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Improving the Performance of Wood Poles

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Excellent performance of wood poles requires properly prepared specifications for the poles and their preservative treatment, careful inspection of poles for compliance with the specification, and regularly scheduled maintenance programs for poles in service.

The specifications must recognize the characteristics of the species used, provide protection of poles from damage during processing and treating, require preservative penetrations and retentions consistent with the size of the pole and service conditions, and yet permit the suppliers maximum flexibility in selecting that combination of practices which is both safe and cost effective.

Quality of the pole and the treatment must be verified by experienced, well-informed inspectors solely responsible to the purchaser. Because the best specifications require interpretation, the inspector must be capable of making decisions that will hold down costs without endangering pole performance.

Good specifications and good inspection will keep maintenance costs low but problems will develop. To provide the reliable information the pole manager needs before deterioration becomes obvious and danger poles occur, the initial sampling inspection must be made early. Cores or plugs must be brought into the laboratory where skilled personnel have the knowledge and equipment necessary to determine the condition of wood and to make reliable estimates of residual pole strength. This will permit the pole inspector to do what he does best—look for unsafe poles—and enable the pole manager to maintain a safe, efficient wood pole system.

The ease with which trees can be cut and used makes this renewable resource unique among structural materials. Unlike metal and plastic which are produced with specific properties for specific uses, wood must be selected for each use by specifying which characteristics are acceptable and which are prohibited.

In the United States, the characteristics of wood poles are set forth in Standard 05.1–1979, of the American National Standards Institute (ANSI) (1).* For long service poles are treated with preservatives in accordance with Standards of the American Wood-Preservers' Association (AWPA) (2). Purchasers of poles usually reference these specifications although they may cite exceptions and include additional requirements.

The keys to excellent and economical performance from wood poles are:

1. Pole and preservative treating specifications that recognize the characteristics of the species used, protect the poles from damage during processing and treating, require preservative penetrations and retentions consistent with the size of the pole and service conditions, and yet permit the suppliers maximum flexibility in selecting those combinations of practices which are most cost-effective;
2. Careful inspection of new poles for compliance with those specifications; and,
3. Regularly scheduled maintenance programs for poles in service.

*Numbers in parentheses refer to information cited.

Pole Specifications

ANSI Standards

ANSI Standard Specifications and Dimensions for Wood Poles-05.1, has long provided a basis for selecting poles but improvements are needed. Small poles of most species have been tested (28) and their fibre stress values determined. Ponderosa pine poles also should be tested because their low wood density and clusters of large knots may not permit extrapolation of presently available data. Strength data are sorely needed on poles over 55 feet in length. Two factors that merit special attention are fungal decay and density.

Fungal Decay. ANSI 05.1 prohibits decay except for firm red heart, hollow pith centers in tops, butts or knots, and knots containing decay not associated with heart rot. The standard distinguishes between advanced decay which "is readily recognized," and incipient decay "that has not proceeded far enough to soften or otherwise perceptibly impair the hardness of wood" and "is usually accompanied by a slight discoloration or bleaching of the wood."

Advanced decay can be readily recognized in durable heartwood species such as cedar where the demarkation between rot and sound heartwood is very abrupt. In nondurable heartwoods such as Douglas-fir and in thick-sapwood pines the demarkation between rot and sound wood frequently is very difficult to determine, even by the experts, and certainly not be present field inspection methods. Nor is "a slight discoloration or bleaching of the wood" usually present or easy to detect, especially in the presence of sap stain which is permitted provided it "is not accompanied by softening or other disintegration (decay)."

Incipient decay merits far more consideration in pole standards because this invisible stage of decay can cause strength reductions of 40 to 80 percent (Table 1). Of the strength properties listed, hardness, which is used as an indication of incipient decay in Standard 05.1, is the least affected during the early stages of decay.

On the other hand, the detection of decay should not result automatically in the rejection of a pole any more than should the presence of a knot. Decay fungi differ widely in the rate of their affect on wood strength and on the formation of fruit bodies. *Schizophyllum commune,* for example, rapidly invades sapwood forming numerous small conks but probably causes little or no reduction in pole strength. Unlike knots which are easy to see and to measure, incipient decay is very difficult to detect much less determine its extent. We need to know much more about decay in poles and to develop techniques for assessing its effects on strength so that, like knots, we can include reasonable safeguards in pole specifications. In view of the concern about pretreatment decay of poles, the need for such information is all the more urgent.

