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WOOD POLE MAINTENANCE MANUAL: 2012 EDITION

JEFFREY J. MORRELL

Oregon State UNIVERSITY

Forest Research Laboratory

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THE AUTHOR

Jeffrey J. Morrell is Professor of Wood Preservation in the Department of Wood Science and Engineering at Oregon State University.

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Forestry Communications Group
Oregon State University
202 Peavy Hall
Corvallis, OR 97331
Voice: (541) 737-4270
Email: ForestryCommunications@oregonstate.edu

Editing, design, and layout by Caryn M. Davis, Forestry Communications Group, OSU College of Forestry, Corvallis.

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ABSTRACT

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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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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 that 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

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 types of 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 inches; sapwood of Douglas-fir is somewhat thicker, ranging from 1 to 3 inches. 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 inches. Sapwood can often be distinguished from heartwood through the use of chemical indicators that are based upon differences in pH between sapwood and heartwood (AWPA 2008).

Sapwood of the three 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 Douglas-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.

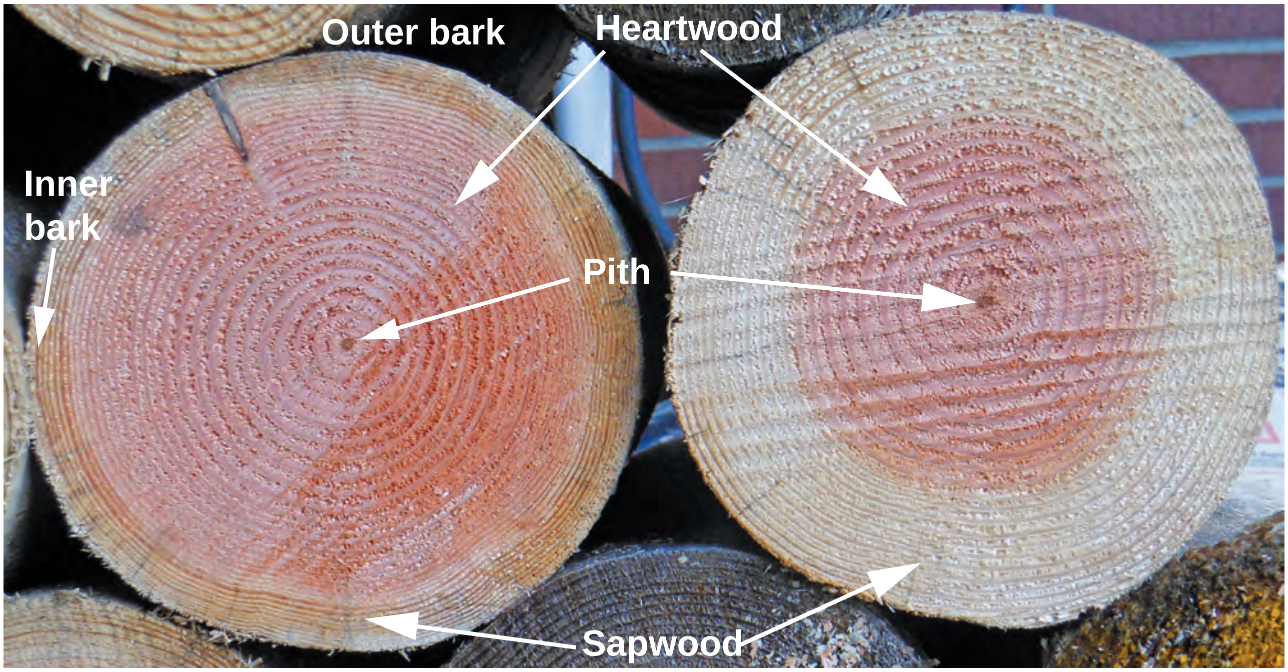


Figure 1. Cross sections of Douglas-fir showing typical sapwood (left) and deep sapwood (right).

In addition to sapwood and heartwood, there are differences in annual growth that produce distinct rings in most temperate woods species. Cells produced early in the season have large cell lumens and thin cells walls and are termed earlywood. Cells produced later in the season are thicker walled with smaller cell lumens and are termed latewood.

Ninety percent of coniferous wood is made up of minute, hollow fibers (called tracheids) oriented lengthwise along the tree stem, which transport water and nutrients from the roots up through the sapwood to the leaves (Figure 2). 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 toward the center of the tree as ribbons of unequal height and length. These rays (a mixture of tracheids and parenchyma cells) 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.

Density has little or no relationship to durability. Dense woods can have little durability, while light woods, such as western redcedar, can be quite durable.

Growth Rate

The American National Standards Committee Standard ASC 05.1 specifies maximum growth rates in the outer 2 to 3 inches of a pole (depending on pole size). This requirement reflects a tendency for faster grown wood to be less dense and therefore weaker. This standard also allows for use of poles with slightly faster growth, provided that the percentage of denser latewood is high.

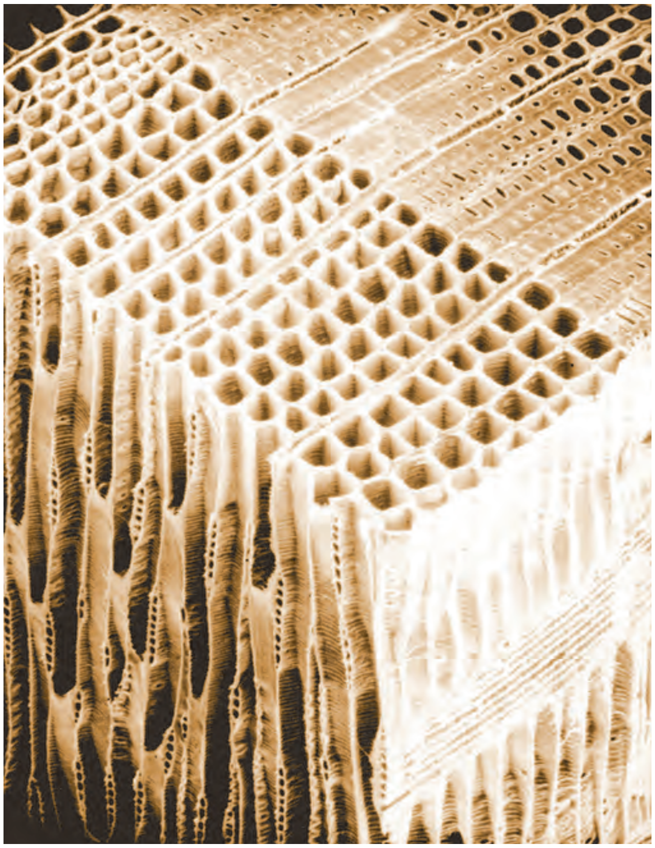


Figure 2. In this greatly enlarged view of fibers in Douglas-fir, large, open ends of thin-walled springwood fibers change abruptly to thick-walled summerwood fibers. Horizontal ribbons of short ray fibers are interspersed among long vertical fibers that make up about 90% of the wood. Photo provided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

Moisture Content

Sapwood, which conducts nutrients in water from the roots to the leaves, is nearly saturated with water in a standing tree. Wood density tends to be lower at the top, enabling a tree to store large quantities of water where it will be readily available to the leaves. Heartwood usually contains much less water than sapwood. Because of its low density, cedar can hold much more water than

Douglas-fir can. 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 inch 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, MC can be calculated as:

MC = (initial weight/oven dry weight) - 1 x 100

OR

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

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

MC = (initial weight/oven dry weight) - 1 x 100

MC = (60.2/28.0) - 1 x 100

MC = 115% MC

OR

MC = [(initial weight - oven dry 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 two 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-inch-long probes with uncoated tips should be driven into the wood so that the meter is read every 1/2 inch. 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 a 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 pine is much more susceptible to decay. Poles to be air seasoned should be placed

Figure 3. Air seasoning poles.

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 and causes little or no strength loss; it is most commonly used to dry Douglas-fir 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 a period of 3 to 5 d.

Steam conditioning can be 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. This process is less commonly used and has largely been replaced by kiln drying.

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. These include pre-boring, incising, deep incising, radial drilling, through-boring, and kerfing.

Pre-boring 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).

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

Figure 4. (a) Decay at the bolt hole and (b) pole failure caused by decay in a field-drilled hole.

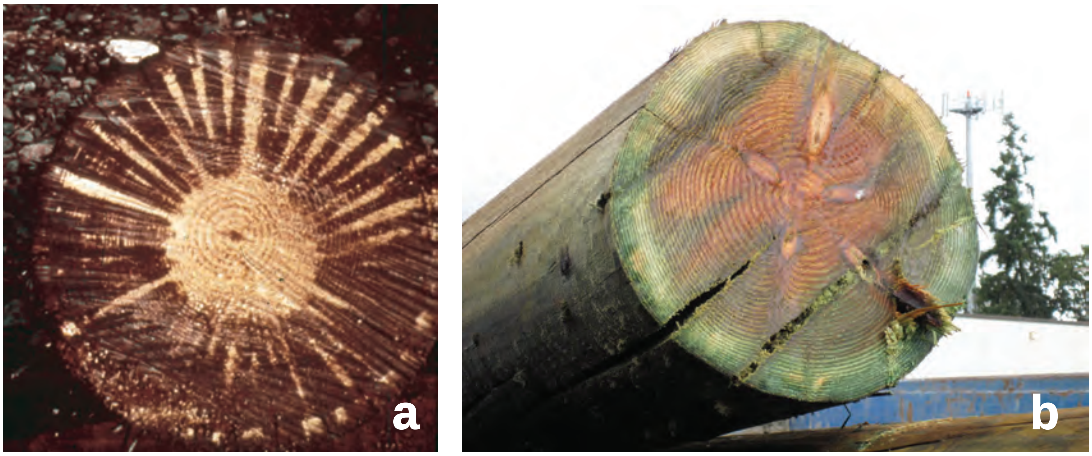


Figure 5. Incising and through-boring can markedly improve preservative penetration. (a) Cross section of a deep-incised pole and (b) a copper naphthenate through-bored pole.

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.

Deep incising and radial drilling improve on conventional incising, the effect of which is generally limited to the outer 3/4 inch of the wood. In deep incising, a series of 3-inch-long knives are driven into the wood around the groundline area (Figures 5 and 6). Similarly, radial drilling involves drilling a series of holes to depths ranging from 3 to 5 inches 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.

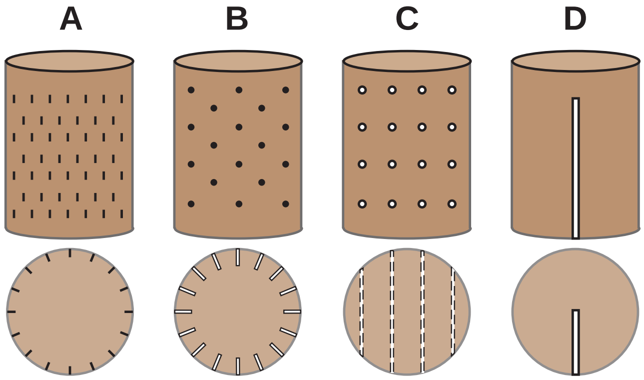


Figure 6. (A) Deep incising, (B) radial drilling, (C) through-boring, and (D) kerfing can improve treatment of the affected zone.

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).

Although incising, radial drilling, and through-boring improve the depth of preservative treatment, none control in-service checking, which results in exposure of untreated wood. These processes all protect the zone to which they are applied, but do not markedly affect the risk of decay above or below that zone.

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. Engineers have long expressed concerns about the effects of holes or cuts on pole flexural properties. Extensive full-scale tests indicate that these processes do produce slight reductions in properties; however, the losses are more than offset by the improvement in treatment that limits subsequent decay development in the critical groundline zone.

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

SHRINKAGE AND CHECKING

As poles dry or season, they lose water from the surface, but they 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 or liquid 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, the number of small checks decreases; however, a few checks drive deep into the wood. 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 softwood poles eventually develop deep checks (1/8 to 1/2 inch 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, most 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 (Figure 8). The development of checks before treatment results in well-treated checks that help to reduce the risk of internal decay.

