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Inspection and Treatment of Poles in Service

A Survey

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By

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Report No. P-6
December 1962

Forest Products Research
FOREST RESEARCH LABORATORY
OREGON STATE UNIVERSITY
Corvallis

FOREST RESEARCH LABORATORY

The Forest Research Laboratory is part of the Forest Research Division of the Agricultural Experiment Station, Oregon State University. The industry-supported program of the Laboratory is aimed at improving and expanding values from timberlands of the State.

A team of forest scientists is investigating problems in forestry research of growing and protecting the crop, while wood scientists engaged in forest products research endeavor to make the most of the timber produced.

The current report stems from studies of forest products.

Purpose . . .

Fully utilize the resource by:

- developing more by-products from mill and logging residues to use the material burned or left in the woods.
- expanding markets for forest products through advanced treatments, improved drying, and new designs.
- directing the prospective user's attention to available wood and bark supplies, and to species as yet not fully utilized.
- creating new jobs and additional dollar returns by suggesting an increased variety of salable products. New products and growing values can offset rising costs.

Further the interests of forestry and forest products industries within the State.

Program . . .

Identify and develop uses for chemicals in wood and bark to provide markets for residues.

Improve pulping of residue materials.

Develop manufacturing techniques to improve products of wood industries.

Extend service life of wood products by improved preserving methods.

Develop and improve methods of seasoning wood to raise quality of wood products.

Create new uses and products for wood.

Evaluate mechanical properties of wood and wood-based materials and structures to increase and improve use of wood.

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ACKNOWLEDGMENTS

The authors are indebted to the following cooperating organizations for financial support of this study and to their representatives for encouragement and guidance in making this survey:

Bonneville Power Administration	O. F. Hand
Northwest Public Power Association	D. W. Jones
Pacific Power & Light Company	Larry Palmer
Portland General Electric Company	D. L. Brown

A special note of thanks is due Erik Bromberg, Bonneville Power Administration Library, for assistance in the search of the literature, to Dr. T. C. Scheffer, U. S. Forest Products Laboratory, for reviewing the manuscript, and to the many members of the staff of the Forest Research Laboratory, Oregon State University, who assisted in preparing this final report.

INSPECTION AND TREATMENT OF POLES IN SERVICE

A SURVEY

John S. Mothershead
Robert D. Graham

INTRODUCTION

Steady increase in number and age of poles has focused attention on need for improved methods to inspect and treat poles in service. This survey and discussion of existing literature is intended to show relationships that exist between the many disciplines involved and to provide a basis for research necessary to develop improved methods.

Wood poles have been used by utilities to support conductors from the beginning of transmission of electrical energy. The Timber Resources Review, U. S. Department of Agriculture, 1955, estimated that about 86,300,000 poles were in service in 1949 and predicted that 120 million poles will be installed by 1975.

When poles and labor were low in cost, untreated poles of durable heartwood species such as cedars and chestnut were used. As costs of supports and labor mounted, emphasis was placed on serviceability obtained by butt treatments of these durable-heartwood poles. Concern for decreasing supplies of durable-heartwood species led to full-length pressure treatment of woods that were not naturally durable and, recently, to full-length treatment of durable-heartwood poles as well.

Preservative treatments by pressure and thermal processes have enhanced greatly the life expectancy of poles. Improvements in these processes can be expected to provide wood poles to meet stringent requirements of the future. In the meantime, increasing attention is being given to maintenance of these supporting structures in an attempt to extend their service life.

Since the key to good maintenance is good inspection, the authors hope that this report will assist in developing reliable programs for inspection and stimulate further research essential to inspecting and treating of poles in line.

WOOD-POLE DETERIORATION IN GENERAL

Wood in service is subject to deterioration from weathering, fire, insects, and fungi or other microorganisms. Study of deterioration in wood is not limited to knowledge of the complex nature of deteriorating agents, but must include knowledge of the wood species involved, of the response of wood to changes in its environment, and of preservatives that might control deterioration. Excellent texts are available on wood in general (34)*, wood technology (3), wood chemistry (32), forest pathology (1), fungus physiology (6), and wood preservation (2,17). Of particular importance is a comprehensive review of literature dealing with decay of timber and its prevention, by Cartwright and Findlay (5); a supplemental survey of recent work on timber decay was published by Findlay in 1956 (12). Useful lists of publications have been compiled on wood preservation (22), wood-moisture relationships (18), thermal properties of wood (21), and decay in pulpwood (15).

Decay fungi are believed to be the primary cause for deterioration of wood in use (266) and are the major cause for deterioration and failure of poles in the northeastern United States (121). Insects, such as termites and carpenter ants, frequently are associated with decay fungi in deterioration of poles (121,266) and other wood structures (5). Decay is the primary cause of failure in service tests of treated and untreated posts and poles (138,169,185). Graham and Miller (169) reported that during an 11-year period in which 338 test posts failed, cause of failure was 74 per cent from decay, 22 per cent from decay and insects, and 4 per cent from termites. Because decay is such an important factor in serviceability of wood products in contact with the ground, this survey will deal solely with deterioration of wood by decay fungi.

Increasing awareness of the problem of pole deterioration and of need for improved maintenance procedures is evidenced by the recent series of wood pole conferences (25,26,27,35). These conferences likely will continue until reasonable solutions can be found through research (9,23,29,121,259).

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*Numbers in parentheses refer to similarly numbered references.

PROPERTIES OF WOOD RELATED TO DECAY

A knowledge of wood is basic to an understanding of wood-decay relationships and to methods that might be adopted to detect, prevent, or control decay.

Anatomy of wood

Wood consists of an interlocking cellular matrix composed of cellulose (about 65 per cent), lignin (about 30 per cent), and other materials (about 5 per cent) (40,52,60). Wood derives its strength from long crystalline cellulosic chains that are "cemented" together by amorphous lignin. Much of the volume of wood consists of void areas within cells which help give wood a high strength-weight ratio (42).

About 95 per cent of the cells in wood are elongated in the vertical direction in standing trees; their length is roughly 100 times their diameter (3). The remaining 5 per cent of cells are elongated in a horizontal plane and extend from within the bark into the wood towards the pith, much like rays from which they derive their name. Number, size, shape, and distribution of ray cells vary between tree species, as do other characteristics of wood. Void spaces within cells are connected by apertures in the cell walls called pits. Pits are important in distributing liquid preservatives in wood.

In temperate climates, wood is characterized by growth rings that are composed of alternating bands of light springwood and dense summerwood, commonly called "grain" (3). These alternating layers appear in the living tree as concentric nested cones and are the typical bands seen in a "ring count". Within the outer few inches or less of most trees, the water-saturated white sapwood changes into heartwood of lower moisture content and, in many species, of darker color (330, 337). These changes, which are not well understood, usually are accompanied by decrease in permeability of the wood to liquids (36,71,392).

Wood-liquid relationships

Amount, distribution, and movement of liquids and gases through wood are of prime importance both to activities of wood-destroying organisms and to movement and deposition of preservative chemicals within wood (41,323,346).

Movement of water in wood is not simply a single-phase flow process; rather, it is a complex physical system in which liquid moves between and within cells of the wood by a series of phase changes from liquid to vapor and back to liquid (3). During movement, liquid or gas is subjected to forces resulting from capillarity, differences in water-vapor pressures, inequalities in concentration of liquid and vapor, and chemical bonding forces exerted by wood cellulose (70,314,317). Differences in composition and structure of wood species result in differences in amount of water present (332,350) and in the rate of moisture movement (393). Environmental conditions, particularly rainfall and temperature, also influence moisture content of wood in service (34).

Dimensions of wood change in response to movement of moisture into and out of the wood (3,34). Magnitude of dimensional changes depends on wood species, state and amount of water in wood (50), and upon the portion (i.e., springwood-summerwood, high-low density, heartwood-sapwood, radial-tangential-longitudinal direction) of the wood under observation (46, 364). Shrinking and swelling occur only at conditions below the "fiber-saturation point" (48), which is that moisture content at which the cell walls are saturated, but no free water exists in the cell cavities (about 30 per cent based on oven-dry weight of wood for most species). The fiber-saturation point has been shown to vary inversely with increase in temperature (395).

Resultant physical forces exerted in wood by differential shrinking and swelling often exceed the cohesive forces holding the cells together and cause wood to check (crack) (390). Checks are of particular concern to preservative treatment of wood, for checks occurring after treatment can break through the protective envelope of treated wood and expose unprotected wood beneath (33,38). MacLean (56) made an intensive study of factors involved in checking of wood before and after treatment.

Attempts have been made to control or to prevent checking by introducing various chemicals into wood (339,353,394) and to induce changes within wood to control dimensional changes (397). Effectiveness and status of chemical seasoning for control of checking have been summarized by Loughborough (53). Nayer (59) studied the swelling of wood in various organic solvents.

Efforts have been directed toward improved understanding of movement and distribution of preservatives in wood (17,60,134,135). Influence of temperature on rate of heat transfer in wood and on permeability of wood to liquids are important considerations in preservative treatment of wood (57,331,365,366). Wetting agents apparently are of no value in increasing rate of uptake of aqueous preservative solutions applied by soaking wood (396), but may have some value in pressure treatment of wood (311).

Chemical considerations

Chemical constituents of wood have been studied intensively (32), usually by analytical procedures of the Technical Association of the Pulp and Paper Industry. Campbell and Bryant (324) have studied procedures for determination of pH of wood. The chemical nature of extractives, which are factors in natural durability of wood, have been investigated (37,340).

Campbell (77) and Cowling (83) investigated the chemistry of biological decomposition of wood by decay fungi. Some changes appear necessary in standard analytical procedures if they are to be used for decayed wood (223,231). Iron stains, as from metal fastenings, have been reported to accelerate decay of some untreated woods (357).

Heat, which may alter chemical properties of wood (58,76), has been examined as a means of killing fungi and of increasing resistance of wood to decay (76). Effects of radiation on physical and chemical properties of wood (351,354) and as a means of sterilizing wood (91) are receiving increasing attention.

Natural durability of wood

Sapwood of trees grown in temperate climates is not naturally durable when exposed to moist conditions (86). Heartwood of some trees used for poles, such as the cedars and redwood, is very durable, but heartwood of many pole species, such as pine and Douglas fir, is only moderately durable (7,43,66). Natural durability varies not only between species of wood (45,67,328), but within species (406), and within a tree (39,45). As a rule, extractive content and durability of heartwood vary inversely with height in the tree and directly with distance from the center of the tree (39,54,65).

Durability of heartwood is related to both amount and type of extractive it contains (86). Durability of western red cedar heartwood is attributed to thujaplicins and other water-soluble extractives (39,54,61, 62,64). Southam and Ehrlich (69) found that extreme dilutions of water-soluble extractives from cedar can be stimulatory to fungi grown on cultures containing varying concentrations of the extract. They also determined that fungi can become accustomed to the extract and develop strains on previously lethal dosages. Rings of "included sapwood" in target-pattern cedar heartwood were found to be deficient in fungicidal extractives (55).

MacLean and Gardner (54) found that where typical variations in color occur in western red cedar heartwood, a change from lighter to darker color coincided with a reduction in natural preservative content. Western red cedar heartwood posts from the same source selected for light and dark color had an average service life of 23 and 22 years respectively (169). Findlay and Pettifor (49) concluded that lower specific gravity and reduced strength properties of dark wood in heartwood of western red cedar were brought about by fungal attack. Earlier, Eades and Alexander (44) decided that coloration was not an indicator for decay in western red cedar.

Richards (63) found that neither position within the sapwood of the log nor original specific gravity had any consistent effect on decay resistance of the wood. Southam and Ehrlich (68) found that for a single species of wood, there may be a tendency toward greater initial decay resistance in wood of high specific gravity, but this may be nullified or even reversed as decay progresses; ring frequency was of no value as an indicator of decay resistance. Schmitz (67) concluded that specific gravity and rings to an inch are not necessarily indications of durability, since durability is influenced also by the species of fungi prevalent in a locality.

WOOD-DESTROYING FUNGI

Decay in wood is caused by simple forms of plant life called fungi which, lacking chlorophyll, are unable to manufacture their own food. Fungi develop from seed-like spores that germinate under suitable conditions to produce unicellular strands of hyphae. Hyphae spread throughout wood to establish an extensive root-like system called a mycelium. Extending hyphae secrete enzymes that are capable of breaking cellulose, lignin, and other constituents of cell walls of wood into simple organic substances that can be utilized by the fungus as food. Eventually, aerial structures are formed in which microscopic-size spores are produced in millions. Processes of wood decay have been described thoroughly by Findlay (12, 13, 14, 87) and others (8, 16, 31, 73, 121). Hatfield (51) has discussed structure of wood as it relates to wood-destroying fungi.

Identification and classification

Literature on taxonomy and morphology of fungi responsible for deterioration of wood, primarily in living trees, has been assembled by Boyce (1). Available information on different types of decay of wood products and methods for preventing decay has been summarized by Cartwright and Findlay (5). Both publications are excellent sources for references on all aspects of wood decay.

Most wood-destroying fungi belong to the botanical class called Basidiomycetes, which are characterized by distinctive fruiting bodies varying from insignificant structures to elaborate fruitifications such as mushrooms, toadstools, and conks (1). Fruiting bodies usually do not occur until the fungus has achieved a high degree of development (1, 5, 349). Identification of a particular wood-destroying fungus requires extensive technical knowledge and frequently is difficult, particularly if no fruiting body is present.