Density. Wood density (one measure of pole strength) is controlled in Standard 05.1 by requiring an average of six rings per inch in the outer two or three inches except that "poles with four and five rings per inch are acceptable if 50 percent or more summerwood is present." Unfortunately, ring count alone or with a summerwood requirement is only a rough indicator of wood density. A better method is needed to weed out low-strength poles and to avoid the rejection of suitable poles.

The Pilodyn, a spring-loaded needle penetration testing device, appears promising as a rapid method for determining the density of trees (5), the strength of poles with surface rot (6), and for detecting low strength ponderosa pine poles (27). This device merits evaluation for use in ANSI Standard 05.1.

AWPA Standards

Preservative treating Standards of the AWPA have provided long protection for cedar poles with their thin sapwood and durable heartwood, for thick-sapwood pines and for small poles (less than 40 feet long) of all species. Sapwood depth is reflected in the penetration requirements (Table 2). A minimum and maximum penetration is specified for thin-sapwood nondurable heartwood species such as Douglas-fir and western larch, but not for the durable heartwood cedar or thick-sapwood ponderosa and southern pines. U.S. Forest Products Laboratory report 15 (6) is an excellent guide for the selection; procurement, and use of preservative-treated wood purchased under Federal Specification TT–W–571 or under AWPA Standards.

Neither of these standards, however, addresses the seasoning problems inherent in the protection of large poles (over 40 feet long) of thin-sapwood, nondurable-heartwood species such as Douglas-fir and western larch.

Green or partly seasoned large poles. When unseasoned (green) or partly air-seasoned large poles are kiln dried (13,18) or Boulton dried (heated in high-boiling-point oils or creosote under a vacuum) (7), the temperatures and heating times used are sufficient to kill decay fungi or insects that may be present in the poles. However, large poles cannot economically be dried to the moisture contents they attain in service (13). The results—some poles continue to dry and check (18) exposing the large central core to attack by wood-destroying organisms. Kiln drying at temperatures of 230°

Table 1. Expected Strength Loss at an Early Stage of Decay (5-10% weight loss) in Brown Rotted Softwoods.*

Property	Strength loss, %
Toughness	80
Impact bending	80
Static bending	70
Compression perpendicular to grain	60
Tension parallel to grain	60
Compression parallel to grain	45
Shear	20
Hardness	20

*Courtesy of Dr. W. W. Wilcox, Forest Products Laboratory, Univ. of Calif. (23).

Table 2. Wood Characteristics and Preservative Penetration Requirements for Poles

Species	Average Sapwood depth	Heartwood treatability along the grain	Penetration of preservative required: Depth	Sapwood	Minimum	Maximum
	In.		In.	%	In.	In.
Western red cedar	0.75	Very poor	0.50 or	100	-0-	--
Lodgepole pine	1.5	Poor	0.75 and	85	0.75	--
Douglas-fir						
Pacific Coast	1.5	Fair	0.75 and	85	0.75	1.60
Interior, North	0.75	Very poor	0.50 and	100	0.50	0.75
Western larch	0.75	Poor	0.50 and	100	0.50	0.75
Ponderosa and southern pine	4	Fair Poor	2.50 or	95	-0-	--

and 270°F reduced modulus of rupture about 15 percent (18).

Seasoned poles. In an attempt to overcome the checking problem in Douglas-fir poles, some electric utility companies have specified that poles must be air-seasoned to moisture contents of 30 to 20 percent at depths up to 2.5 inch. Moisture content is to be determined with electrical resistance-type moisture meters. A moisture content of 30 percent is typical of green Douglas-fir heartwood while a moisture content of 20 percent is well above the moisture content that poles usually attain in service so poles continue to check.

To attain a moisture content of 20 or 25 percent at depths of 2 to 2.5 inches requires two or more years of air-seasoning in western Oregon and Washington. This long seasoning time could explain some of the internal decay reported in Douglas-fir poles in the Northeast after three to six years of service (29).

A complication in such moisture content requirements is the accuracy of the moisture meter which decreases rapidly above an oven-dry wood moisture content of 20 percent. In Douglas-fir the difference between the meter readings and the oven dry moisture content steadily increases above 20 percent (11).