Many utilities incorporate a pre- or post-treatment MC requirement 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 inches 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. This is particularly true in drier climates where the poles are likely to dry to much lower in-service moisture levels. These requirements must be applied cautiously, however; 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

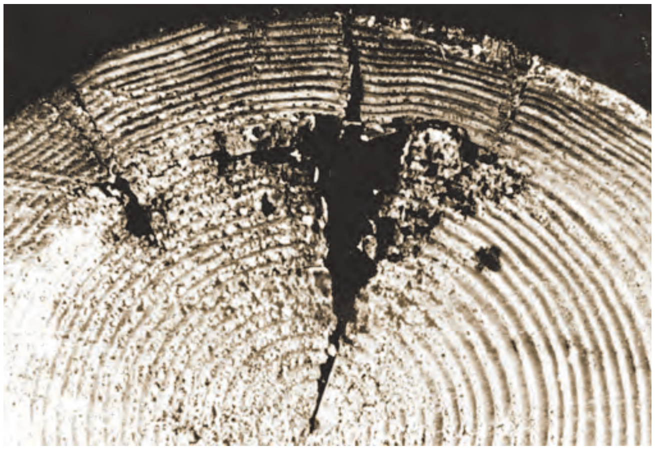


Figure 8. Narrow checks that widened and deepened after treatment have exposed the untreated heartwood of this Douglas-fir pole to decay fungi.

of drying required. Poles that are exposed in dry regions (precipitation <20 inches annual precipitation) should be drier before installation because 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 Protection Association. These systems are either oil- or water-based. Preservatives listed under the AWPA Standards have been reviewed by technical committees for their effectiveness under a variety of regimes. Chemicals that meet these standards are expected to produce equivalent biological performance, although they may have other attributes such as color or "climbability" that make them attractive in a given utility.

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. 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. Creosote can be used either as a stand-alone preservative or diluted with a heavy petroleum solvent

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. The one major concern with penta is the presence of dioxins; however, manufacturing processes have sharply reduced the amount of dioxin. 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 liquefied petroleum gas (Arsenault 1973). The use of heavy aromatic oils tends to produce the best performance with this chemical. These oils are typically specified in AWPA Standard P9 Type A.

Copper naphthenate was developed in the early 1900s. 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, combined with 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), copper azole (CA), and ammoniacal copper quaternary (ACQ). Although CCA and ACZA 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.

CCA was first developed in the 1930s in India. It is an acid system containing copper oxide, arsenic pentoxide, and chromium trioxide. The system 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; however, 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.

ACZA, originally formulated without zinc as ammoniacal copper arsenate (ACA), was first developed in the 1930s in California. ACA and ACZA use ammonia to solubilize the metals. Once applied to the wood, the ammonia evaporates and the metals 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, ACZA is typically used to treat refractory woods such as Douglas-fir.

ACQ is among the most recently standardized preservatives for wood poles. This formulation uses ammonia or ethanol amine to solubilize copper and it adds a quaternary 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 that of other alkaline copper systems.

Copper Azole Type B (CA-B) is also a recently standardized system that uses copper as the primary biocide, with a small amount of a triazole compound to protect against fungi that are tolerant of copper. Like ACQ, this system is not widely used for poles.

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 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/ft^3 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. The AWPA Use Category standards provide a map showing relative risk of decay across the United States (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 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

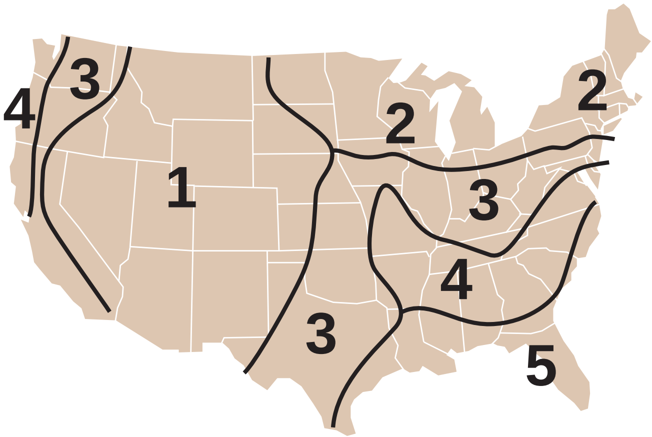


Figure 9. Relative risk of decay in poles (1 = low risk, 5 = high risk) exposed in various sites in the United States.

poles for drier or cooler climates, where the decay hazard is lower. The other two treatment methods use elevated pressure in a treatment vessel or retort to force chemical into the wood to the required depth (Figure 10).

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. 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.

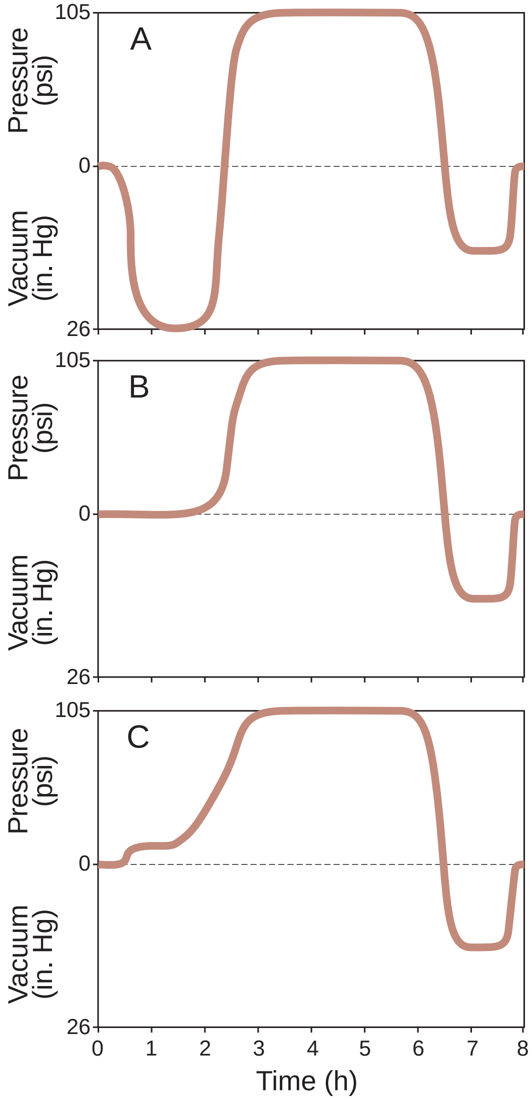


Figure 10. Typical vacuum pressure cycles used to impregnate wood poles with preservative. (A) Full-cell, (B) Rueping, and (C) Lowry processes.

Empty-cell processes were developed in the early 1900s. 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.

In addition to the initial vacuums and pressure processes, most treatment processes also incorporate practices that relieve internal pressure, recover solution from the wood, or encourage fixation reactions. Expansion baths at the end of oil-borne processes heat the wood to relieve internal pressure. Removing this pressure reduces the risk of bleeding in service. Similarly, steaming heats the wood surface to force chemical from the wood, cleans the surface, and can accelerate fixation reactions with water-based systems. All of these processes produce a cleaner pole. Many of these processes are incorporated in a series of specifications termed Best Management Practices that are used to produce treated wood for use in or near aquatic environments.

Treatment Specifications

Treatment of wood poles is specified under the AWPA Use Category 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. For example, higher loadings of chemical may not always increase service life and they can sometimes lead to higher loss rates into the surrounding environment.

Pole treatments are specified under the Use Category System under Standards U1 and T1. U1 lists the various chemicals that can be used for various commodities, while T1 lists the various process requirements. Utility poles are specified under Use Categories 4 A, 4B or 4C where 4A is the lowest risk of decay and 4C is the highest for land-based poles. Utilities can use either prior experience or a risk map in the Standard to determine the appropriate level for their system.

Fire Protection

Poles in some areas are also subjected to fire risk. This becomes a special concern in rural areas, particularly when poles are treated with either CCA or ACZA. There are a number of field applied fire retardant barriers. These systems have been shown to limit the risk of fire damage for at least 5 years. There are also temporary fire retardants that can be applied shortly before a fire. In addition, some utilities have used barriers, such as aluminum or steel sheets to protect the wood. While these systems can be effective, care must be taken since the sheets trap water and can sometimes accelerate decay.

Other Treatment Requirements

In addition to preservative loading, utilities may incorporate other requirements into their specifications. Among the most common are surface color and cleanliness. Some utilities require that poles be treated to a uniform color, particularly with penta, and this is accomplished by using the proper solvent and avoiding the accumulation of debris in the treatment solution. Pole bleeding can be minimized by varying process conditions to avoid over-treatment and relieve excess pressure remaining inside the pole (Figure 11). This pressure can eventually force preservative to the pole surface. The most comprehensive procedures for reducing bleeding are described by the Western Wood Preservers' Institute Best Management Practices (WWPInstitute.org).

Preservative migration from poles

All preservatives used for wood poles have some degree of water solubility and will migrate from the wood into the surrounding soil over time. This ability to migrate is essential for their function since the chemical must be able to move into a fungus or insect to be effective. Numerous field surveys indicate that this chemical migration is limited to a zone 6 to 12 inches around the pole. As a result, the risk of environmental contamination from a properly treated pole is minimal. There are specially designed pole barriers for use in especially sensitive environments where utilities feel extra protection is warranted.

Barriers

A variety of barrier products have recently emerged that are applied to the area below the

Figure 11. Example of bleeding from a creosote-treated pole.

groundline (Figure 12). These systems do not contain any biocides and are designed to limit preservative migration from the pole and to limit soil contact. These two activities should improve pole performance. Barrier systems include sock–like materials that are applied prior to pole installation and polyurea coatings that are applied at the treating plant. These systems have the greatest potential use where poles are used in sensitive environments or where poles might be installed in concrete, making future inspection extremely difficult. Barrier systems that use hard coatings may have an impact on an inspector's ability to perform future inspections.

Figure 12. Example of a commercially applied pole barrier used to protect the belowground portion of a pole.

Pole tops

Pole top decay can become a problem on older poles and, if allowed to progress, can eventually necessitate pole replacement. A number of systems are available for capping poles (Figure 13). Caps can be simple plastic discs that have spaces underneath to allow for air-exchange or they can be plastic wraps that exclude all moisture. Field tests indicate that these systems markedly reduce the risk of pole wetting which in turn reduces the risk of internal decay.

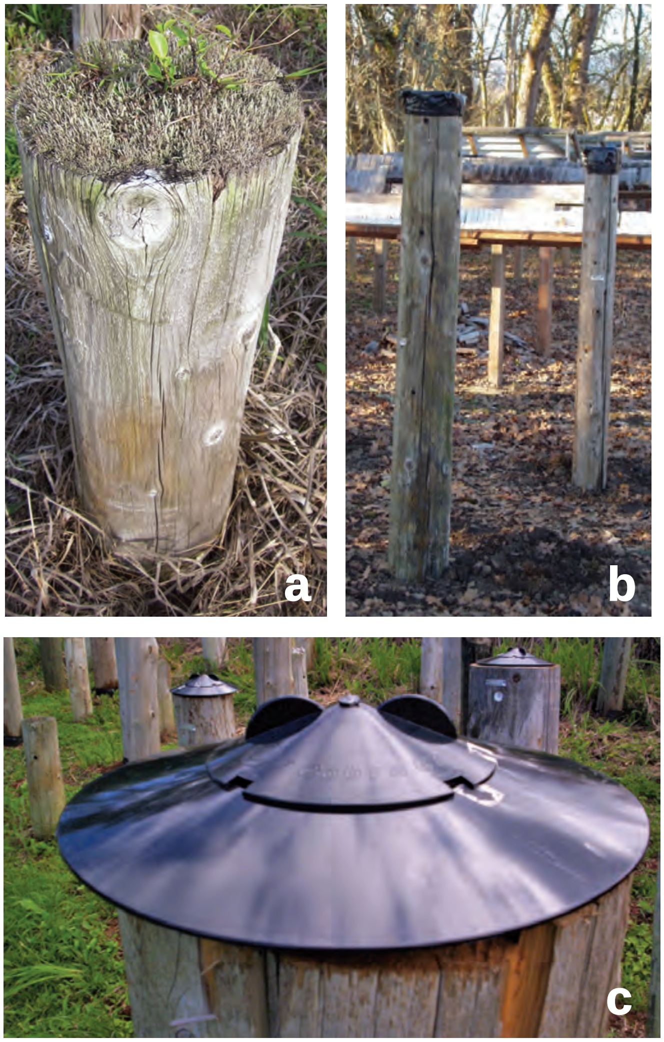


Figure 13. (a) example of an older, non-capped pole top with extensive decay, (b and c) commercially available pole caps.