Problems of classification and identification of fungi are under constant study and revision by mycologists (319, 326). Users of wood products can be of valuable assistance to mycologists by collecting samples of wood containing decay from which the causal organism can be isolated and identified (120).

Wood-destroying fungi usually are divided into two broad groups, brown rots and white rots, based on their destructive action in wood (1,5,17,83). "Brown rots" utilize primarily cellulose and leave lignin relatively untouched, which gives the remaining wood a brown, crumbly appearance. "White rots" destroy both cellulose and lignin in about equal proportions and often leave wood with a bleached appearance, or with white pockets of cellulosic material. These groups can be separated in cultures by their reactions to tannic acid and gallic acid media (84). As a rule, white rots are associated with hardwoods, while brown rots are associated with softwoods, but there are notable exceptions to this generalization (83). Identification of specific fungi growing in cultures have been based on color (97), odor (220), and anatomical features (105).

Physiology

Cochrane (6) has described many of the complex physiological relationships of fungi as a general plant classification. Where knowledge of particular physiological factors is lacking with regard to fungi, he has attempted to make interpretations or suggestions of methods of study from comparisons with more complete information available on physiology of yeasts and bacteria.

Fungi require for growth a source of food, sufficient but not excessive moisture, oxygen, and a suitable range in temperature (73,86, 107) together with other specific environmental conditions that may be vital for particular species or genera (6). Requirements vary with species of fungus (90). Although certain wood-destroying fungi may prefer a single wood species or genera, fungi will develop rapidly in most woods under the following conditions: (a) moisture content near the fiber-saturation point (20,110,115,116) or when the relative humidity of the surrounding environment is high enough to induce such a condition (122), (b) an air content of about 20 per cent of the wood volume (115), and (c) when temperatures range from 76 to 82 F (19,81,99,103,104). Type of nitrogen present (89,100,101,111) and pH (119) may be important to growth of fungi.

Fungi are tolerant of extreme conditions for short periods of time and, if changes are not rapid, some fungi can survive in a dormant state for extended periods of very dry or very wet, abnormally hot or cold, and other adverse conditions (85,88,108,110). Fungi vary greatly in their tolerance to heat (114). For example, growth of some fungi is inhibited at 110 F (103), yet Chidister (82) found that a temperature of 150 F for 75 minutes was necessary to kill other fungi. MacLean (365) found that it was impractical to attain a temperature of 150 F in large size poles and timbers by steaming which he considered necessary to kill fungi. Montgomery (104) and Snell (114) found that moist heat was more effective than dry heat in killing fungi.

Fungi can be killed by ultraviolet light and by dielectric heating (88), but ultraviolet light does not penetrate wood well, and dielectric heating presents practical problems when applied to large pieces of wood. Frejdin and Krapivina (91), from their study of the effects of radiation on 33 fungi, believed that a dosage of about 1.0 M rad would be lethal to all fungal and insect pests, while damage to wood properties by radiation would not start until doses of 50 M rad were reached (one rad equals 100 ergs per gram of absorbed energy).

Chemistry

Complex systems of enzymes secreted by fungi (109, 113) fragmentize chemical components of wood (74, 79, 96), assimilate these fragments, and further dissociate the fragments into organic compounds of low molecular weight (72, 93, 118) that can be utilized by fungi for growth.

The chemistry of decaying wood has been studied by Boswell (74), Campbell (77, 78, 79), and Cowling (83). Chemical action of fungi were studied by noting changes in solubility of wood in selected solvents, changes in chemical composition, and degree of polymerization of cellulose. Other methods of study included isolation and identification of enzymes associated with the fungus (109, 113) and identification of byproducts of fungal attack (72, 92).

Chemical studies have indicated differences in effect of white rot and brown rot fungi on wood. In advanced stages of decay, the effect of white rot fungi is similar to action of acid-alcohol solutions on wood (78), whereas effect of brown rot fungi is similar to acid hydrolysis (74, 80). Cowling (83) found that a white rot fungus caused a gradual change in solubility, chemical composition, and degree of cellulose polymerization as decay progressed. On the other hand, a brown rot fungus caused solubility to increase rapidly during early stages and decrease during later stages of decay, rapid decrease in cellulose content with an increase in proportion of beta-cellulose, rapid lowering of the degree of cellulose polymerization, and but little decrease in lignin content based on moisture-free weight of original wood. Differences in effect of these fungi on wood were attributed by Cowling to the enzyme system present in each fungus. White rots appeared to be able to utilize nearly all wood components in proportion to amounts present. Brown rots appeared to be able to utilize beta-cellulose much more slowly than alpha- and gamma-cellulose, and appeared unable to utilize lignin, although lignin may be altered as necessary to gain access to cellulose (83).

Both Cowling (83) and Campbell (79) reported that, in wood undergoing decay, solubility in one per cent alkali (based on oven-dry wood) rises to a maximum and declines at a much earlier stage with white rots (about 5 per cent weight loss) than with brown rots (about 20 per cent weight loss). This relationship is important in view of common use of solubility in one per cent alkali as a test for presence of decay (5,227, 231,252).

Effect on physical properties of wood

During decay, wood changes color, odor, and conductivity; loses luster, dry weight, and strength; and increases in water-holding capacity and shrinkage (1,3,5,34,45,107,121). Severely rotted wood may become strongly luminescent (5).

Hartley (231) analyzed critically existing literature on amount and consistency of the effects of fungi on different properties of wood in an attempt to determine which property could best be measured to evaluate decay in laboratory tests of preservatives and of natural decay resistance of wood. Assessment of damage during early stages of decay was a secondary objective of his search. From the standpoint of wood in service, however, assessment of this damage is of primary importance, because losses in strength can be high during incipient stages of decay (83,233).

Loss of weight is the most common criterion for evaluating extent of decay in wood blocks used for laboratory tests (231), but strength tests, usually in correlation with loss of weight, have been investigated to determine their usefulness (231,233,235,241,250). Of many strength tests, Hartley (231) considered toughness and hardness most promising. Toughness (250) and work-to-maximum-load (241), a measure of toughness, show greater reductions than do other strength properties.

Incipient decay may or may not seriously weaken wood, depending on the type of decay (1). At equivalent losses of weight, white rots generally cause less loss in strength than do brown rots (83,233). Kennedy (233) reported that modulus of rupture and work-to-maximum-load in static bending often were reduced drastically with little or no loss of weight; decay caused by the brown rot, Poria monticola, generally induced higher losses of strength than that caused by the white rot, Polyporus versicolor. Mulholland (241) reported a highly significant loss in strength after a loss of only about 2 per cent of the dry weight of wood attacked by Poria monticola. He pointed up the danger of using too broad a classification for durability when rating wood to be used in places where strength is important.

Soft rots and other micro-organisms

Soft rots, which belong to simple forms of plant life called Ascomycetes and some Fungi imperfecti, may be more important in deterioration of wood than has been recognized heretofore. Duncan (335) reviewed information available on these micro-fungi which are able to tolerate greater extremes in temperature and moisture conditions and higher concentrations of wood preservatives than can the usual wood-destroying fungi. Their action on wood is not so apparent nor so rapid as that of Basidiomycetes, but together they may account for deterioration of wood under conditions where decay would not be expected to occur (336,358). Soft rots are associated with the phenomenon that has been regarded as aging and ultimate deterioration of wood in service (384).

There are indications that bacteria (343), or incipient stages of fungal attack prior to the time wood is cut (106), may contribute to the subsequent decay of wood in service by other organisms. Common mold fungi that attack only ray cells of wood have been used to infect freshly cut posts and poles to improve treatability (359,361,362).

Research needs on deterioration of wood products

Cartwright and Findlay (5) pointed to lack of appropriate texts on decay of wood products in contrast to voluminous information on decay of living trees. Although their text has helped correct this situation, their information on decay of poles is limited to slightly more than one page and is limited primarily to conditions as they occur in Great Britain. Boyce (1) deals with decay of posts, poles, piling, mine timbers, and ties in 4 pages. Zabel (121) emphasized need for " a great deal more information on identity, sequences, and interactions of the many micro-organisms which inhabit and decay wood products in use in various regions." He considered such information useful in forming realistic recommendations for control and in development of effective preservatives and treatments. A tentative proposal for a coordinated and uniform program of collecting and identifying causal organisms in decay of wood products in the northeastern United States was proposed by Zabel (120).

Relationships between decay of living trees and continuation of decay of this wood in service by the same fungi is far from clear. Cartwright and Findlay (5) state, "It is an interesting and hitherto incompletely explained fact that comparatively few of the fungi which occur in standing trees are important as causes of decay in felled timber." Yet, in their discussion of principal decays of standing trees, they note that a number of these fungi will continue to develop in felled trees if adequate moisture conditions are maintained. Boyce (1) states, "Furthermore, certain decays continue to develop under favorable conditions after the tree is converted, so that placing wood with incipient decay in use where decay durability is essential can result in unusually rapid deterioration." *Poria monticola*, which causes rapid losses in strength and weight during early stages of decay (233,241), commonly causes a heart rot of living trees as well as decaying wood in service (1). Richards (349) also notes that fungi which infect living trees may continue to grow after the tree is cut. Fritz (92), in discussing current opinion that as a rule rots initiated in standing trees do not continue under conditions of service, states, "This is doubtless true of many types of decay, but some fungi are known to remain active in felled timber and, with regards to others, incomplete records leave us in doubt as to their reactions to such changes in environment."

Difficulties encountered in detecting decay, particularly early stages, have been emphasized by many investigators. Boyce (1) warns, "Incipient decay is dangerous since it is easily overlooked and, in some types of decay, notably brown rot, the wood is seriously weakened in the incipient stage and should not be used where strength is required." Richards (349), in discussing defects in cross ties caused by fungi, cautions, "The incipient stage of these rots is the important one to consider since ties containing advanced decay will be culled anyway. Very frequently it is next to impossible to detect incipient decay."

PRESERVATIVES

Traditionally, attack on wood by fungi and insects has been prevented or controlled either by keeping wood dry (below a moisture content of 20 per cent based on oven-dry weight), or by depriving these organisms of a palatable source of food by introducing toxic or inhibitory chemicals into wood (28,30,129,186,363). Since moisture content seldom is subject to control in poles, this section will deal with chemicals that can be applied to poles either prior to, or during, service. Methods of evaluating preservative value of chemicals are discussed in some detail, since these test procedures also might be followed to evaluate effectiveness of treatments applied to poles in line.

Type of preservative

Preservatives commonly are divided into 2 types; those that are soluble in water, and those that are soluble in oil. Oil-soluble preservatives are used extensively where treated wood is subject to leaching (141,205,218,322). However, some water-soluble preservatives are used alone, or in combination with oil-type preservatives, in supplemental treatment of poles (283,300,306,329).

Oil-type. Oil-type preservatives include a variety of products that may be oily substances derived from natural products, natural or manufactured chemicals that are soluble in a variety of organic carrier solutions, or mixtures of compatible oil-soluble chemicals with desirable properties as preservatives.

Creosote, a high-boiling liquid obtained from distillation of coal tar (17), has been used successfully for many years as a wood preservative and continues to give satisfactory results under test and use (138, 151). Creosote is a complex mixture of organic compounds, many of which have varying degrees of preservative value (188). Although composition of creosote may vary depending on source of coal tar and distillation conditions, it must meet standards prescribed in the American Wood-Preserver's Association (AWPA) Manual of Recommended Practices (AWPA Standard P1). Creosote may be diluted with petroleum (AWPA Standards P3 and P4, or with coal tar (AWPA Standard P2), and has been fortified with pentachlorophenol (156,207). Low-temperature coal-tar creosotes (128,161) and lignite- and oil-tar creosotes (158) have been tested for preservative value.

Petroleum by-products containing naphthenic acids have been combined with various metals, notably copper and mercury, to form oil-soluble preservatives of the metallic naphthenates (17). Copper naphthenate was found to be an effective preservative, with toxicity depending on quantity of metallic ion present (216). Naphthenates impart some water repellency by forming a wax-like coating on wood (141).

Pentachlorophenol has found extensive use as a wood preservative in recent years (17). It is soluble in a wide range of solvents, particularly petroleum oils (170,180). The petroleum carrier, which may influence preservative value of the treating solution (155,162), also may affect the distribution (171,172) and permanence (180) of the preservative. Properties of the solution, such as lightness of color and paintability, can be controlled by suitable choice of solvent and selection of additives such as anti-blooming agents (170). Tests conducted with pentachlorophenol indicate that it is an effective preservative for control of most wood-destroying insects and fungi (205,218).

Oil solutions of pentachlorophenol have been converted to emulsions (190) or greases (292) for applications where a heavy, viscous material is desirable to hold the preservative in place. Pentachlorophenol can be converted to a water-soluble preservative by formation of the sodium salt (sodium pentachlorophenate) for application where solubility in water may be advantageous (17).

Standards have been developed for use of pentachlorophenol and copper naphthenate in petroleum solution (AWPA Standards P8 and P9).

Water-borne. Although resistance to leaching is often desirable for preservatives, some water-soluble salts have been effective under conditions where leaching is no problem, or where solubility in water may be an advantage to migration and distribution of preservative (306). Many water-soluble inorganic and organic salts are toxic to fungi.

