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Wood Pole Maintenance Manual
(1996 Edition)

by

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College of Forestry

Forest Research Laboratory
Oregon State University

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The Author

Jeffrey Morrell

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Introduction

Wood poles have been used for over a century to support telephone and electric lines throughout North America. In the beginning, poles of selected species such as American chestnut (*Castanea dentata*) and western redcedar (*Thuja plicata*) were used untreated. Those naturally durable woods provided reasonable service life, but as utilities rapidly expanded their systems, increased demand for poles forced a switch to alternative species. The alternative species had good mechanical properties but generally lacked natural durability; thus, they required supplemental treatment.

Wood species differ widely in the degree to which they accept treatment. Those differences result in variations in performance, which affect decisions on how to maintain poles for maximum service life. Maintaining wood poles to maximize service life involves the development of good specifications for treatment, inspection after treatment to assure conformance to the standard, a well-developed inspection program to detect poles that are decaying in service, and a program to supplementally protect decaying poles. This manual describes the properties of wood used for poles, methods of treatment, and the process of inspection and remedial treatment. Although these guidelines were specifically developed for Douglas-fir (*Pseudotsuga menziesii*), western redcedar, and southern pine (*Pinus* spp.), they can be applied to poles of virtually all coniferous species.

Wood

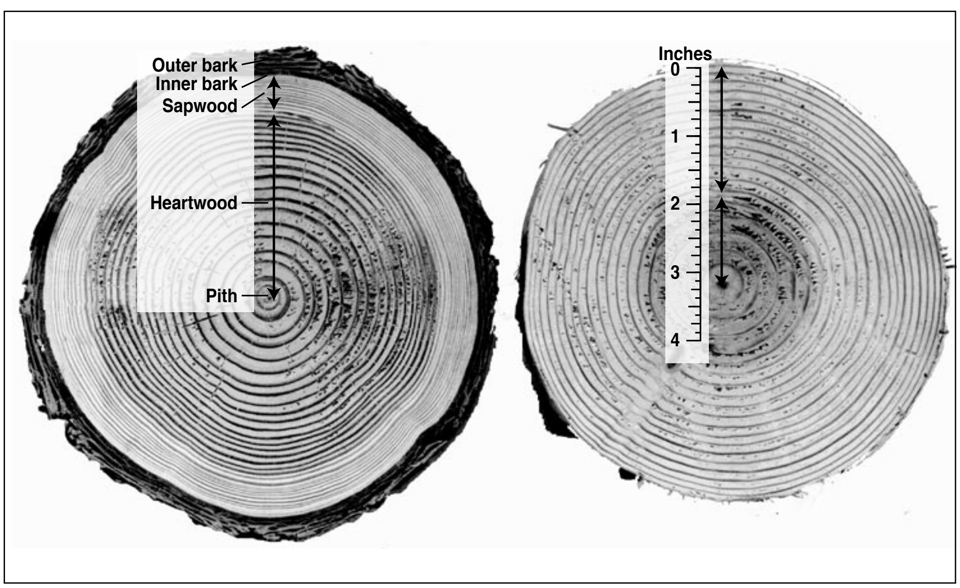

Figure 1. Cross sections of Douglas-fir show typical sapwood (left) and deep sapwood (right).

When you cross-cut almost any Douglas-fir, southern pine, or western redcedar log, you will see that the tree is divided into distinct zones (Figure 1). The outer and inner bark, which can be peeled away, protect the tree from fungi and insects, and from drying. Bark is normally removed from poles during processing because it attracts many wood-boring insects, retards drying, and prevents preservative treatment. Inside the bark layer is the sapwood, a normally white-to-cream-colored band of wood in which fluids move up and down the living tree.

Inside that zone is the heartwood, which consists of older, dead sapwood. Heartwood of many species is red or brown and may be more durable than the sapwood.

Sapwood depth varies widely within and among wood species, depending on the health of the tree. Sapwood of western redcedar is thin, rarely exceeding 3/4 in.; sapwood of Douglas-fir is somewhat thicker, ranging from 1 to 3 in. The thickness of Douglas-fir sapwood may be increasing as timber is more intensively managed to encourage growth. Sapwood of southern pine and ponderosa pine (*Pinus ponderosa*) is extremely thick, ranging from 3 to 5 in. Sapwood can often be distinguished from heartwood through the use of chemical indicators, which is based upon differences in pH between sapwood and heartwood (AWPA 1995).

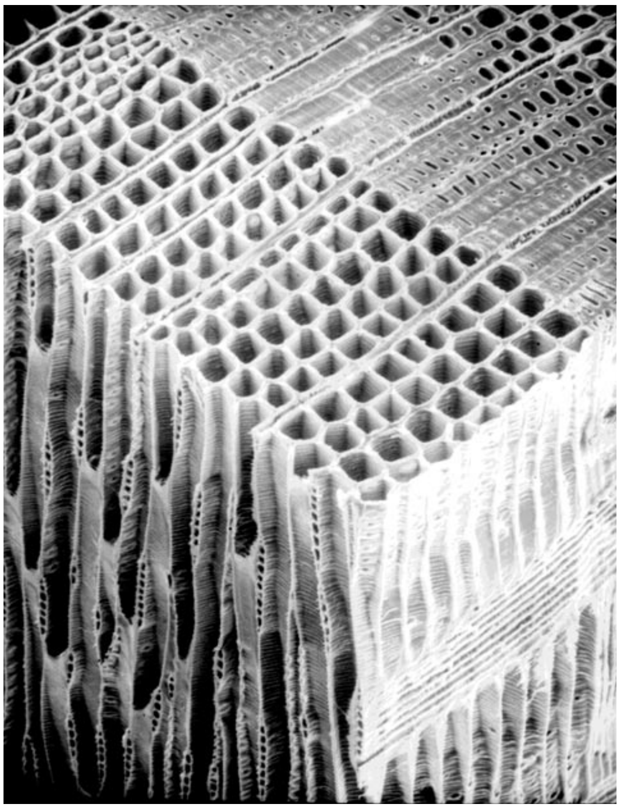

Figure 2. In this greatly enlarged view of fibers in Douglas-fir, large, open ends of thin-walled springwood fibers change abruptly to thick-walled summerwood fibers. Horizontal ribbons of short ray fibers are interspersed among long vertical fibers that make up about 90% of the wood. Photo provided courtesy of the N.C. Brown Center for Ultrastructure Studies, College of Environmental Science and Forestry, State University of New York, Syracuse.

Sapwood of the 3 primary pole species has little natural durability and is susceptible to fungal and insect attack as long as it remains wet. As the sapwood ages in a live tree, it begins to die, and, in some species, the dying cells convert their contents into a diverse array of compounds called extractives. Some extractives are toxic to insects and decay fungi and can protect the heartwood for many years. One of the best examples of this is western redcedar, which has highly durable heartwood. Heartwood of Doug-las-fir and southern pine is classified as moderately durable. Some species produce no detectable heartwood, but those species are not typically used for poles. Poles from species with durable heartwood have long service lives, especially when the sapwood receives some supplemental preservative treatment. Users should be aware, however, that the durability of heartwood does vary among trees of the same species.

Ninety percent of coniferous wood is made up of minute, hollow fibers oriented lengthwise along the tree stem (Figure 2), which transport water and nutrients from the roots up through the sapwood to the leaves. The length of these fibers is 100 times longer than the width. The remaining 10% of the wood is composed of short, hollow, brick-shaped ray cells oriented from the bark towards the center of the tree as ribbons of unequal height and length. These rays distribute food, manufactured in the leaves and transported down the inner bark, to the growing tissues between the bark and wood.

Density

Density is a measure of weight per unit volume. Because of its low density, wood of cedar is light when dry, but may be very heavy when wet. Low-density wood contains more voids than does high-density wood and, therefore, more space for water. One cubic foot of water-free (ovendry) western redcedar weighs about 19 lb, about 9 lb less than Douglas-fir, which is more dense.

Because density reflects the thickness of the fiber walls, it indicates the strength of the wood. The higher the density of wood at a specified moisture content (MC), the greater its strength. Therefore, a cedar pole must be larger in diameter than a Douglas-fir pole to support the same load.

Moisture Content

Sapwood, which conducts nutrients in water from the roots to the leaves, is nearly saturated with water in a standing tree. The lower density at the top enables a tree to store large quantities of water where it will be readily available to the leaves. Heartwood usually contains much less water.

Because of its low density, cedar can hold much more water than Douglas-fir. In freshly cut cedar trees, the MC of sapwood and heartwood approaches 250% and 60% respectively, calculated on a water-free wood basis. Ponderosa and southern pine both contain high percentages of sapwood, which holds more water than does heartwood.

Moisture content is expressed as a percentage of the dry weight of the wood. To determine the amount of water in wood, weigh pieces of the wood, then dry them in an oven at 220°F until their weights remain constant (wood 1 in. thick or less usually dries within 24 h). Do not use wood that contains resin or pitch for MC determinations, because it evaporates with the water.

Then, the moisture content can be calculated as:

MC = (initial weight/ovendry weight) - 1 x 100

or

MC = [(initial weight - ovendry weight)/ovendry weight] x 100

For example, if 1.0 ft^3 of Douglas-fir sapwood weighs 60.2 lb and its ovendry weight is 28.0 lb, the calculations would be:

MC = (initial weight/ovendry weight) - 1 x 100

MC = (60.2/28.0) - 1 x 100

MC = 115% MC

or

MC = [(initial weight - ovendry weight] x 100

MC = [(60.2 - 28.0)/28.0] x 100

MC = 115% MC

Moisture content also can be determined with a moisture meter that measures the electrical resistance between 2 probes driven into the wood with a sliding hammer (Salamon 1971, James 1975). Because a moisture gradient indicates moisture distribution in a pole much better than does a single reading at a specified depth, the 3-in.-long probes with uncoated tips should be driven into the wood so that the meter is read every 1/2 in. The uncoated pins read MC only at the tip. Before driving the probes into the wood, be sure that they are parallel to each other and are aligned with the long fibers of the wood; that way, the probes will not break off and the data will be more accurate. The meter is useful for an MC range of 7 to 25%, but accuracy decreases rapidly outside this range (Graham *et al.* 1969). Creosote and oil-based preservatives have little effect on meter readings, but inorganic water-based preservatives may cause large errors (James 1976).

Seasoning

Wood poles that are treated with preservatives must be dried either before or during preservative treatment. The simplest moisture removal method is air seasoning, in which poles are stacked in well-ventilated piles for 1 to 12 mo (Figure 3). Air seasoning is inexpensive because it requires little equipment and minimal handling of the wood. This method does necessitate a large storage area for poles, and it includes the cost of carrying a large white, or untreated, wood stock in anticipation of orders. It also permits the entry of fungi and insects into the wet wood. Despite these drawbacks, air seasoning remains a common method for drying Douglas-fir and western redcedar poles before treatment. Air seasoning is less frequently used for southern pine because of its greater susceptibility to decay. Poles to be air seasoned should be placed in well-aerated stacks with stickers (spacers) between rows to allow airflow. These poles should be kept at least 1 ft above the ground on well-drained sites that are free of vegetation.

The need to produce poles quickly (without the long drying times required for air seasoning) has encouraged the development of alternative seasoning processes, which include Boulton seasoning, steam conditioning, and kiln drying. These processes reduce wood moisture near the surface of the pole and, if carried out for a sufficient period, can heat-sterilize the wood, eliminating fungi or insects that became established between felling and treatment.

Boulton seasoning was first developed in 1878. It involves placing the wood in a treatment cylinder, adding treatment solution, and applying a vacuum while raising the temperature to between 190 and 210°F. The vacuum lowers the boiling point of water, permitting vaporization of water in the wood in a process that may last 6 to 48 h. Boulton seasoning is a relatively mild method for removing water from wood, which causes little or no strength loss; it is most commonly used to dry Douglas-fir poles.

Figure 3. Air seasoning poles.

Kiln drying is increasingly used for southern pine and Douglas-fir poles. In this process, the poles are placed on carts with stickers between the poles to permit air flow. The poles are then placed into a kiln, where they are subjected to combinations of elevated temperatures and rapid air flow. The rate of drying is controlled by the velocity of air passed through the kiln, as well as by temperature and relative humidity (RH). Kiln schedules that dry the poles too rapidly can result in excessive checking or in case-hardening of the wood, a process that makes subsequent preservative treatment more difficult. Careful control of temperature, RH, and air velocity can produce dry, high-quality poles over 3 to 5 days.

Steam conditioning is used to treat southern pine poles while the moisture levels remain elevated (~40% MC). Partially seasoned poles are steamed for up to 20 h at 240°F in a process that results in the drying of the wood near the surface and the redistribution of moisture deeper within the pole. As a result, the wood can be treated at higher overall MC, reducing energy costs. Steam conditioning is typically used to treat southern pine poles with oil-based preservatives; it is not permitted for Douglas-fir, western redcedar, or ponderosa pine because of concerns about the potential for temperature-induced strength loss in these species. Southern pine is less susceptible to this damage.

Pretreatment Processing

In addition to seasoning, there are a number of steps a utility can take to improve pole performance and reduce long-term maintenance costs.

Preboring all holes used for attachments such as guy wires or cross-arms helps to protect the preservative-treated shell from damage. Field drilling exposes untreated wood, creating the potential for aboveground decay (Figure 4).

Figure 4. Decay in a field-drilled pole.

Incising can be used in the treatment of species in which the thin bands of sapwood pose a major challenge. Incising involves using sharpened metal teeth to punch a series of small holes into the wood, improving the uniformity of treatment to the depth of the incisions. Wood treats more easily along the grain, and incising exposes more longitudinal flow paths, thereby improving treatment (Figure 5). Incising is recommended for western redcedar poles; utilities also incise Douglas-fir, lodgepole pine (*Pinus contorta*), and western larch (*Larix occidentalis*), particularly in the groundline zone.

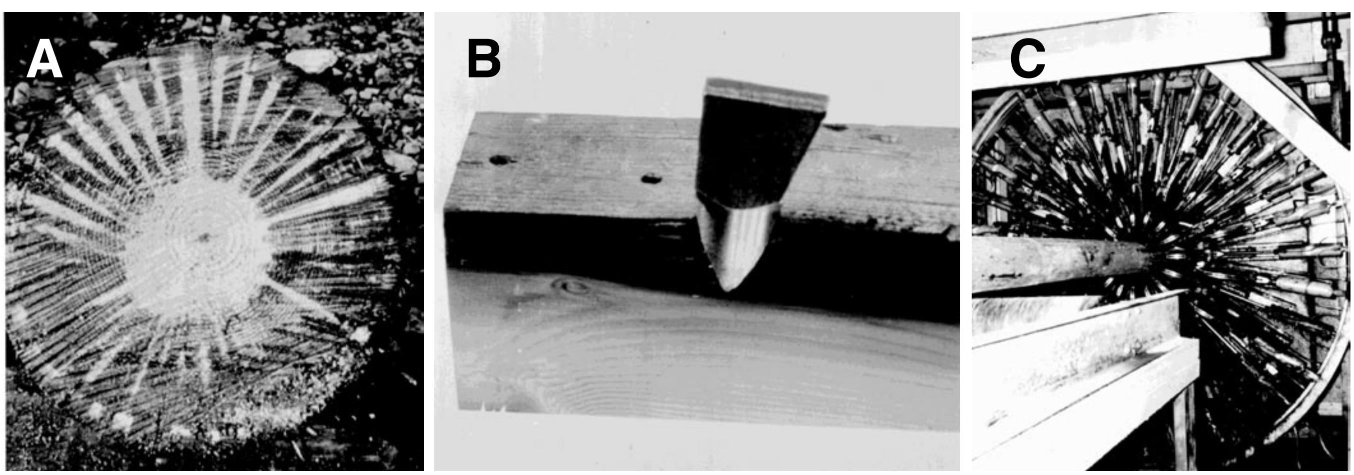

Figure 5. Incising can markedly improve preservative penetration. A) Cross section of a deep incised pole, B) side view of incisor teeth penetrating wood, and C) commercial pole incisor.