AGENTS OF DECAY

Wood can be degraded by a variety of living and non-living agents. The most important non-living agent is ultraviolet light, which degrades the wood surface (Figure 14). This damage occurs very slowly and is normally not an issue for poles.

FUNGI

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

Decay fungi are, by far, the most destructive of the organisms that inhabit wood. Fungi require water, air, a favorable temperature, and food (Figure 15). Wood with MC below 20% (oven-dry 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 16). However, not all fungi produce large, visible fruiting bodies; they may produce microscopic structures that also produce large numbers of spores. 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.

"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 17). 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

Figure 14. Weathering of a cedar pole turns the surface grey, but the wood underneath is unaffected.

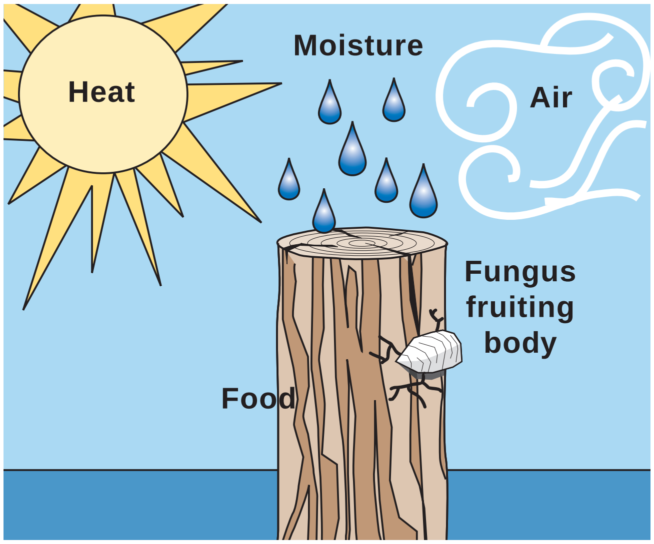


Figure 15. Requirements for decay.

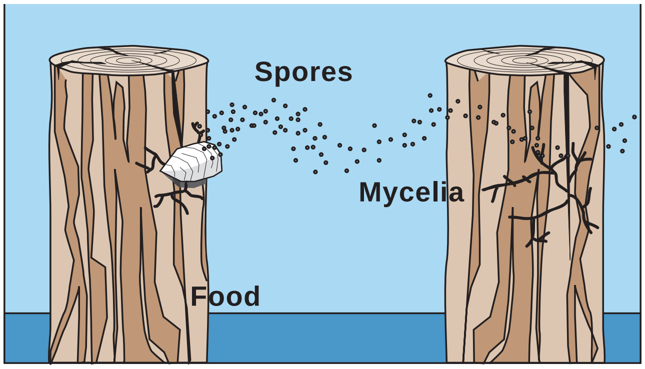


Figure 16. The conk (fruit body) of a decay fungus produces microscopic spores that, finding suitable conditions for growth, infect other wood products. Fungal threads spread decay through moist wood.

Figure 17. 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.

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 18).

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. Brown rot fungi are important because they cause very substantial strength losses at the early stages of decay.

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

Brown and white rot fungi tend to be inside the pole where moisture conditions are more stable. They are often associated with deep checks that penetrated past the original treatment zone. While their damage is important, they can generally be controlled by the application of volatile or water diffusible treatments. The end result of internal decay is a shell of treatment surrounding a hollow core. The thickness of that

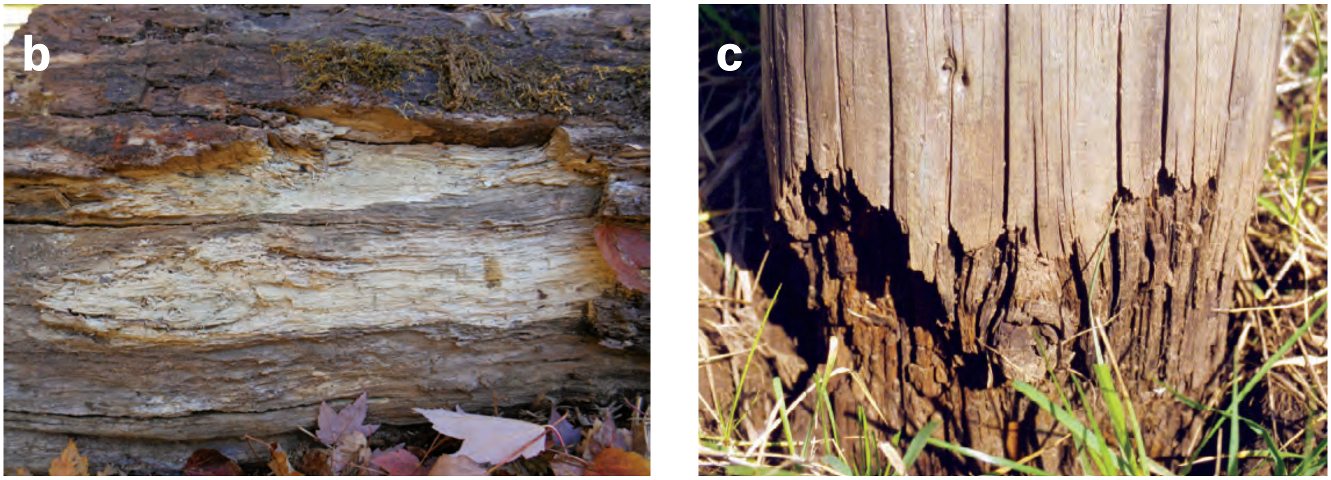


Figure 18. (a) Brown, (b) white, and (c) soft rot.

original treatment can determine whether an internally decayed pole is salvageable.

Soft rot fungi attack the surfaces of both hardwoods and conifers, particularly where preservative levels have declined below their initial treatment levels through leaching. Soft-rot fungi slowly cause external softening of treated wood, resulting in extensive damage below ground. Soft rot fungi are most prevalent on southern pine poles, although they are also common on poles of Douglas-fir that have been treated with pentachlorophenol in either methylene chloride or liquefied petroleum gas. Although neither of these treatments is currently used, many poles treated with these systems remain in service. Soft rot fungi are especially important because they reduce the effective pole circumference, producing very sharp declines in flexural properties. Many of these fungi are also tolerant of preservatives, allowing them to attack wood that may have lost some, but not all of its original treatment.

Non-decay Fungi

Numerous non-decay fungi also inhabit wood; they feed on cell contents, certain components of cell walls, and the products of decay. Frequently, only non-decay 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 non-decay fungi gradually detoxify preservatives, preparing the way for decay fungi. Some rapidly growing non-decay fungi may interfere with efforts to culture the slower growing decay fungi from wood. The interaction of fungi, both decay and non-decay 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 and use wood as a food source; there is virtually no external evidence of their presence until winged adults emerge and swarm in late summer and early fall. These social insects have a well organized colony structure with a queen, workers and soldiers. Workers feed nearly continuously and a large colony can approach one million workers. Collections of wings outside the nest in checks or other collection areas, discarded by reproductives (alates) as they mate to start new colonies, may be the first indicator of termite presence. Some species also produce mud tubes up the pole surface or inside checks that indicate the presence of an infestation. Although their lengths vary from 1/4 inch or less (subterranean and drywood) to 3/4 inch (dampwood), termites have bodies of fairly uniform width; the reproductives have wings of equal length (Figure 19).

Figure 19. A termite colony includes many workers that burrow in wood for food and shelter, soldiers that protect the colony from other insects, and one egg-laying queen. (a) These reproductives later will fly from the nest to initiate new colonies (photo credit: Scott Bauer, USDA Agricultural Research Service, Bugwood.org). (b) Usually poles show no sign of termites until the reproductives emerge, discard their wings, and mate to start new colonies (photo credit: Gerald J. Lenhard, Louisiana State University, Bugwood.org).

Subterranean termites are wide-spread and cause extensive damage, especially in southern states but they are also present in drier parts of the country. Sure signs of their presence are the mud tunnels that the termite workers build from their nests in the ground up across treated wood or concrete to non-treated wood above. Subterranean termites are distributed between 50° N and 50° S latitude although there may be

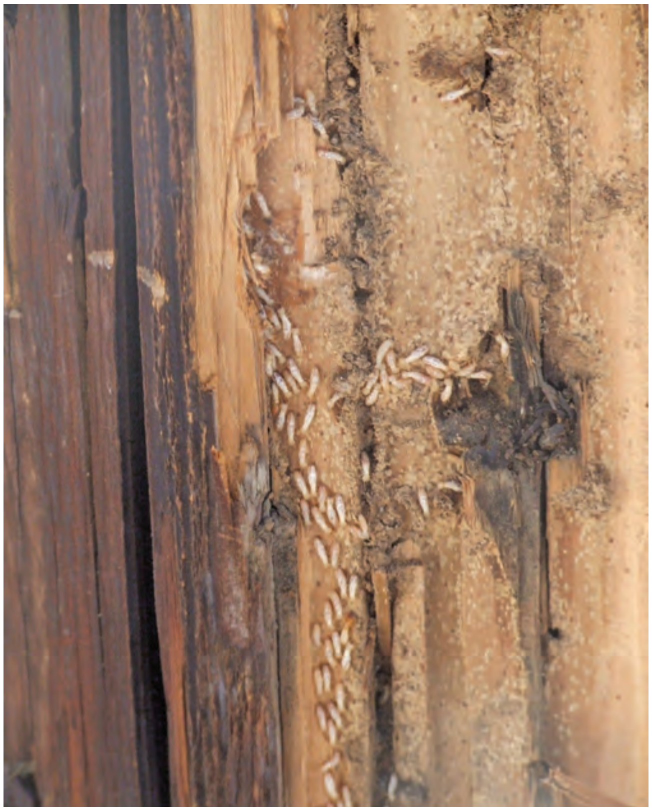


Figure 20. Example of termite damage to wood. Note the debris and termite excrement on the wood.

isolated occurrences north of this zone. Global changes in climate are likely to extend this range.

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 6 to 7 million workers. Fortunately, this species is currently only found in Hawaii, along the Gulf Coast and in extreme southern California. The presence of this termite in Hawaii, however, has resulted in a requirement that all wood used in houses be preservative protected.

Dampwood termites (*Zootermopsis augusticollis*) inhabit moist wood in, on, or above the ground along the Pacific Coast. The workers of this species are very large and easily identified, while the soldiers have extremely large pincers. This species can be a problem in poles, but it is most often associated with very deep wide checks or prior woodpecker attack. In both cases, the openings allow moisture to enter, creating ideal conditions for attack. Dampwood termites appear to be very susceptible to preservative treatments.

Drywood termites feed on dry wood, primarily in the southern United States and the Pacific Southwest. These species can live in wood at 12% MC, and the only evidence of their presence is the frass or insect droppings that they periodically expel from their colonies. (Figure 20). Drywood termites can invade poles and crossarms, where their presence is difficult and expensive to detect. The best preventative method is a well-treated preservative shell.

The initial treatments currently used for poles are all capable of preventing termite attack, but checks or other damage to the wood can create non-treated zones where termites can invade. Termites are best controlled by producing a well-treated pole without deep checks that penetrate beyond the treated shell.

Carpenter ants are also social insects with a queen and major or minor workers (Figure 21). The ants have a restricted waist, and the reproductives have wings of unequal length. The dark-colored ants grow as long as 3/4 inch. 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 in the wood Figure 22). Ants must leave the nest to find food and are frequently seen scurrying around poles particularly at night (they are nocturnal). They are difficult to control because they do not eat the wood. They also tend to have a main nest along with satellite nests. This makes it

Figure 21. In contrast to termites, carpenter ants (Camponotus sp.) have restricted waists and reproductives have shorter wings of unequal length (photo credit: Clemson University - USDA Cooperative Extension Slide Series, Bugwood.org).

Figure 22. Carpenter ant damage in poles. 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.

difficult to treat the pole and expect to eliminate the infestation. A well-treated pole without checks penetrating beyond the treated shell is the best method for preventing carpenter ant attack.