Among these are certain copper, zinc, mercury, and arsenic salts (131, 168,200,203); sodium, potassium, and ammonium fluorides and bifluorides (132,199); boric acid and borates (143); dinitrophenol (17); and others (206). These often are used in combinations to obtain desired properties (134,135,136,206).

Test results indicate there is more variability between specific fungi in tolerance to certain water-soluble salts than with oil-type preservatives (152,199,200). With copper salts, the particular salt used appears to determine effectiveness of the copper ion as a preservative (168,193). Effectiveness of fluoride compounds may depend on species and condition of the wood (132), or environment, particularly the presence of soluble calcium salts (183). Mercuric and arsenic salts are effective preservatives, but must be used with care because of high toxicity to humans and livestock (289). Boron has proved an effective and economical preservative for use where leaching is not a hazard (143).

Preservative salts of low solubility can be deposited in wood by sequential treatment with different water-soluble chemicals. In the "double diffusion" process (125), a water-soluble salt is allowed to diffuse into the wood to be treated. A second salt then is diffused into the same area and reacts with the first salt to form a precipitate that is toxic to fungi and termites. Preservative salts formed in this method are leached more slowly than are soluble salts (127).

Other chemicals. Various chemicals with certain desirable properties as preservatives have been explored (345). Effectiveness of water repellents (321,404) and preservative value of fire-retardants have been investigated(386). Methyl bromide and chloropicrin have been used as fumigants to kill fungi in infected timber (327,375). Such gases have greater penetrability in wood than do most liquid solutions, but do not provide residual preservative action. Other compounds suggested as preservatives include colloidal solutions (348), combinations of nitrophenols and alpha-sulfonates (356), dyes (402,403), odoriferous chemicals and essential oils (369), and various extracts from wood (388,400).

Evaluation of preservatives

When treated wood gives many years of satisfactory service under conditions imposed upon it, the preservative may be assumed to be serving its function well. Evidence of preservative value from service records and close observation of test poles, however, takes many years. Expedient methods are followed to screen chemicals for their preservative value and to study other properties, such as resistance to leaching and tendency to bleed.

Several accelerated tests in laboratory and field have been developed to evaluate wood preservatives (137,142,201, 205). Methods of improving (159,164) and accelerating such tests through weathering devices (160,166), and methods of mathematical analysis (192) have been devised. Correlations have been obtained between rapid, small-scale laboratory tests, field tests on stakes, and post and pole-sized field-exposure tests (148,150,379).

Chemical methods have been useful in studying penetration (153, 195,322,380,392), retention (126,165,173,363), distribution (125,133, 146,172), and permanence (171,180,189,347) of common preservatives. Special techniques have been devised for analysis of components of oil-type (154,177,215) and water-borne (147,196,204,214) preservatives.

Laboratory tests. Tests of preservatives under laboratory conditions provide fairly rapid methods for screening preservatives (197). Two basic techniques employed for laboratory evaluation of preservatives are agar-plate and soil-block tests (210).

In the agar-plate method, one, or more, common wood-destroying fungus is grown in culture on agar gel under ideal growing conditions. This procedure is identical with conditions used to study growth characteristics for identification of fungus species (105). A small amount of this actively growing fungus is placed in the center of a plate containing a definite concentration of the preservative to be tested in agar. Effect on growth of the fungus is observed for several weeks and compared with a control culture containing no preservative.

The agar-plate method commonly is used to test the toxicity of preservatives to specific fungi (or conversely, tolerance of specific fungi for particular preservatives) (152,199,200,217). From these tests are established "threshold values" (the concentration of preservative necessary to inhibit all fungus growth) of various preservatives. Fungi that are particularly tolerant of certain preservatives serve for comparison (178,198). Comparative toxicities of various fractions of preservative solutions also are determined in this manner (128,167,174, 179).

A modification of the agar-plate technique, called the agar-block method, has been developed to test preservatives in the presence of wood (201,210). A small block of sapwood is treated carefully with a certain concentration of preservative and then placed in the center of an actively growing fungus culture. Value of the preservative in preventing infection is determined by observing change in weight of the block over a period of several weeks.

In the soil-block method, an active culture of test fungus is introduced to an untreated, nondurable block of sapwood that has been half-buried in special soil. When the culture is well-established in this block, a second block treated with test preservative is positioned on top of the first, and measurements of amount and rate of decay are taken at regular intervals. Duncan (155-164) used this method to obtain threshold values for both weathered and unweathered blocks treated with a wide variety of preservatives. The soil-block test has been studied, and methods devised for close control of conditions (47, 123, 164, 202, 209), and has been employed extensively in laboratory evaluations of preservatives (ASTM Standard D 1413) (130, 184, 207). A series of soil-block tests can be completed in about 6 months.

Cochrane (6) has detailed many of the refined techniques involved in laboratory examinations of fungus physiology and has commented on applicability of certain of these techniques and deficiencies in the methods for specific studies. He also has elaborated on the mechanisms of toxicity of various types of chemicals toward fungi.

Field tests. Field tests provide information on preservatives in a reasonable period of time under conditions approaching those encountered in outdoor use. Although laboratory tests are expedient and desirable for screening preservatives and determining certain properties, laboratory-proved preservatives are subjected to various additional natural factors when tested in the field (187).

After satisfactory performance in laboratory tests, the preservative usually is tested in the field with small treated stakes ("graveyard tests") half-buried in an upright position (201). After definite periods of exposure, the stakes are removed and carefully examined and evaluated for extent of damage from termites or fungi. These tests lend themselves to tests of large numbers of samples under varying conditions in a comparatively small space (140, 142). Observations may be made frequently on replicate samples for rapid evaluation (218) in a single year, or they may be extended over several years (194). Modifications of the test have been devised to prevent tops of the stakes from drying and to allow for easier study and return to the exposure plot, as well as acceleration of the test (181).

By the time a preservative has proved successful in laboratory and stake tests, it usually is accepted for limited application in service. Tests of preservatives do not stop here, however, but continue with tests on larger wood products such as fence posts (138, 139, 169, 374), or pole-size samples (185). These tests are conducted in uniformly spaced field plots to facilitate frequent observations (201). Methods of evaluation and analysis of results have been devised (211).

Service tests and records. Further evaluation of preservatives under conditions of actual use can be accomplished by complete and frequent inspections of test structures in service (309, 312) and by analyses of service records maintained on treated poles (182, 212). Reports of the

Utilization and Service Records Committee published in the annual Proceedings, American Wood-Preservers' Association, represent one attempt to develop service data.

DETECTION OF WOOD DECAY

Cartwright and Findlay (5) described in detail procedures to be followed for detection of decay in wood; they relied largely on cultural techniques to determine extent of decay. Hartley (231) reviewed literature on laboratory techniques for determination of decay and attempted to evaluate techniques that might be followed. Partch (244) described and commented on equipment that might be used to detect defects in wood.

Laboratory examination

Careful examination in laboratory of wood suspected to contain decay is seldom dependent upon a single test. Evaluation of the nature, degree, and extent of decay commonly depends on interpretation of macroscopic and microscopic evidences of decay, together with various physical and chemical tests (121).

Wood in process of decay changes in character as decay progresses. Depending on species of wood and species of fungus involved, the wood may change in color, odor, texture, resonance, and strength (3,5,97,121). Few, if any, of these characteristics will be evident in early (incipient) stages of decay. Presence of sporophores (fruiting bodies), mycelial fans, or crumbly pockets of wood are indications that the fungus has reached advanced development (5). Some fungi cause noticeable changes in color, commonly red, purple, brown, mottled white, or dark narrow bands called zone lines during incipient stages of decay (97,121). When present, these discolorations are of considerable value in diagnosing limits of infection, but many fungi cause only imperceptible changes in appearance of the wood during early stages of decay. Other agencies such as heat or chemicals may cause discolorations similar to those caused by incipient decay (121).

Thin sections of wood suspected to contain decay can be examined microscopically for presence of hyphae with clamp connections typical of most wood-destroying fungi (121). Several histological stains have been developed to aid in distinguishing fungal strands from surrounding woody tissue (222,225,251). Other microscopic evidences of fungal activity such as bore holes, shrinkage cracks, thinning of cell walls, and enlargement of pit openings (5,83,121), are valuable in establishing extent of decay and may be useful in determining the type of fungus involved

(83). Special techniques such as X-ray contact microradiography (133) and use of the polarizing microscope (308) and the electron microscope (83) have been of value to investigations of fungal infection. Microscopic examination has supplemented other investigations of fungi, as in following anatomical changes in decaying wood for correlation with strength tests (255).

Cultural examination (growth of fungi on artificial media), which is one of the oldest and most positive methods for detecting presence and extent of fungal activity, has been described in detail by Cartwright and Findlay (5). It is the only positive method for identification of fungus species when fruiting bodies are lacking (87, 105). Gallic and tannic acid media for growing fungi have been used to help distinguish white rots from brown rots (84). Diagnostic value of the odors of cultures of wood-destroying fungi has been verified (220). Cultures have been used to determine physiological characteristics of specific fungi, such as optimum temperature (103), moisture requirements (116), and pH limits (119). Stock cultures of common wood-destroying fungi are maintained as a continuing source of material for inoculation of wood blocks to observe effects of certain fungus species on a particular species of wood (90, 96, 110), or for inoculation of new cultures to study toxicity of preservatives (152, 199, 200, 217).

Chemical examinations of decayed wood have indicated many differences between sound and decayed wood (223, 252) and have indicated differences in chemical action of wood-destroying fungi (83). Increased alkaline solubility has been taken as indication of decay (79, 368) and methods have been devised to improve simplicity and rapidity of the determination (227). Osmium tetroxide has been found useful as a color test in detecting presence of brown rot in some wood species (224). Alizarine Red S has proved a useful color test for early decay in storage of southern pine (236). Difference in heat of reaction upon addition of alkali has been proposed as a method of distinguishing wood species (382); heat of reaction for a particular wood species may be influenced by the presence of decay. Other chemical reagents used to differentiate between wood species (398) may be affected by presence of decay fungi. Calorific value of hardwood has been shown to decrease with decay (232).

Effects of decay on strength of wood offer another means of detecting decay. Much research has been devoted to determining relationships between change in strength properties and loss in weight caused by decay organisms (233, 235, 241). Specific tests of strength, such as static bending (238, 248), impact bending (252, 358), toughness (247, 255, 360), resistance to compression (219), and nail-holding power (228) have been studied. Most tests have been conducted on small samples exposed to cultures of known fungi, but tests also have been conducted on wood decayed under service conditions (313). The criterion for amount of decay usually has been loss in weight. These tests show, however, that appreciable loss of strength can occur before loss in weight becomes perceptible.

A refined method of testing degree of decay of wood in culture by static bending below proportional limit has been developed by Mateus (238); the test is more sensitive than loss of weight and allows progress of decay to be followed. Tests of toughness indicate only minor differences in effects of white and brown rots on wood (247), but impact—bending tests indicate marked differences in effect on wood of the 2 types of wood-destroying fungi (252). These and other physical tests may indicate simplified methods for determining degree and type of decay in wood in service.

Field methods

In general, laboratory methods for detection of decay are complex, time-consuming, and require exact conditions and careful observation. This is not to say that some laboratory techniques described could not be applied to field detection or could not be used in examination of samples taken in the field. Nor does it mean that field methods need not be exact in requirements; to the contrary, field tests for detection of decay are more difficult to devise in many ways than laboratory tests, in that they must be simple to apply, accurate in appraisal, and, most difficult of all, rapid in evaluation.

Common methods of detecting presence of decay in poles are described in the section on Inspection of Poles in Service. Methods of field detection of decay described below are limited to applications not now common and, in most instances, still in exploratory stages of development.

Differences in moisture-holding capacities of sound and decayed wood may be useful in detecting decay (83). A standard resistance-type moisture meter, although quantitatively inaccurate above fiber-saturation point, can detect high, intermediate, or low moisture content and has been suggested as a method of determining whether or not wood is subject to decay (240). Difference between readings of resistance-type and dielectric-constant moisture meters (371,401) also has been used as a test for decay (246).

Ultrasonic energy has been used extensively in recent years for detection of internal character of metals (325,333,372) and concrete (399). Some experimentation on application of ultrasonic equipment for measurement of properties (234,389) and flaws in wooden structures has been conducted (253,254,370). Morris (239) has compiled an extensive list of references on applications of ultrasonics for wood industries.

Since density of wood usually varies inversely with degree of decay, density-measuring devices can be used to detect decay when sufficient differences in density have taken place. Beta-rays have been used to determine variation of springwood and summerwood density of increment cores (221, 245, 249). Gamma-radiation has been investigated as a means of detecting defects in logs and trees (229); good results have been reported by measuring both changes in amount of transmitted radiation (242, 243) and amount of radiation reflected using a backscatter technique (237).

Still another form of radiation, X-rays (381), appears to hold promise in detection of decay. Radiographs have been used successfully to locate and determine extent of shipworm galleries in wood exposed in marine waters (342, 373) and may be useful in locating galleries of termites or carpenter ants often associated with decay. Radiography has been applied to location of decay in standing trees (226) and with some success to pole-size sections containing decay pockets (230). X-ray equipment for in-service inspection has been employed by one company for several years (275). X-rays apparently are of little significance in killing insects that may inhabit wood (387) and probably are ineffective in halting fungal growth.

Problems in field detection of decay center on accurate means of diagnosis of field data and methods for detection of incipient stages of decay rather than on lack of detection equipment.