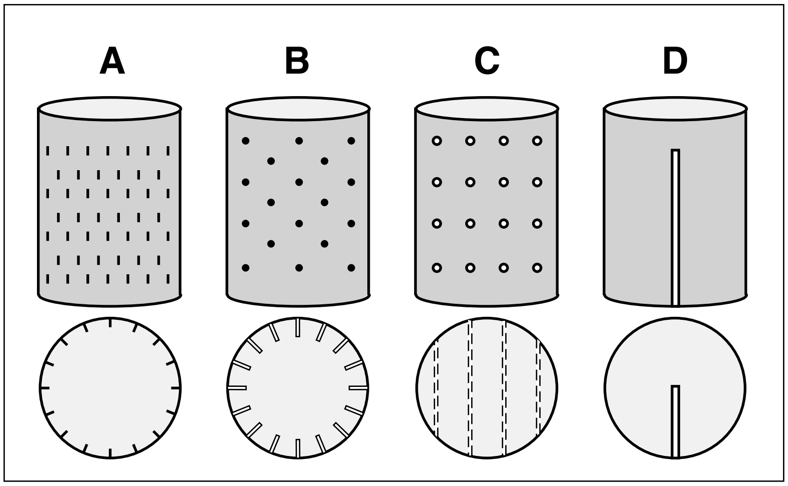

Figure 6. A) Deep incising, (B) radial drilling, (C) through-boring, and (D) kerfing can improve treatment of the affected zone.

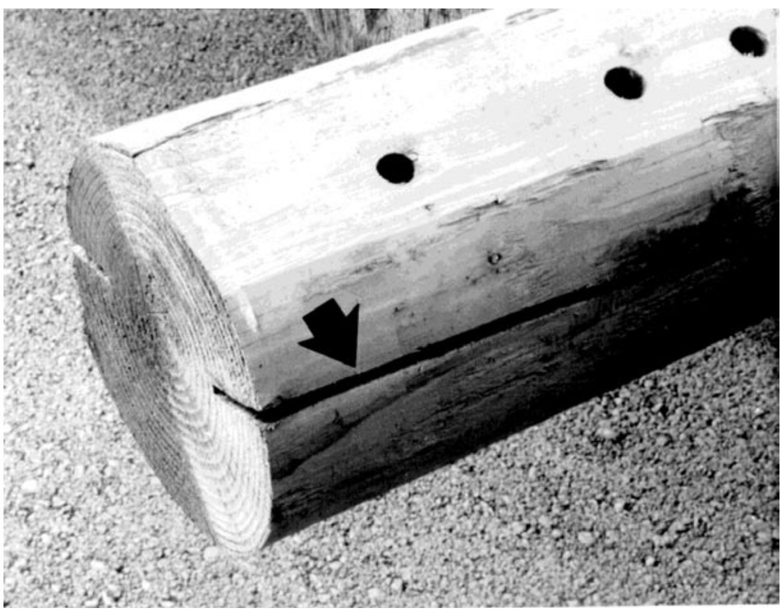

Figure 7. Kerfing (arrow) can be used to control checking of poles, thereby reducing internal decay in service.

Deep incising and radial drilling improve on conventional incising, the effect of which is generally limited to the outer 3/4 in. of the wood. In deep incising, a series of 3-in.-long knives are driven into the wood around the groundline area. Similarly, radial drilling involves drilling a series of holes to depths ranging from 3 to 5 in. in a diamond-shaped pattern in the groundline zone. Both of these processes allow preservative treatment to the depth of the knife or drill, which increases the zone of protected wood (Figure 6).

Through-boring takes radial drilling further in that holes are drilled at a slightly downward-sloping angle completely through the pole in the critical groundline zone. Through-boring can produce nearly total treatment of the groundline zone (Figure 6).

While incising, radial drilling, and through-boring improve the depth of preservative treatment, none control in-service checking, which results in exposure of untreated wood.

Kerfing involves making a saw cut to the pith of the pole prior to treatment (Figures 6 and 7). Once treated, the kerf acts to relieve subsequent drying stress, preventing the development of checks that penetrate beyond the treated shell. It is important to note that decay can occur above the kerfed zone; however, kerfing markedly reduces the incidence of internal decay in thin sapwood species around the groundline.

Radial drilling, deep incising, through-boring, and kerfing are all typically used on species with thin sapwood and low to moderately durable heartwood. They are primarily used on Douglas-fir, but would also find application on western larch and lodgepole pine.

Shrinkage and Checking

As poles dry or season, they lose water from the surface, but shrink only when MC drops below 30%. This is the fiber saturation point, the point when the wood fibers contain a maximum amount of water, but there is no "free water" in the cell lumens. Wood shrinks more along than across the growth rings. As a result, many small, V-shaped seasoning checks form in the surface of poles. As drying continues deeper into the wood,

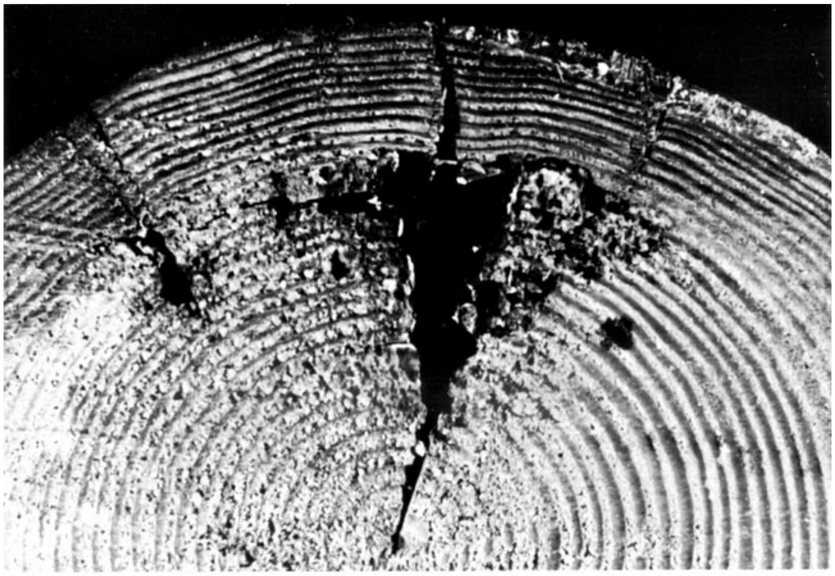

Figure 8. Narrow checks that widened and deepened after treatment have exposed the untreated heartwood of this Douglas-fir pole to rot decay fungi.

the number of small checks decreases, but a few checks drive deep into the wood (Figure 8). Deep checks to the center indicate a well-seasoned pole and do not adversely affect strength. Numerous small checks do not always reliably indicate the extent of seasoning because some poles check very little as they dry. However, most poles eventually develop deep checks (1/8 to 1/2 in. wide). Pretreatment seasoning removes moisture from the wood and encourages check development before treatment.

Even under the most favorable drying conditions, however, large poles require a long time for the heartwood to completely dry to in-service equilibrium MC. Consequently, some poles are treated with preservatives and put in service while they still have high internal MC. As checks on these poles continue to deepen, they expose untreated wood to attack by wood-destroying organisms, which results in the development of internal decay. The development of checks before treatment results in well-treated checks; this helps to reduce the risk of internal decay.

Many utilities incorporate a pre- or post-treatment MC into their specifications to ensure that the wood is dry before treatment or that it will not check excessively once in service. A typical pretreatment MC might be 20 to 25% at 2 in. from the surface, although this will sometimes vary seasonally to reflect both the difficulty of seasoning during wet periods and the inability of in-cylinder treatment processes to remove some of this moisture.

Most utilities also limit the maximum width and length of checks to avoid creating a hazard to linemen climbing the poles. These requirements must be applied cautiously, since unreasonable check limitations will force treatment at higher MC when the poles have not yet developed a normal checking pattern. These poles will then continue to dry after treatment and may develop even deeper checks that penetrate beyond the treated zone.

The degree of drying required before treatment will vary by species and by ultimate exposure site. For example, southern pine can be treated at higher MC through the use of presteaming, although care must be taken to ensure uniform treatment gradients. Douglas-fir and western redcedar poles are normally treated when dry (approximately 25% MC). Ultimate exposure conditions may also affect the degree of drying required. Poles that are exposed in dry regions (<20 in. precipitation/yr) should be drier before installation since they are more likely to develop deep checks. Users should carefully consider the impacts of drying and check requirements on initial pole costs and ultimate service life.

Preservatives

Wood poles can be treated with various preservatives specified under the standards of the American Wood Preservers' Association. These systems are either oil- or water-based.

Oil-Based Preservatives

Oil-based systems include creosote, pentachlorophenol (penta), and copper naphthenate. Creosote and penta are both restricted-use pesticides; those seeking to use these liquid chemicals must be licensed by an appropriate state agency. Although wood treated with these chemicals is not restricted, users should carefully read and follow all product information with regard to application.

Creosote is the oldest preservative in general use for wood protection; it was patented in 1838 by John Bethell. Creosote is a mixture of polynuclear aromatic hydrocarbons produced by the destructive distillation of coal for coke production. Creosote is an oil substance that is typically used undiluted for wood-pole treatments. It is highly effective against many decay organisms and provides long service life. One hazard is that contact with this chemical can sensitize the skin to sunlight.

Pentachlorophenol (penta) was developed in the 1930s as an easily synthesized substitute for creosote. Penta is normally used in a heavy hydrocarbon solvent (P-9 Type A) for treatment of wood poles. Penta is broadly toxic to fungi and insects, but its use has declined over the past 10 yr because of concerns about dioxin, a natural by-product of penta synthesis. Despite its potential drawbacks, penta remains the preservative of choice for many utilities because of its excellent field performance. The solvent system used with penta has a marked influence on performance, as evidenced by the diminished performance of poles treated with penta in liquified petroleum gas (Arsenault 1973). The use of heavy aromatic oils tends to produce the best performance with this chemical.

Copper naphthenate was developed in 1911. It is produced by combining copper with naphthenic acids derived from the oil-refining process. Copper naphthenate has been available for wood-pole treatments for many years, but its slightly higher cost and a general satisfaction with penta have limited its use. Unlike creosote and penta, copper naphthenate is not a restricted-use pesticide, and it is commonly used to field-treat cuts or holes made in poles after initial preservative treatment.

In addition to the previously described systems, a variety of newer oil-based chemicals are being evaluated for wood poles. These include chlorothalonil and isothiazolone. The development of new systems for protecting wood poles is generally slow because of both the need for highly reliable protection and a general reluctance on the part of utilities to accept new treatments rapidly without first performing limited tests within their systems. It is likely, however, that we will see a gradual evolution to a new generation of less broadly toxic preservatives for wood poles.

Water-based Preservatives

Water-based preservatives for wood poles include chromated copper arsenate (CCA), ammoniacal copper zinc arsenate (ACZA), ammoniacal copper arsenate (ACA), and ammoniacal copper quarternary (ACQ). Although CCA, ACZA, and ACA are restricted-use pesticides, wood treated with these systems is not. Wood treated with ACQ is not restricted, and ACQ itself is not a restricted-use pesticide.

Water-based systems produce clean, residue-free surfaces. Many utilities object to the hardness of poles treated with these systems, however, as well as a tendency for the wood to be more conductive when wet. Another concern with water-based preservative treatment is that the processes require lower temperatures. Treatment with ACZA does sterilize the wood, as does kiln drying before treatment with CCA, but an alternative sterilization process must be used when air-seasoned poles are treated with CCA.

First developed in the 1930s in India, CCA is an acid system that uses chromium reactions with the wood to fix the copper and arsenic. The process takes several days to many weeks, depending on the wood temperature. CCA is increasingly used to treat poles of southern pine, but it is difficult to impregnate Douglas-fir with CCA. Thus, this chemical/species combination is not recommended unless material is selected by pretreatment permeability trials.

ACA was first developed in the 1930s in California; it uses ammonia to solubilize copper and arsenic. Once applied to the wood, the ammonia evaporates and the copper and arsenic precipitate. The presence of ammonia and the use of heated preservative solutions generally result in deeper preservative penetration than is found with CCA. For this reason, ACA is typically used to treat refractory woods such as Douglas-fir. At present, ACA is no longer used in the United States, although some treated product is imported from Canada. ACZA is a variation on ACA, which was standardized in the 1980s. This system adds zinc to produce better fixation of arsenic, thereby producing a more stable product.

ACQ is among the most recently standardized preservatives for wood poles. This formulation uses ammonia to solubilize copper and adds a quarternary ammonium compound to limit the potential for damage by copper-tolerant fungi. This preservative is not yet widely used for wood poles, but comparative field tests suggest that its performance will be similar to CCA or ACZA.

New water-based systems are under development, including copper azole and copper dimethyldithiocarbamate. Although these systems show promise, it will be some years before they are extensively used for wood-pole treatment.

Preservative Treatments

Preservative treatment involves forcing oil- or water-based preservatives into wood to a desired depth of penetration at a level or retention that confers biological protection. The depth of penetration varies with wood species; western redcedar requires the shallowest penetration and southern pine the deepest. Penetration requirements are generally based

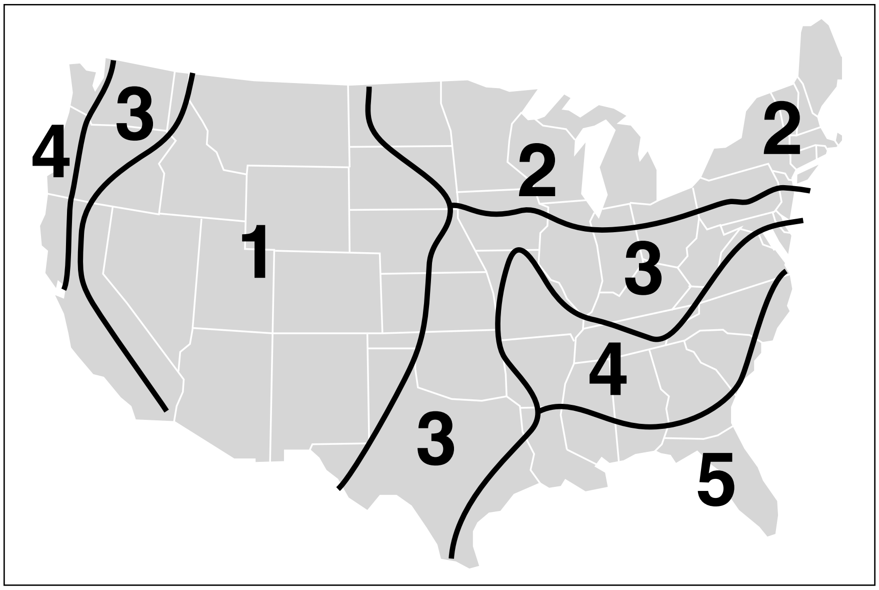

Figure 9. Relative risk of decay in poles (1 = low risk, 5 = high risk) exposed in various sites in the United States.

upon the amount of sapwood present and the ease with which it can be treated. Retention is expressed as the weight of preservative per volume of wood (lb/cft or kg/m^3); this varies with wood species and application. For example, wood poles used in warmer, wetter climates are exposed to a higher risk of decay and are usually treated to a higher retention than are those exposed to drier, cooler conditions (Figure 9).

