of decay in the system. The relationship of the incidence of decay and insect attack to the quality of preservative treatment and age of the poles can be used to identify portions of the system that should be more carefully examined. This sample will also determine the need for additional inspections, digging inspection for surface decay, external supplemental treatments, and internal remedial treatments.

The number of poles initially sampled depends on prior knowledge of the system. If little is known about the treatments and condition, the U.S. Rural Electrification recommends inspecting a minimum of 1,000 poles in continuous pole-line groupings of 50 or 100 poles in several areas of the system. The percentage of poles rejected and deteriorating provides a measure of the scope and nature of the pole-maintenance program.

Ground inspection may be modified to reflect conditions in a particular wood-pole system, but should include the following activities:

- **Examining pole condition above ground.** Note the general condition, including damage to the pole or its attachments and seasoning checks that extend below groundline. In general, the wider the checks, the deeper they penetrate and the more likely they are to expose untreated heartwood. Look for round or elliptical holes made by emerging beetles, external termite tunnels, and woodpecker damage. Probe the wood for decay just below the surface.
- **Sounding.** Sound the pole with a hammer starting near the widest check at the groundline and reaching as high as possible. Hollow-sounding poles should be inspected further to determine the extent of damage. Sounding should never be the only technique used because often decaying poles are not detected.
- **Drilling.** After sounding, drill downward at a 45° angle near the groundline, starting near the widest check. Listen for speed changes in the drill that might indicate softer wood. Also, examine the shavings for the fine particles or discoloration typical of decay. After drilling, measure preservative penetration and use a shell-depth indicator to determine the shell thickness. Instead of drilling, an increment core can be removed and examined for decay and preservative penetration. Inspectors often make three borings at equidistant sites around the pole, beginning adjacent to the largest check and spiraling upward at 15- to 30-cm intervals. If the pole is sound, the inspection is complete and all holes can be plugged. If decay or insect attack is found, further coring to determine the extent of damage may be necessary. Drill holes at higher points on the pole until sound wood is reached. Poles with a very shallow shell or with large internal voids extending above the groundline should be marked for immediate replacement so that linemen do not climb them.
- **Digging.** To check for surface rot, expose the pole to a depth of 45 cm. Brush away the dirt and probe suspicious areas with a dull tool or shovel. Remove as much softened wood as possible and use a tape to measure the residual circumference of the pole. Determine from minimum circumference tables if the pole should be replaced, remedially treated, or reinforced.
- **Treating holes or cuts made during inspection.** Unless supplemental treatments are to be applied, all cuts or borings should be treated with a concentrated preservative solution or paste. Bore holes should be plugged with tight-fitting, preservative-treated dowels. Wear goggles and gloves during application because preservative can squirt out as the plugs are driven in. Appropriate preservatives include 10 percent pentachlorophenol and 2.0 percent (as copper) copper naphthenate in diesel oil.
Remedial Treatment

The three possible outcomes of inspection are that the pole is sound and can continue in service; that the pole is too badly damaged to save and must be replaced; or that the pole has some damage, but still has years of useful life. Poles in the third group need supplemental preservative treatments, but it may also be a good idea to consider additional treatment of sound poles.

External Preservatives

Preservative treatments are applied to the wood surface as sprays above or at the groundline or as pastes below ground. Chlordane or chlorpyrifos is often applied to the soil around the base of poles to provide a barrier against subterranean termites. These sprays need to be reapplied at 5- to 10-year intervals. Sprays are also useful above ground when the zone to be protected is shallow. The wood surface should be flooded with preservative (Figure 25). In North America, 10 percent pentachlorophenol or 2 percent copper naphthenate sprays applied at 10- to 15-year intervals have significantly improved the surface condition of western redcedar poles.

Pastes are used to control soft-rot attack. They normally include waterborne chemicals that diffuse into the wood to eliminate fungi established near the surface and oil-borne chemicals that stay near the surface to create a barrier against renewed attack. As much decayed wood as possible is scraped away from the wood surface, without removing sound material. The preservative paste or grease is brushed or dabbed on the surface to the recommended thickness and then a plastic or paper wrap is applied to keep the chemicals close to the pole (Figure 26). Care should be taken to avoid tearing the wrap during backfilling. Most wraps are applied to a zone extending from a few centimeters above the groundline to about 45 cm below ground, but deeper bandaging is sometimes necessary. Preservatives include pentachlorophenol, creosote, copper naphthenate, sodium fluoride, sodium arsenate, sodium dichromate, and sodium octaborate tetrahydrate. Insecticides may be added, but these are not very effective because they do not penetrate the wood.