Beetles that attack poles typically invade the wood while the bark is still on the freshly fallen tree. The adult lays eggs that hatch into larvae that tunnel beneath the bark. If the bark is not removed in a timely manner, the larvae will then move into the wood. An effective sterilization treatment will kill the larvae; however, inadequate treatment can allow the beetle to survive, continue its life cycle and emerge once the pole has been placed in service.

The most common beetles in poles are buprestids, also called flat-headed or metallic wood borers (Figure 23). The golden buprestid is the most common of these beetles in the Pacific Northwest. This beetle has a life cycle that can range from 2 to 40 y. The 3/4-inch-long, metallic golden or green adult makes an elliptical hole as it emerges from the pole to mate. 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. This 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, the ANSI specifications reject poles with beetle holes.

Figure 23. Golden buprestid beetle (Buprestis aurulenta). As an indication of internal rot in the aboveground portion of poles, look for the oval holes (0.5 in. long), that the buprestid beetle leaves as it emerges from wood. Many holes could mean an unsafe pole.

Woodpeckers

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 24). Woodpecker holes also open the pole interior to moisture intrusion, creating an ideal environment for fungal and insect attack. Dampwood termite colonies have been found 30 to 40 ft above ground in abandoned woodpecker nests.

Woodpeckers will tend to be more prevalent in forested areas; however, there are very few areas in a rural or suburban setting that would not be suitable for woodpecker habitat. Woodpeckers also appear to choose poles because they offer a clear unobstructed view of the area, allowing them to avoid predators. Woodpeckers are federally protected and it is illegal to disturb nesting birds.

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 (Figure 25). These methods, however, usually do not prevent woodpecker damage. Heavy galvanized hardware cloth applied tightly over much of the pole has been the most successful preventative measure, but can cause problems when poles must be climbed. The use of ACZA-treated poles has been reported to reduce, but not completely prevent woodpecker damage. 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. It is critical that woodpecker holes be repaired as soon as possible so that they do not provide entry points for other agents of decay.

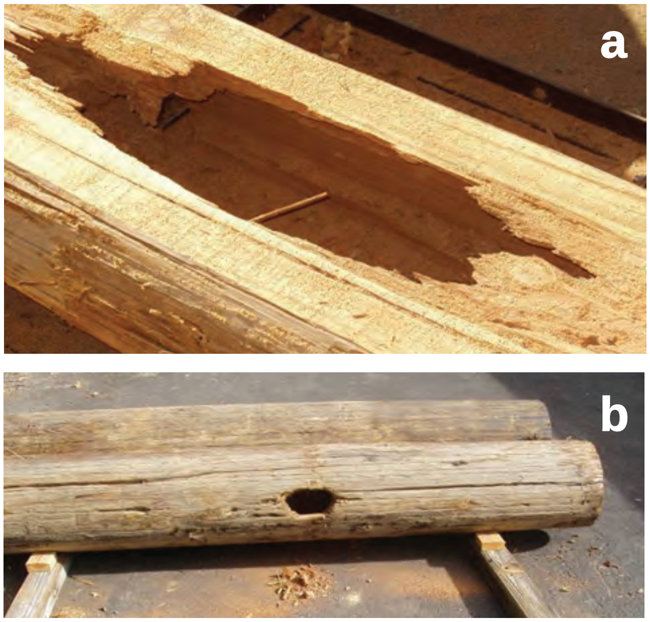


Figure 24. (a) Example of a woodpecker hole on the pole surface and (b) the extent of void associated with a nest.

Figure 25. A section of old pole containing a woodpecker nest attached to a new pole in hopes of discouraging new attack.

Marine Borers

Utility poles are rarely used in salt water contact, but where they are, utilities must be concerned about marine borers. Non-treated wood piles and poles in saline coastal waters are attacked rapidly by marine borers. Shipworms (*Bankia* or

Teredo spp.) riddle interior wood with long holes, and *Limnoria* (gribbles) burrow small tunnels near wood surfaces (Figure 26).

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 inch in diameter and 2 ft in length (Figure 26).

Gribbles, small crustaceans about 1/10 inch 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 non-treated wood. Pentachlorophenol-treated wood should not be used in marine waters. Non-treated wood such as bracing should not be fastened to treated wood below the tidal zone, because borers can become established in the non-treated 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

The treater is responsible for ensuring adherence to specifications and plants routinely test the quality of their treated poles prior to shipping. Utilities 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. New pole inspection combines a final check on wood quality with an assessment of treatment quality. The inspector checks the pole for knots that exceed the specification, the presence of excessive spiral grain, checks or splits, and other wood defects limited in the ASC 05.1 Standard (ANSI 2008). The inspector then removes increment cores from the designated sampling zone and assesses preservative penetration. The cores are then collected, combined and ground to a fine powder so that they can be analyzed for chemical content. This is most often done using an x-ray fluorescence analyzer. The treatment quality inspection follows the standards

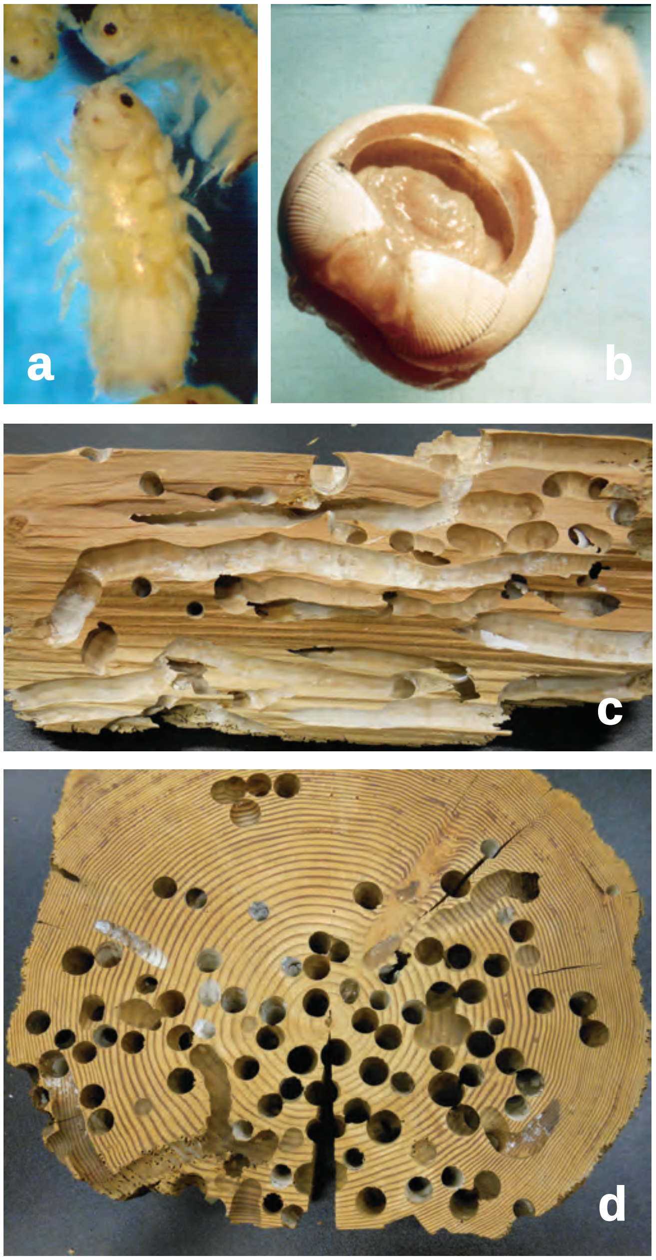


Figure 26. Marine borers attack wood in coastal waters where salinity and oxygen supply are favorable. Gribbles (a) make smaller tunnels near the surface (photo courtesy Wikimedia Commons). Shipworms (b) are marine borers that make long tunnels (c,d).

of the American Wood Protection Association or the Rural Utility Services.

This practice provides a final check on pole quality and helps to identify potential problems before costly construction time is wasted installing an inferior pole. Inspection can occur in the plant or at the final destination. The small cost associated with inspection is easily offset by avoiding placing an inadequately treated pole in service.

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.

Figure 27. Crossarms (a) with and (b) without end-plates that limit end-checking. Note the large checks on non-plated ends.

Inspection programs and the tools they use vary widely depending on the wood species, chemical treatments, and climate to which the poles are exposed.

CROSSARMS

Crossarms are a critical, but often overlooked element in a utility structure. Crossarms are exposed to less severe decay risk than the pole itself, but eventually, decay will develop in these elements. Tests of arms removed from service suggest that they are often removed while still retaining sufficient capacity. This often occurs because excessive weathering makes the arm appear weak. In other cases, checks developing on the upper surface of the arm trap moisture and allow fungi to grow. At least one crossarm manufacturer produces arms coated with a polyurea polymer that may provide long term protection against checking and ultra-violet light damage.

The other types of damage incurred by crossarms are splits or deep checks. These splits can widen to the point that insulator bolts fall out of the arm. Field trials indicate that end-plates can markedly reduce this checking (Figure 27). Arm damage can also be limited by the application of polyurea coatings (Figure 28).

Figure 28. Polyurea-coated arms designed to reduce the risk of checks developing on the upper surface.

POLE INSPECTION PROGRAMS

The timing and extent of a pole inspection program varies greatly depending on the climate, geography, wood species, initial preservative, and age of the system (Table 1). The risk of decay above the ground can be estimated using average monthly temperatures and days with precipitation to produce a climate index (Scheffer 1971). The risk of decay in soil contact also varies and maps have been developed to guide utilities. For example, wood exposed in cool, dry regions, such as those in the Upper Great Basin, can be inspected less frequently than wood in sub-tropical southern Florida (Figures 29 and 30). In wetter regions, internal decay typically starts 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. It can be difficult to predict the rate of decay in ground contact because soil conditions can have such a major impact on biological activity. As a result, inspection programs are best determined using local data on pole performance. In addition, the Rural Utility Service has developed maps of decay risk and these are cited in the AWPA Standards.

Wood species and the initial treatment chemical can strongly influence both the type and frequency of inspection due to the rates and types of decay. Most decay in well-treated southern pine poles occurs below the groundline on the wood surface. As a result, inspections that include digging, combined with an inspection and probing of the wood surface below groundline, are essential for detecting damage in this species. Most pole strength is in the outer 2-3 inches, so external surface decay can have a significant impact on the strength of the pole. Douglas-fir, western larch, western redcedar, and lodgepole pine are more prone to internal decay at and/or below the groundline (although older cedar may also have some external decay), which makes internal inspection critical for early decay detection.

The initial treatment chemical can also influence inspection. For example, poles treated with pentachlorophenol in liquefied petroleum gas by either the Dow® or the Cellon® process tend to have surface decay below the ground level, regardless of the wood species. As a result, digging inspections are required for poles treated by these processes, regardless of species. Conversely, CCA- or ACZA-treated poles tend to have much slower rates of surface decay, and excavation is probably advisable after approximately 30 y of service (although some partial excavation prior to that is advisable to make sure that poles are performing as expected in your system). Finally, inspection in the through-bored region is not necessary because the wood is thoroughly treated in that zone. The wood above that level should be inspected.

Most utilities in North America physically inspect poles on a cycle of 8-15 y. This inspection comes in addition to annual drive-by inspections used by some utilities to detect obvious physical defects such as cracked insulators, split pole tops or other damage that can be seen from either the ground or air. An examination of national field inspection data suggests that a cycle of 8-12 y is best; rejection rates increase markedly when a longer cycle is employed for utilities in areas with moderate decay risks (Figure 30). Shorter

Table 1. Recommended pole inspection schedules, from RUS 1730B-121 (1996).

Decay zone	Years before initial inspection	Years before subsequent re-inspection	Percent total poles inspected each year
1	12–15	12	8.3
2 & 3	10–12	10	10.0
4 & 5	8–10	8	12.5

Note: see Figure 9 (p. 9), AWPA Use Category Standards.

cycles may be advisable in areas with extreme decay risk, such as those along the Gulf Coast of the United States. Utilities in extremely dry areas may extend their cycle because the risk is so low, but they should use their own data to decide whether this extension is advisable. Even within these areas; however, there may be locations where the decay risk is high, such as in zones where the soil is irrigated. A good inspection process incorporates local knowledge in order to tailor the program to the system. Obviously, it is not possible to treat each pole as an individual, but it is possible to identify problem areas within a system where climate, wood species, or initial treatment type may require some different steps in order to ensure long service life.