Moisture content requirements are not a solution to checking problems in large poles.

Solutions to the Checking Problem

Deterioration resulting from the checking problem in large poles could be reduced greatly by revising AWPA Standards to include practices required by many electric utility companies—kerfing, perforating and deep incising.

Kerfing. Making a sawcut to the center of poles from the butt end to almost five feet above the goundline is an effective method for reducing checking and preventing exposure of untreated wood in this critical zone (15, 23). First tested on round spar crossarms which were kerfed full-length to the center and stored outdoors for three years, the average check width decreased while the width of the kerf increased (9).

Kerfing should be applicable to all pole species, especially in dry climates to poles with heartwood which is difficult to treat along the grain such as cedar, lodgepole pine, western larch and interior Douglas-fir. Although some transmission poles have been kerfed for two-thirds their length, kerfing will reduce the strength of poles with much spiral grain.

One electric utility virtually eliminated the rejection of Douglas-fir poles because of checking through predrilled bolt holes by making opposed 1.5-inch deep kerfs downward 18 inches from the top at 90° or 45° to the holes (9).

Deep incising. Puncturing Pacific Coast Douglas-fir crossties with openings led to the development of incising equipment for sawn timbers about 1920 and opened the crosstie market to western species. Incising has long been required for certain woods in AWPA Standards. The properly spaced $^{3}/_{16}$-inch-wide chisel teeth cut endgrain to a depth of 0.75 inch permitting uniform preservation penetration along the grain of the wood to the depth of the incisions. The trend in recent years has been to tapered teeth which, though less disfiguring, cut less end grain and result in less uniform treatment. Incising will not provide uniformly deep penetration of preservatives in heartwoods that are difficult to penetrate along the grain.

To overcome the checking problem of Coast Douglas-fir poles in service, the groundline zone is perforated with parallel holes through the pole (4,11,14), or incised to a depth of 2.5 inches by teeth mounted on hydraulic rams (3). Preservative penetrates the incised zone to the depth of the openings. Tooth incising had little effect on pole strength (3) but hole perforating reduced the section modulus an estimated 10 percent and the modulus of rupture of that portion of the poles about 23 percent (11). Because of taper, long poles break well above the groundline so the holes have relatively little effect on the loads which long poles can carry (4,11,14). Nevertheless, an increase of one pole class for perforated poles is a wise precaution.

The decision on the length of the deeply incised zone depends largely on where the poles will be used. In dry climates, the incised zone may terminate a foot or two above the groundline. In wet climates, areas where carpenter ants, buprestid beetles or subterranean or drywood termites are prevalent, the incisions should extend from several feet below ground well up the pole to where checking in service is unlikely to occur.

The depth of the incisions should be determined by the minimum shell thickness required to support the load. Some electric utilities require radial drilling of 0.25 inch holes to depths up to 6.5 inches depending on pole length. A radial drilling pattern that extended from seven feet below to one foot above the groundline had little or no effect on pole strength (22). Incising patterns that extend well above ground can have an adverse effect on strength of large poles.

Reduced Pole Costs

Kerfed cedar, Douglas-fir, larch or lodgepole pine poles, or deeply incised Pacific Coast Douglas-fir poles with their low heartwood moisture content need only to be dried until the sapwood moisture content is low enough for the proper preservative treatment of the sapwood or, in incised poles, to the depth of the incisions. Unduly long air-seasoning times will be avoided reducing the risk of decay. Fumigants* used to control internal decay of poles in service, also appear promising for preventing internal decay when applied to poles prior to air-seasoning. Their persistence in poles (Figure 1) should provide long protection after the poles are placed in service.

By selecting the most cost-effective combination of seasoning practices to meet their customers' delivery dates, the treating industry can save energy while keeping pole costs down.

Deep penetrations and retentions specified for perforated or incised poles will assure long performance of poles even should decay develop in the untreated core while poles are in service.

Shallow incising. Full-length incising frequently is required for Douglas-fir poles. Depth of the incisions can vary from ¼ to 1 inch. Neither staggered incisions nor incisions in line reduced checking of round spar crossarms (9) although the latter may appear to do during the early stages of drying.