INSPECTION OF POLES IN SERVICE

Need for standard procedures for inspection of poles in line was recognized by the American Wood-Preservers' Association in 1939 (263); recommendations for standard inspection procedures were submitted to the Association in 1940 (264). Importance of preventing checking of poles in service was recognized as early as 1931 when an AWPA Committee recommended an investigation of "development and effect of checks and cracks in poles and timbers during seasoning, treatment and afterwards" (258). Since that time, others have emphasized need for adequate and scientifically founded inspections in maintenance (23,257). Recent inspections have indicated that checks in poles occurring after treatment are a prime factor leading to premature failure of poles (33, 259). During the past few years, problems of pole inspection and maintenance have been pointed out and discussed at various pole conferences throughout the United States (25,26,27,35).

Many standard procedures have been recommended or developed by individual organizations for inspecting poles in line (256,262,265, 266,267,268,271,272,274); most provide for supplemental preservative treatment at time of inspection (261,283,310). Smith (273) made recommendations and outlined costs for contracts to inspect and treat.

<u>Initial and subsequent inspections</u>

Initial inspections may be scheduled as early as 8 years or as long as 24 years after installation of poles, depending on species of wood, type of preservative treatment, and service conditions. The initial inspection usually consists of spot checks of 5-10 per cent of poles in arithmetical progression (266, 268,272,274). Random-sampling methods have been developed to obtain a reliable index of conditions of poles in a system (268,269). However, a 100 per cent inspection has been recommended when initial inspection occurs 12 years, or longer, after installation (272).

Timing of subsequent inspections may depend on judgment of the inspector or on conditions found in the initial inspection. A pole-by-pole inspection as soon as practical after initial spot check has been suggested when 5 per cent or more of the poles are found to contain decay (268,272), or when 1 per cent of the poles contain advanced decay (272). Subsequent inspections can be scheduled in 3-5 years, if less than 5 per cent of the poles contain minor decay (272).

<u>Inspection procedures</u>

Most inspection procedures are patterned after those proposed by the American Wood-Preservers' Association (264), which are reproduced in the Appendix. Procedures followed by individual companies will depend on such factors as service conditions, species and size of pole, type of initial preservative treatment, time lapse between installation and inspection or between inspections, and experience and training of personnel. Procedures usually recommend inspection of the top, then of the portion immediately above ground, and finally the portion below ground.

Some procedures call for an accurate inspection of the aerial portion of each pole by climbing, if necessary (262,266,270), while others specifically forbid climbing for reasons of safety (272).

Poles usually are sounded with a hammer from ground level to as high as the inspector can reach to detect internal pockets of decay. An increment borer or drill may be used to determine location and extent of the pocket. Increment borings have been taken at ground level in the vicinity of checks, particularly checks with exposed untreated wood, to detect decay in the ground-line area.

The below-ground portion of poles may be inspected by tapping the pole with a dull prod to detect external decay, or all poles may be excavated to a depth of 14 inches or more for visual examination. Where internal decay may be indicated by sounding or visual evidence, size and location of the pocket is determined by increment borings or with a drill with a long bit.

Defect in any area of the pole sufficient to call for replacement of the pole usually obviates further inspection.

Frequently, procedures for inspection require that a preservative treatment be applied to the excavated portion of poles before backfilling (261,268,270,272,276); others make no mention of treatment at time of inspection (256,262,266). Although some procedures are detailed, all depend largely upon experience and judgment of the inspector for an estimate of the condition of poles.

Residual strength of poles

Allowances are made for decay found during inspection by reducing the safe loads that poles will carry. Deductions for surface decay usually are made by measuring the effective circumference of the pole at the ground line by excluding the decayed area (261,265,270). Where internal decay is detected, deductions commonly are related to reductions in effective circumference by means of charts, tables, and rules-of-thumb (262,266,268,271,276).

Since reductions are based on visual examination of the surface of poles and of borings from poles, detection of decay is of primary importance to reliability of estimates of residual strength. Few procedures attempt to define decayed wood. One procedure (272) states:

"Decay will be evidenced by crumbly wood in part of the core." Another (262) cautions: "When the wood shows only discoloration or partial decay beyond the area of complete rot, do not remove any more wood. By partial decay is meant a change in the composition of the wood which reduces somewhat the strength of fibers but still provides a substantial portion of the original strength." Simeone (391) noted, "A serious problem arises, however, in the evaluation of a 'sound' shell." From his examination of a pole that failed unexpectedly, having a "sound" shell of 4.5 inches around a carpenter ant nest with a diameter of 3.5 inches, he concluded, "even when decay is not visible to the naked eye, the weakening that occurs with the initial phases of decay is likely to be present when carpenter ants attack."

Precautions to avoid infection of sound poles

Nearly all procedures emphasize the following precautions to avoid infection of poles that are soundat time of inspection:

- Avoid use of sharp instruments for sounding and prodding.
- Avoid unnecessary removal of sound wood.
- Plug holes with decay-resistant or treated wood dowels.

Graham (259) recommended as an added precaution that holes made during inspection be flooded with preservative prior to plugging with treated dowels.

Supplemental inspection methods

A semi-automatic, semi-portable, X-ray device was used after 1940 with good results to inspect butt-treated western red cedar and untreated northern white cedar poles (275). Radiographs obtained provide a permanent record and can be used to study rates of deterioration of poles. Recently, portable X-ray equipment weighing 85 pounds, or less, has been developed by Field Emission Corporation, McMinnville, Oregon. This equipment, which has a 3-pound emitting source on a cable up to 100 feet in length, can be used to X-ray wood or metal on any part of the pole.

Portable ultrasonic equipment, such as that manufactured by Branson Instruments Inc., Stamford, Conn., also may find application in rapid detection of defects in wood. Radiation devices of the gamma- and beta-ray type may prove useful in detecting variation in density of wood such as occurs in advanced stages of decay (221,237,242,245).

TREATMENTS FOR POLES IN SERVICE

Treatments for poles in service are intended either to halt existing deterioration, or to prevent infection where untreated wood is exposed or where original treatment is no longer sufficient to provide protection. Factors involved in supplemental treatment of poles are discussed by Amadon (256) and Hatfield (265). Cost of inspection and supplemental treatment extended over anticipated increase in service life of poles must be competitive with cost of replacement to be justified economically (9,273,282,285).

Treatments for above-ground portions of the pole

Above-ground portions of a pole may become subject to infection at points where moisture may accumulate, such as tops and points of hardware attachment, or in sapwood of untreated poles (shell-rot). Cut-offs and holes drilled in treated poles during or after installation should be protected with suitable preservative (AWPA Standard M4). Pockets of decay in tops of poles have been drilled out and filled with preservative (315) and pole caps containing preservative (376) have been developed to prevent or control decay. Shell-rot in untreated cedar poles led to development of spray treatments for surface decay (347, 355) and attempts to evaluate effectiveness of these treatments (341). Application of grease-type preservatives under pressure to checks and cracks has been used in an attempt to protect these vulnerable points of infection (301).

Ground-line treatments for poles

The ground-line area of a pole, the section between 2 or 3 feet above and below ground level, is the area of the pole most subject to attack by wood-deteriorating agencies. Sufficient water for fungal growth is available from the ground without exclusion of oxygen. Since preservative may be leached from the pole into the surrounding soil, additional protection often may be necessary for this area of the pole.

Andrews and Leach (278) compiled 46 references, including 17 patents, on supplemental ground-line treatments for poles in service. Some methods of supplemental treatment have been practiced for many years (295). Initially, these treatments were developed for untreated cedar poles, but in recent years have been applied as booster treatments to poles treated prior to installation. One of the earliest methods adopted was charring with an oxy-acetylene torch, followed by flooding the surface with creosote (293,298). Others involved sterilizing the pole surface and surrounding ground by forming a funnel-shaped reservoir around the base of the pole; providing a barrier with galvanized metal (286,305), concrete (281), or simply by compacting the soil (299); filling the depression with adsorbent material such as sand(286,299,305) or peat moss (278); and filling the reservoir with creosote (281,286,299), creosote mixed with water-soluble preservative salts (277,305), or salts such as arsenic (304) with preservative value. Before 1948, controlled tests had been conducted to determine effectiveness of such treatments (287,306,307) and indicated good results, but were largely confined to tests on poles that had no initial treatment.

Supplemental treatments by injection of water-soluble preservative mixtures into the pole with needle devices (300,329), or by application of a paste-like preservative mixture to the pole surface and relying on "osmotic" pressure differences for diffusion of salts into the pole (283) have been in use for a number of years. Other preservative mixtures in paste or grease form (280,292,310,378) have been developed for direct application to the pole surface. Most treatments require removal of obviously decayed wood. In some instances, preservative is held against the pole by an impervious wrapper (352). Proprietary supplemental preservative treatments are available from a number of chemical companies (261,276,284,289,329).

With exception of injection methods, supplemental treatments are applied to the surface of the pole and depend on migration of toxic chemical into the pole for protection. Tests indicate that ground-line treatments provide sufficient toxic material in the pole to protect from decay in the outer inch or less (the sapwood area usually treated in the original treatment) (296,302), but not beyond. Conclusions are that existing ground-line treatments are of some value in replacing preservative lost from the outer circumference of the pole, or in providing protection for poles having no initial treatment or insufficient treatment, but are of little or no value in halting or preventing internal decay (279, 297). Research on treatment of poles with internal decay and on evaluation of these treatments is notably lacking.

Other treatments

Some thought has been given to methods of sterilizing poles by means other than preservatives. Heat treatments have been suggested, and experiments indicate that temperatures near 150 F are lethal to most fungi (82,104). Logs for production of veneer have been heated electrically to temperatures over 200 F (338). Coatings for poles have been suggested, but little practical experimentation has resulted (367). Methods of chemically modifying wood to prevent swelling and shrinking, or increasing resistance to decay have been investigated in laboratory (339). Inducing chemical changes by radiation apparently holds little promise (351).

CONCLUSIONS

Wood is particularly well-suited for use as utility poles because of its natural shape, flexibility of use, high strength-to-weight ratio, and non-conductive properties, but it has the disadvantage that it is subject to attack by wood-destroying organisms.

Much is known about fungi in general, but information is needed on particular species involved and the nature of decay of poles in service.

Detection of decay in advanced stages is not difficult, but methods of detecting decay during early stages of development are needed if methods of saving poles that have started to decay are to be effective.

Trained personnel and improved methods for inspecting the interior of poles are needed to improve the system of inspection of poles in service.

Present methods of in-service treatment of poles are fairly effective in preventing decay of the outer surface of poles both above and below ground, but appear to be far from satisfactory for treatment of internal decay. Methods of applying preservatives to poles in service that will result in improved penetration, retention, distribution, and permanence of toxic chemicals are needed.

Application of newly discovered and improved techniques and equipment in other fields may contribute to solution of problems in inspection and maintenance of poles.

Preservative treatments have increased greatly the service life of wood poles, but further improvements are required to meet stringent demands of the future.

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General

1. Boyce, J. S. Forest Pathology, third ed. McGraw-Hill Book Co., Inc., New York, Toronto, London. 572 p. 1961.

2. Broese van Groenou, H., H.W.L. Rischen, and J. van den Berge. Wood Preservation During the Last 50 Years. A.W. Sijthoff's Uitgevermaatschappij N.V., Leiden, Holland. 318 p. 1951.

3. Brown, H.P., A.J. Panshin, and C.C. Forsaith. Textbook of Wood Technology, 1st ed., vols. I & II. McGraw-Hill Book Co., Inc., New York, Toronto, London. 652 p. and 783 p. 1949, 1952.

4. Canadian Woods: Their Properties and Uses. Forestry Branch, Forest Products Laboratories Division, Ministry of Resources and Development. Edmond Clouthier, King's Printer and Controller of Stationery, Ottawa, Canada. 367 p. 1951.

5. Cartwright, K.St.G., and W.P.K. Findlay. Decay of Timber and its Prevention. Chemical Publishing Co., Inc., Brooklyn, New York. 294 p. 1950.

6. Cochrane, V.W. Physiology of Fungi. John Wiley & Sons, Inc., New York; Chapman and Hall, Limited, London. 524 p. 1958.

7. Comparative Decay Resistance of Heartwood of Different Native Species Under Conditions that Favor Decay. For. Prod. Lab., U. S. Dept. of Agri., Tech. Note 229, Madison, Wisc. n.d.

8. Davidson, R.W. "The Cause and Prevention of Deterioration in Wood." Proceedings, Wood Pole Institute, Colorado State Univ., Fort Collins, Colorado. June, 1960.

9. Doolittle, F.B. "Evaluation of Service Life Justifies More Durable Poles." Proceedings, Amer. Wood-Pres. Assn., 50, pp 224-231. 1954.

10. Eades, H.W. British Columbia Softwoods: Their Decays and Natural Defects. Dept. of Interior, Forest Service, Bull. No. 80, Canada. 1932.

11. Ericksen, W.S. The Distribution of Stress in a Wood Pole Bent by Radial End Load. For. Prod. Lab., U. S. Dept. of Agri., Rpt. No. R1933, Madison, Wisc. 1953.

12. Findlay, W.P.K. "Timber Decay-A Survey of Recent Work." Forestry Abstracts, 17 (3 & 4), pp 312-327, 477-486. 1956.

13. Findlay, W.P.K. "Deterioration of Wood by Fungi and its Prevention by Chemical Treatments." Chem. & Indust., 22, pp 662-665. May 30, 1959.