External preservatives may also be applied to poles being moved to new locations or to those that are to be embedded in concrete, where subsequent inspection is difficult. Some utilities ap-
ply bandages to poles whenever they perform an excavation inspection in the belief that digging disrupts the protective zone of soil formed by preservatives leaching from the wood. There is little evidence to support this. In many cases, however, a supplemental preservative treatment improves the reliability of the pole at a small overall cost. In temperate climates, wrap systems are reapplied at 10- to 15-year intervals; however, more frequent supplemental treatments may be necessary in tropical regions. Inspecting selected wrapped poles for renewed surface decay is the best way to decide on retreatment schedules. Where necessary, samples can be removed and analyzed for chemical content to assess the residual degree of protection.

Internal Preservatives

Treatments applied for internal damage by fungi or insects do not generally control external decay and should be used in combination with a preservative bandage where necessary. Internal treatments are separated into two broad groupings: those that do not move far from the point of application and those that move some distance through the wood as gases or liquids. The former are called void treatments and usually consist of an oil-borne preservative and an insecticide. The treatment is pumped or poured into an inspection hole drilled directly into the void and is intended to coat and protect the void from further attack. Typical treatments contain pentachlorophenol or copper naphthenate in diesel oil with chlorpyrifos, chlordane, or lindane as the insecticide. These treatments are efficient where the void can be treated directly.

Decaying poles are sometimes treated with chemicals that diffuse as liquids or gases through the wood for some distance from the point of application (Graham 1973, Morrell and Corden 1986). Diffusible gases and liquids must be applied to sound wood above or below the void to be most effective.

In Europe, rods or pastes impregnated with water-soluble chemicals are used to arrest decay in window frames and railway sleepers (ties). This method has been adapted for utility poles. Rods are inserted into inspection holes, which are then plugged with tight-fitting, preservative-treated doweling. Water present in the wood releases the chemical from the rods, and it diffuses through the wood. Field trials on two formulations—one based on sodium octaborate tetrahydrate (Impel) and the other based on sodium fluoride (Woodpil)—suggest excellent diffusion, but the protective period provided by these treatments has not yet been determined.

Fumigants are chemicals that are applied as liquids but become gases, allowing them to move through even the most impermeable wood. The liquid chemical is poured into the holes used for internal inspection. Treatment holes should spiral upward from the groundline because a large number of holes in the same plane severely reduces pole strength. The number of holes depends on the circumference, so that large poles receive more chemical because they have more holes (Table 2).

Once the holes are plugged, the liquid becomes a gas, which diffuses through the wood. The conversion of liquid to gas occurs over a 1-month period in temperate climates, but should occur more rapidly under tropical conditions. Complete diffusion across the cross section occurs fairly rapidly after treatment. Longitudinal diffusion up to 3.6 m from the point of application has been reported. The chemical eliminates decay fungi established in the wood. Some chemicals may remain in the wood for a long time after treatment (Helsing et al. 1984). In the western United States, fumigants have been detected in wood poles 20 years after treatment; however, residual times under more severe tropical conditions are very much shorter (Morrell and Giron 1987). Dosages used in remedial treatment do not appear to be sufficient to control termite or beetle attack unless the fumigant enters a nest or gallery directly as a liquid, and the chance of this occurring is low.

Four fumigants are used for wood-pole treatments. Of these, metham sodium is by far the most common chemical, primarily because of its ease of handling. Only metham sodium and methylisothiocyanate (MITC) are registered for wood use in the Philippines, but all four fumigants are discussed for reference purposes.

- Metham sodium (32.1 percent sodium n-methyldithiocarbamate) is not a good fungicide by itself, but once it contacts the wood, it decomposes to produce MITC, a potent fungicide. This chemical then diffuses through the wood to eliminate established decay fungi. Although metham sodium is caustic and burns the skin on contact, it is generally easy to
TABLE 2. Diameter, length, and number of holes required to deliver fumigant, by pole circumference and fumigant dosage.

<table>
<thead>
<tr>
<th>Hole size</th>
<th>Diameter (cm)</th>
<th>Length (cm)</th>
<th>&lt;80 cm poles, 500-ml dosage</th>
<th>80-113.5 cm poles, 750-ml dosage</th>
<th>&gt;113.5 cm poles, 1000-ml dosage</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1.5</td>
<td>37.5</td>
<td>8</td>
<td>11</td>
<td>16</td>
</tr>
<tr>
<td></td>
<td>45.0</td>
<td></td>
<td>6</td>
<td>9</td>
<td>12</td>
</tr>
<tr>
<td></td>
<td>1.9</td>
<td>37.5</td>
<td>5</td>
<td>7</td>
<td>10</td>
</tr>
<tr>
<td></td>
<td>45.0</td>
<td></td>
<td>4</td>
<td>6</td>
<td>8</td>
</tr>
<tr>
<td></td>
<td>52.5</td>
<td></td>
<td>4</td>
<td>5</td>
<td>7</td>
</tr>
<tr>
<td></td>
<td>60.0</td>
<td></td>
<td>3</td>
<td>5</td>
<td>6</td>
</tr>
<tr>
<td></td>
<td>2.1</td>
<td>52.5</td>
<td>3</td>
<td>4</td>
<td>6</td>
</tr>
<tr>
<td></td>
<td>60.0</td>
<td></td>
<td>3</td>
<td>4</td>
<td>5</td>
</tr>
</tbody>
</table>

*Values have been rounded upward.*

handle, particularly under tropical conditions. Unfortunately, the protective period provided by this chemical is shorter than that for the other fumigants available and it has no apparent effect on insect infestations.