Such incising can improve uniformity of treatment in portions of Coast Douglas-fir poles with thin sapwood. On the other hand, if the treater can meet preservative penetration-retention requirements without incising, this requirement only adds to the cost of the pole—it should best be left optional.

Improperly done, incising can cause "shelling" (loosening of layers of wood), can be excessive and weaken poles, or can loosen small segments of wood just below the incisions creating a hazard for linemen climbing poles. Although AWPA Standard C1 makes rejection of such poles possible by making "the material unfit for the use intended," a stronger statement is needed to protect against poor incising practices.

INSPECTION OF NEW POLES

Clear, concise specifications aid quality control of "white" and treated poles, reduce rejects and help to hold down pole costs because all parties involved know what is expected. Nevertheless, differences of opinion on specifications will arise because some characteristics such as "decay" are described in vague terms while others, such as "compression" wood, though described more clearly are far from clear in practice.

Compression wood, abnormal growth rings with a high percentage of dense summerwood which shrinks excessively along the grain, is prohibited by Standard 05.1 in "the outer 1 inch of all poles." Though easily seen on the ends, obvious "compression wood" sometimes shrinks normally while less obvious compression wood can shrink excessively. Compression wood can be detected at the plant by cutting a one-inch thick wafer from the pole ends and measuring shrinkage and swelling along the grain of suspected compression wood and of normal wood with a micrometer. Normal wood shrinks about 0.1-0.3 percent whereas compression wood shrinks about 1 percent or more.

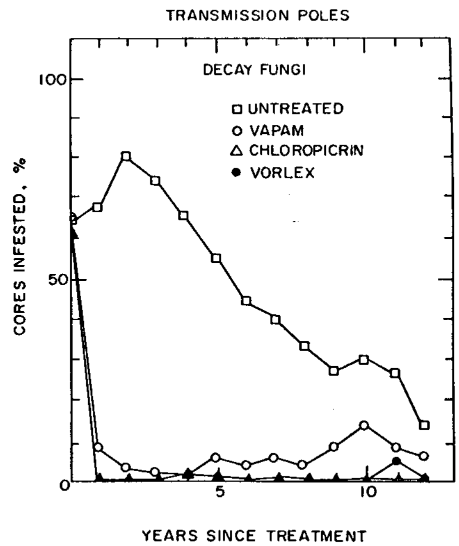

Figure 1.—Changes in fungal population of internally decaying pressure-treated Douglas-fir poles treated with fumigants. Each value is based on 12 cores removed each year from 6 or more poles.

The inspector, while dealing with many such interpretations of the standards, must rigidly enforce essential requirements (knot limitations, preservative penetration and retention requirements to name a few). He must also exercise good judgement to avoid unnecessary rejection of poles for differences of opinion that do not affect pole performance. To avoid bias the inspector should be solely responsible to the pole purchaser.

Knowledgeable, experienced inspectors play a vital role in the procurement of high performance poles.

POLE MAINTENANCE

Investments in wood pole systems with replacement values from $15 million to $2 billion or more provide unique opportunities for saving both lives and sorely needed funds. Bonneville Power Administration reported an annual investment savings of $2.25 million and New York State Electric & Gas

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* Discussed later in section on supplemental treating practices.

Corp. anticipates annual investment savings of $1.5 million from the use of chemicals to control internal decay of poles.

Good specifications and good inspection of new poles help keep maintenance costs low but regularly scheduled maintenance, aided by computers (10) can catch problems that are sure to develop before they become serious.

Present Inspection Practices

Presently, virtually all pole inspection is limited to the detection of poles with advanced decay. Sonic testing with a hammer or Pol-Tek, drilling, coring or determining electrical resistance with a moisture meter or Shigometer can detect such poles but cannot be depended upon to detect early decay (17). Unsafe poles are least difficult to detect but as the extent of deterioration decreases the skill and experience required of the operator to detect the deterioration increases. A wood pole maintenance manual has been prepared to aid inspectors (17).

Field decisions on the condition of poles are based on thickness of the "sound" wood as determined by feel, appearance of shavings, or inserting a thin steel rod to hook "sound" wood. Depth of preservative treatment is seldom measured. Such techniques may work reasonably well on durable heartwood poles which usually have an abrupt transition from sound to rotten wood. In nondurable woods where incipient decay may extend many inches or feet from rot into adjacent sound-appearing wood, strength estimates based on shell thickness are overly optimistic guesses, especially so if depth of preservative treatment is unknown. Which pole would you consider safest—one having three inches of "sound" shell of which one-half inch is penetrated or one having a three-inch treated shell?