14. Findlay, W.P.K., and J.G. Savory. Dry Rot in Wood. Dept. of Scientific and Industrial Research, Bull. No. 1, London. 1960.

15. Glennie, D.W., and H. Schwartz. Review of the Literature on Decay in Pulpwood, Its Measurement and Its Effect on Wood Properties and Pulp Quality. Forest Products Laboratories, Dept. of Resources and Development, Mimeo. 0-153, Ottawa, Canada. Mar. 1950.

16. Hatfield, I. "Wood Destroying Organisms--III. Application of Knowledge and Skill to Control Problems." Pest Control, 26(6), p 36. 1958.

17. Hunt, G.M., and G.A. Garratt. Wood Preservation, 2nd ed. McGraw-Hill Book Co., Inc., New York, Toronto, London. 417 p. 1953.

18. Kozlik, C.J. Bibliography of Wood-Moisture Relationships. For. Res. Lab., Ore. State Univ., Corvallis, Oregon. April, 1960.

19. Leutritz, J., Jr. "The Destruction of Wood by Fungi and its Prevention--Wood Preservation." N. Y. Acad. Sci., Trans., (ser.2) 13, pp 177-181. Mar. 1951.

20. Lindgren, R.M. An Overall Look at Wood Deterioration. For. Prod. Lab., U. S. Dept. of Agri., Rpt. No. 1966, Madison, Wisc. 1953.

21. List of Publications on Thermal Properties of Wood. For. Prod. Lab., U. S. Dept. of Agri., Rpt. No. 2222, Madison, Wisc. 1961.

22. List of Publications on Wood Preservation. For. Prod. Lab., U. S. Dept. of Agri., Rpt. No. 704, Madison, Wisc. 1960.

23. Opsal, P.M., and H.E. Troxell. "Facts Developed by Experts are Prime Need in Pole Maintenance". Electrical World, 155, (15), pp 44-46. Apr. 10, 1961.

24. "Preservatives and Methods of Application." Wood (London), 21(6), pp 236-238. June 1956.

25. Proceedings, Eastern Wood Pole Conference. State Univ. Col. of Forestry, Syracuse Univ., Syracuse, New York. Sept. 1961.

26. Proceedings, Southeastern Wood Pole Conference. Univ. of Florida, Gainesville, Florida. Aug. 23-25, 1960.

27. Proceedings. Wood Pole Institute. Colorado State Univ., Fort Collins, Colorado. June 15-17, 1960.

28. Protection Against Wood-Destroying Organisms. For. Prod. Lab., U. S. Dept. of Agri., Rpt. No. R1903-13, Madison, Wisc. 1952.

29. Rixse, J.H. "Where Do We Go From Here?" Proceedings, Eastern Wood Pole Conference, State Univ. Col. of Forestry, Syracuse Univ., Syracuse, New York, pp 105-108. Sept. 1961.

30. Verrall, A.F. "How to Prevent Fungus Damage to Wood Structures." For. Prod. Jour., 7(1), pp 15A-17A. Jan. 1957.

31. Weathering and Decay. For. Prod. Lab., U. S. Dept. of Agri., Tech. Note 221 rev., Madison, Wisc. April, 1956.

32. Wise, L.E., and E.C. Jahn. Wood Chemistry, 2nd ed., vol. 2. Reinhold Publishing Corp., New York (Amer. Chem. Soc. Monograph Series). 1952.

33. Womack, R.J., and R.D. Graham. Survey of Pressure-Treated Douglas-fir Poles in Service West of the Coast Range. Progress Report 3, Project 26C-13, For. Res. Lab., Ore. State Univ., Corvallis, Oregon. Dec., 1960. (unpublished).

34. Wood Handbook. For. Prod. Lab., U. S. Dept. of Agri., Agricultural Handbook No. 72. 1955.

35. Wood Pole Conference. School of Forestry, Ore. State Univ., For. Res. Lab., Corvallis; Gen. Ext. Div. , Ore. State System of Higher Ed. 1960.

Properties of Wood Related to Decay and Its Prevention

36. Bailey, I.W. "The Preservative Treatment of Wood--I. The Validity of Certain Theories Concerning the Penetration of Gases and Preservative into Wood." Forestry Quarterly, 11. 1913.

37. Barton, G.M., and J.A.F. Gardner. "The Chemical Nature of The Acetone Extractive of Western Red Cedar." Pulp and Paper Magazine of Canada, 55 (10), pp 132-137. 1954.

38. Blew, J.O. The Control of Checking After Treatment in Poles with Thin Sapwood. For. Prod. Lab., U. S. Dept. of Agri., Rpt. No. WP-51, Madison, Wisc. n.d.

39. Cartwright, K.St.G. "The Variability in Resistance to Decay of the Heartwood of Home-Grown Western Redcedar (Thuja plicata) and its Relation to Position in the Log." Forestry, 15, pp 65-75. 1941.

40. Core, H.A., and W.A. Cote. "The Structure of Wood As Applied to the Pole Species." Proceedings, Eastern Wood Pole Conference, State Univ. Col. of Forestry, Syracuse Univ., Syracuse, New York, pp 6-14. Sept. 1961.

41. Desch, H.E. "Moisture in Wood." Wood (London), 13(12), pp 347-348. 1948.

42. DeZeeuw, C.H. "Some Physical Considerations of Wood Poles." Proceedings, Eastern Wood Pole Conference, State Univ. Col. of Forestry, Syracuse Univ., Syracuse, New York, pp 112-123. Sept. 1961.

43. Diller, J.D., and E.J. Koch. "Further Results on the Relative Durability of 40 Wood Species to House Decay Fungi." Phytopathology, 46, p 467, abstr. Aug. 1956.

44. Eases, H.W., and J.B. Alexander. Western Redcedar: Significance of its Heartwood Colorations. Dept. of Interior, Forest Service Circ. 41, Canada. 1934.

45. Englerth, G.H., and T.C. Scheffer. "Tests of Decay Resistance of Four Western Pole Species." Jour. of Forestry, 53(3), pp 556-561. Mar. 1955.

46. Erickson, H.D. "Tangential Shrinkage of Serial Sections Within Annual Rings of Douglas Fir and Western Red Cedar." For. Prod. Jour., 5(4), pp 241-250. Aug. 1955.

47. Etheridge, D.E. " A Method for the Study of Decay Resistance in Wood Under Controlled Moisture Conditions." Canadian Jour. of Botany, 35(5), pp 615-618. Sept. 1957.

48. The Fiber Saturation Point of Wood. For. Prod. Lab., U. S. Dept. of Agri., Tech. Note No. 252, Madison, Wisc. 1944.

49. Findlay, W.P.K., and C.B. Pettifor. "Dark Coloration in Western Red Cedar in Relation to Certain Mechanical Properties." Empire Forestry Jour., 20, pp 64-72. 1941.

50. Hale, J.D. "The Anatomical Basis of Dimensional Changes of Wood in Response to Changes in Moisture Content." For. Prod. Jour., 7(4), pp 140-144. April 1957.

51. Hatfield, I. "Wood Destroying Organisms--I. Composition and Structure of Wood." Pest Control., 26(2), p 26. 1958.

52. Lewis, H.F. "The Significant Chemical Components of Western Hemlock, Douglas Fir, Western Red Cedar, Loblolly Pine, and Black Spruce." Tappi, 33, pp 299-301. 1950.

53. Loughborough, W.K. Chemical Seasoning: Its Effectiveness and Present Status. For. Prod. Lab., U. S. Dept. of Agri., Rpt. No. D1721, Madison, Wisc. Aug. 1948.

54. MacLean, H., and J.A. F. Gardner. "Distribution of Fungicidal Extractives (Thujaplicin and water-soluble phenols) in Western Redcedar Heartwood." For. Prod. Jour., 6(12), pp 510-516. 1956.

55. MacLean, H., and J.A. F. Gardner. "Distribution of Fungicidal Extractives in Target Pattern Heartwood of Western Redcedar." For. Prod. Jour. 8(3), pp 107-108. 1958.

56. MacLean, J.D. "Seasoning and Checking of Timbers Before and After Treatment." Proceedings, Amer. Wood-Pres. Assn., 52, pp 35-48. 1956.

57. MacLean, J.D. "Thermal Conductivity of Wood." ASHVE Jour. reprint. 1956.

58. Mitchell, R.L., R.M. Seborg, and M.A. Millet. "Effect of Heat on the Properties and Chemical Composition of Douglas Fir and its Major Components." Jour. For. Prod. Res. Soc., 3(4), pp 38-42. Nov. 1953.

59. Nayer. Swelling of Wood in Various Organic Solvents. Univ. of Minnesota, Minneapolis, Minnesota. 1948.

60. Preston, R.D. "The Fine Structure of Wood with Special Reference to Timber Impregnation." Rec. Annual Conv., Brit. Wood Pres. Assn., pp 31-72. 1959.

61. Rennerfelt, E. "Investigations of Thujaplicin, a Fungicidal

Sub$tance in the Heartwood of Thuja plicata." Physiol. Plant., Copenhagen, pp 245-254. 1948.

62. Rennerfelt, E., and G. Nacht. "The Fungicidal Activity of Some Constituents of Heartwood of Conifers." Svensk bot. Tidskr., 49, pp 419-432. 1955.

63. Richards, D.B. "Decay Resistance and Physical Properties of Wood." Jour. of Forestry, 48(9), pp 420-422. 1950.

64. Roff, J.W., and J.M. Atkinson. "Toxicity Tests of a Water-soluble Phenolic Fraction (thujaplicin-free) of Western Redcedar." Canadian Jour. of Botany, 32, pp 308-309. 1954.

65. Scheffer, T.C. "Decay Resistance of Western Redcedar." Jour. of Forestry, 55(6), pp 434-442. June 1957.

66. Scheffer, T.C., and G.H. Englerth. "Decay Resistance of Second-growth Douglas-fir." Jour. of Forestry, 50, pp 439-442. 1952.

67. Schmitz, H. Studies in Wood Decay--I. Laboratory Tests on the Relative Durability of Some Western Coniferous Woods with Particular Reference to Those Growing in Idaho. Univ. of Idaho, School of Forestry, Bull. No. 1, Moscow, Idaho. 1921.

68. Southam, C.M., and U. Ehrlich. "Decay Resistance and Physical Characteristics of Wood." Jour. of Forestry, 41, pp 666-673. 1943.

69. Southam, C.M., and J. Ehrlich. "Effects of Extracts of Western Redcedar Heartwood on Certain Wood-Decaying Fungi in Culture." Phytopathology, 33, pp 517-524. 1943.

70. Stamm, A.J. Passage of Liquids, Vapors, and Dissolved Materials Through Soft Woods. U. S. Dept. of Agr. Tech. Bull. 929. 1946.

71. Wardrop, A.B., and G.W. Davies. "Morphological Factors Relating to Penetration of Liquids into Wood." Holzforschung, p. 129. Nov. 1961.

Wood-Destroying Fungi

72. Birkinshaw, J.H., W.P.K. Findlay, and R.A. Webb. "Biochemistry of the Wood-Rotting Fungi--II. A Study of the Acids Produced by Coniophora cerebella." Biochem. Jour., 34, pp 906-916. 1940.

73. Boocock, D. "Insect and Fungal Enemies of Timber--II. The

Development, Spread and Classification of Fungi." Timber Technology, 68(2250), pp 153-155. April 1960.

74. Boswell, J.G. "The Biochemistry of Dry-rot in Wood--III. An Investigation of the Decay of Pine wood Rotted by Merulius lacrymans." Biochem. Jour., 32(1), pp 218-229. 1938.

75. Buckland, D.C. "Investigation of Decay in Western Redcedar in British Columbia." Canadian Jour. Res. C, 24(5), pp 158-181. 1946.

76. Buro, A. "The Effect of Heat-Treatment on the Fungus Resistance of Pine and Beech." Chemical Abstracts, 49(2), p 1327. Jan. 25, 1955.

77. Campbell, W.G. "The Biological Decomposition of Wood." in Wise, L.E., and Jahn, E.C. Wood Chemistry, vol 2, pp 1061-1116, Reinhold, N. Y. 1952.

78. Campbell, W.G. "The Chemistry of the White Rots of Wood--I. The Effect of Wood Substance of Polystictus versicolor." Biochem. Jour., 24(4), pp 1235-1243. 1930.

79. Campbell, W.G. "The Chemistry of the White Rots of Wood--III. The Effect on Wood Substance of Ganoderma applanatum, Fomes fomentarius, Polyporus adjustus, Pleurotus ostreatus, Armillaria mellea, Trametes pini, and Polystictus abietinus." Biochem. Jour., 26, pp 1829-1838. 1932.

80. Campbell, W.G., and G. Booth. "Effect of Partial Decay on the Alkali Solubility of Wood." Biochem. Jour., 23, pp 566-572. 1929.

81. Cartwright, K.St.G., and W.P.K. Findlay. "Studies in the Physiology of Wood-Destroying Fungi--II. Temperature and Rate of Growth." Annals. of Botany (London), 48, pp 481-495. 1934.

82. Chidester, Mae Spradling. Further Studies on Temperatures Necessary to Kill Fungi in Wood. U. S. Dept. of Agri., Washington, D. C. 1939.