- Vorlex (20 percent MITC in chlorinated C3 hydrocarbons) has been used on a limited basis for treatment of wood poles in North America, but its high volatility and toxicity make it difficult to handle. Vorlex is long lasting, still providing protection to Douglas-fir poles 20 years after treatment. Preliminary studies suggested that it might be effective against wood-boring insects, but field trials were unsuccessful.

- Methylisothiocyanate is the most recently developed chemical for wood-pole treatment and is the active ingredient of both metham sodium and Vorlex. MITC is one of the most effective wood fumigants and has a protective period exceeding 13 years in temperate climates. The risk of spilling during application is decreased because it is normally a solid at room temperature. However, its melting point is 35°C, a temperature often reached in tropical environments, so storing treatment vials on ice prior to treatment is recommended.

Field trials of MITC under tropical conditions are now underway.

- Chloropicrin (96 percent trichloronitromethane), a highly volatile tear gas, is the most effective fumigant for wood treatment, providing protection against renewed fungal attack for over 20 years. Its high volatility makes application difficult, but chloropicrin can be used safely in situations away from inhabited areas, such as on long-distance transmission poles in North America.

An advantage of fumigants is that treatments can be repeated at regular intervals using the original treatment holes, eliminating loss of strength when new holes are drilled. Their major disadvantages are the risk of worker exposure due to spilling during application or loss of chemical where treatment holes inadvertently cross checks. In temperate climates, using MITC reduces the risk, but its low melting point makes it less attractive in tropical regions. Further studies are underway to identify solid chemicals for fumigant treatment of wood poles.

Wood poles in temperate climates have been subjected to remedial treatments for many years, so transfer of that technology to the more severe decay environments of the tropics should be relatively straightforward. Unfortunately, preliminary
tests suggest that treatments provide much shorter residual protection under tropical conditions. Although remedial treatments may help to retain scarce wood poles and maintain reliable power, the dosage level and frequency of retreatment may need to be adjusted. Utilities are strongly advised to establish controlled tests on poles in their systems to develop more precise retreatment cycles.

Pole Reinforcement

In many instances replacing a pole may be less expensive than restoring it, but reinforcement may be an option for poles that carry a heavy load of conductors or that are in difficult-to-reach locations. Reinforcement can be accomplished in a number of ways (Figure 27). In the simplest case, a pole stub is driven into the ground as near the decaying pole as possible and attached with metal bands, which are then tightened. The bands transfer the load from the old pole to the stub, restoring some of the original strength to the structure. Many utilities routinely stock short, preservative-treated sections for this purpose. A more advanced method is a metal c-brace, which is also driven into the ground next to the pole and attached using metal bands to transfer the load, but has the advantage of leaving most of the pole accessible for future maintenance. Recently developed reinforcement systems include epoxy-reinforced fillers, metal-reinforcement casings, and fiberglass wraps. In each of these systems, wood-reinforcement bonding is critical for load transfer and wood moisture content can severely reduce strength development.

Figure 27. Poles can be reinforced by use of (A) short pole stubs, (B) c-braces, and (C) steel cases.
Reinforcement systems are costly and not amenable to the small-diameter poles typical of the Philippine electric system, although they may have limited application for selected high value structures. When reinforcement is considered, it is important to arrest existing insect or fungal problems to prevent further loss of strength.

Record Keeping

A lack of program continuity can be a major problem in a utility system because many actions and decisions have long-term implications. For example, a pole is often scheduled for inspection and retreatment 3 to 10 years after the original inspection, so future inspectors need to be provided with adequate documentation. Record keeping should be implemented in a way that permits regular updating and access to information. Record keeping once meant maintaining large books of pole records and meticulously adding new data, a task most utilities chose to ignore. The availability of personal computers has made this task simpler. Utilities can adapt spread sheets to their particular situations and, by careful coding, can permit searches for specific poles in a system. A simple record-keeping system can in that way identify poles most in need of action and thus save the utility money.

Over time inspectors gradually become more knowledgeable about wood defects, and their accuracy in evaluating structures increases. Regular training sessions, where linemen learn about the latest information on inspection techniques, chemical safety, and wood properties can speed up this process. Training sessions can also provide feedback from inspectors, identifying problems with the system. Many utilities use slow work periods for these sessions.