Under current inspection practices, based on the detection of obvious deterioration, the initial inspection is delayed far too long. Usually, some poles already have reached the danger stage and the inspector decides whether a pole is "sound" or should be treated, stubbed or replaced. This is an awesome responsibility for a person who has neither the training nor tools to make such decisions and whose income very frequently depends on the number of poles inspected—and treated.

Present Supplemental Treating Practices

Remedial treating practices for control of decay in poles have relied upon the movement of oil-and-water-soluble chemicals into wood. Evidence of their ability to reinforce the original preservative in the outer one inch of poles is convincing (19,20,21,25) but conflicting evidence has been obtained of their value for protecting wood deeper in poles (21,25). Water-soluble preservatives applied to the surface or placed inside poles gradually reduced the population of decay fungi inside Douglas-fir poles over a five-year period, but a volatile chemical applied internally alone or with a water-soluble chemical was far more effective (8).

Volatile fungitoxic chemicals (Vapam-sodium N-methyldithiocarbamate, Vorlex-methylisothiocyanate and dichloropropenes, and chloropicrin-trichloronitromethane) placed inside decaying pressure-treated Douglas-fir transmission poles in service virtually eliminated decay fungi within one year—their effectiveness continued for at least 10 years (Table 3) (8) and, more recently, 12 years (Figure 1). Vapors of these chemicals move throughout the pole for about eight to ten feet below and above the treating holes. The presence of fungitoxic vapors of Vorlex and chloropicrin in the poles 12 years after application strongly suggests that retreating cycles may approach or exceed 15 years. Chloropicrin moved through heartwood of western redcedar poles as well as it did through Douglas-fir heartwood (24).

Future Maintenance Practices

The pole manager needs reliable information on the condition of poles before deterioration becomes obvious and danger poles occur to assure the continued safe and economical operation of a pole line or pole system. To provide that information, the initial sampling inspection must be made early. Cores or plugs must be brought into the laboratory where skilled personnel have the knowledge and equipment necessary to determine the condition of wood and to make reliable estimates of residual pole strength.

Table 3. Untreated and Fumigant-treated Douglas-fir Poles with Decay Fungi[1]

Year	Untreated	Vapam Wrapped	Vapam Unwrapped	Vorlex wrapped	Chloropicrin wrapped
1968	8	8	8	8	8
1969		Poles treated with fumigant			
1970	8	4	4	0	1
1971	8	1	1	0	0
1972	8	0	1	0	0
1973	8	0	0	0	0
1974[2]	7	4	4	0	1
1975[3]	7	1	0	0	0
1976[4]	5	2	3	1	0
1977[4]	5	2	1	0	0
1978[4]	4	3	2	0	0
1979[4]	5	3	2	0	1

[1]Slight variation from previously reported tables are due to data revision.
[2]Seven untreated poles remain in test.
[3]Poles remaining in test: untreated, 7; vapam wrapped, 7; vapam unwrapped, 7; vorlex wrapped, 7; chloropicrin wrapped, 6.
[4]Five untreated poles remain in test.

The pole inspector will then be free to do what he does best—make a visual examination of the pole for signs of problems—large checks, surface decay, sawdust piles and the carpenter ants that made them, woodpecker holes, elliptical buprestid beetle holes and loose hardware. His primary job will be to take wood plugs both below and above ground for laboratory study.

In the laboratory, the plugs will be examined for preservative penetration and evidence of fungal attack, assayed for residual preservative protection, cultured for decay fungi and, when needed, tested for certain strength properties. These data will enable the pole manager to determine with high reliability how many poles are:

- Sound and well protected
- In need of supplemental external or internal treatment
- Worth stubbing
- Potentially dangerous and should be scheduled for replacement.

Early inspection and laboratory evaluation of the condition of poles will permit the manager to schedule poles for external treatments before surface decay develops and for internal treatments to eliminate decay fungi before pole strength is threatened. Future inspections can be scheduled to develop the information needed to maintain a safe, efficient wood pole system.

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