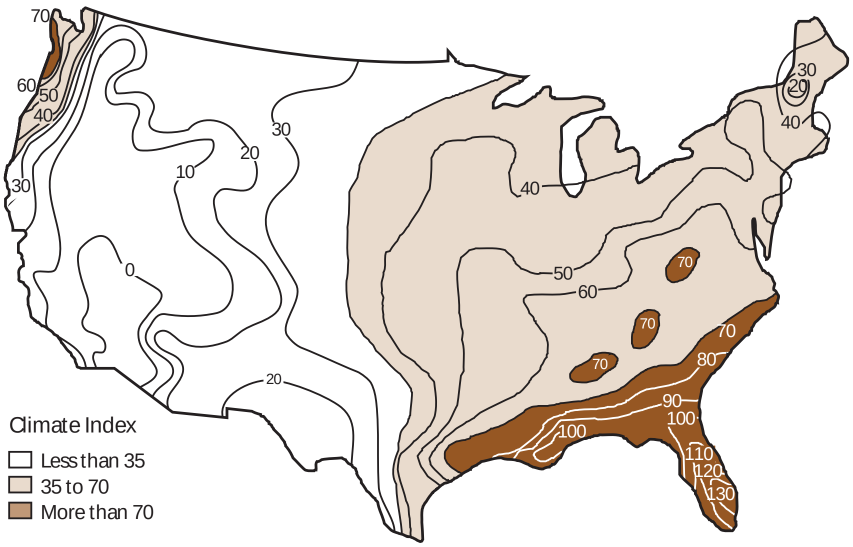


Figure 29. This climate-index map of the United States provides an estimate of potential for decay of wood above ground (Scheffer 1971).

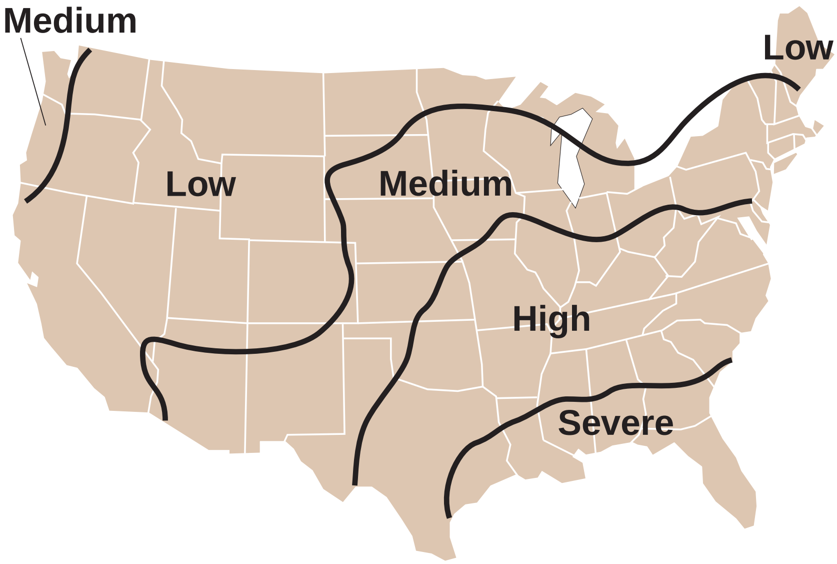


Figure 30. Decay hazard map, as reported by the Rural Electrification Administration (REA), is derived from the decay hazard to which the wood is exposed.

THE INITIAL INSPECTION

When first evaluating a line or system, it is helpful to thoroughly inspect a smaller population of representative poles through an excavation 18-20 inches deep and 360° around the pole. 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.

The number of poles sampled in the initial inspection will depend on prior maintenance practices, as well as the exposure hazard (Figure 30). Where personnel continually check poles above and below ground and detect developing problems, the initial sampling inspection may be limited to relatively few poles in certain lines or in 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 (e.g., 300) of a similar age, species, and treatment that were produced by the same manufacturer. RUS 170B-121 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" (RUS 1996). 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 and extent of digging to suit the local conditions. Some utilities use what is called a partial excavation, where they dig only one-third of the pole's circumference in the groundline area. These "partial excavations" can vary in depth from 6-20 inches or deeper. If nothing is found, the exposed surface is treated with a supplemental paste and a wrap or a premade bandage, and the hole is filed in. If decay is evident, then the rest of the pole should be excavated.

Digging 18 inches deep will reveal surface decay in most areas, but you may have to dig deeper in dry areas where 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. Most southern pine poles should be excavated. The exception would be younger CCA-treated poles (<30 y old). Older CCA-treated poles should receive at least a partial excavation. Internal decay pockets can also occur well below or above the groundline, depending on local conditions.

To Culture or Not to Culture?

Early decay in the pole interior is difficult to detect visually. It can be helpful during the initial sampling of poles in a system to culture the wood for decay fungi. Culturing involves removing increment cores from the poles and placing the core on nutrient media (called agar) in petri dishes. Any fungi in the wood can then grow onto the media surface where they can be identified. Most decay fungi have distinctive characteristics that make them easy to distinguish; however, the process requires trained personnel, such as plant pathologists, who use microscopes to distinguish between decay and non-decay fungi. Although numerous cores can be cultured simultaneously, this process is not feasible for large-scale inspection. It is most useful for determining the risk of decay in a line. Culturing can also indicate whether it is advisable to remedially treat poles that might not have visible decay.

For example, inspection of Douglas-fir transmission poles installed 10 y 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 one or two 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 internal (Figure 31), external, or a combination of both on the same pole (Figure 32). Appearances can be deceiving, however.

Figure 31. Internal decay.

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 by boring and probing 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 and strength of the pole, forcing replacement or reinforcement. (Figure 33).

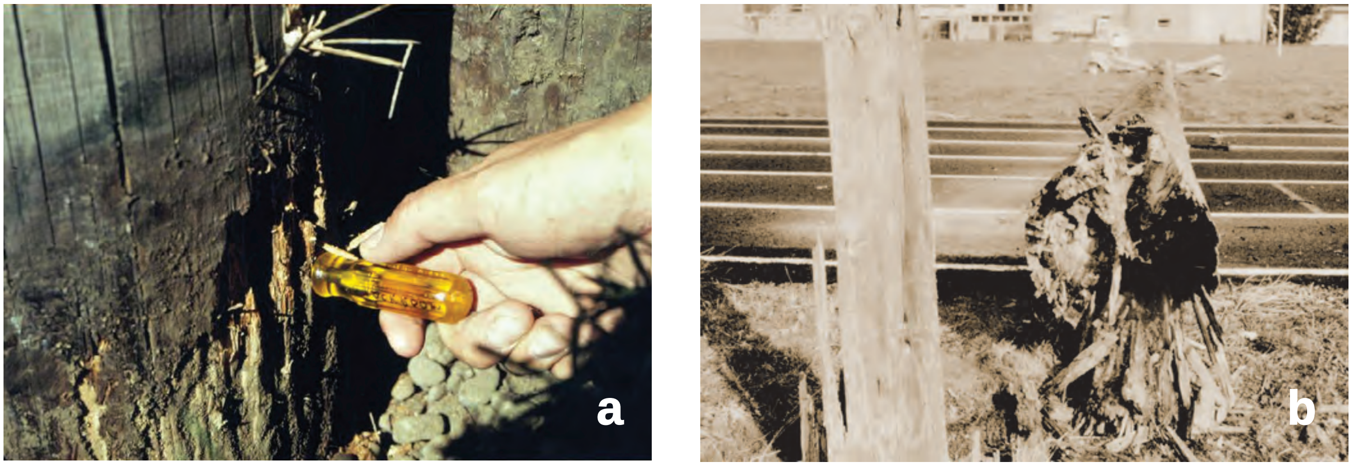


Figure 32. Both external (a) and internal decay (b).

Figure 33. Examples of steel trusses used to reinforce deteriorated poles.

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 and they can be surprisingly abundant in desert areas. Metal wraps around butt-treated cedar as well as around older, full-length treated poles to protect against fire can encourage decay and termite attack of unprotected sapwood beneath the wrap. The same can apply to fire retardant coatings that do not breathe, such as polyurea coatings.

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 y and reach the visible advanced stage called rot within 2 to 4 y under ideal conditions. Any cuts or borings made in the field should be treated. Pole tops should have a cap to protect against decay. The cap sheds water, creating conditions that are less suitable for fungal attack.

INCIPIENT DECAY

Before it is visible, decay can produce dramatic reductions in wood strength (Wilcox 1978). Termed "incipient decay," this damage 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. Microscopic examination and the culturing of wood remain the only ways to detect decay fungi at the earliest stages of attack; however, these are clearly not feasible for regular pole inspection. As a result, inspectors must be fairly conservative when estimating remaining pole flexural properties.

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 sound wood, is frequently confused with rot on the surface of poles below the groundline. If in doubt, use the "pick test" (Figure 34). Lift a small sliver of wood with a pick or pocket knife and notice whether it splinters (sound) or breaks

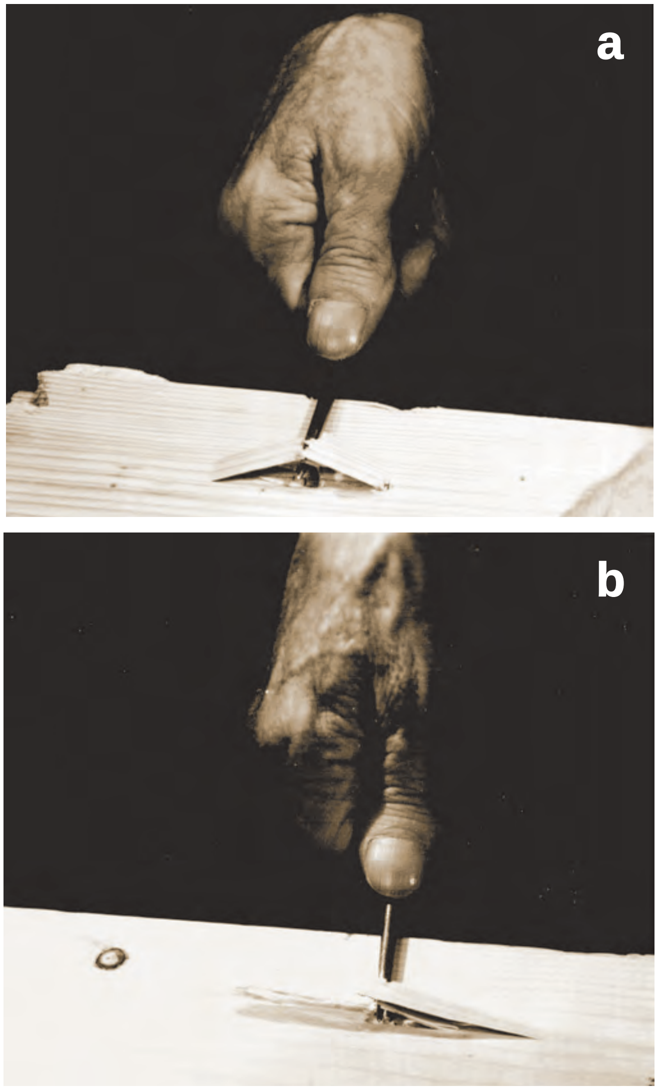


Figure 34. Use the "pick test" to detect rot. When a sliver of wood is lifted, abrupt failure (a) usually indicates rot, whereas a splintering failure (b) indicates sound wood. Photo courtesy of the U.S. Forest Products Laboratory, Madison, WI.

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 that abruptly changes to the adjacent sound heartwood. In Douglas-fir and southern pine, 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 gauge with a hook 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 allow the presence of visible decay in the butts of cedar poles, they limit the distance from the butt that decay pockets can extend in cedar. This decay is allowed because the smaller pockets do not affect strength in this location and the fungi that caused the damage do not survive the seasoning and treatment process.