Literature Cited


JAMES, W.L. 1976. Effects of wood preservatives on electric moisture meter readings. USDA Forest Service, Forest Products Laboratory, Madison, WI, USA. Research Note FPL-0106. 20 p.

JAPANESE STANDARDS ASSOCIATION. 1982. Preservation treatments of wood by pressure processes. Japanese Industrial Standard. JIS A9002-


Appendix: Selected Information on Wood and its Preservation

This list of reference materials developed as an outgrowth of numerous workshops held for groups of major consumers and producers of treated wood products that are used in adverse environments. The references are listed alphabetically by title for eight topics: wood, seasoning, decay, insects, preservation, maintenance, specifications, and service records. Several items are available from the six U.S.A. sources listed and numbered below. Corresponding numbers, or other sources, are given with the citations.

Sources

1. American Wood-Preservers’ Institute
   1651 Old Meadow Road
   McLean, VA 22101
2. Superintendent of Documents
   U.S. Government Printing Office
   Washington, D.C. 20402
3. Forestry Publications Office
   College of Forestry
   Oregon State University
   Corvallis, OR 97331-5708
4. Publications Orders Agricultural Communications
   Oregon State University
   Administrative Services A422
   Corvallis, OR 97331-2119
5. USDA Forest Service Forest Products Laboratory
   P.O. Box 5130
   Madison, WI 53705
6. Forestry Media Center
   College of Forestry
   Oregon State University
   Peavy Hall 248
   Corvallis, OR 97331-5702

Wood

— Canadian wood, their properties, and uses. 1951. 367 p. Published by: Controller of Stationery, Ottawa, Canada.

Seasoning


This slide-tape package (114 slides, 35 minutes) details the anatomy of wood, how preservatives are retained, and why wood shrinks and swells.

— Western woods use book. 1973. 316 p. Published by: Western Wood Products Association, 1500 Yeon Building, Portland, OR 97204, USA.

This book includes structural data and design tables, with chapters on wood preservation and fire protection.


This is an invaluable storehouse of information about wood.


Decay


Insects


— Termites and termite control. 1934. Edited by C.A. Kofoid. 734 p. Published by: University of California Press, Berkeley, CA, USA.

This out-of-print book is a source of extensive information on termites.


Preservation

— A guide to establishing a pressure-treating plant for small sawed and round wood products in Colorado. 1971. By K. Kilborn, 50 p. Published by: Department of Forest and Wood Sciences, Colorado State University, Fort Collins, CO 80521, USA.


— Annotated bibliography on prevention and control of decay in wooden structures (including boats). 1971. By T.L. Amburgey. 123 p. Published by: Southern Forest Experiment Station, USDA Forest Service, P.O. Box 2008, Gulfport, MS 39502, USA.


5 List of publications on wood preservation. 1974. 9 p.

— On the antiseptic treatment of timber. 1884. By S.B. Boulton. Minutes of Proc., Institution of Civil Engineers (London) 78:97-211.

This wood preserver's "gem" is well worth the search.


This slide-tape package (94 slides, 28 minutes) covers theoretical aspects of fluid flow as related to the treating process, movement of preservatives through wood, and practical aspects of preservation.


This slide-tape package (121 slides, 24 minutes) discusses the uses of pressure-treated wood, how wood is prepared for treating, and how the treating processes work.


These volumes, detailed analyses of available knowledge by 17 authors, include numerous references plus recommendations for future research.


This slide-tape package (80 slides, 22 minutes) briefly explains the principal concepts of the structure, drying, and pressure treating of wood.

**Wood preservation minicourse.** Undated. By R.D. Graham. $25 to rent, $140 to purchase.

This slide-tape package (144 slides, 45 minutes) provides a condensed explanation of wood structure, how wood dries, penetration of preservatives into wood, and pressure wood-preserving processes.

### Maintenance


- **Methods for inspection of standing poles in overhead lines.** 1959. By Transmission
and Distribution Committee. 20 p. Published by: Edison Electric Institute, 90 Park Ave., New York, NY 10016, USA.


Specifications


This book, updated periodically, gives national standards for treated wood products and the chemicals used to preserve them.


Service Records


This publication lists agencies engaged in testing treated materials. It also includes the results of extensive tests of untreated and treated posts of many woods.


This manual is designed as a user's guide to wood pole maintenance in the Philippines, where tropical conditions create an environment conducive to decay. Basic information is provided on the properties of wood, including native hardwoods, and on fungi and insects as agents of biodegradation. The manual covers methods of preserving poles, pole maintenance, pole-system inspection, and remedial treatments. The appendix lists pertinent publications.
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