Three general treatment processes are used to impregnate wood poles. In the thermal process, dry poles are placed in either a large tank or a closed cylinder. Oil-based preservative is added to cover the wood and is heated over a 6- to 18-h period. The oil is pumped out of the vessel, then pumped back in in a process that cools the oil slightly. As the cooler oil touches the hotter wood, a partial vacuum is created, which draws additional preservative into the wood. The thermal process is used primarily to treat western redcedar, although it is occasionally used to treat lodgepole pine, western larch, or Douglas-fir poles for drier or cooler climates, where the decay hazard is lower.

The other 2 treatment methods use elevated pressure in a treatment vessel or retort to force chemical into the wood to the required depth. The full-cell process was developed in 1836 by John Bethell. It begins with an initial vacuum to remove as much air as possible from the wood (Figure 10a). The preservative solution is then added to the treatment vessel and the pressure is raised (100 to 150 psi). Gauges on the treatment vessel allow the treater to determine how much solution has been absorbed by the wood; this information, in combination with the amount of wood in the treatment cylinder and the retention required, dictates the length of the treatment cycle. Once the desired amount of solution has been absorbed, the pressure is released. The release of pressure forces some preservative from the wood in a process called kickback. After the pressure period, a series of vacuums are drawn to recover excessive preservative and minimize bleeding. In addition, poles of some species are steamed to clean the surface and enhance fixation reactions. The full-cell process is normally used to treat wood poles with water-based preservatives whose concentration can be changed to achieve the desired retention.

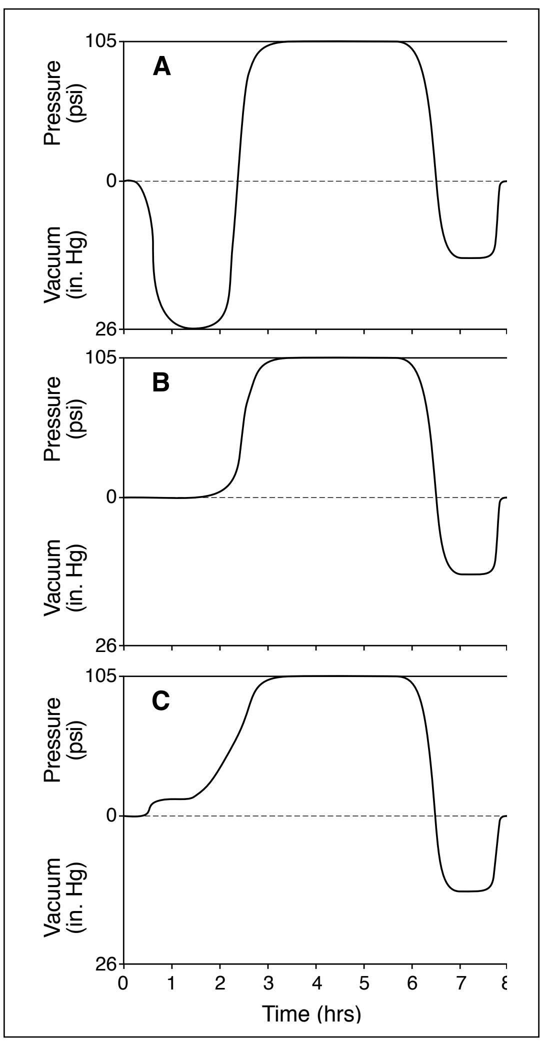

Figure 10. Typical vacuum pressure cycles used to impregnate wood poles with preservative. A) Full-cell, B) Rueping and C) Lowry processes.

Empty-cell processes were developed in the early 1900s (Figure 10 b, c). In these treatments, the process begins when preservatives are introduced into the treatment cylinder at atmospheric pressure without a vacuum. In the absence of a vacuum, air trapped in the wood at the start of the pressure cycle is compressed; at the end of the pressure period it expands and carries additional preservative or kickback from the wood, reducing retention. Kickback can be further increased by introducing a slight pressure prior to the addition of preservative, thereby increasing the amount of trapped, compressed air and the subsequent kickback. Empty-cell processes are normally used to treat poles with oil-based preservatives and are used to reduce the amount of preservative injected into the wood, thereby producing a cleaner, drier pole.

Treatment Specifications

Treatment of wood poles is specified under the AWPA Standards, which set minimum levels for penetration and retention of preservatives for wood poles and define process limitations for each species. The standards are results-oriented, in that they specify chemical levels but do not require a specific treatment method for achieving the goal. Successful treatment is confirmed by post-treatment sampling. The standards should be considered minimum specifications. Utilities that desire greater treatment, however, should carefully consider the costs and benefits of additional requirements.

Agents of Decay

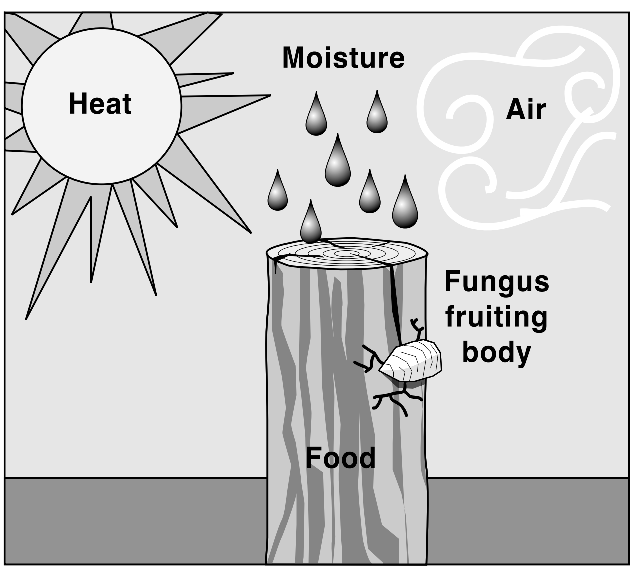

Figure 11. Requirements for decay.

The structural integrity of wood may be destroyed by decay fungi that feed on wood. Wood also contains a wide variety of so-called nondecay fungi that usually do not weaken wood. Insects, woodpeckers, and marine boring animals also can extensively damage wood structures in some areas.

Fungi

Decay fungi are by far the most destructive of the organisms that inhabit wood. Fungi require water, air, a favorable temperature, and food (Figure 11). Wood with MC below 20% (ovendry basis) usually is safe from fungi. Lack of air limits fungal growth only when wood is submerged in water or buried deep in the ground. Freezing temperatures stop fungal growth but seldom kill fungi. Above 32°F, fungal activity increases, peaking between 60 and 80°F and decreasing as temperatures approach 100°F. Most fungi are killed at temperatures exceeding 150°F.

Decay Fungi

Mushrooms and "conks" are typical fruiting bodies of decay fungi; they produce billions of microscopic seed-like structures called spores (Figure 12). In favorable conditions, these spores germinate and produce hyphae, minute thread-like strands that penetrate throughout wood. The hyphae secrete enzymes that dissolve the cellulose and lignin of wood into simpler chemicals that fungi can use as food.

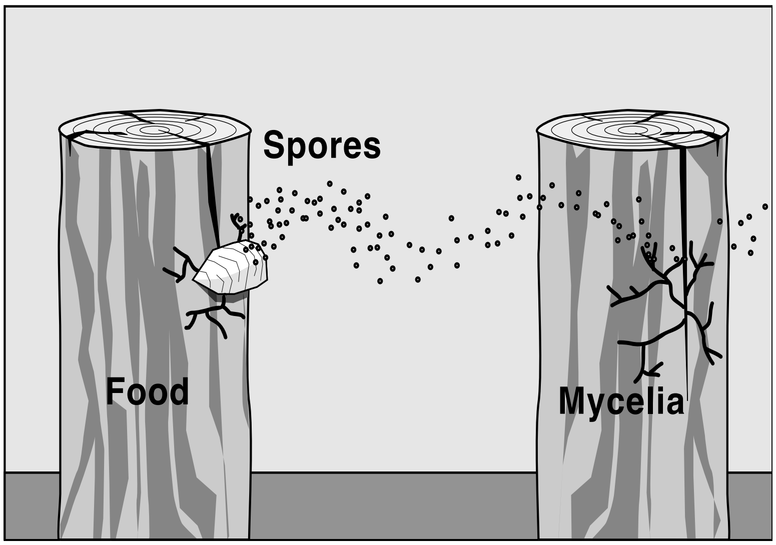

Figure 12. The conk (fruit body) of a decay fungus produces microscopic spores that, finding suitable conditions for growth, infect other wood products. Fungal threads spread decay through moist wood.

"Decay" describes wood in all stages of fungal attack, from the initial penetration of hyphae into the cell wall to the complete destruction of the wood. Early fungal attack on wood usually can be detected only by microscopic examination or by incubating wood on nutrient agar for outgrowth of decay fungi (Figure 13). If decay fungi can be cultured from wood that appears visually sound, the solid wood is in the incipient stage of decay. During the early stages of decay, some fungi may discolor or substantially weaken the wood, especially its toughness.

As decay continues, wood becomes brash (breaks abruptly across the grain), loses luster and strength, and noticeably changes in color; eventually, it may be completely destroyed. Wood that is visibly decayed, greatly weakened, and conspicuously brash or soft is in the advanced stage of decay called rot. Three groups of fungi, brown rot, white rot, and soft rot, cause wood degradation; each affects the wood in a different manner (Figure 14).

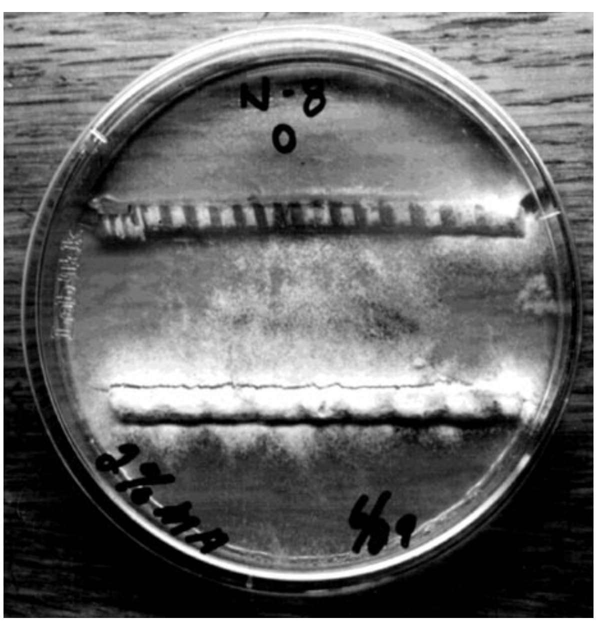

Figure 13. A decay fungus growing over malt agar from a sound-appearing increment core is a positive sign of decay, even though the pole may contain no visible rot.

Brown rot is a brown, advanced decay that crumbles when dry and is common in most softwoods. Although it is called "dry rot," this nomenclature is misleading because at one time the wood must have been wet enough to support fungal growth. At very early stages of decay, brown rot fungi preferentially remove cellulose from the wood, producing extensive strength loss and significantly damaging the wood's utility.

White rot fungi are more prevalent on hardwoods, although they are present in many conifer species. In the advanced stage of decay, white-rot fungi bleach or whiten wood or they form small white pockets in rotten brown wood.

Soft rot fungi attack both hardwood and conifers, particularly where preservative levels have declined below their initial treatment levels through leaching. Soft-rot fungi that slowly cause an external softening of treated wood have extensively damaged poles below ground. Soft rot fungi are most prevalent on poles of southern pine, although they are also common on poles

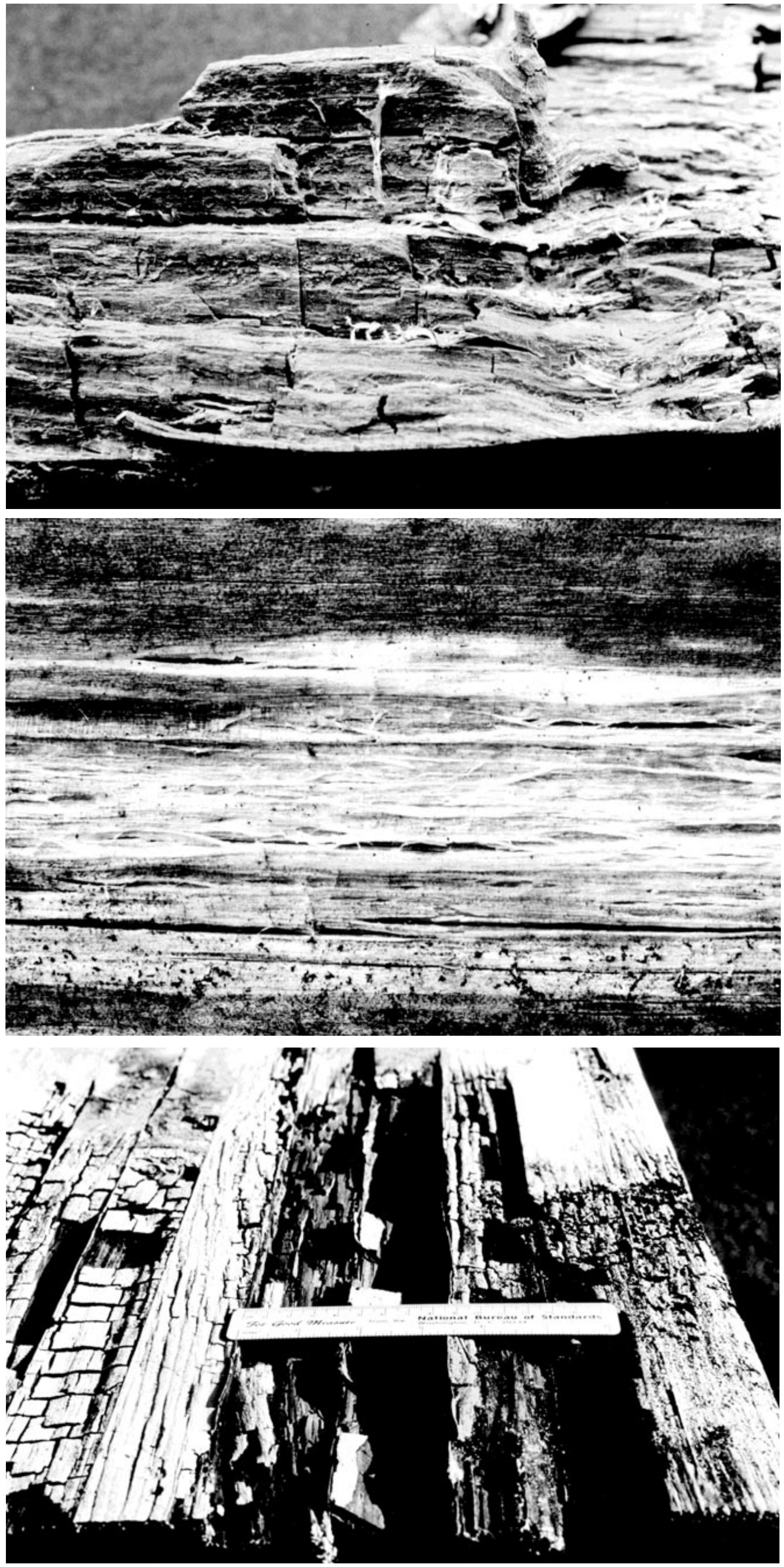

Figure 14. Brown, white, and soft rot (top to bottom).

of Douglas-fir that have been treated with pentachlorophenol in either methylene chloride or liquified petroleum gas.