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 within a drilled hole with a metal gauge with a hook 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, the earlier remedial treatments can be applied to arrest the attack and retain the structural integrity and strength 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, wire brush, or dull probe can be used to detect belowground rot on the pole surface and internally, in some cases. Cutting the blade of a shovel back several inches facilitates the removal of earth around poles and from the surface of poles. The pole is excavated to a depth of 18 to 24 inches; the scraper is then rubbed along the surface. If scraping exposes untreated or decayed wood, treat that area with a preservative paste or a groundline bandage. Be careful not to confuse softer, wet wood with decay. A scraper or wire brush can often be useful in identifying internal decay, particularly when the decay occurs at or near the bottom of the excavation where a hammer is difficult to use effectively (see below). With a thin shell, an experienced inspector can pick-up an audible difference between solid wood and internal decay when the brush or scraper is rubbed along the surface.

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 (16-24 oz) hammer that is comfortable to swing and strong enough to withstand 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 inch in diameter can be welded to the back of the hammer to make a starter hole for an increment borer bit.

Drills

Drilling into the wood at a steep angle produces a hole through which the pole interior can be further investigated. Some utilities use a 3/8-inch diameter bit for this purpose, but larger diameter bits are used where the hole will also be used to apply remedial treatments. A careful inspector will listen to the drill as it enters the wood. Sudden speeding up of the drill indicates softer wood that merits further investigation. Drills used for this purpose can be gas or battery powered. 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 3/8-inch diameter bits; for Douglas-fir or western redcedar, inspectors often use 13/16-inch or 7/8-inch diameter bits. The latter bits create an ideal hole or "reservoir" for subsequent application of remedial treatments for arresting internal decay.

Increment Borer

Figure 35. 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.

Increment borers were originally used to measure tree growth and consist of a hollow, fine-steel bit that is twisted into the pole along with an extractor for removing the wood core from inside the tube (Figure 35). The cores can be examined for visible decay and measured for shell thickness and depth of preservative treatment. Starter holes created with a metal punch welded on one face of an inspection hammer can speed coring and reduce breakage of the expensive bits. Gas or battery-powered drills can also be used, but must be used carefully to avoid damaging the bits. To speed drilling, special chucks can be fabricated to fit into a variable-speed power drill. This arrangement works well, but be careful not to damage the bit by drilling too fast. If boring resistance increases, back out and remove the core before boring deeper. Unusual or abrupt force can snap the bit or can pack wood in so tightly that the bit must be cleared of compacted wood by drilling with a smaller diameter bit. Rubbing increment borers with a moistened bar of soap or wax eases drilling.

Increment corers work best when the cores are taken at a 90° angle to the pole in order to cut across growth rings. It is also important 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

An important part of the inspection process is determining how much residual shell remains in a pole along with the extent of any internal decay. The inspection hole, either drilled or from an increment borer, provides a convenient measurement location. The shell-depth indicator is a calibrated metal rod with a hook on the end

Figure 36. 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.

Figure 37. The Shigometer™ measures electrical resistance to detect rot in poles. Use an increment borer to determine the nature of the defect.

Figure 38. A resistance-type meter can be useful for detecting MC levels that are high enough (over 20%) for decay. As a sliding hammer drives two 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.

(Figure 36). The indicator is inserted into the hole and pulled back out so that the hook rides along the wood. 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°. The rod will occasionally overestimate the residual shell, but it is a useful tool for identifying dangerous poles. Some inspectors automatically subtract 1/2 inch from the measurements to account for the decayed wood. The rods can be home-made or purchased from pole-inspection agencies.

SHIGOMETER®

The Shigometer® (Figure 37) was developed for detecting decay in living trees by 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 two twisted, insulated wires with the insulation removed near the tip is inserted to various depths into a hole 3/32 inch 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).

MOISTURE METER

Resistance-type meters can be used to detect wood with MC exceeding 20%, the safe limit to prevent decay (Figure 38). They are also useful for assessing post-treatment MC specifications. Long electrodes can measure moisture to a depth of about 2-1/2 inches. 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 because they are limited in the zone they can inspect and are not able to detect decay; instead, they can only detect the conditions where it might occur.

Decay-Detecting Drills

Although conventional drills create a large hole in the pole, decay-detecting drills use a small, 1/8-inch diameter bit to bore into the pole (Figure 39). As the bit enters the wood, the bit rotation is recorded (either on paper or electronically), providing a viewable graph of the pole's internal condition. These graphs can be saved for record keeping purposes. 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 could later grow over the inspection hole. Poles cannot "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. These devices are especially useful where there may be concerns about drilling too many holes or where unsightly holes might be objectionable. They are also useful for above-ground inspection near attachments or on crossarms.

Figure 39. The resistograph drill uses a very fine bit to detect voids or softer wood that may be decayed.

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 40). These characteristics affect both the speed at which the wave moves across the pole (time-of-flight) and the shape of the wave that exits the wood (attenuation of the wave). Large voids,

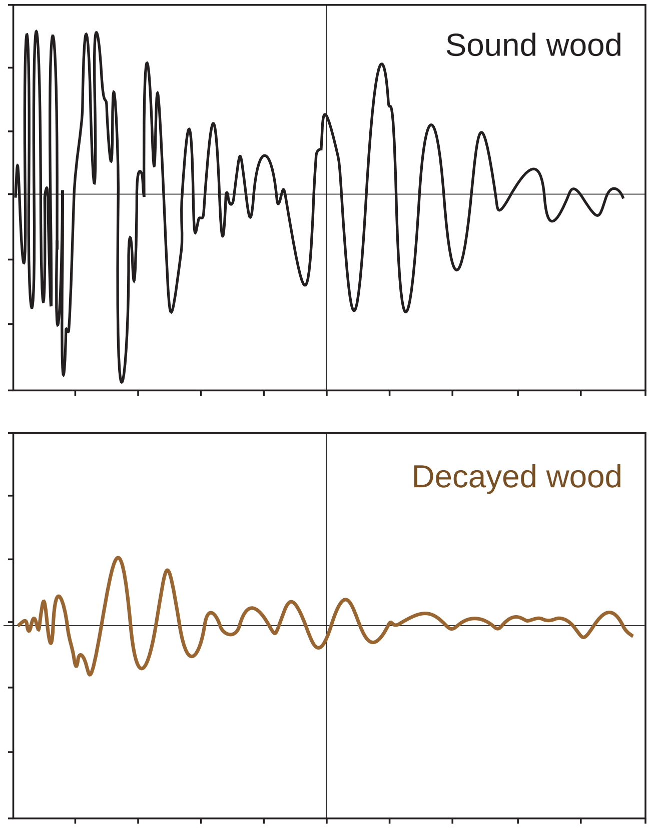


Figure 40. Strong and weak acoustic signals showing sound and weak wood, respectively.

Figure 41. Pole test with an acoustic inspection device.

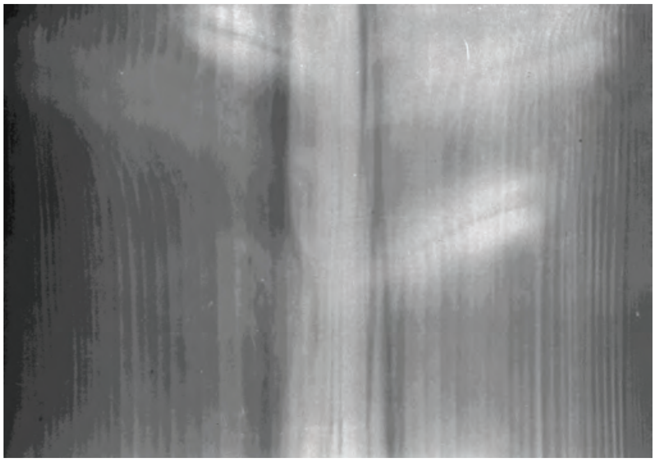


Figure 42. X-ray of wood.

checks, ring shakes, 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 provided more reliable estimates of pole condition (Figure 41). The developers of acoustic devices then tested poles both sonically and in bending to failure and used statistical techniques to relate sonic parameters 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 based upon the relationship between modulus of elasticity and modulus of rupture. Thus, a strong pole with significant decay may produce a reading similar to a weaker 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 are best used as supplemental tools to the conventional inspection methods and should never be the sole inspection method used (Wright and Smith 1992). One especially useful application is for re-inspection of poles that have been rejected by prior physical inspection. The acoustic device can be used to help assess pole properties to determine whether the pole can be restored or needs to be replaced. This process must take place in conjunction with a remedial treatment program in order to arrest any existing decay, otherwise pole condition can continue to decline.

X-RAY TOMOGRAPHY

Like the bones in our bodies, wood varies widely in density, and those variations can be detected with x-rays (Figure 42). X-rays were 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.

The use of x-ray tomography, similar to that used in the medical field, has been explored for this purpose but the cost and speed make it largely impractical for field use. Continued improvements in computing power may someday make this technology feasible. Even with 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. Methods are needed for rapidly separating natural wood characteristics from defects that threaten a pole. This technique could provide a powerful new inspection tool when methods for segregating defects from natural wood characteristics are developed.

GROUND PENETRATING RADAR

Ground penetrating radar has recently been commercialized for assessing the internal condition of both poles and crossarms. The process produces three dimensional maps of internal condition (density) using a system mounted on either a truck or a helicopter. At present, the system does not appear to be practical for rapid inspection of every structure, but it can be useful for detailed analysis of critical structures. In addition, the system does not detect decay, so it must be used in conjunction with some other inspection process.

MECHANICAL POLE TESTER (MPT)

The MPT essentially deflects the pole a short distance at the groundline and then uses the resulting load/deflection data to calculate a modulus of elasticity (MOE) of the pole. This value is, in turn, used to estimate modulus of rupture (MOR). This device has been used in Australia for many years and is just beginning to see application in the United States. The advantages include the ability to directly test flexure instead of relying on acoustic tests to derive MOE; however, the device cannot distinguish between a strong, decaying pole and a non-decaying, but weaker pole. As a result, the device is best used in conjunction with other devices or methods that can detect decay.

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 43). 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 whether viable fungi remain in the wood. This is more of a research technique and would not be feasible for decay detection on a larger scale.

INFRARED ASSESSMENT

Infrared technologies are used in a variety of industries to measure minor changes in temperature. Temperature differences can be useful in inspecting wood because the temperature of wet or decaying wood will change at different rates from that of sound wood. Infrared devices detect these differences and thus can be used to image or map decay pockets. These devices are not currently used for pole inspection but have some potential applications.

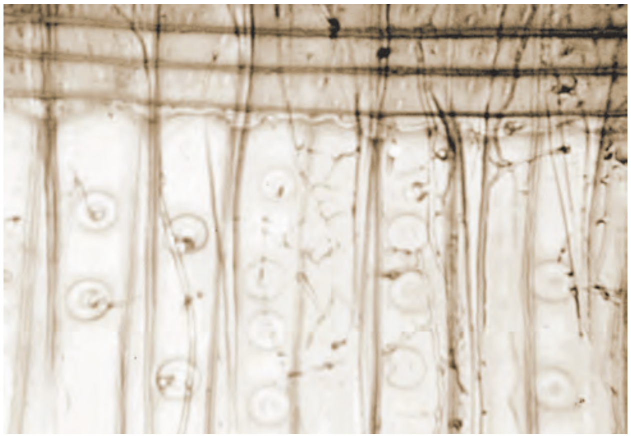


Figure 43. Hyphae of a decay fungus in a wood section.

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 the following:

- elliptical holes made by buprestid beetles
- mounds of sawdust and the carpenter ants that make them
- mud tubes in checks made by termites
- woodpecker holes

Examine cedar poles for surface rot and shell rot that are typical of non-treated 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 and around the circumference. Excavated poles should be sounded below ground. "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° beginning at the groundline or slightly above in wetter areas and farther down the pole in drier climates. 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.

Generally, all poles in service for more than 15 y should be inspected by drilling. In some cases, depending upon pole species, original treatment and geographical location, poles should be bored earlier.

- ***If the wood is solid,*** rate the pole as good.
- ***If rot is present,*** drill or core the pole at additional points around the circumference and above or below the defect until there is no sign of decay.

Measure shell thickness in each hole, depth of preservative treatment (if using an increment borer), and pole circumference. From minimum circumference tables such as those used by RUS 1730B-121 (1996), but modified for your system, determine if the pole should be replaced, reinforced, left in service and remedially treated to stop or prevent the decay, or scheduled for re-inspection.

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 minimum 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 re-inspection.