83. Cowling, E.B. Comparative Biochemistry of the Decay of Sweetgum Sapwood by White-Rot and Brown-Rot Fungi. U.S. Dept. of Agri., Forest Service, Tech. Bull. No. 1258. Dec. 1961.

84. Davidson, R.W., W.A. Campbell, and D. J. Blaisdell. "Differentiation of Wood-Decaying Fungi by Their Reactions on Gallic or Tannic Acid Medium." Jour. of Agri. Res., 57(9), pp 683-695. 1938.

85. Diller, J.D., and E.J. Koch. The Effects of Environmental Conditions on the Growth of Merulius lacrymans. Northeastern Forest Expr. Sta., Station Paper No. 149, Upper Darby, Pa. 1960.

86. Factors That Influence the Decay of Untreated Wood in Service and Comparative Decay Resistance of Different Species. For. Prod. Lab., U. S. Dept. of Agri., Rpt. No. 68, rev., Madison, Wisc. Oct. 1958.

87. Findlay, W.P.K. "Decay of Timber by Fungi." Endeavor, 8(31), pp 112-119. 1949.

88. Findlay, W.P.K. "Physiology of Wood-destroying Fungi." Wood (London), 19(7), pp 297-298. July 1954.

89. Findlay, W.P.K. "Studies in the physiology of Wood-Destroying Fungi--I. The Effect of Nitrogen Content Upon the Rate of Decay of Timber." Annals of Botany (London), 48, pp 109-117. 1934.

90. Findlay, W.P.K. "Studies in the Physiology of Wood-destroying Fungi--III. Progress of Decay under Natural and Controlled Conditions." Annals of Botany (London), 4(16), pp 701-712. 1940.

91. Frejdin, A.S., and T.G. Krapivina. "Sterilizing Wood with the Aid of Ionizing Radiation." Lesn. Z., Arhangels'sk, 3(2), pp 117-120. 1960. (RUSS.) from Forestry Abstracts, No. 3761. July 1961.

92. Fritz, C.W. "Decay and Stains in Wood." in Canadian Woods; Their Properties and Uses, pp 161-180, Forestry Branch, Forest Products Laboratories Division, Ministry of Resources and Development, Edmond Clouthier, King's Printer and Controller of Stationery, Ottawa, Canada. 1951.

93. Gadd, O. "Wood Decay Resulting from Rot Fungi." Paperi ja Puu--Papper och Trä, 39(8), pp 363-74. Aug. 1957.

94. Haasis, F.W. "A Study of Laboratory Methods for Investigating the Relation Between Moisture Content of Wood and Fungal Growth." Phytopathology, 22(1), pp 71-84, reprint. Jan. 1932.

95. Hatfield, I. "Wood Destroying Organisms--II. Diagnosing Causes of Wood Deterioration." Pest Control, 26(4), p 50. 1958.

96. Hawley, L.F., L.C. Fleck, and C.A. Richards. "Effect of Decay on the Chemical Composition of Wood." Indust. & Engin. Chem., 20, pp 504-512. 1928.

97. Hubert, E.E. "The Diagnosis of Decay in Wood." Jour. of Agri. Res., 29, pp 523-567. 1924.

98. Hubert, E.E. Effect of Kiln Drying, Steaming, and Air Seasoning on Certain Fungi in Wood. U. S. Dept. of Agr. Bull. 1262, pp 1-20. 1924.

99. Humphrey, C.J., and P.V. Siggers. "Temperature Relations of Wood-Destroying Fungi." Jour. of Agr. Res., 47, pp 997-1008. 1933.

100. Hungate, R.E. "Nitrogen Content of Sound and Decayed Coniferous Wood and its Relation to Loss in Weight During Decay." Botan. Gaz., 102, pp 382-392. 1940.

101. Kaufert, F.H., and E.A. Behr. "Susceptibility of Wood to Decay: Effect of Urea and Other Nitrogenous Compounds." Indust. & Engin. Chem., Ind. ed., 34, pp 1510-1515. 1942.

102. Kimmey, J.W., and R.L. Furniss. Deterioration of Fire-Killed Douglas-fir. U. S. Dept. of Agr. Tech. Bull. No. 851. Sept. 1943.

103. Lindgren, R.M. "Decay of Wood and Growth of Hymenomycetes as Affected by Temperature." Phytopathology, 23, pp 73-81. 1933.

104. Montgomery, H.B.S. "An Investigation of the Temperature Lethal to Some Wood-Decaying Fungi." Trans. Brit. Mycol. Soc., 20, pp 293-298. 1936.

105. Nobles, M.K. "Studies in Forest Pathology--VI. Identification of Cultures of Wood-rotting Fungi." Canadian Jour. Res., C, 26, pp 281-431. 1948.

106. Roth, E.R. "Effect of Invisible Decay on Deterioration of Untreated Oak Ties and Posts." Jour. of Forestry, 41, pp 117-121. 1943.

107. Scheffer, T.C. Physical and Chemical Changes Associated with Wood Decay. N.E. Wood Util. Council Bull. 45, pp 125-135. Apr. 1957.

108. Scheffer, T.C., and M.S. Chidester, "Survival of Decay and Blue-Stain Fungi in Air-Dry Wood." Southern Lumberman, 177, pp 110-112. Dec. 15, 1948.

109. Schmitz, H. "Studies in Wood Decay II--Enzyme Action in Polyporous volvatus and Fomes igniarius." Jour. of Gen. Physiology, 6, pp 795-800, reprint. 1921.

110. Schmitz, H., and F. Kaufert. "Studies in Wood Decay VII-- How Long Can Wood-Destroying Fungi Endure Immersion in Water?" Proceedings, Amer. Wood-Pres. Assn., 34, pp 83-87. 1938.

111. Schmitz, H., and F. Kaufert. "Studies in Wood Decay VIII--The Effect of the Addition of Dextrose and Dextrose and Asparagine on the Rate of Decay of Norway Pine Sapwood by Lenzites trabea and Lentinus lepideus." Amer. Jour. of Botany, 25 (6), pp 443-448, reprint. 1938.

112. Schmitz, H., and F. Kaufert. "The Effect of Certain Nitrogenous Compounds on the Rate of Decay of Wood." Amer. Jour. of Botany, 23(9), pp 635-638. 1936.

113. Shimazono, H. "Oxalic Acid Decarboxylase, a New Enzyme from the Mycelium of Wood-Destroying Fungi." Jour. Biochem., 42(3), pp 321-340. 1955.

114. Snell, W.H. "The Effect of Heat upon the Mycelium of Certain Structural-Timber-Destroying Fungi within Wood." Amer. Jour. of Botany, 10(8), pp 399-411. 1923.

115. Snell, W.H. "The Relation of the Moisture Contents of Wood to its Decay." Amer. Jour. of Botany, 16, pp 543-546. 1929.

116. Snell, W.H., N.O. Howard, and M.V. Lamb. "The Relation of Moisture Content of Wood to its Decay." Science, 62, pp 377-379. 1925.

117. Thomas, G.P., and R.W. Thomas. "Studies in Forest Pathology--XIV. Decay of Douglas fir in the Coastal Region of British Columbia." Canadian Jour. of Botany, 32, pp 630-653. 1954.

118. Whitaker, D.R., and P.E. George. "Studies in the Biochemistry of Cellulolytic Micro-organisms--II. Metabolic Products of Polyporus abietinus, Peniophora gigantea, and Hydnum septentrionale." Canadian Jour. of Botany, 29, pp 176-181. 1951.

119. Wolpert, F.S. "Studies in the Physiology of the Fungi--XVII. The Growth of Certain Wood-Destroying Fungi in Relation to the H-ion Concentration of the Media." Ann. Missouri Botanical Garden, 11, pp 43-97. 1924.

120. Zabel, R. Committee Report on Project to Determine Fungi Causing Wood Products Decay in the Northeast. N.E. Wood Util. Council, Bull. 45, pp 103-110. Apr., 1957.

121. Zabel, R.A. "Wood Deterioration." Proceedings, Eastern Wood Pole Conference, State University College of Forestry, Syracuse Univ., pp 124-136, Syracuse, New York. Sept., 1961.

122. Zeller, S.M. "Humidity in Relation to Moisture Imbibition by Wood and to Spore Germination on Wood." Ann. Missouri Botanical Garden, 7, pp 51-74. 1920.

Preservatives

123. Aplin, T.E.H., and E.W.B. DaCosta. The Effect of Jar Aeration on the Rate of Decay in Accelerated Decay Tests. Commonwealth Sci. & Ind. Res. Org., Div. of Forest Prod., Sub-Project P13-10, P.R.1, Forest Prod. Lab., South Melbourne, Australia. Mar. 1954.

124. Badcock, E.C. "New Methods for the Cultivation of Wood-Rotting Fungi." Trans., British Mycol. Soc., 25, pp 200-205. 1941.

125. Baechler, R.H. "Effects of Treating Variables on Absorption and Distribution of Chemicals in Pine Posts Treated by Double-diffusion." Jour. For. Prod. Res. Soc., 3(5), pp 170-176. Dec. 1953.

126. Baechler, R.H. Inspection of Preservative Treatment of Poles. For. Prod. Lab., U. S. Dept. of Agri., Rpt. No. 2206, Madison, Wisc. 1960.

127. Baechler, R.H. "Resistance to Leaching and Decay Protection of Various Precipitates Formed in Wood by Double Diffusion." Proceedings, Amer. Wood-Pres. Assn., 37, pp 23-31. 1941.

128. Baechler, R.H. "Toxicity of Various Fractions of Low-Temperature Coal-tar Creosote." Proceedings, Amer. Wood-Pres. Assn., 49, pp 12-17. 1953.

129. Baechler, R.H., and E. Bateman. " A Relation Between Chemical Constitution and Higher Toxicity." Proceedings, Amer. Wood-Pres. Assn., 32, pp 178-181. 1936.

130. Baechler, R.H., and H.G. Roth. Laboratory Leaching and Decay on Pine and Oak Blocks Treated with Several Preservative Salts. Amer. Wood-Pres.' Assn. reprint. 1936.

131. Balzer, I. "Wood Impregnation with Some Inorganic Salts." Chem. Abstracts, 49(1), p 555. Jan. 10, 1955.

132. Bavendamm, W., and W. Schneider. "Investigations on the Practical Application of the Brush and Trough Method by Using Bifluorides for the Impregnation of Timber." Holz Roh u. Werkstoff, 17(7), pp 284-291. 1959.

133. Belford, D.S. "The Impregnation of Timber by Water-borne Preservatives--II. X-Ray Contact Microradiography." Jour. Appl. Chem., 10(8), pp 345-347. Aug. 1960.

134. Belford, D.S., and C.D. Cook. "The Distribution of Salts in Timber Pressure Treated with a Water-borne Preservative." Wood (London), 24(10), pp 411-412. Oct. 1959.

135. Belford, D.S., and C.D. Cook. "Research on a Water-borne Preservative; an Investigation into the Distribution of Salts in Pressure Treated Timber Using an Electron Microscope." Wood (London), 25(8), pp 330-332. Aug. 1960.

136. Bellman, H. "Mutual Compatability of Wood Preservatives." Forestry Abstracts, 15(4), p 519. Oct., 1954. Schädlingsbedampfung, 45(1), Hamburg, pp 1-8. 1953.

137. Blew, J.O., Jr., J.A. Richards, and R.H. Baechler. "Evaluating Wood Preservatives." Proceedings, For. Prod. Res. Soc., pp 230-37. 1951.

138. Blew, J.O., and J.W. Kulp. Service Records on Treated and Untreated Fence Posts. For. Prod. Lab., U. S. Dept. of Agri., Rpt. No. 2005, rev., Madison, Wisc. 1959.

139. Blew, J.O., Jr., and J.W. Kulp. Comparisons of Wood Preservatives in Mississippi Post Study. For. Prod. Lab., U. S. Dept. of Agri., Rpt. No. 1757, Madison, Wisc., progress reports to 1961. Jan. 1961.

140. Blew, J.O., Jr. Comparison of Wood Preservatives in Stake Tests. For. Prod. Lab., U. S. Dept. of Agri., Rpt. No. 1761, Madison, Wisc., progress reports to 1961. Mar. 1961.

141. Bulman, R.A. "The Development and Use of Naphthenates for Timber Preservation." Rec. Annu. Conv., Brit. Wood Pres. Assn., pp 36-63. 1955.

142. Carr, D.R. Comparative Tests with Wood Preservatives. Forest Res. Inst., Tech. paper no. 4, New Zealand Forest Service, Wellington, New Zealand. Supplement no. 1. 1955.

143. Carr, D.R. "The Effectiveness of Boron as a Timber Preservative." Timber Technology, 67 (2242), pp 335, 337-38, 67 (2243), pp 371, 373-75. 1959.

144. Carter, E.P. "Preliminary Report on an Accelerated Soil Burial Test Method for Evaluating the Effectiveness of Proprietary Wood Preservatives Applied by Non-pressure Methods." For. Prod. Jour., 7(1), pp 27-31. Jan. 1957.

145. Chapman, A.D. "Effect of Steam Sterilization on Susceptibility of Wood to Blue-Staining and Wood-Destroying Fungi." Jour. of Agr. Res., 47, pp 369-374. 1933.

146. Cockcroft, R. "Movement of Creosote in Wood Caused by Drying of Volatile Solvents." Wood, (London), 22(8), pp 331-337. Aug. 1957.