Nondecay Fungi

Numerous nondecay fungi also inhabit wood; they feed on cell contents, certain components of cell walls, and the products of decay. Frequently, only nondecay fungi can be isolated from rotten wood because the decay fungi, having run out of food, have died. Sapwood-staining fungi may reduce the toughness of severely discolored wood; other nondecay fungi gradually detoxify preservatives, preparing the way for decay fungi. Some rapidly growing nondecay fungi may interfere with efforts to culture the slower growing decay fungi from wood. The interaction of fungi, both decay and nondecay types, and their roles in the decay process are still to be defined.

Insects

Wood in or above ground may be attacked by termites, carpenter ants, or beetles. Termites work within wood; there is virtually no external evidence of their presence until winged adults emerge and swarm in late summer and early fall. Then their wings, discarded for mating and starting new colonies, may indicate their presence. Although their lengths vary from 1/4 in. or less (subterranean and drywood) to 3/4 in. (dampwood), termites have bodies of fairly uniform width; the reproductives have wings of equal length (Figure 15).

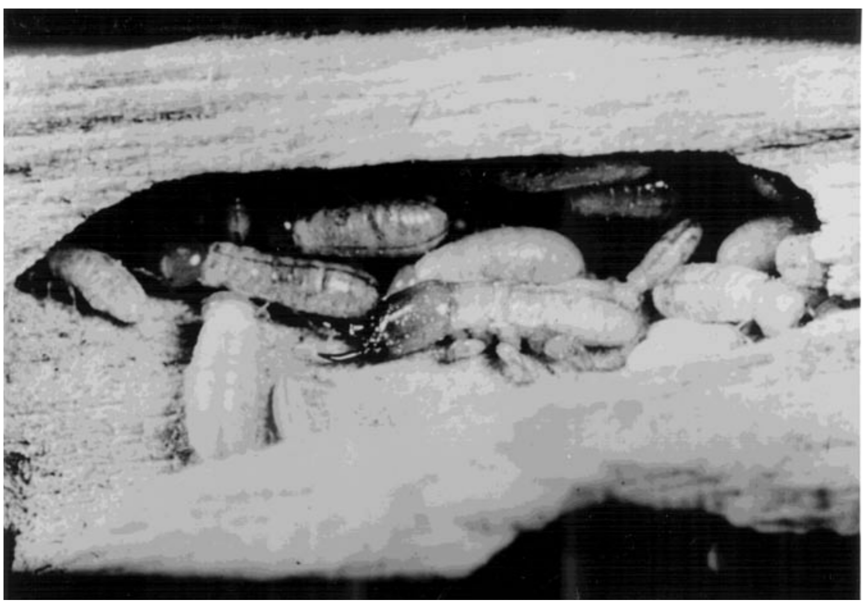

Figure 15. A termite colony includes many workers that burrow in wood for food and shelter, soldiers that protect the colony from other insects, and 1 egg-laying queen. Usually poles show no sign of termites until the reproductives emerge, discard their wings, and mate to start new colonies.

Subterranean termites are widespread and cause extensive damage, especially in southern states. Sure signs of their presence are the mud tunnels that only subterranean termites build from their nests in the ground up across treated wood or concrete to untreated wood above. In warmer portions of the country, wood may also be subject to very aggressive attack by an introduced species, the Formosan termite (*Coptotermes formosanus*). This subterranean termite has large colonies with as many as 1 million workers. Fortunately, this species is currently only found along the Gulf Coast and in extreme southern California.

Dampwood termites inhabit moist wood in, on, or above the ground along the Pacific Coast. Drywood termites feed on dry wood, primarily in the southern United States and the Pacific Southwest. Termites are best

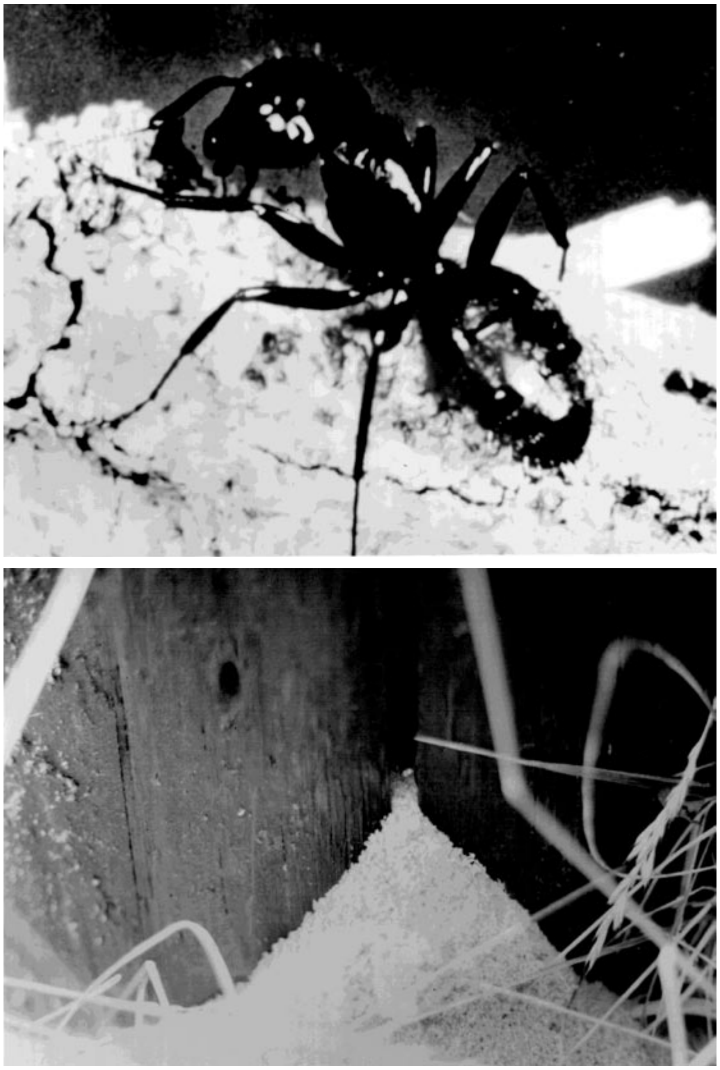

Figure 16. Carpenter ants also live in colonies, hollowing out nests in poles for shelter. A pile of sawdust at the base of the pole is a sure sign of their presence. In contrast to termites, ants have restricted waists and reproductives have shorter wings of unequal length.

controlled by producing a well-treated pole without deep checks that penetrate beyond the treated shell.

Carpenter ants have a restricted waist and the reproductives have wings of unequal length (Figure 16). The dark-colored ants grow as long as 3/4 in. Unlike termites, which eat wood, ants hollow out wood only for shelter, forming piles of "sawdust" at the base of poles, which attest to their presence. Ants frequently may be seen scurrying around poles in search of food. They are difficult to control because they do not eat the wood. A well-treated pole without checks penetrating beyond the treated shell is the best method for preventing carpenter ant attack.

Although many different beetles attack wood products, the golden buprestid is the most common in the Pacific Northwest. These beetles lay their eggs on freshly fallen logs with the bark on. The eggs hatch and the larvae burrow into the wood. Once inside, the larvae tunnel through the wood for 2 to 40 years. The 3/4-in.-long, metallic golden or green adult makes an elliptical hole as it emerges from the pole to mate (Figure 17). Trained pole-maintenance personnel recognize these elliptical holes as indicators of internal rot often associated with beetle attack. Numerous emergence holes may indicate an unsafe pole.

Beetles in other wood species may be indicators of prior insect attack. For example, western redcedar heartwood may have been attacked by another species of buprestid beetle as a standing tree. That species attacks only living trees, and the damage does not spread in the finished product. Similarly, some buprestid species attack wounds in standing southern pine. Those beetles do not cause further damage in the finished products.

Beetle damage, while not always a long-term problem, can be an indicator of poor handling. As a result, most wood-pole specifications reject poles with beetle holes.

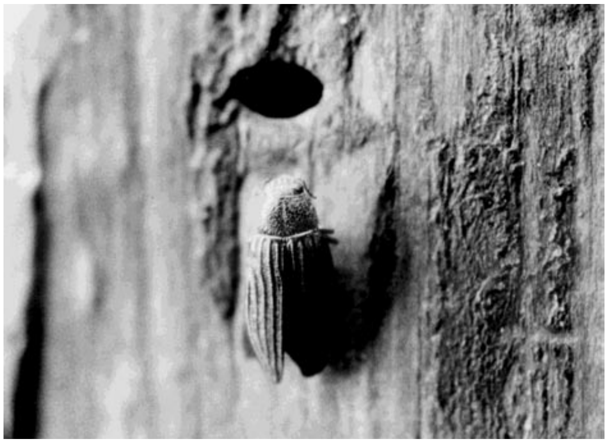

Figure 17. As an indication of internal rot in the aboveground portion of poles, look for the oval holes, 1/2 in. long, that the buprestid beetle leaves as it emerges from wood. Many holes could mean an unsafe pole.

Woodpeckers

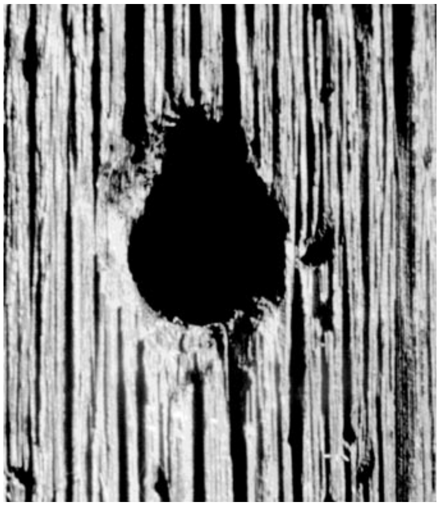

Figure 18. Woodpecker damage.

Woodpeckers sometimes nest in poles, drum on poles as part of their mating rituals, use poles as a source of insects, store acorns in small holes as a future food source, and make holes for other unknown reasons (Figure 18). The woodpecker problem can be compounded by fungal decay, because the holes permit water to enter poles. Chemical repellents, plastic wraps that deny the birds a toehold, and stuffed owls have been tried as woodpecker deterrents. When poles with woodpecker damage have been replaced, the pole section containing the nest cavity has even been retained and attached to the new pole at its original height. These methods, however, usually do not prevent woodpecker damage. Heavy galvanized hardware cloth applied tightly over much of the pole has been most successful preventative measure, but can cause problems when poles must be climbed. Damage is most often repaired by treating the wood with preservative and filling holes with an epoxy resin or foam. These actions, however, do not prevent renewed attack.

Marine Borers

Untreated wood piles and poles in saline coastal waters are attacked rapidly by marine borers. Shipworms (*Banlae* or *Teredo* spp.) riddle interior wood with long holes, and *Limnoria* (gribbles) burrow small tunnels near wood surfaces (Figure 19).

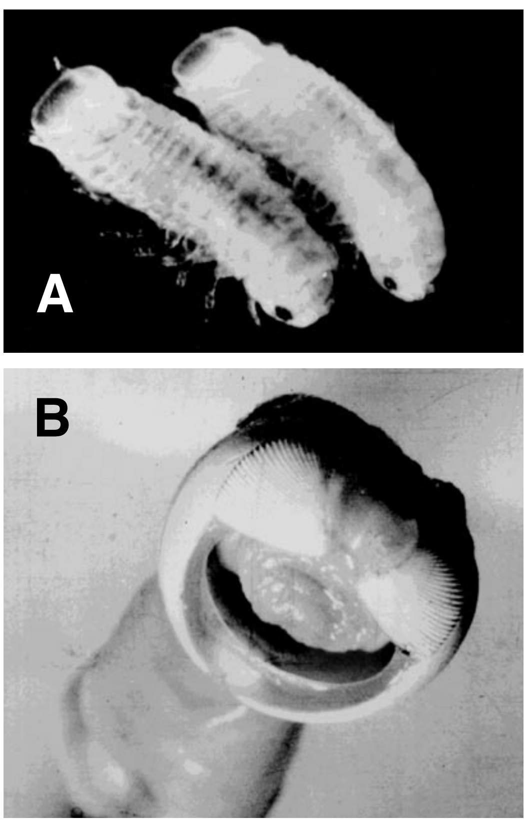

Figure 19. A) gribbles and B) shipworms are marine borers that attack wood in coastal waters where salinity and oxygen supply are favorable.

Shipworms are bivalves (mollusks) with a pair of small shells at their heads. As small larvae, they burrow into wood and continue to tunnel away from the hole. Their tunnels may be up to 3/4 in. in diameter and 2 ft in length.

Gribbles, small crustaceans about 1/10 in. long, tunnel in large numbers just below the surface of wood. Waves then break off these weakened surface layers, which gradually reduces the effective diameter of the wood.

Marine borers are very destructive in southern latitudes, where wood needs special preservative treatments (south of San Francisco, CA or New York Harbor, NY). In northern latitudes, they do little damage to wood that has been pressure-treated with marine-grade creosote or wood with high retentions of certain water-based salts, unless cracks, bolt holes, or cuts expose untreated wood. Pentachlorophenol-treated wood should not be used in marine waters. Untreated wood such as bracing should not be fastened to treated wood below the tidal zone, because borers can become established in the untreated wood and penetrate the treated wood. Where damage occurs, plastic wraps or concrete barriers have proven useful for arresting attack by cutting off oxygen to the organism.

Inspection of New Poles

While the treater is responsible for ensuring adherence to specifications, the utility may find it helpful to have in-house or third-party inspection of all incoming poles to ensure compliance. In-house inspection is usually most practical for large utilities with specially trained quality control staff. Third-party inspection is more appropriate for smaller utilities that buy fewer poles. In both instances, poles are inspected visually for the presence of natural defects (ANSI 1992). Increment cores are removed for measuring preservative penetration and retention. This practice provides a final check on pole quality and helps to identify potential problems before poles are shipped by the manufacturer.

Inspection of In-Service Poles

For many years, utilities installed poles with little thought to the necessity of regular maintenance. The need to minimize potential liabilities while maximizing the investment in wood poles has encouraged many utilities to institute regular programs of inspection and retreatment. Inspection programs and the tools they use vary widely depending on the wood species, chemical treatments, and climate to which the poles are exposed.