DIGGING INSPECTION

To check for surface rot, dig around the pole to a depth of 18 inches in wet climates and deeper, if necessary, in dry climates. Some utilities initially limit digging to one side of the pole and only completely excavate if surface decay is found in the smaller zone. This reduces inspection costs, but may miss some decay in the non-excavated zone. Brush the pole free of dirt and examine its surface for rot. Probe suspicious areas for soft wood that may be indicative of decay. Scrape the surface with a dull tool, shovel, or chipper to remove all rotten wood. If in doubt, use the "pick test" 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 reinforcement, replacement, given a supplemental treatment, or scheduled for re-inspection.

HOLES MADE DURING INSPECTION

Unless the hole is to be used for the application of internal remedial treatment, some utilities treat all openings made during inspection with a preservative solution or paste (for example, 2% copper naphthenate as Cu) prior to plugging all holes with tight-fitting preservative-treated dowels or plastic plugs. Wear protective goggles when this is done, 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 at the groundline, especially those in lines of mixed-age poles, 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 still well protected by the original preservative, the additional cost of the groundline treatment may be 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 for these poles.

TREATMENT OF IN-SERVICE POLES

Once a pole has been found to be visibly decaying, the inspector must make one of three 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. To comply with NESC requirements, poles must be replaced or rehabilitated when they have 67% or less of the original required strength. In most cases, utilities require a minimum of 2 inches 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 44).

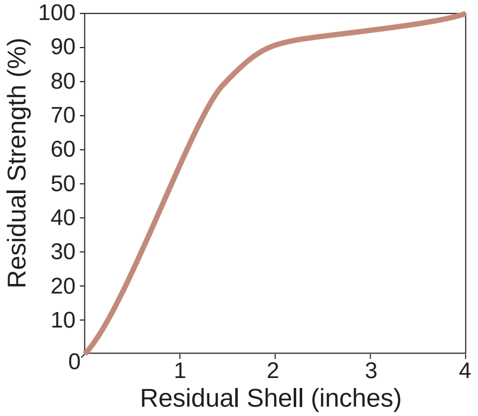


Figure 44. Theoretical strength vs. residual shell thickness of a pole.

Deciding on the fate of poles with external decay requires a different approach. The inspector measures the residual circumference after all of the decayed wood has been removed and makes adjustments for any internal decay or exposed decay pockets, then consults a chart showing the amount of circumference permitted for a pole of that class. Poles that retain adequate shell thickness, percent remaining strength, or circumference are then remedially treated. There are strength calculating programs available that calculate the percent of remaining strength and/or residual circumference, taking into account the orientation of defects relative to the line of lead. The inspector simply inputs in the field the measurements associated with the decay or defect conditions and the program outputs percent remaining strength and/or residual circumference.

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, estimated annual savings of $53 million resulting from pole maintenance in 1983 dollars. Regular inspection coupled with aggressive remedial treatment markedly extends pole service life.

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 10-15 y 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 will reduce the effective cross-sectional area and 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 various oil and water soluble preservatives. The water-soluble components were presumed to diffuse for relatively short distances (1/2 inch for Douglas-fir, 2 to 3 inches 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. More recent formulations also include copper, permethrin, bifenthrin, and tebuconazole.

Wraps or bandages are typically applied at the groundline, then extended downward for 18-24 inches (Figure 45). Preservative pastes are


Figure 45. Applying groundline treatment.

applied at the specified label thickness, then covered with polyethylene backed paper; the soil is then backfilled against the barrier. Some external systems are also supplied in self-contained wraps that require no chemical application to the wood surface. These treatments are generally designed to protect the wood for about 10 y.

INTERNAL TREATMENTS

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, boron, and copper naphthenate have been used for internal void treatments. Although these chemicals will kill insects on direct contact, their ability to penetrate the wood is a more important component of their use. Boron and fluoride can diffuse with moisture.

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 poles that have well-defined rot pockets and an abrupt transition between sound and decayed wood. In addition, many 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 non-treated test poles to assess the chemicals' ability to arrest expansion of voids, and to evaluate other effects of treatments.

INTERNAL DIFFUSIBLE TREATMENTS

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 and water diffusible chemicals as internal treatments provided a new technology for controlling decay.

Fumigants

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.

Four fumigants, metham sodium (32.7% sodium n-methyldithiocarbamate in water), chloropicrin (97% trichloro-nitromethane), methylisothiocyanate or MITC (97% active in aluminum vials), and dazomet (Tetrahydro-3,5-dimethyl--2H- 1,3,5-thiodiazine-2-thione) are registered for wood use (Figure 46). All are restricted-use pesticides in the United States. Applicators must pass a state test on pesticide handling and safety before using these chemicals.

Metham sodium is a caustic, 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 7-10 y and to southern pine poles for 3-6 y. These differences appear to reflect the higher permeability of southern pine, which enhances chemical diffusion through the wood.

Chloropicrin is among the most effective wood fumigants and has been detected in wood up to 20 y after application. This highly volatile,

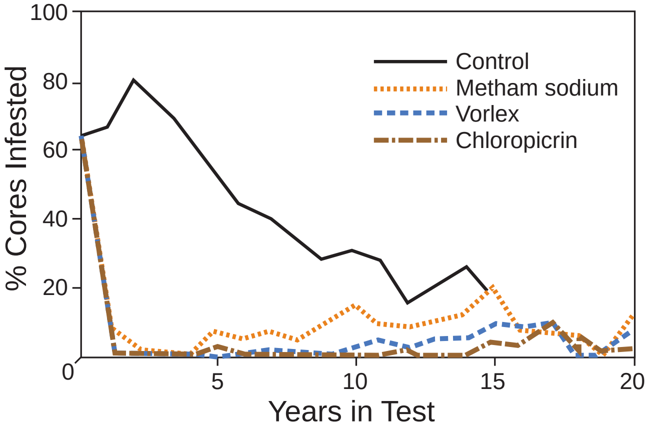


Figure 46. Ability of selected fumigant treatments to eliminate decay fungi in Douglas-fir poles.

difficult-to-handle chemical must be applied by applicators wearing respirators and there are strict requirements for signage on vehicles carrying this chemical. As a result, its use is largely confined to poles that are away from inhabited areas.

MITC 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 (MITC-Fume). The entire ampule is added to the pole. Field trials indicate that this chemical is more effective than metham sodium, and is much safer and easier to apply.

Dazomet is a caustic, crystalline powder that decomposes in the presence of water to produce MITC along with an array of other compounds. Although it initially produces less MITC than either metham sodium or solid MITC, it tends to produce protective levels in the wood for longer time periods than either of these systems. The slow initial MITC production may be a concern when treating poles with active decay. The initial breakdown rate can be accelerated by the addition of copper naphthenate at the time of application. Field trials are underway to determine the rate of MITC production in drier climates.

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 the wood with any moisture present 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. In general, it takes 2-3 y to reach protective levels with boron rods; however, these levels remain effective for up to 15 y in poles. Thus, the slow release rate is offset by the long protective period. The negative aspect of the slow release rate is the fact that active fungal decay can continue to occur until the boron levels reach the threshold for fungal protection.

In North America, boron rods are produced by heating material to a molten state and then pouring this liquid into a mold. The cooled rods are glass-like and release boron as they are wetted. Two systems are available, a boron rod and a boron/copper rod. Both work equally well.

Fluoride and fluoride/boron rods are more chalk like and less dense than boron or boron/copper rods. As a result, they contain less active ingredient. Fluoride has been used for decades for fungal control and is used in Australia in a fluoride/boron rod. Fluoride tends to remain in the wood for longer periods and moves at least as well as boron.

At present, the primary advantage of fluoride and boron over fumigants is applicator safety; the drawbacks include little 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. Once they do diffuse into place, however, the field data indicate that they remain at effective levels for up to 15 y after installation.

DRILLING TREATMENT HOLES

Drill a reasonable number of holes to obtain good distribution of the fumigant or the water-diffusible chemical in rod form, 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 liquid fumigant in poles. Note that the hole length allows for the insertion of a 3-inch treated plug. Shorter plastic plugs may allow for the use of shorter holes. One utility recommends that the number of holes meets the limits of knot sizes in Table 2 of American National Standard 05.1 (ANSI 2008).

Because water-soluble rods vary in diameter and length, consult the product label to determine the number of rods needed to treat a particular diameter pole. Plug treatment holes as described above.

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

Hole dimensions in inches		Pints of fumigant	Pole circumference* in inches		
Diameter	Total length	per inch of hole	< 32 (3/4 pint)	32–45 (1 pint)	> 45 (2 pints)
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

* Total dosages per pole are in parentheses.

Starting at the groundline, drill a hole directly toward the center of the pole at a steep downward angle that will not go through the pole or through seasoning checks where much of the fumigant could be lost (Figure 47). 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 6-12 inches between holes. If more than two treating holes intersect an internal void or rot pocket, re-drill 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 void connects to a seasoning check. Where a rot pocket is above the groundline, drill holes in solid wood below and above the pocket.

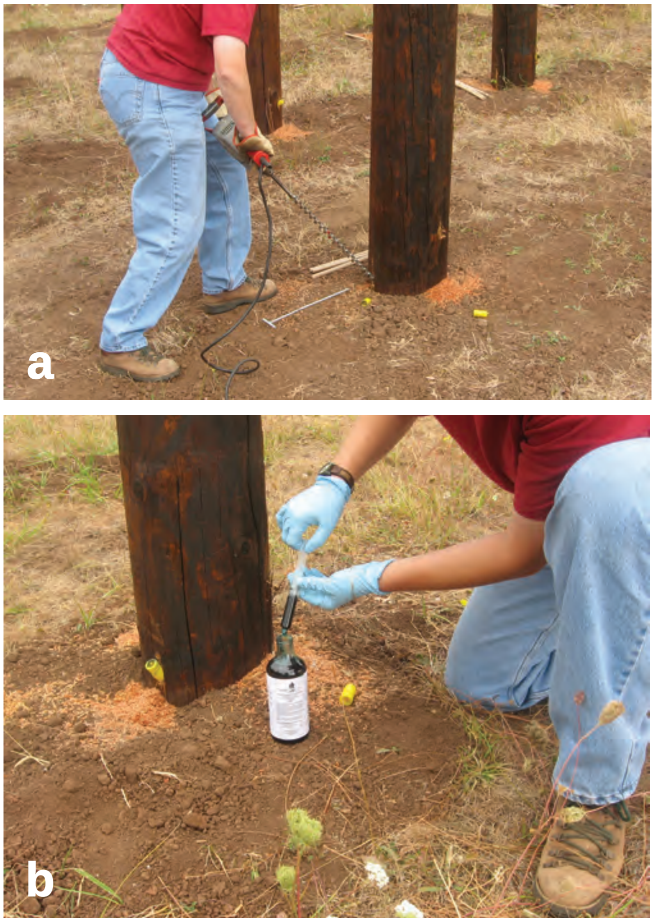


Figure 47. Fumigant application includes drilling holes at a steep angle (a), adding chemical (b), then plugging the holes. In (b), copper accelerant is being added to a dazomet treatment. Note the plastic plugs, which are used to plug inspection and treatment holes.

APPLYING INTERNAL TREATMENTS

Pour powdered dazomet or liquid fumigants from polyethylene bottles directly into holes drilled into the pole. Care should be taken to avoid overfilling the holes. MITC-Fume tubes are uncapped and inserted into the treatment hole. Water-diffusible chemicals in concentrated rod form should be inserted into the treatment holes.

Drive tight-fitting, preservative-treated wooden dowels or plastic plugs into the holes to minimize chemical loss. Threaded plastic plugs 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.

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 y. Those in drier climates may be inspected at 15-y intervals; most utilities, however, use a 10-y retreatment cycle. Metham sodium, chloropicrin, MITC and dazomet all appear to be effective for 10 y in Douglas-fir, and limited studies suggest that the results should be similar in western redcedar. Retreatment cycles with fumigants will tend to be shorter in southern pine because the chemicals dissipate and wood degrading organisms invade the wood more rapidly.

Most utilities add more chemical to the original treatment holes. Questions remain about what to do when retreating with dazomet, since some residual chemical is often present in the holes. Some utilities now add small amounts of additional dazomet plus more copper naphthenate accelerant. Retreatment cycles for boron and fluoride remain poorly defined because 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. Unless there is a compelling reason to do otherwise, re-inspection should use the original inspection holes for assessing decay and chemical application. This minimizes the potential effects of repeated drilling on pole properties.