147. Cockcroft, R. "A New Method for Detecting the Presence and Depth of Penetration of Boron in Treated Timber." Holzforschung, 14(4), pp 117-119. Oct. 1960.

148. Colley, R.H. "The Evaluation of Wood Preservatives--Interpretation and Correlation of the Results of Laboratory Soil-block Tests and Outdoor Test Plot Experience, with Special Reference to Oil-type Materials." Bell System Tech. Jour., 32, I., pp 120-169. Jan. 1953. II., pp 425-505. Mar. 1953.

149. Colley, R.H. "Evaluation of Wood Preservatives." Bell Telephone System Monograph, No. 2118. 1953.

150. Colley, R.H. "Correlating Evaluation Tests of Wood Preservatives." Jour. For. Prod. Res. Soc., 4(1), pp 43-51. 1954.

151. "Cooperative Creosote Tests." Proceedings, Amer. Wood-Pres. Assn., 46, pp 68-79. 1950.

152. Cowling, E.B. "The Relative Preservative Tolerances of 18 Wood-destroying Fungi." For. Prod. Jour., 7(10), pp 335-359. Oct. 1957.

153. Determining Penetration of Wood Preservatives. For. Prod. Lab., U. S. Dept. of Agri., Tech. Note No. 163, Madison, Wisc.

154. Dietrichs, H. H., and W. Sandermann. "Studies in the Field of Wood-Preserving Chemistry. Part VIII. Paper Chromatography and Analysis of Wood Preservatives." Holz als Roh u. Werkstoff, 16(9), pp 340-346. 1958. Transl. Commonw. Sci. Ind. Res. Organ., Aust. No. 4621. BNB/Aust/CSIRO Trans. No. 1170.

155. Duncan, C.G., and C.A. Richards. "Evaluating Wood Preservatives by Soil-block Tests: 1. Effect of Carrier on Pentachlorophenol Solutions. 2. Comparison of Coal-tar Creosote, a Petroleum Containing Pentachlorophenol or Copper Naphthenate and Mixtures of Them." Proceedings, Amer. Wood-Pres. Assn., 46, pp 131-151. 1950.

156. Duncan, C.G., and C.A. Richards. "Evaluating Wood Preservatives by Soil-block Tests: 3. The Effect of Mixing a Coal-tar

Creosote and a Pentachlorophenol Solution with a Petroleum; a Creosote with a Coke-oven Tar or Pentachlorophenol Solution." Proceedings, Amer. Wood-Pres. Assn., 47, pp 264-274. 1951.

157. Duncan, C.G., and C.A. Richards. "Evaluating Wood Preservatives by Soil-block Tests: 4. Creosotes." Proceedings, Amer. Wood-Pres. Assn., 47, pp 275-287. 1951.

158. Duncan, C.G. "Evaluating Wood Preservatives by Soil-block Tests: 5. Lignite-tar and Oil-tar Creosotes." Proceedings, Amer. Wood-Pres. Assn., 48, pp 99-104. 1952.

159. Duncan, C.G. "Evaluating Wood Preservatives by Soil-block Tests: 6. Exploratory Tests Toward Improving the Method." Proceedings, Amer. Wood-Pres. Assn., 49, pp 49-55. 1953.

160. Duncan, C.G. "Evaluating Wood Preservatives by Soil-block Tests: 7. Progress on the Development of a Laboratory Weathering Method." Proceedings, Amer. Wood-Pres. Assn., 50, pp 41-51. 1954.

161. Duncan, C.G. "Evaluating Wood Preservatives by Soil-block Tests: 8. Low-temperature Coal-tar Creosote." Proceedings, Amer. Wood-Pres. Assn., 51, pp 11-15. 1955.

162. Duncan, C.G. "Evaluating Wood Preservatives by Soil-block Tests: 9. Influence of Different Boiling Fractions of the Petroleum Carrier on the Effectiveness of Pentachlorophenol and Copper Naphthenate." Proceedings, Amer. Wood-Pres. Assn., 53, pp 13-20. 1957.

163. Duncan, C.G. "Evaluating Wood Preservatives by Soil-block Tests: 10. Effect of Species of Wood on Preservative Threshold Values." Proceedings, Amer. Wood-Pres. Assn., 54, pp 172-177. 1958.

164. Duncan, C.G. Studies of the Methodology of Soil-block Testing. For. Prod. Lab., U. S. Dept. of Agri., Rpt. No. 2114, Madison, Wisc. 1958.

165. England, R.F., and Boettiger. Retention of Wood Preservative Chemicals in Red Oak Lumber as Determined by Spectrographic Means. Puget Sound Naval Shipyard, Progress Report No. E-225B, Bremerton, Washington. 1955.

166. Gillander, H.E., and others. "The Weathering of Creosote." Indust. & Engin. Chem. 26, pp 175-83. 1934.

167. Gersonde, M. "Toxic Sensitivity of Different Strains of Wood-destroying Fungi." Holz als Roh u Werkstoff, 16(11), transl.

no. 128, pp 221-26. June, 1958.

168. Goldstein, I.S., W.A. Dreher, and E.B. Jeroski. "Preservative Action of Bound Copper and Zinc." For. Prod. Jour., 11 (3), pp 128-130. Mar. 1961.

169. Graham, R.D., and D.J. Miller. Service Life of Treated and Untreated Fence Posts on the T.J. Starker Post Farm. For. Res. Lab., Oreg. State Univ., Progress reports 1-11, and supl. 1961.

170. Hatfield, I., and S.S. Sakornbut. "Relationship of Oil Carriers to Utility of Pentachlorophenol as a Wood Preservative." Jour. For. Prod. Res. Soc., 5(5), pp 361-364. Oct. 1955.

171. Hatfield, I., and R.G. VanAllen. "Studies of Pentachlorophenol Motility in Relation to Solvent Translocation--I. Evaporation Rate and Residual Content of Penta-petroleum Preservative Solutions Outside of Wood Structures." Proceedings, Amer. Wood-Pres. Assn., 54, pp 23-33. 1958.

172. Hatfield, I., S.S. Sakornbut, E.F. Kaeible, W.W. Paris. "Studies of Pentachlorophenol Motility in Relation to Solvent Translocation--II. Pentachlorophenol Distribution in Pressure Treated Pole Stubs and Crossarms in Service." Proceedings, Amer. Wood-Pres. Assn., 56, pp 166-175. 1960.

173. Hearn, A.H. "Creosote Retention as Determined by Toluene Extraction of Treated Wood." Proceedings, Amer. Wood-Pres. Assn., 50, pp 122-140. 1954.

174. Heiks, R.E., S.E. Blum, and J.E. Burch. "Toxicity of β,β'-oxydipropionitrile Soluble and Insoluble Fractions of Creosote and Petroleum Oils to Wood-destroying Fungi by the Soil-block Method." Jour. For. Prod. Res. Soc., 4(3), pp 123-126. June 1954.

175. Heiks, R.E., S.E. Blum, J.E. Burch, and R.L. Jentgen. "Rapid Solvent Extraction Methods for Detecting Admixtures of Petroleum or Petroleum Derivatives and Coal Tar Creosote." Proceedings, Amer. Wood-Pres. Assn., 51, pp 18-28. 1955.

176. Henry, W.T., and committee. "Report of Committee P-6, Methods of Evaluation of Wood Preservatives." Proceedings, Amer. Wood-Pres. Assn., 46, pp 53-61. 1950.

177. Hudson, M.S. "Colorimetric Determination of Creosote in Old Poles." For. Prod. Jour., 8(11), pp 340-44. Nov. 1958.

178. Hudson, M.S. "Poria radiculosa, A Creosote Tolerant Organism." Jour. For. Prod. Res. Soc., 2(2), pp 73-74. 1952.

179. Humphrey, C.J., and R.H. Fleming. The Toxicity to Fungi of Various Soils and Salts Particularly Used in Wood Preservation. U. S. Dept. of Agri., Bull. No. 227, Washington, D. C. 1915.

180. Kelso, W.C., E.A. Behr, and R.E. Hill. "Pentachlorophenol Gradients in Pressure Treated Wood Under Exposure to Weather." Jour. For. Prod. Res. Soc., 5(5), pp 369-377. Oct. 1955.

181. Klem, G.G. "A New Method for Testing Treated Wood Specimens." For. Prod. Jour. 7(9), pp 20A-21A. Sept. 1957.

182. Kulp, J.W., and J.O. Blew. First Report on Tests of Service Life of Poles in REA-financed Electric Systems. Rural Electrication Administration, REA Bull. 169-29. 1955.

183. "Laboratory Tests on Wood Preservatives." For. Prod. Res. Board. Forestry Abstracts, 15(1), p 109. Jan. 1954.

184. Leutritz, J.J. "Wood Soil Contact Culture Technique for Laboratory Study of Wood-destroying Fungi, Wood Decay and Wood Preservation." Bell System Technical Jour., 25, pp 102-135. 1946.

185. Lumsden, G.Q. "A Quarter Century of Evaluation of Wood Preservatives in Poles and Posts at the Gulfport Test Plot." Proceedings, Amer. Wood-Pres. Assn., 48, pp 27-47. 1952.

186. MacLean, J.D. "Factors that have an Important Bearing on the Preservative Treatment of Round Timbers." Proceedings, Amer. Wood-Pres. Assn., pp 162-171. 1950.

187. Madhosingh, C. "Tolerance of Some Fungi to a Water-soluble Preservative and its Components." For. Prod. Jour., 11(1), pp 20-22. Jan. 1961.

188. Mayfield, P.B. "The Toxic Elements of High-Temperature Coal-Tar Creosote." Proceedings, Amer. Wood-Pres. Assn., 47, pp 62-88. 1951.

189. Mayfield, P.B. "The Exudation of Oil-type Preservatives from Treated Wood." Jour. For. Prod. Res. Soc., 4(1), pp 52-55. Feb. 1954.

190. McGehee, H.T., and R.G. Van Allen. "Laboratory Studies on the Emulsification Properties of Petroleum Oils Used with Pentachlorophenol at Treatment Plants." Proceedings, Amer. Wood-Pres. Assn., 48, pp 224-245. 1952.

191. McKnight, T.S. "Some Physical Factors Influencing the Effectiveness of Preservatives." For. Prod. Jour., 7(12), pp 441-444. Dec. 1957.

192. McKnight, T.S. "Application of the Logistic Function to Toxicity Testing of Wood Preservatives." For. Prod. Jour., 8(3), pp 96-98. Mar. 1958.

193. McKnight, T.S., and E. Merrall. "Fungistatic Effectiveness and Leachability of Copper Abietate and Formate Preservatives." For. Prod. Jour., 8(9), pp 256-257. Sept. 1958.

194. McNeal, S. Tests of Fence Post Preservatives. Ark. Agri. Expt. Sta. Bull. 519. Mar. 1952.

195. Neubauer, L.W., and R.F. Grah. "Absorption Rates of Penta by Various Species of Wood." Agri. Engin., 34, pp 534-537. Aug. 1953.

196. Phillips, L.S., and R.H. Baechler. A Review of Articles on Methods for Determining Arsenic, Boron, Chlorine, Fluorine, and Zinc that Might be Useful in Wood Preservation. For. Prod. Lab., U. S. Dept. of Agri., Rpt. No. WP-58, Madison, Wisc. Oct. 1961.

197. Price, E.A.S., and C.D. Cook. "Recent Developments in the Evaluation of the Permanence and Toxicity of Wood Preservatives." Rec. Annu. Conv., Brit. Wood Pres. Assn., pp 107-136. 1955.

198. Puri, Y.N., R.P. Sharma, and B.K. Bakshi. "Toxic Resistance of Poria monticola to Copper and Zinc in Nutrient Medium." Jour. Sci. & Indus. Res., 18C(8), pp 149-152. Aug. 1959.

199. Richards, C.A. "The Comparative Resistance of 17 Species of Wood-destroying Fungi to Sodium Fluorides." Proceedings, Amer. Wood-Pres. Assn., 20, pp 37-44. 1924.

200. Richards, C.A. "The Comparative Resistance of 18 Species of Wood-destroying Fungi to Zinc Chloride." Proceedings, Amer. Wood-Pres. Assn., 21, pp 18-22. 1925.

201. Rudman, P. "Methods of Testing Durability--I. Field Tests." Forest Products Newsletter, CSIRO. 268, pp 1-3. Oct. 1960. "Methods of Testing Durability--II. Laboratory Tests." Forest Products Newsletter, CSIRO 269, pp 1-3. Nov. 1960.

202. Sakornbut, S.S., and R.J. Balske. "The Effects of Soil, Moisture, and Aeration Variables in Bio Soil-block Culture Method." For. Prod. Jour., 7(11), pp 404-407, Nov. 1957.

203. Schmitz, H., and F. Kaufert. "Studies in Wood Decay--VI. The Effect of Arsenic, Zinc and Copper on the Rate of Decay of Wood by Certain Wood-destroying Fungi." Phytopathology, 27(7), pp

780-790, reprint. 1937.

204. Schuch, K. "Determination of Fluoride in Wood." Holz als Roh u Werkstoff, 11, pp 64-66. 1953.

205. Sedziak, H.P. "The Evaluation of Two Modern Wood Preservatives." Jour. For. Prod. Res. Soc., 2(5), pp 260-268. Dec. 1952.