Pole Inspection Programs

The timing and extent of a pole inspection program vary greatly depending on the climate, geography, wood species, initial preservative, and age of the system (Table 1). The risk of decay can be estimated using average monthly temperatures and days with precipitation to produce a climate index (Scheffer 1971). For example, poles exposed in cool, dry regions, such as those in the Upper Great Basin, can be inspected less frequently than those in sub-tropical southern Florida (Figure 20). In wetter regions, internal decay typically occurs at or slightly below the groundline, whereas in drier regions it often extends more deeply below the ground. Similarly, internal decay in wetter regions can extend many feet up from the ground. Some aboveground internal inspection should be considered for older poles in these regions or for poles in coastal regions.

In addition, wood species and the initial treatment chemical can strongly influence both the type and frequency of inspection. Most decay in well-treated southern pine

Table 1. Schedules for pole inspection by climate index and decay zones.[a]

Climate index[b]	Decay zone	Initial inspection (years)	Subsequent reinspection (years)	Poles inspected each year (%)
Less than 35	1	12–15	12	8.3
35–65	1 and 3	10–12	10	10.0
More than 65	4 and 5	8–10	8	12.5

[a]Adapted (except climate index) from REA (1974)

[b]Scheffer (1971); see Figure 20.

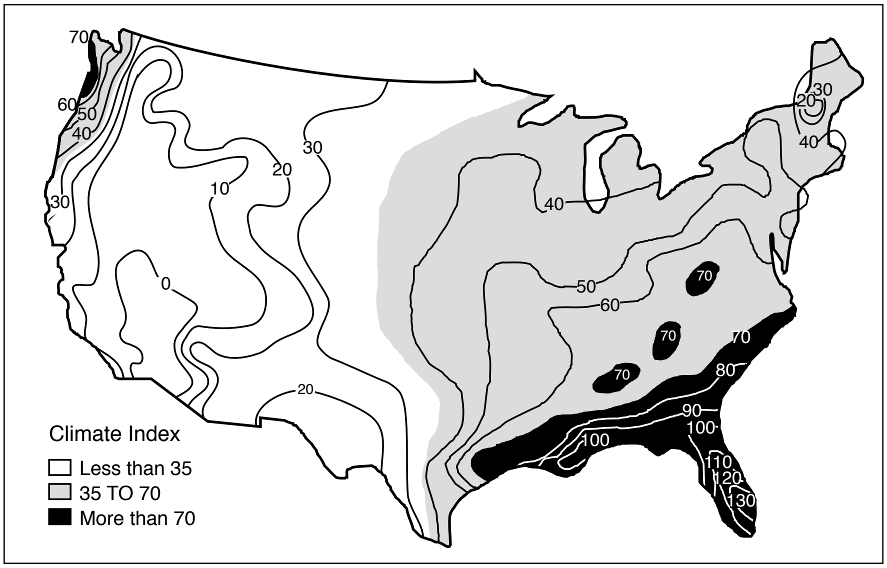

Figure 20. This climate-index map of the United States provides an estimate of potential for decay of wood above ground (Scheffer 1971).

poles occurs below the groundline on the wood surface. As a result, inspections that include digging and probing of the wood surface below groundline are essential for detecting damage in this species. Douglas-fir, western larch, western redcedar, and lodgepole pine are more prone to internal decay below the groundline (although older cedar may also experience some external decay), which makes internal inspection critical for early decay detection.

The choice of treatment chemical can also influence inspection. For example, poles treated with pentachlorophenol in liquified petroleum gas by either the Dow® or the Cellon® process tend to experience surface decay below ground regardless of the wood species. As a result, digging inspections are required for poles treated by these processes, regardless of species.

The Initial Inspection

When first evaluating a line or system, it is helpful to thoroughly inspect a smaller population of representative poles. These poles can provide useful information on wood species, original treatment, seasoning checks, insect attack, internal or external decay, and any other defects. The pre-inspection can also identify populations of poles that should receive extra attention.

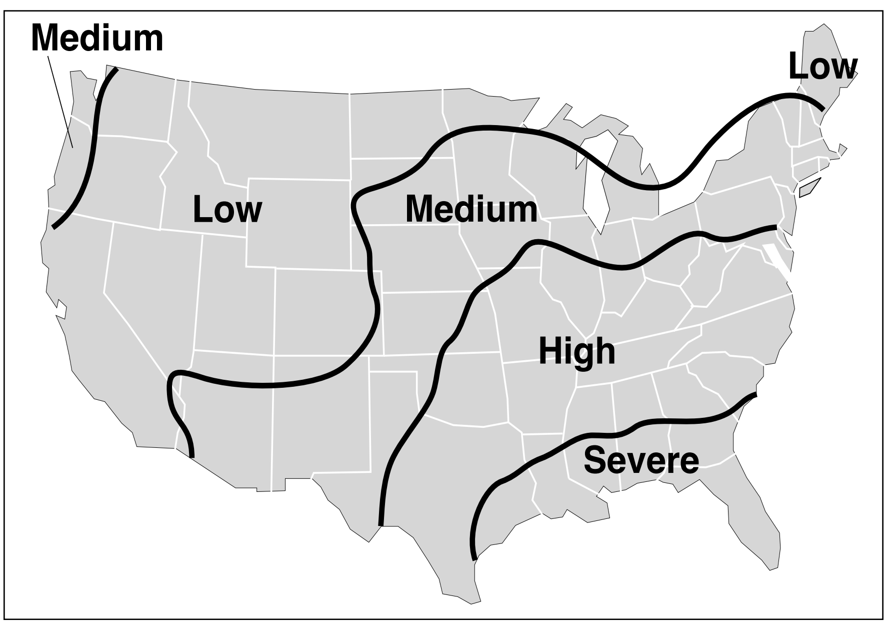

Figure 21. Decay hazard as reported by the Rural Electrification Administration (REA) is derived from the decay hazard to which the wood is exposed.

The number of poles sampled in the initial inspection will depend on prior maintenance practices, as well as the exposure hazard (Figure 21). Where personnel continually check poles and detect developing problems, the initial sampling inspection may be limited to relatively few poles in certain lines or certain areas. If little is known about a pole system, the inspection could involve a statistical sampling of poles in each line throughout the system. Some utilities sample a set number of poles (for example 300) of a similar age, species, and treatment, that were produced by the same manufacturer. REA (1974) generally recommends inspecting "a 1,000 pole sample made up of continuous pole line groupings of 50 or 100 poles in several areas of the system." The percentage of poles deteriorating and rejected then becomes a basis for decisions on the scope and nature of the pole maintenance program. The 1000-pole sample is arbitrary. Utilities should use some judgment based upon more intimate knowledge of their pole plant to determine appropriate initial samples.

To Dig or Not to Dig?

Initial pole inspection should include digging, because poles can be sound above the groundline but badly decayed below. As poles age and as poles of new species or with new preservative treatments are installed, do not hesitate to make early digging inspections to find out how the poles are performing. As you become better acquainted with the condition of poles in your system, you can vary the frequency of digging to suit the local conditions.

Digging 18 in. deep will reveal surface decay in most areas, but you may have to dig deeper in dry areas where cedar poles can decay below the incised zone (about 1 ft above to 3 ft below the groundline). One utility found that cedar poles set in gravel decayed "from the butt up." To get the facts, inspect and cut up poles removed from service. Although surface rot is uncommon in pressure-treated Douglas-fir poles, it does occasionally occur, so some initial digging is still necessary to ensure that it is absent in your locality. Internal pockets of decay can occur well below or above the groundline, depending on local conditions.

To Culture or Not to Culture?

The initial inspection of pole lines of thin-sapwood, nondurable-heartwood species should include the culturing of cores for decay fungi. Culturing cores from poles takes about 4 wk. Trained personnel, such as plant pathologists, must then use microscopes to distinguish between decay and nondecay fungi. Although numerous cores can be cultured simultaneously, this process is not feasible for large-scale inspection.

Inspection of Douglas-fir transmission poles installed 10 yr earlier revealed only a few poles with internal rot; yet 30% of the poles contained decay fungi warranting a program of internal treatment (Zabel et al. 1980). In western Oregon, for each Douglas-fir pole that contained rot, we found 1 or 2 poles that contained decay fungi. These decay fungi represent a future risk of damage that can be easily controlled by active remedial treatments.

Decay can be either external or internal (Figure 22). Appearances, however, can be deceiving. Poles that look weathered or checked are often rejected because of their appearance, but further inspection often reveals that the damage is shallow. Checks have little or no effect on strength. A careful internal inspection is always warranted before arbitrarily rejecting a pole.

External decay is typically found in older southern pine poles below the groundline. This damage develops slowly, but eventually reduces the effective circumference of the pole, forcing replacement or reinforcement.

Figure 22. External (left) and internal decay (right).

Caution

Pole inspectors in areas with low hazards of decay or termites should not be complacent. Warm, dry climates are conducive to pole checking. Both surface and internal decay of poles can occur below ground in dry climates in areas along rivers or in irrigated land. It is important to inspect poles in these areas to a depth of 3 ft below the groundline. Termites can attack wet wood anywhere. Metal wraps around butt-treated cedar poles to protect against fire can encourage decay and termite attack of untreated sapwood beneath the wrap.

Linemen sometimes cut longer poles to length during installation. This practice is costly, since it wastes wood, but it also exposes untreated wood at the top. Internal decay can begin in untreated pole tops within 1 yr and reach the visible advanced stage called rot within 2 to 4 yr under ideal conditions. Pole tops should have a cap to protect against decay.

Incipient Decay

Before it is visible, the decay, termed incipient decay, can produce dramatic reductions in wood strength (Wilcox 1978). Incipient decay also can extend 4 ft or more above internal rotten areas in the groundline zone of Douglas-fir poles. Because incipient decay is invisible to the unaided eye, it cannot be reliably detected in the field. Research on chemicals as color indicators for decaying wood or changes in electrical and chemical properties of wood eventually may lead to field detection methods. Meanwhile, microscopic examination or culturing of wood remain the only ways to detect decay fungi at the earliest stages of attack.

Sound or Rotten?

Eventually, decaying wood becomes discolored or the physical properties of its fibrous structure change sufficiently to be recognized as rot. Sound wood has a fibrous structure and splinters when broken across the grain, whereas rotten wood is brash and breaks abruptly across the grain or crumbles into small particles. Decaying wood also may have an abnormal moldy or pungent odor. Wet sound wood, which is much softer than dry

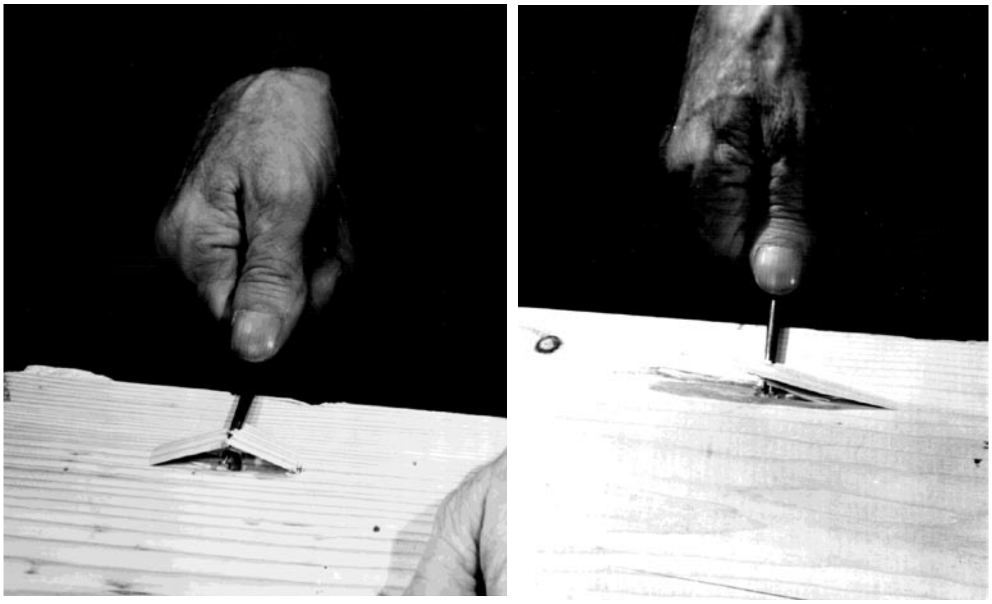

Figure 23. Use the "pick test" to detect rot. When a sliver of wood is lifted, abrupt failure usually indicates rot (left), whereas a splintering failure indicates sound wood (right). Photo provided courtesy of the U.S. Forest Products Laboratory, Madison, WI.

sound wood, is frequently confused with rot on the surface of poles below groundline. If in doubt, use the "pick test" (Figure 23). Lift a small sliver of wood with a pick or pocket knife and notice whether it splinters (sound) or breaks abruptly (rotten). Sound wood has a solid feel when scraped or probed. Surface rot feels soft and usually has minute fractures like charred wood. Remember—"sound" and "solid" wood cannot be reliably distinguished in the field!

As discussed earlier, rot in cedar heartwood may occur as voids or as well-defined pockets of rotten wood abruptly changing to the adjacent sound heartwood. In Douglas-fir, the change from rotten to sound wood is much less distinct because incipient decay usually extends a considerable distance from the rot.

Drilling and probing with a metal rod may reveal natural voids that can be confused with decay, or wet wood may drill easily like decayed wood. Ring shake, a natural separation along a growth ring, usually creates a short radial void with wood on both sides that feels solid. Internal radial checks create long narrow voids that may or may not be coated with preservative. In cedar poles, decay pockets caused by fungi in living trees can be misleading. While ANSI specifications limit the distance from the butt that decay pockets can extend, smaller pockets that do not affect strength can extend for some distance above these limits. Fortunately, few fungi that decay living trees continue to decay wood in service.

Surface rot can be detected by scraping, probing with a dull tool, or visually examining the wood. Internal decay is detected by sounding, drilling, coring, measuring electrical resistance, or feeling a metal probe as it is pulled across the growth rings. Poles with extensive rot are easy to detect, but detection becomes more difficult as the extent of the rot decreases. The sooner decay can be detected, however, the earlier preservative treatments can be applied to retain the structural integrity of poles. Field personnel should practice scraping, probing, lifting slivers, drilling, and coring both sound and decaying poles to develop and improve their ability to detect rot. Use pole sections removed from service to verify predictions by boring, then cutting, the cross section to see the actual damage. Select the equipment that best meets your needs. Some sources of equipment are listed in the Equipment Appendix.

Inspection Tools and Techniques

Scraping Devices

A shovel, scraper with triangular blade, or dull probe can be used to detect belowground rot on the pole surface. Cutting the blade of a shovel back several inches facilitates removal of earth around poles and from the surface of poles. The pole is excavated to a depth of 18 to 24 in.; then the scraper is rubbed along the surface. If scraping exposes untreated wood, treat that area with a grease-like preservative paste or groundline bandage. Be careful not to confuse softer, wet wood with decay.

Hammer

In the hands of an experienced inspector, a hammer is a simple, rapid, and effective tool for sounding poles to detect internal rot. Use a lightweight hammer that is comfortable to swing and strong enough to stand repeated solid blows to the pole. Start hammering as high as you can reach, and work down the pole. Experienced inspectors can tell much about a pole by the "feel" of the hammer during sounding. A sharp ring indicates sound wood, whereas a hollow sound or dull "thud" indicates rot. Because seasoning checks, internal checks, and knots can affect the sound, suspicious areas should be drilled or cored with an increment borer. A leather punch 1/4 in. in diameter can be welded to the back of the hammer to make a starter hole for an increment borer bit.