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.

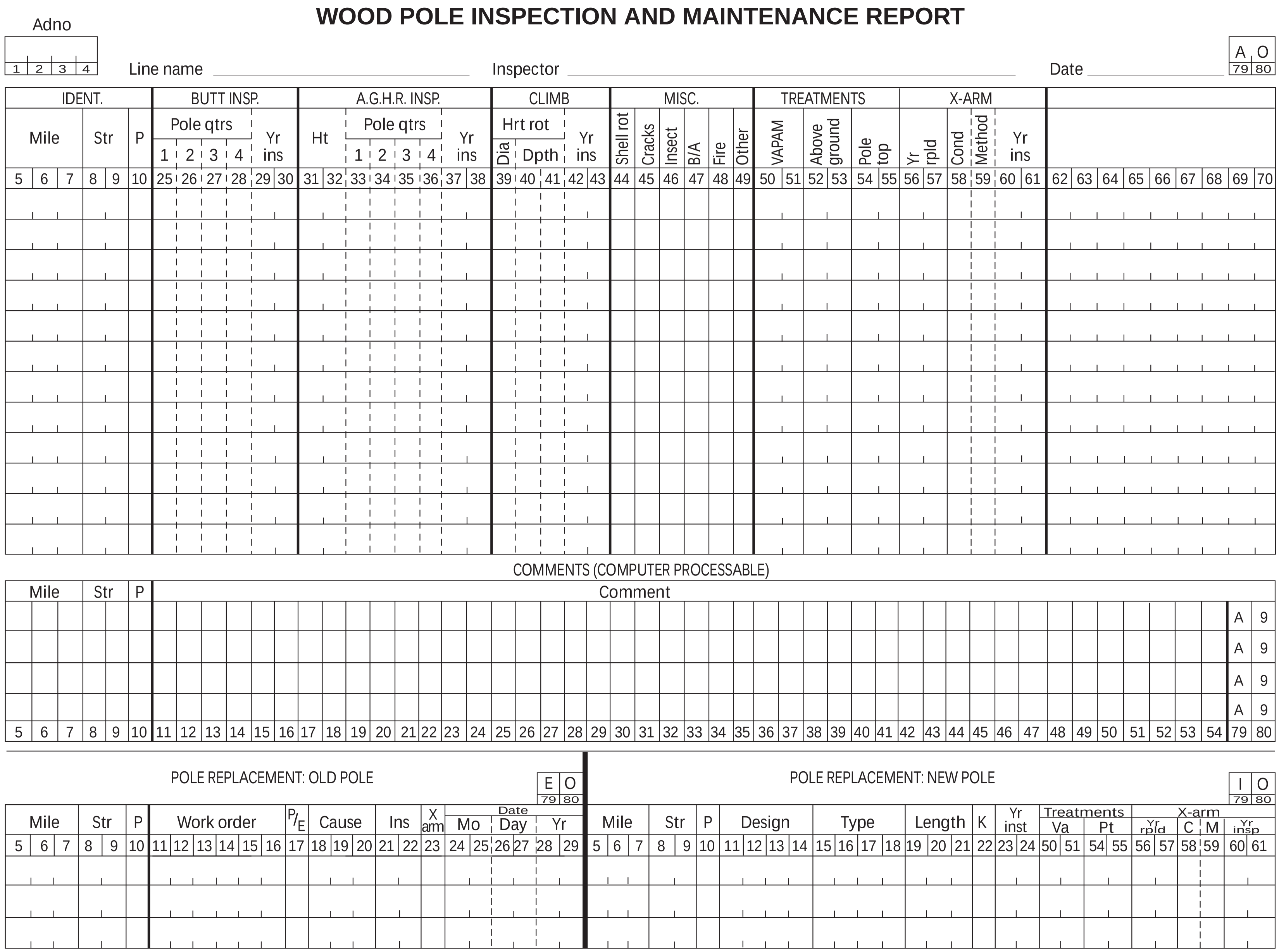
Controlling aboveground decay can be both expensive and challenging. Metham sodium, MITC and dazomet are registered for aboveground use and should effectively control decay. Diffusible rods or pastes can also be used for this application, but both require moisture for movement. Therefore, the treatment holes must be close enough to the decay zone to ensure that moisture is present for diffusion.

Field-damaged wood on the 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 and Data Management

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 (Figure 48). 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), presence of above ground defects such as woodpecker holes and split or decayed tops and the types of internal and external treatments applied for each year. This information can then be used to identify poles that are in need of immediate remedial attention.



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				
			Pole qtrs						Pole qtrs					Hrt rot																
Mile	Str	P	1	2	3	4	Yr ins	Ht	1	2	3	4	Yr ins	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	Date Day	Date 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	Treatments Pt	X-arm Yr rpld	X-arm C	X-arm M	X-arm 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 48. Example of field inspection form.

A good database can be a powerful tool for tracking the performance of various treatments and specifications, for prioritizing maintenance, and for identifying other system issues. For example, Bonneville Power Administration workers 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 used to be a labor intensive process, but the development of handheld data loggers eliminates the need for paper and permits the field inspector to enter all pertinent inspection data directly. These systems can store data for later transfer directly to a personal computer or can even be transferred directly from the field. The risk of error can be further reduced through the use of bar codes on poles or GPS coordinates. These systems can be integrated so that a line crew can access data on how to best get to a structure and prior pole treatments, as well as prepare work orders for items identified in the inspection. Whatever system is employed, all software and hardware should be thoroughly compatible and should be usable without extensive training. Databases that require extensive training to access will be under-utilized. Examples of several handheld data entry systems are listed in the Equipment Appendix.

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EQUIPMENT APPENDIX

A. ACOUSTIC DEVICES

EDM International
4001 Automation Way
Fort Collins, CO 80525
(Pole Test)
www.edminternational.com

Metriguard
P.O. Box 399
Pullman, WA 99163
www.metriguard.com

PoleScan
PO Box 342
Orewa, Auckland
New Zealand
www.polescan.com

B. DRILLS (RESISTOGRAPH)

IML, Inc
1275 Shiloh road, Suite 2780
Kennesaw, GA 30144
800-815-2389
www. Imlusa.com

C. MOISTURE METER

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

Wagner Electronic Products
326 Pine Grove Road
Rogue River, OR 97537
www.wagnermeters.com

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

D. INSPECTORS

Osmose Utilities Services, Inc.
215 Greencastle Road
Tyrone, GA 30290
www.osmoseutilities.com

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

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

McCutchan Inspection
PO Box 397
Banks, OR 97106

Intec Services, Inc.
4001 Automation Way
Fort Collins, CO 80255
Ph 970-482-6550
www.intecservicesinc.com

Independent Inspection Co.
P.O. Box 1776
Havre, MT 59501
http://www.iic-us.com/

Utility Pole Technologies
708 Blair Mill Rd.
Willow Grove, PA 19090
www.utiliconltd.com/utiliconpolemaintenance.htm

Estrada Consultants LLC
PO Box 1239
Redmond, OR 97756
aestrada@bendcable.com

Southeast Woodland Services
431 Caines Landing Road
Conway, SC 29526
www.southeastwoodland.com

E. INCREMENT BORERS

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

Forestry Suppliers, Inc.
P.O. Box 8397
Jackson, MS 39284-8397
www.forestry-suppliers.com

F. REMEDIAL TREATMENTS

1. Wraps/Bandages

ISK Biocides, Inc.
416 East Brooks Road
Memphis, TN 38109
www.woodguard.com

Osmose Utilities Services, Inc.
215 Greencastle Road
Tyrone, GA 30290
www.osmoseutilities.com

Copper Care Wood Preservatives, Inc.
P.O. Box 707
Columbus, NE 68602-0707
www.coppercarewoodpreservatives.com

Genics Inc.
561 Acheson Rd., 53016 Hwy 60
Acheson, AB T7X 5A7 CANADA
www.genicsinc.com

Poles, Inc.
336 Clarksley Road
Manitou Springs, CO 80829
www.poles.com

Preschem Ltd
147-149 Herald Street
Cheltenham, Victoria 3192
Australia
www.preschem.com

2. Internal Treatments

a. Fumigants

Osmose Utilities Services, Inc.
215 Greencastle Road
Tyrone, GA 30290
www.osmoseutilities.com
(Metham sodium, chloropicrin, MITC-Fume)

ISK Biocides, Inc.
416 East Brooks Road
Memphis, TN 38109
www.woodguard.com
(Metham sodium)

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

Copper Care Wood Preservatives, Inc.
P.O. Box 707
Columbus, NE 68602-0707
www.coppercarewoodpreservatives.com
(dazomet)

Poles, Inc.
336 Clarksley Road
Manitou Springs, CO 80829
www.poles.com
(metham sodium, dazomet)

b. Diffusible Rods

Genics, Inc.
561 Acheson Rd., 53016 Hwy 60
Acheson, AB T7X 5A7 CANADA
www.genicsinc.com
(copper boron rods)

Intec Services, Inc.
4001 Automation Way
Fort Collins, CO 80525
Phone 970-482-6550
www.intecservicesinc.com
(boron rods)

Poles, Inc.
336 Clarksley Road
Manitou Springs, CO 80829
www.poles.com
(boron rods)

Wood Care Systems
PO Box 2160
Kirkland, WA 98083
www.ewoodcare.com
(boron rods)

Osmose Utilities Services, Inc.
215 Greencastle Road
Tyrone, GA 30290
www.osmoseutilities.com
(sodium fluoride rods)

G. Bolt Hole and Surface Preservative Treatments

Copper Care Wood Preservatives, Inc.
P.O. Box 707
Columbus, NE 68602-0707
www.coppercarewoodpreservatives.com

Poles, Inc.
336 Clarksley Road
Manitou Springs, CO 80829
www.poles.com

Nisus Corporation
100 Nisus Drive
Rockford, TN 37853
www.nisuscorp.com

Osmose Utilities Services, Inc.
215 Greencastle Road
Tyrone, GA 30290
www.osmoseutilities.com

H. PLUGS

Osmose Utilities Services, Inc.
215 Greencastle Road
Tyrone, GA 30290
www.osmose utilities.com
(plastic and wood plugs)

Materials Procurement L.L.C.
7885 Guemes Island Road. Suite 40.
Anacortes. WA. 98221
www.replugs.com
(plastic plugs)

Morgan Lumber Co.
625 West Indian Creek Road
Collinwood, TN 38450
(wood plugs)

Poles, Inc.
336 Clarksley Road
Manitou Springs, CO 80829
www.poles.com
(plastic and wood plugs)

I. HANDHELD DATA LOGGERS AND DATA MANAGEMENT

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

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

SPIDA Software
560 Officecenter Place
Gahanna, OH 43230
www.spidasoftware.com

Varasset
Accent Business Services Inc.
7710 Northeast Greenwood Drive, Suite 170
Vancouver, WA 98662
www.varasset .com

J. DRILLS

Forestry Suppliers, Inc.
P.O. Box 8397
Jackson, MS 39284-8397
www.forestry-suppliers.com

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

K. OTHER DEVICES

MPT
Deuar Pty Ltd
92 Hawthorn Road
Morayfield, Queensland
Australia 4056
www.deuar.com

1. Pole Setting Foams

Chemque
6101 Guion Road,
Indianapolis, IN 46254
www.chemque.com

GRA Services
5000 East 2nd Street
Edmond, OK 73034-7545
www.graservices.com

Intec Services, Inc.
4001 Automation Way
Ft. Collins, CO 80525
www.intecservicesinc.com/

Rainbow Technology Corporation
261 Cahaba Valley Pkwy
Pelham, AL 35124
www.rainbowtech.net

2. Pole Reinforcements

GRA Services
5000 East 2nd Street
Edmond, OK 73034-7545
www.graservices.com
(Fiberglass and steel reinforcements)

Laminated Wood Systems
PO Box 386
Seward, NE 68434
www.lwsinc.com
(Phase riser, steel reinforcements)

Osmose Utilities Services, Inc.
215 Greencastle Road
Tyrone, GA 30290
www.osmoseutilities.com
(steel reinforcements and ET Truss)