Increment Borer

Increment borers were originally used to measure tree growth; they have hollow, fine-steel bits that are used to extract wood cores. These are examined for visible decay and measured for shell thickness and depth of preservative treatment (Figure 24).

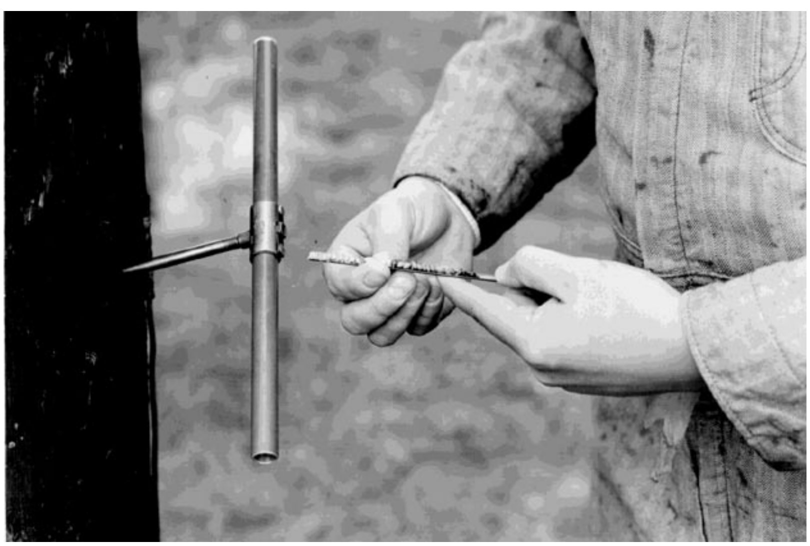

Figure 24. Cores extracted with an increment borer permit detection of rot, as well as measurement of shell thickness and depth of preservative penetration. Cores can be retained and cultured for fungi.

To speed coring and reduce breakage of the expensive bits, make starter holes 1/2 in. deep and 3/8 in. in diameter with a punch mounted on a hammer or with a battery-powered drill. If boring resistance increases, back out and remove the core before boring deeper. Unusual or abrupt force can snap the bit or pack wood in so tightly that the bit must be cleared of compacted wood by drilling with a smaller diameter bit. Rubbing bits with a moistened bar of soap or wax eases drilling.

To speed drilling, special chucks can be fabricated to fit into a variable-speed power drill. This arrangement works well, but be careful to not damage the bit by drilling too fast.

For good cores, bore at a 90° angle to the pole to cut across growth rings. Be sure to regularly sharpen the bits with a fine hone, especially when cores become twisted and difficult to remove. Cores taken with a dull borer may appear decayed or damaged. Some suppliers of increment borers also sharpen bits. Keep the bits free of rust or pitch. To avoid corrosion, keep a small can of machine oil on hand to coat the outside of the bit during use and to coat the inside after use, especially during wet weather. A rifle cleaning kit is handy for cleaning increment borers.

Shell-thickness Indicator

Figure 25. A shell-thickness indicator detects rot in poles by "feeling" growth rings in sound, but not rotten, wood when inserted or removed from snug-fitting holes.

To determine the thickness of solid—but not necessarily sound—wood, insert a thin metal rod (Figure 25) into the hole made by coring or drilling. When the rod is pulled back with pressure against the side of the hole, the hook at the end should catch on the edge of the rot pocket. When pushing a tight-fitting shell-thickness indicator into a hole, you can feel the tip of the hook pass from one growth ring to another in solid wood, but not in rotten wood. Inscribe marks on the sides of the rod to indicate the shell thickness at different drilling angles, usually 45° and 90°. Although the rod will occasionally overestimate residual shell, it is a useful tool for identifying dangerous poles. The rods can be home-made or purchased from pole-inspection agencies.

Shigometer®

The Shigometer® was developed for detecting decay in living trees by (Figure 26) measuring electrical resistance (Shigo *et al.* 1977). It should be used in wood with MC at or above 27%, which is typical of decaying wood at the groundline of poles. A probe with 2 twisted, insulated wires with the insulation removed near the tip is inserted to various depths into a hole 3/32 in. in diameter. A marked change in electrical resistance as the probe goes deeper indicates rot or a defect. The device effectively detects rot, but it also can yield "bad" readings on apparently sound poles. For example, free water in the wood may affect resistance. As a precaution, drill or core all poles to determine the nature of the defect. The Shigometer® should be used by trained personnel and calibrated frequently (Zabel *et al.* 1982).

Figure 26. The Shigometer™ measures electrical resistance to detect rot in poles. Use an increment borer to determine the nature of the defect.

Moisture Meter

Resistance-type meters (Figure 27) can be used to detect wood with MC exceeding 20%, the safe limit to prevent decay. They are also useful for assessing post-treatment

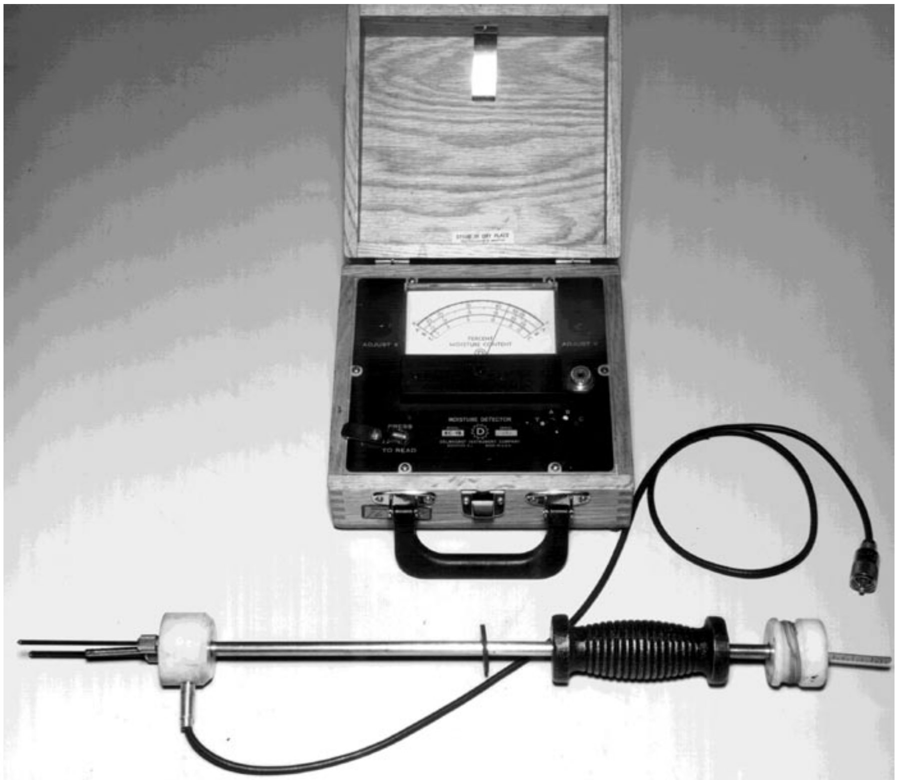

Figure 27. A resistance-type meter can be useful for detecting MC levels that are high enough (over 20%) for decay. As a sliding hammer drives 2 electrodes into the wood, a ruler emerging from the top of the hammer measures their depth. Shanks of the electrodes are coated so moisture readings are made between the uninsulated points.

MC specifications. Long electrodes can measure moisture to a depth of about 2 1/2 in. Because the high MC of decaying wood (usually greater than 30%) causes steeper-than-normal moisture gradients in poles decaying internally, the meter becomes a useful tool for determining the extent of decay in poles and other timbers. For example, meter readings above 20% and steep moisture gradients can indicate the height of decaying wood in Douglas-fir poles with rot below, but not above, the groundline. Similar readings in poles without rot should be suspect. Moisture readings below 20% indicate the absence of conditions for fungal growth to the depth of the electrodes.

Check the batteries regularly, and calibrate the meter frequently. Make sure the coating on the shank of the electrodes is intact. When necessary, correct meter readings for ambient temperature and wood species. Moisture meters should be considered secondary tools for inspection, since they are limited in the zone they can inspect and are not able to detect decay, only the conditions where it might occur.

Mechanical Boring

Most inspection programs for detecting internal decay use gas-powered drills equipped with shipauger-type bits 3/8 in. or greater in diameter. The inspector bores into the wood, listening to the sound of the motor as the bit enters the wood. Decayed wood will be softer and easier to bore. Chips from sound wood tend to be bright and larger than those from decayed wood. In addition, shavings from weak wood will be darker and more easily broken than those from sound wood. For southern pine poles, inspectors typically use 9/16-in. diameter bits; for Douglas-fir or western redcedar, inspectors often use 13/16-in. diameter bits. The latter bit creates an ideal hole for subsequent application of remedial treatments for arresting internal decay.

Decay-Detecting Drills

While conventional drills create a large hole in the pole, decay-detecting drills use a small, 1/8-in. diameter bit to bore into the pole (Figure 28). As the bit enters the wood, the bit rotation is recorded, providing

Figure 28. Drill detector.

a permanent record of the pole's internal condition. Bits require fewer rotations to penetrate weaker, decayed wood than sound material. These devices were originally developed for detecting decay pockets in living trees, where the tree can later grow over the inspection hole. Poles can not "grow over" the hole; therefore, some caution must be exercised to ensure that the poles are flooded with a supplemental preservative to avoid creating avenues of entry for decay fungi. The use of these devices must also be considered as experimental, because the effects of different wood species, specific gravities, and MC on inspection results have not been fully documented. In addition, the ability of these devices to detect internal decay has not been compared with that of conventional inspection techniques.

Acoustic Inspection

The desire for nondestructive inspection techniques that do not cause wood damage has stimulated the development of acoustic inspection devices. In principle, a sound wave moving across a wood pole is affected by all characteristics of the material, including growth rings, moisture, checks, decay pockets, knots, and a myriad of other wood properties (Figure 29). These characteristics affect both the rate or speed with which the wave moves across the pole and the shape of the wave that exits the wood. Large voids, checks, ringshakes, or internal burst increase the time required for a sound wave to traverse a pole cross section. Early acoustic inspection devices used time-of-flight to detect voids, but the effectiveness of those devices was limited by the presence of natural defects that affected time-of-flight in a similar manner. Later devices used time-of-flight, but also recorded the changes in wave-form, or modulation of the sound wave as it passed through the pole, which provides more reliable estimates of pole condition (Figure 30). The developers of acoustic devices then tested poles both sonically and in bending to failure and used statistical techniques to relate sonic param-

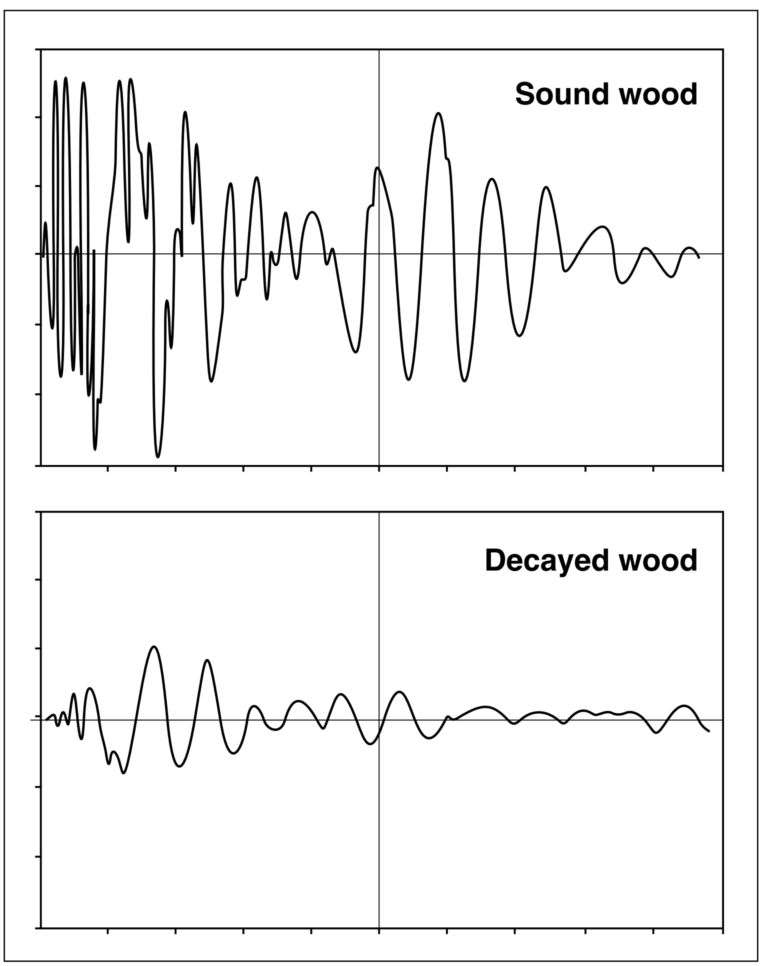

Figure 29. Acoustic signal (weak/strong) showing weak vs. sound wood.

eters to residual strength. Data from this population was then used to produce estimates of residual modulus of rupture of poles in service.

These devices do not detect decay; instead, they use acoustic parameters to estimate residual strength. Thus, a strong pole with significant decay may produce a reading similar to a weak pole without decay. In this case, the device might infer that no action was required on either pole; however, the initially strong pole would continue to decay between inspections and could fail. There is considerable debate concerning the merits of the currently available systems. They should, at best, be viewed as supplemental tools to the conventional inspection methods and should never be the sole inspection method used (Wright and Smith 1992).

Figure 30. Pole test: an example of an acoustic inspection device.

X-Ray Tomography

Like the bones in our bodies, wood varies widely in density, and those variations can be detected with x-rays (Figure 31). X-ray was used in the 1960s and early 1970s for in situ inspection of wood poles, but the process was slow, the equipment was bulky, and interpretation of the resulting x-rays was difficult. As a result, the technique was abandoned.

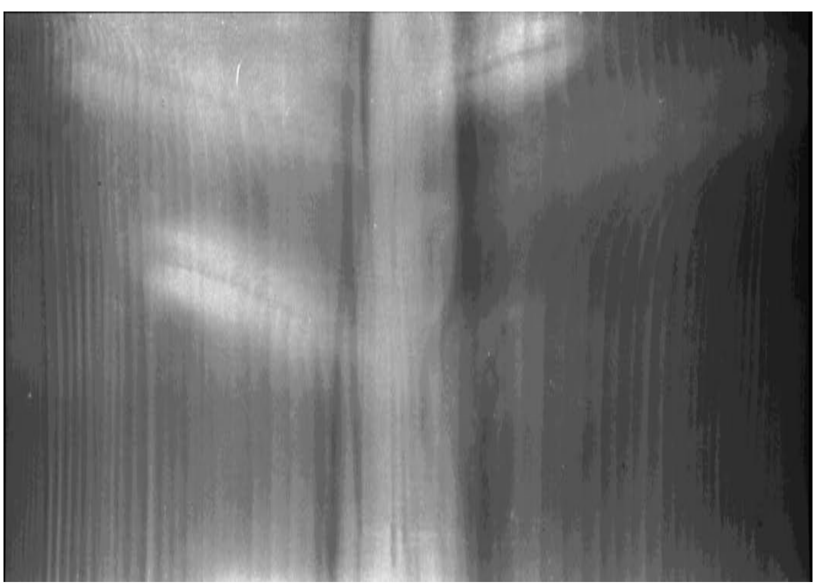

Figure 31. X-ray of wood.

Recently, however, x-ray inspection has been reexplored. X-ray tomography uses multiple x-rays around a pole at selected heights to construct a 3-dimensional map of the internal condition of the pole. Until recently, the equipment required to complete these analyses was too bulky for field use, but improvements in computing power and miniaturization of key components has brought this technology closer to the field. Despite these improvements, however, considerable research will be needed to fully understand the resulting variations that may occur in the field. For example, variations in moisture can affect x-ray attenuation, producing the image of a decay pocket. This technique could provide a powerful new inspection tool when methods for segregating defects from natural wood characteristics are developed.

Microscopic Decay Detection

Most inspection techniques detect decay in its intermediate to advanced stages, when the damage is clearly visible. Ideally, an inspector would detect damage at an earlier stage when treatment chemicals are more effective. At present, the most reliable technique for detecting the early stages of decay is microscopic examination of either wood fibers or thin sections cut from the wood (Figure 32). Microscopic analysis is tedious and time consuming, and is not suitable for routine evaluations. It is, however, useful for delineating the cause of failure in specific cases. The observer looks for bore holes, cell-wall thinning, and other evidence of fungal attack. One shortcoming of this technique is that it cannot determine whether the attack was actively occurring at the time of failure. Culturing wood from the same zone can help determine if viable fungi remain in the wood.

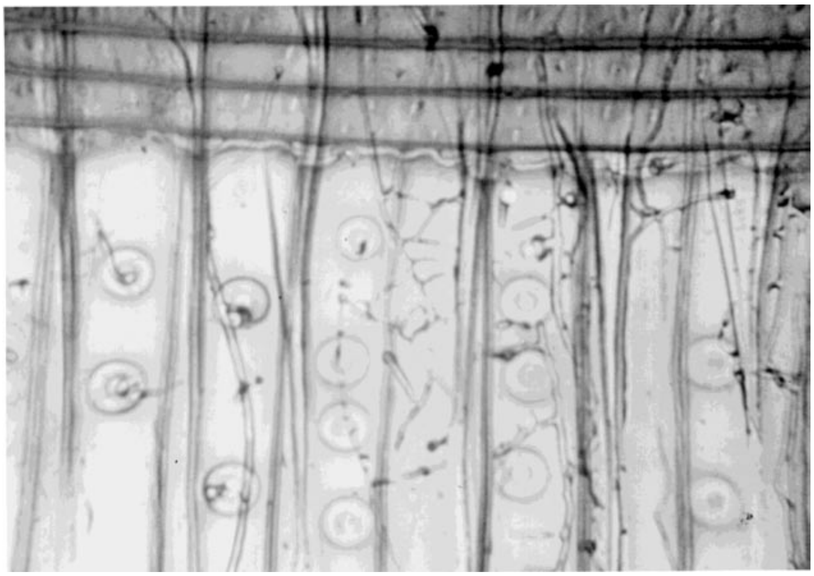

Figure 32. Hyphae of a decay fungus in a wood section.

Mechanical Deflection Tests

In addition to small-scale mechanical tests for assessing pole condition, larger scale tests have been employed in some systems. These systems most commonly apply a force above the groundline and measure deflection to calculate a residual strength. While these techniques can provide some measure of residual pole stiffness, they do not detect decay. As a result, decaying poles that were originally very strong in their respective classes may appear as strong as a sound but originally weaker pole. This can provide a deceptive image of the relative health of a pole system. In addition, pole configuration, particularly the presence of guy wires, can affect test results. Mechanical deflection tests may, however, have a place as a supplemental inspection tool for assessing poles that are in critical load areas.

Procedure for Inspecting Poles From the Ground

This general procedure for inspecting poles from the ground should be modified to meet the requirements of your pole system.

Condition of Pole Above Ground

Note the general condition of the pole, unusual damage to the pole or attachments, and the size and location of seasoning checks. In general, the wider the checks, the deeper they penetrate and the more likely they are to expose untreated heartwood; however, some narrow checks can be very deep.

Look for elliptical holes made by buprestid beetles, for mounds of sawdust as well as the carpenter ants that make them, and for woodpecker holes.

Examine cedar poles for surface rot and shell rot that are typical of untreated sapwood above the treated butt. Surface rot below the groundline of pressure-treated Douglas-fir poles can occur with Cellon® or Dow® process poles. Inspect the top of the pole for evidence of splits, cracked insulators, and other defects.

Sounding

Sound the pole from as high as you can reach to the groundline. "Bad" poles usually are easy to detect and, as you gain experience, you will become more proficient in detecting isolated suspicious areas that should be cored or drilled. Sounding alone is a poor inspection procedure that locates only the worst poles.

Drilling or Coring

After sounding, drill holes downward into the pole at an angle of about 45° at the groundline or slightly above, so that water cannot collect in the holes. Determine shell thickness and depth of preservative treatment. Poles that sound "good" should be drilled or cored at the groundline or, better yet, 1 ft below the groundline, near or below the widest check. All poles in service for more than 15 yr should be inspected by drilling.

- **If the wood is solid**, rate the pole as good—until culturing results are available to indicate otherwise.
- **If rot is present**, drill or core the pole at additional points around the circumference. Measure shell thickness, depth of preservative treatment, and pole circumference. From minimum circumference tables such as those used by the REA (1974), but modified for your system, determine if the pole should be replaced, reinforced, left in service and remedially treated to stop the decay, or scheduled for reinspection.

  Poles that sound suspicious should be drilled or cored in those areas and near the widest check at or below the groundline.
- **If the shell is inadequate** (i.e., fails National Electric Safety Code for bending strength), schedule the pole for reinforcement or replacement.
- **If the shell is adequate**, remove cores at additional points; depending on shell thickness, schedule the pole for replacement, stubbing, supplemental treatment, or reinspection.

Digging Inspection

To check for surface rot, dig the pole out to a depth of 18 in. in wet climates and deeper, if necessary, in dry climates. Some utilities initially limit digging to 1 side of the pole and only completely excavate if surface decay is found in the smaller zone. This reduces inspection costs. Brush the pole free of dirt and examine its surface for rot. Probe suspicious areas for soft wood. Scrape the surface with a dull tool, shovel, or chipper to remove all rotten wood. If in doubt, use the "pick test" (Figure 23) to check for rot.

To detect internal rot, drill or core the pole below the largest check. If rot is present, determine shell thickness and preservative penetration. Measure the pole circumference after the rot has been removed from the surface. Using the minimum circumference tables, determine if the pole should be scheduled for replacement, given a supplemental treatment, or scheduled for reinspection.

Holes Made During Inspection

Unless the hole is to be used for application of internal remedial treatment, treat all openings made during inspection with a double-strength preservative solution or paste (for example, 2% copper naphthenate), and plug all holes with preservative-treated dowels. Wear protective goggles, because preservative may squirt out of the hole when the dowel is driven.

Treating Excavated Poles

Preservatives may bleed, migrate, or leach from poles into the surrounding soil, and, in some cases, creosote or pentachlorophenol in heavy petroleum solutions may build up a protective barrier around the pole. Removal of this treated soil during excavation often is considered reason enough for applying an external supplemental treatment to poles with no evidence of surface decay.

Many pole managers consider the added cost of such treatment as good insurance that the outer shell of the poles will be protected until the next inspection 8 or more years later. A policy of treating all excavated poles, especially those in lines of mixed-age poles, at the groundline removes a difficult decision from the inspector's shoulders and can be a good habit. On the other hand, if the external shell of a pole is free of rot and well protected by preservative, the additional cost of the groundline treatment is an unnecessary maintenance expense. Experience, good records, and random follow-up inspections can be useful for developing criteria for each component of an inspection. Since conditions for preservative users vary with climate, wood species, and chemical treatment, utilities should consider some analysis of residual preservative content in the surface of excavated poles before applying supplemental external preservatives. One utility performing such an analysis on Douglas-fir poles treated with penta in heavy oil found that residual chemical levels were far in excess of those needed and eliminated excavation and external treatment, saving nearly $40 per pole.

Treatment of In-Service Poles

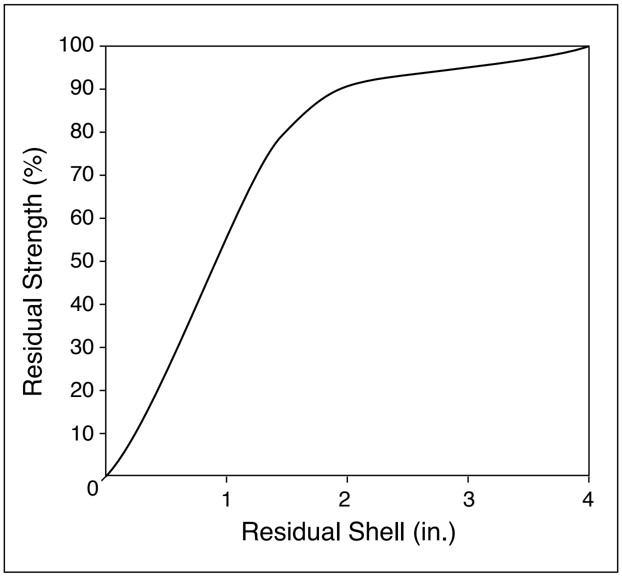

Figure 33. Strength vs. residual shell thickness of a pole.

Once a pole has been found to be visibly decaying, the inspector must make 1 of 3 decisions based on the amount of sound wood remaining and the configuration of the pole. The poles can be accepted with remedial treatment, accepted with remedial treatment and reinforcement, or rejected. These decisions are often based upon prior experience within the system. In most cases, utilities require a minimum of 2 in. of remaining sound wood in the outer shell of poles with internal decay, although thickness requirements can vary with pole load, configuration, or climatic conditions. These requirements reflect the fact that most of the bending strength of a pole lies in the outer shell (Figure 33). Deciding on the fate of poles with external decay requires a different approach. The inspector measures the residual circumference after all of the decay wood has been removed and consults a chart showing the amount of circumference permitted for a pole of that class. Poles that retain adequate shell thickness or circumference are then remedially treated.

For a utility, the economic benefits of a maintenance program, compared with no maintenance program at all, can be exceptional. The extension of average pole service life by a maintenance program results in the deferral of capital replacement costs and reduced disposal costs. New York State Electric & Gas Corp., a mid-sized utility that has a wood pole plant with a pole replacement cost of $1.3 billion, estimates an annual savings of $53 million resulting from pole maintenance.

External Treatments

Aboveground

External decay above the ground can occur in western redcedar poles that were initially treated only in the butt zone. Sapwood above this zone decays and separates from the more durable heartwood. These separations create a hazard for personnel climbing the pole. Until recently, this damage was controlled by spraying the surface of the pole with a 2% solution of copper naphthenate in diesel oil. Spraying was performed at 10- to 15-yr intervals and was a highly effective method for protecting this wood. Concerns about the potential effects of chemicals that drifted from the poles during the spray operation, however, have largely curtailed this practice. Utilities that continue to specify butt-treated western redcedar should be aware that sapwood decay will eventually occur, and that damage may prevent climbing. Thus, butt treatments should not be used in wetter climates. The lower cost of butt-treated poles should therefore be weighed against the costs of performing future maintenance from bucket trucks.

Belowground

Decay below the groundline is normally controlled by the application of external preservatives, either in thickened pastes or deposited on self-contained wraps. For many years, external preservatives included mixtures of pentachlorophenol, creosote, arsenic, sodium fluoride, dinitrophenol, or chromium. The water-soluble components were presumed to diffuse for relatively short distances (1/2 in. for Douglas-fir, 2 to 3 in. in southern pine) into the wood to control the existing fungal attack, whereas the oil-based components were presumed to stay near the wood surface where they acted as barriers against renewed attack. Concerns about the safety of many components in older systems have resulted in a shift to formulations containing copper naphthenate, sodium fluoride, or boron. Recent studies suggest that these systems perform similarly to older systems.

Wraps or bandages are typically applied at the groundline, then extended downward for 18 to 24 in. Preservative pastes are applied at the specified label thickness, then covered with polyethylene; the soil is then backfilled against the plastic. These treatments should protect the wood for about 10 yr.

Internal Treatments

Groundline Decay Control

Internal Void Treatments

Poles that contain large voids caused by insects or fungal attack are often treated with internal void chemicals. These treatments are injected under low pressure into a hole drilled directly into the void, and are presumed to coat the surface of the void to prevent further expansion. They may also kill any insects in the galleries where the chemicals penetrate. Void treatments generally consist of a water-based preservative, but they may also contain insecticides. Sodium fluoride or boron are normally used for internal void treatments, although sodium arsenate, a common insecticide, may also be added with the fluoride. Although these chemicals will kill insects on direct contact, their ability to penetrate the wood is a more important component of their use.

The value of internal void treatments in a regular maintenance program is the subject of some debate; utilities should carefully examine their use. These chemicals are most effective in wood species such as western redcedar, which have well-defined rot pockets and an abrupt transition between sound and decayed wood. In addition, most voids are check associated and therefore have a connection to the surrounding soil. Pumping chemicals under pressure can permit them to escape from the pole into the surrounding soil. When considering the use of void treatments, utilities may want to set up treated and untreated test poles to assess the chemicals' ability to arrest expansion of voids, and to evaluate other effects of treatments.

Fumigants

Until the late 1960s, internal remedial treatments were largely restricted to oil- or water-based chemicals. These chemicals were unable to move through the heartwood and were largely ineffective for controlling internal decay. The identification of fumigants as internal treatments provided a new technology for controlling decay. Fumigants are either liquid or solid at room temperature, but have high vapor pressures. As a result, fumigants rapidly become gases and are able to move throughout the wood.

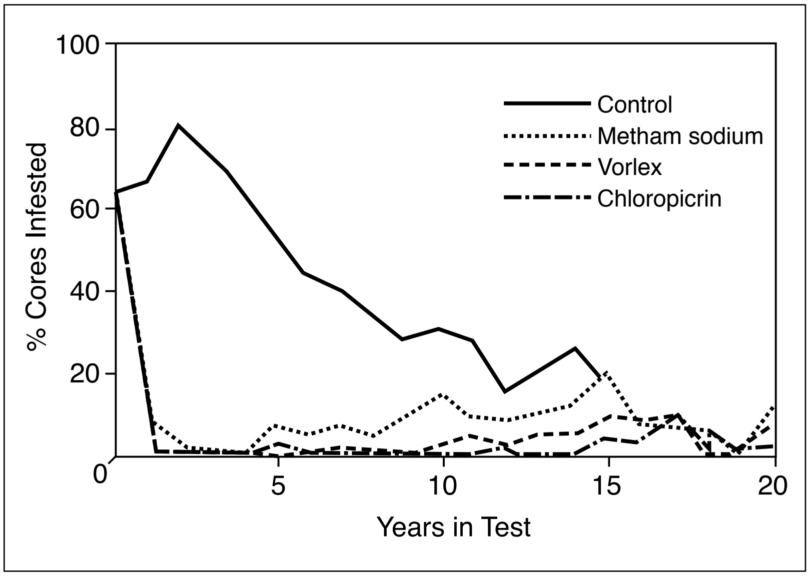

Figure 34. Ability of selected fumigant treatments to eliminate decay fungi in Douglas-fir poles.

Table 2. Number of holes required in poles of different sizes to hold varying amounts of liquid fumigant.

Hole		Fumigant	Pole circumference[a]		
Diameter (in.)	Total length[a] (in.)	Amount per in. of hole (pt)	Less than 32 in. (3/4 pt)	32-45 in. (1 pt)	More than 45 in. (2 pt)
5/8	15	0.010	6	-	-
	18	0.010	5	-	-
3/4	15	0.015	4	6	-
	18	0.015	-	5	-
	21	0.015	4	-	
	24	0.015	-	3	6
7/8	21	0.024	-	3	5
	24	0.024	-	-	4

[a]Total dosages per pole are in parentheses

Three fumigants, metham sodium (32.7% sodium n-methyldithiocarbamate in water), chloropicrin (97% trichloronitromethane), and methylisothiocyanate or MITC (96% active in aluminum vials), are registered for wood use (Figure 34). All are restricted-use pesticides in most states. Applicators must pass a state test on pesticide handling and safety before using these chemicals.

Metham sodium is a yellowish liquid with a strong sulfur odor like rotten eggs. This fumigant must decompose into methylisothiocyanate to become active. Previous trials suggest that metham sodium provides protection to Douglas-fir poles for 7 to 10 yr and to southern pine poles for 3 to 6 yr. These differences appear to reflect the higher permeability, which enhances chemical diffusion through southern pine.

Chloropicrin is among the most effective wood fumigants and has been detected in wood up to 20 yr after application. This highly volatile, difficult to handle chemical must be applied by applicators wearing respirators. As a result, its use is largely confined to poles that are away from inhabited areas.

The most recently registered fumigant is MITC. This fumigant is a solid at room temperature, but sublimes directly to a gas. Pure MITC is caustic and causes skin burns, but this problem is overcome by placing the chemical into sealed aluminum vials prior to application. The entire ampule is added to the pole. Field trials indicate that this chemical is at least as active as metham sodium, but is much safer to apply.

Figure 35. Fumigant application includes drilling holes at a steep angle, adding chemical, then plugging the holes.

Drilling Treatment Holes

Drill a reasonable number of holes to obtain good distribution of the fumigant, but stagger the holes so they do not weaken the pole. Table 2 specifies the number of holes of different diameters and lengths needed to place various amounts of fumigant in poles. Note that the hole length allows for the insertion of a 3-in. treated plug. Another utility recommends that the number of holes meet the limits of knot sizes in Table 2 of American National Standard 05.1 (ANSI 1992).

Starting at the groundline, drill a hole directly towards the center of the pole at a steep downward angle (Figure 35) that will not go through the pole or through seasoning checks where much of the fumigant could be lost. If the hole intersects a check, plug that hole and drill another. Space the remaining holes equally around the pole upward in a spiral pattern with a vertical distance of 6 to 12 in. between holes. If more than 2 treating holes intersect an internal void or rot pocket, redrill the holes farther up the pole into relatively solid wood where the fumigant will gradually volatilize and move through the wood. Much of the fumigant placed in rot pockets will be lost if the seasoning checks connect. Where a rot pocket is above the groundline, drill holes in solid wood below and above the pocket.

Applying Fumigant

Pour liquid fumigants from polyethylene bottles directly into holes drilled into the pole. Care should be taken to avoid overfilling the holes. Drive tight-fitting, preservative-treated wooden dowels into the holes to minimize chemical loss. Some utilities use threaded plastic plugs for this purpose, which are driven in with a hammer but can be removed for reapplication of fumigant. Some users have noted that these plugs deform to an oval shape in some poles, but the effect of the deformation on treatment is not known. Wood dowels generally must be drilled out whenever poles are retreated. This process can enlarge the treatment hole, making it difficult to seal tightly. The use of an oversized plug can overcome this problem.

Water-diffusible Chemicals

Although fumigants are highly effective, their volatility and toxicity have led some utilities to consider alternative treatment systems that are based on water-soluble fungicides such as boron and fluoride. These chemicals are usually applied in a concentrated rod form and move through any moisture present in the wood to eliminate fungal infestations. Borate rods have been widely used in Europe and Australia, where the chemical is reported to move well through most wood species. Trials in North America, however, have produced mixed results on Douglas-fir. In some tests, there was only minimal movement of chemicals away from the original application site. Moisture variation appears to markedly affect performance of these treatments.

Borate can also be applied internally as a part of a copper naphthenate paste. Studies suggest that movement of the copper naphthenate is minimal, while the borate moves for short distances away from the treatment hole.

Fluoride has only recently been registered in the U.S. as an internal void treatment, but it is used in Australia in a fluoride/boron rod. Preliminary trials suggest that this chemical moves as well as boron, although further field data will be required before it is used extensively.

At present, the primary advantage of fluoride and boron over fumigants is applicator safety; the drawbacks include a limited ability to move upward from the point of application, a slower release rate, and a dependency on moisture for movement. The slower release rate can permit fungal infestations to cause more damage before they are finally controlled. Moisture levels vary widely in poles, both positionally and seasonally. Rods placed in drier zones of the wood will be unable to diffuse to the wetter sites. Thus, these alternative technologies appear to require additional testing before they are widely used for wood poles.

Retreatment

The timing of retreatment schedules varies with the wood species and climate. Poles under severe conditions may be inspected as often as every 5 yr. Those in drier climates may be inspected at 15-yr intervals; most utilities, however, use a 10-yr retreatment cycle. Metham sodium, chloropicrin, and MITC appear to be effective for 10 yr in Douglas-fir, and limited studies suggest that the results should be similar in western redcedar. Retreatment cycles with fumigants must be shorter in southern pine because the chemical appears to dissipate and wood degrading organisms invade the wood more rapidly. Retreatment cycles for boron and fluoride remain poorly defined, since the rate of initial movement is limited. Utilities using these chemicals should consider limited mid-cycle inspections to confirm that the chemicals are performing as expected.

Aboveground Decay Control

Although decay at the groundline remains the most prevalent in-service wood problem, decay above ground can also cause severe problems wherever adequate moisture from wind-driven rain occurs. This decay can either be associated with deep checks that form after the pole has been placed in service or from damage to the treated shell during field drilling. Controlling aboveground decay can be both expensive and challenging. Metham sodium and MITC are registered for aboveground use and should effectively control decay. Borate rods and the borate/copper naphthenate paste can also be used for this application, but both require moisture for movement. Therefore, the treatment holes must be close enough to the decay zone to ensure that moisture is present for diffusion.

Field-damaged wood on the wood surface can be remedially treated with an oil-based preservative such as copper naphthenate, applied as soon as possible after the damage occurs. This treatment does not penetrate far into the wood, but provides a surface barrier against fungal attack. Studies also show that applying a concentrated borate paste to the exposed wood in a protected site, such as a bolt hole, can provide excellent protection against fungal attack.

Record Keeping

No inspection and maintenance program is complete without a thorough record-keeping system. At their simplest, accurate records can help identify dangerous poles so they can be removed or repaired as soon as possible. Good records can also be used to track the performance of particular treatments, wood species, suppliers, or specifications. In larger systems, they can be used to monitor performance under different environmental conditions. All of these factors can be used to more carefully allocate scarce maintenance dollars to those poles most in need of attention.

A good initial record should include pole supplier, wood species, chemical treatment, retention, height/class, and year installed. Later entries should include the results of inspections, including preservative penetration, presence of internal decay (with shell thickness), presence of external decay (with loss of circumference), and the types of internal treatments applied for each year. This information can then be used to identify poles that are in need of immediate remedial attention.

Few utilities fully use their pole records; however, a good data base can be a powerful tool for tracking the performance of various treatments and specifications. For example, workers at Bonneville Power Administration carefully followed the performance of the Douglas-fir poles in their system before and after they implemented through-boring of new poles and fumigant treatments of existing poles. In both cases, the results were dramatic—pole failures declined to levels that approached those found with western redcedar and fully justified the use of both through-boring before treatment and maintenance after treatment.

Record keeping can be accomplished with hand-written records (Figure 36), but the time required to transfer field notes often leads to collections of paper that are never transcribed. When notes are transcribed, the potential for errors is always present. The recent development of handheld data loggers can eliminate the need for paper and permit the field inspector to enter all pertinent inspection data directly (Figure 37). These systems can store data for later transfer directly to a personal computer or can even be attached to a modem for transfer directly from the field. The risk of error can be further reduced through the use of bar codes on poles.

Whatever system is employed, all software and hardware should be thoroughly compatible and should be usable without extensive training. Data bases that require extensive training to access will be under-utilized. Examples of several handheld data entry systems are listed in the Equipment Appendix.

WOOD POLE INSPECTION AND MAINTENANCE REPORT

Adno (1 2 3 4) Line name ____________ Inspector ____________ Date ________ A O (79 80)

IDENT.			BUTT INSP.					A.G.H.R. INSP.						CLIMB			MISC.						TREATMENTS			X-ARM					
Mile	Str	P	Pole qtrs 1	2	3	4	Yr ins	Ht	Pole qtrs 1	2	3	4	Yr ins	Hrt rot Dia	Dpth	Yr ins	Shell rot	Cracks	Insect	B/A	Fire	Other	VAPAM	Above ground	Pole top	Yr rpld	Cond	Method	Yr ins	
5 6 7	8 9	10	25	26	27	28	29 30	31 32	33	34	35	36	37 38	39	40 41	42 43	44	45	46	47	48	49	50 51	52 53	54 55	56 57	58	59	60 61	62 63 64 65 66 67 68 69 70

COMMENTS (COMPUTER PROCESSABLE)

Mile	Str	P	Comment		
				A	9
				A	9
				A	9
				A	9
5 6 7	8 9	10	11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38 39 40 41 42 43 44 45 46 47 48 49 50 51 52 53 54	79	80

POLE REPLACEMENT: OLD POLE — E O (79 80)

Mile	Str	P	Work order	P/E	Cause	Ins	X arm	Date Mo	Day	Yr
5 6 7	8 9	10	11 12 13 14 15 16	17	18 19 20	21 22	23	24 25	26 27	28 29

POLE REPLACEMENT: NEW POLE — I O (79 80)

Mile	Str	P	Design	Type	Length	K	Yr inst	Treatments Va	Pt	X-arm Yr rpld	C	M	Yr insp
5 6 7	8 9	10	11 12 13 14	15 16 17 18	19 20 21	22	23 24	50 51	54 55	56 57	58	59	60 61

Figure 36. Example of field inspection form.

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Equipment Appendix

Inspection Equipment

A. Acoustic Devices

EDM
2301 Research Boulevard, #10
Fort Collins, CO 80526-1825
(Pole Test)

Metriguard
P.O. Box 399
Pullman, WA 99163

B. Drills

Shannon Technology Corp.
2999 North 44th Street, Suite 300
Phoenix, AZ 85018
(Decay-detecting drill)

B.C. Instruments
P.O. Box 430
Proctor Road
Schomberg, Ontario L0G1T0
CANADA
(Resistograph)

C. Moisture Meter

Delmhorst Instrument Co.
51 Indian Lane East
Towaco, NJ 07082

Wagner Electronic Products
326 Pine Grove Road
Rogue River, OR 97537

Lignomat USA Ltd.
P.O. Box 30145
Portland, OR 97230

D. Inspectors

Pole-Care Industries
P.O. Box 137
Conyers, GA 30207

Osmore Wood Preserving, Inc.
980 Ellicott Street
Buffalo, NY 14209

National Wood Treating
P.O. Box 1946
Corvallis, OR 97330

Crest Chemical and Inspection Co.
10516 Pearl Street
Northglen, CO 80233

Davey Tree Co.
P.O. Box 351
Livermore, CA 94551

Pole Maintenance Co.
P.O. Box J
Columbus, NE 68601

McCutchan Inspection
8528 N. Lombard Street
Portland, OR 97203

Intec Services, Inc.
P.O. Box 42
Fort Collins, CO 80522-0042

Independent Inspection Co.
P.O. Box 1775
Havre, MT 59501

E. Increment Borers

The Ben Meadows Co.
3589 Broad Street
Atlanta, GA 30341

Forestry Suppliers, Inc.
P.O. Box 8397
Jackson, MS 39284-8397

F. Remedial Treatments

1. Wraps/Bandages

CSI, Inc.
276 SW 43rd Street, Building 3
Renton, WA 98055

ISK Biotech
P.O. Box 9158
Memphis, TN 38118

Osmose Wood Preserving, Inc.
980 Ellicott Street
Buffalo, NY 14209

2. Internal Treatments

a. Fumigants

Osmore Wood Preserving
980 Ellicott Street
Buffalo, NY 14209
(Metham sodium, chloropicrin, MITC-Fume)

ISK Biotech
P.O. Box 9158
Memphis, TN 38118
(Metham sodium)

Great Lakes Chemical Co.
P.O. Box 2200
West Lafayette, IN 47906
(Chloropicrin)

b. Diffusibles

ISK Biotech
P.O. Box 9158
Memphis, TN 38188
(CuRep 20)

CSI
276 SW 43rd Street, Building 3
Renton, WA 98055
(Borate rods)

G. Bolt Hole Treatments

DMG, Inc.
2301 Scranton Road
Cleveland, OH 44133-9988
(Copper naphthenate)

CSI, Inc.
276 SW 43rd Street, Building 3
Renton, WA 98055
(Copper napthenate)

H. Plugs

CSI, Inc.
276 SW 43rd Street, Building 3
Renton, WA 98055

Osmore Wood Preserving
980 Ellicott Street
Buffalo, NY 14209

WS Laidlaw Products, Ltd.
Victoria, B.C. V8X 3N5
CANADA

Morgan Lumber Co.
100 West Washington Street
Jackson, TN 38301

I. Handheld Data Loggers

EDM
2301 Research Blvd, #110
Fort Collins, CO 80526-1825
(Husky FS2/Micropalm data logger)

Corvallis Microtechnology, Inc.
413 SW Jefferson Avenue
Corvallis, OR 97331

J. Drills

Forestry Suppliers, Inc.
P.O. Box 8397
Jackson, MS 39284-8397

The Ben Meadows Co.
3589 Broad Street
Atlanta, GA 30341

Wood Pole Maintenance Video

A 27-minute companion video, “Wood Poles: A User’s Guide to Inspection and Maintenance,” which combines extensive computer graphics and animation with real-world examples, is also available. The video and the Wood Pole Maintenance Manual were designed to be used together for training sessions, presentations, or individual study.

Copies of “Wood Poles: A User’s Guide to Inspection and Maintenance” in VHS format may be purchased for $95 (U.S.). The program is also available for rental (U.S. and Canada only) for a 5-day period for $25 (U.S.) or $35 (Canada). When requesting rental or purchase, refer to catalog #1016 V-T. To order the video, contact the Forestry Media Center, Peavy Hall, Room 248, Oregon State University, Corvallis, OR 97331-5702 (phone: 541-737-4702; fax: 541-737-2668; e-mail: forestrm@ccmail.orst.edu).

Morrell, J.J. 1996. WOOD POLE MAINTENANCE MANUAL. (1996 Edition) Forest Research Laboratory, Oregon State University, Corvallis. Research Contribution 15. 47 p.

The specification, inspection, and remedial treatment of utility poles are addressed. Included are discussions of enhancing specifications for improved performance, techniques for detecting decay and other defects, and chemical treatments available for arresting decay of poles in service.

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