206. Shibamoto, T., Y. Inoue, and Y. Kenjo, "Studies on Water-borne Wood Preservatives." Jour. of Japan Wood Res. Soc. "I.--On the Composition of Commercial Cresols and their Nitration Products," 4(2), p 46. Apr. 1958. "IV.--On the Application of the Cup Method for Assaying the Inhibition Effect of Water-borne Wood Preservatives on the Growth of Fungi,"4(5), p 165. Oct. 1958. "V.--The Effects of pH of Treating Solution of Chloro- and Nitrophenol Preservatives upon Antifungal Activities," 4(5), p 171. Oct. 1958. "VI.--Prevention of Mold Growth on Bamboo Stem Treated with Antifungal Chemicals," 4(6). p 237. Dec. 1958. "VII.--The Result of Evaluation of Wood Preservatives Against Decay of Wood," 5(1), p 31. Feb. 1959. "VIII.--Relation between the Hygroscopicity and the Fixation Phenomena of Treated Wood," 5(3), p 86, June 1959. "XIII.--Synthesis of Fixtan Acids, Their Derivatives and their Critical Micell Concentration in Aqueous Solution," 6(1), p 11. Feb. 1960. "XIV.--Color Change of Treated Wood By Weathering Procedure," 6(3), p 122. June 1960. "XVIII.--Color Change of Wood Treated with Colorants Caused by Weathering," 6(4), p 147. Aug. 1960. "XIX.--Test Result of Chemicals Against Attack by Fungi and Insects," 6(5), p 177. Oct. 1960. (In Japanese, English summaries).

207. Snoke, L.R. "Soil-block Bioassay of a Creosote Containing Pentachlorophenol." Jour. For. Prod. Res. Soc., 4(1), pp 55-57. Feb. 1954.

208. Snoke, L.R. "Observation on a Possible Method of Predicting Soil-block Bioassay Thresholds by Distillation Characteristics of the Weathered Creosotes." Jour. For. Prod. Res. Soc., 4, pp 111-114. Apr. 1954.

209. Snoke, L.R. "Specific Studies on the Soil-block Procedure for Biossay of Wood Preservatives." Bell Telephone System Monograph, 2577. 1956.

210. Varner, R.W., and R.L. Krause. "Agar-block and Soil-block Methods for Testing Wood Preservatives." Indust. & Engin. Chem., 43, pp 1102-1107. May 1951.

211. Walters, C.S. " A Uniform Service Test for Fence Posts." Jour. of Forestry, 52, pp 527. July 1954.

212. White, W.E. Service Records. N.E. Wood Util. Council Bull. 45, pp 31-44, Apr. 1957.

213. Wilson, W.J. "The Determination of Zinc in Wood Preserving Solutions." Analyt. Chim. Acta., 15, pp 508-510. Dec. 1956.

214. Wilson, W.J. "The Detection of Preservatives in Wood with Pyrocatechol Violet." Analyt. Chim. Acta., 21, pp 150-154. Aug. 1959.

215. Wright, J.P., and K.H. Storks. "Symposium and Panel Discussion on Results-type Specification. X-ray Fluorescent Spectra for the Analysis of Preservatives in Wood and Paper Products." Proceedings, Amer. Wood-Pres. Assn., 53, pp 57-89. 1957.

216. Yearsley, M.G. "Final Report on Trials of Copper Naphthenates as Wood Preservatives." Empire Forestry Rev., 36(3), pp 287-291. Sept. 1957.

217. Zabel, R.A. "Variations in Preservative Tolerance of Wood-Destroying Fungi." Jour. For. Prod. Res. Soc., 4(4), pp 166-169. 1954.

218. Zable, R.A., and R.A. Moore. "Relative Effectiveness of Several Oil-soluble Preservatives." For. Prod. Jour., 8(9), pp 258-263. Sept. 1958.

Detection of Decay

219. Armstrong, F.H. "Further Tests on the Effects of Progressive Decay by Trametes serialis on the Mechanical Strength of the Wood of Sitka Spruce." Forestry, 9, pp 62-64. 1935.

220. Badcock, E.C. "Preliminary Account of the Odour of Wood-Destroying Fungi in Culture." Trans., Brit. Mycol. Soc., 23, pp 188-198. 1939.

221. Cameron, J.F., P.F. Berry, and E.W.J. Phillips. "The Determination of Wood Density Using Beta-Rays." Holzforschung, 13(3), pp 78-82. Aug. 1959.

222. Cartwright, K.St.G. "A Satisfactory Method of Staining Fungal Mycelium in Wood Sections." Annals of Botany (London), 43, pp 412-513. 1929.

223. Cowling, E.B. Methods for Chemical Analysis of Decayed Wood. For. Prod. Lab., U. S. Dept. of Agri., Rpt. No. 2177, Madison, Wisc. May, 1960.

224. Cowling, E.B., and I.B. Sachs. "Detection of Brown Rot with Osmium Tetroxide Stain." For. Prod. Jour. 10(11), pp 594-596. Nov. 1960.

225. Diemer, M.E., and E. Gerry. "Stains for the Mycelium of Molds and Other Fungi." Science, n.s. 54, pp 629-630. 1921.

226. Eslyn, W.E. "Radiographical Determination of Decay in Living Trees by Means of the Thulium X-ray Unit." Forest Science, 5(1), pp 37-47. 1959.

227. Fukuyama, G., and K. Kawase. A Simpler Method for Determining the Degree of Wood Decay with Dilute Alkaline Solution. Research Bulletins of The College Experiment Forests, 17(1), pp 151-178, reprint. Hoddaido University, Sapporo. Japan. 1954.

228. Fukuyama, G., and K. Kawase. A Method for Determining the Degree of Wood Decay by Nail Holding Power. Research Bulletins of the College Experimental Forests, 17(1), pp 179-216, Hokkaido University, Sapporo, Japan. 1954.

229. Gray, V.R. Possible Uses of Radioisotopes and Radiation in Timber Research. Timber Development Association, London. 1959.

230. Gregory, G.N. "X-rays and Timber Defects." Jour. Coun. Sci. & Ind. Res., Australia, 13, pp 310-312. 1940.

231. Hartley, C. Evaluation of Wood Decay in Experimental Work. For. Prod. Lab., U. S. Dept. of Agri., Rpt. No. 2119, Madison, Wisc. 1958.

232. Hilborn, M.T. "The Calorific Value of Decayed Cordwood." Phytopathology, 26, pp 905-914. 1936.

233. Kennedy, R.W. "Strength Retention in Wood Decayed to Small Weight Losses." For. Prod. Jour., 8(10), pp 308-314. Oct. 1958.

234. Lee, I.D.G. "A Non-destructive Method for Measuring the Elastic Anistrophy of Wood Using An Ultrasonic Pulse Technique." Timber Development Association, London. 1958. Jour. Inst. Wood Sci. 3, pp 21-32. 1959.

235. Liese, J., and J. Stammer. "Comparative Tests on the Destructive Force of a Few Important Wood-destroying Fungi and the Resulting Decrease in the Strength of the Wood." Angewandte Botanik, 16(4), Berlin, Transl. by Gertrude Krafft. 1934.

236. Lindgren, R.M. Color Test for Early Storage Decay in Southern Pine. For. Prod. Lab., U. S. Dept. of Agri., Rpt. No.

2037, Madison, Wisc. 1955.

237. Loos, W.E. "Applications of the Gamma-Ray Backscatter Technique to the Inspection of Utility Poles." For. Prod. Jour., 11 (8), pp 333-336. Aug. 1961.

238. Mateus, T.J.E. "A Mechanical Test for Studying Wood Preservatives." Rec. Annual Conv., Brit. Wood Pres. Assn., pp 137-170. 1957.

239. Morris, C.O. Ultrasonics for Wood Industries. For. Res. Lab., Oregon State Univ., Report No. E-2, Corvallis, Oregon. Apr. 1960.

240. Moses, C.S., and T.C. Scheffer. Using a Resistance Type Wood Moisture Meter to Appraise Decay Hazard. For. Prod. Lab., U. S. Dept. of Agri., Rpt. No. 2147, Madison, Wisc. 1959.

241. Mulholland, J.R. "Changes in Weight and Strength of Sitka Spruce Associated with Decay by a Brown-rot Fungus, Poria monticola." Jour. For. Prod. Res. Soc., 4(6), pp 410-416. 1954.

242. Parrish, W.B. "Detecting Defects in Wood by the Attenuation of Gamma-Rays." Forest Science, 7(2), pp 137-143. 1961.

243. Parrish, W.B., W.C. Myser, and M.L. Pool. "Radio-isotopes --A Possible Means for Finding Defects in Logs and Trees." Jour. of Forestry, 55 (11), pp 851-852. 1957.

244. Partch, R.E. "Defect Detection Equipment." Proceedings, For. Prod. Res. Soc., 4, pp 180-184. 1950.

245. Phillips, E.W.J. "The Beta-Ray Method of Determining the Density of Wood and the Proportion of Summer-wood." Journal of the Institute of Wood Science, 5, pp 16-28. Aug. 1960.

246. Richards, D.B. "An Electrical Test for Decay in Wood." Jour. For. Prod. Res. Soc., 2(4), pp 25-28. Nov. 1952.

247. Richards, D.B. "Physical Changes in Decaying Wood." Jour. of Forestry, 52(4), pp 260-65. Apr. 1954.

248. Roff, J.W., and H.Shen. "Loss in Stiffness Evaluates Decay Resistance of Wood Treated with Copper Naphthenate." For. Prod. Jour., 9(8), pp 262-65. Aug. 1959.

249. Sandermann, W., W. Schweers, and P. Gaudert. "The Measurement of Wood Density and Determination of Annual Ring Width by means of B-Rays." Forstarchiv., 31(8), pp 126-128. 1960.

250. Scheffer, T.C., T.R.C. Wilson, R.F. Luxford, and C. Hartley. The Effect of Certain Heart-rot Fungi on the Specific Gravity and Strength of Sitka Spruce and Douglas-fir. U. S. Dept. of Agri., Tech. Bulletin No. 779, Washington, D. C. 1941.

251. Vaughn, R.E. "A Method for the Differential Staining of Fungus and Host Cells." Ann. Missouri Botanical Garden, 1, pp 241-242. 1914.

252. Von Peckmann, H., and O. Schaile. "The Change in the Dynamic Strength and the Chemical Composition of Wood by the Attack of Wood-Destroying Fungi." Chemical Abstracts, 47(18), p 9543. Sept. 25, 1953.

253. Waid, J.S., and M.S. Woodman. "A Non-Destructive Method of Detecting Diseases in Wood." Nature, 180, No. 4575, p 47. July 1957.

254. Waid, J.S., and M.S. Woodman. "Ultrasonics Detects Flaws in Trees and Wood." Science Newsletter, 72, p 40. July 20, 1957.

255. Waterman, A.M., and J.R. Hansbrough. "Microscopical Rating of Decay in Sitka Spruce and its Relation to Toughness." For. Prod. Jour., 7(2), pp 77-84, 1957.

Inspection of Standing Poles

256. Amadon, C.H. Pole Inspection and Maintenance. Rural Electrification Admin. 1955.

257. "Check Poles, Check Trouble." Rural Electrification News. June-Jul. 1952.

258. Colley, R.H. "Report of Committee 5-5-1, Poles-Pressure Treatment." Proceedings, Amer. Wood-Pres. Assn., 27, pp 42-44. 1931.

259. Graham, R.D. Use of Douglas-fir Poles in the Pacific Northwest. For. Res. Lab., Ore. State Univ., Corvallis, Oregon. 1961.

260. Grondal, B.L. "Poles--Treated and Untreated." Proceedings, Amer. Wood-Pres. Assn., 45, pp 367-372. 1949.

261. Groundline Treatment of Standing Poles. Chapman Chemical Company, Palo Alto, Calif. n.d.

262. "A Guide to Determine Pole Strength." Electrical World, Engineering reference sheet No. 50-42. Oct. 23, 1950.

263. Haenseler, H.A. "Report of Committee 7-7, Pole Service Records." _Proceedings_, Amer. Wood-Pres. Assn., 35, pp 307-317. 1939.

264. Haenseler, H.A. "Report of Committee 7-7, Pole Service Records." _Proceedings_, Amer. Wood-Pres. Assn., 36, pp 165-178. 1940.

265. Hatfield, I. "Preventative Maintenance for Standing Poles." _Wood Preserving News_, 39 (8), pp 10-23. Aug. 1961.

266. Hearn, A.H. "Maintenance Inspection of Wood Pole Lines." _Wood Pole Conference_, School of Forestry, For. Res. Lab., Ore. State Univ., Corvallis, Oregon. Mar. 1960. _Proceedings_, Wood Pole Institute, Colorado State Univ. June 1960. _Proceedings_, Southeastern Wood Pole Conference. Aug. 1960. _Proceedings_, Eastern Wood Pole Conference, College of Forestry , Syracuse Univ. Sept. 1961.

267. Hearn, A.H. _Pole Line Inspection-Case 18087-8._ American Telephone and Telegraph Company. n.d.

268. _Methods for Inspection of Standing Poles in Overhead Lines_. Transmission and Distribution Committee, Edison Electric Institute, New York, N. Y. 1959.

269. _A Method of Sampling a Group of Poles_. by Corporation for Economic and Industrial Research, for Osmose Wood Preserving Company of Amer. Inc. 1959.

270. "Pole Inspection for Rural Electric Systems." _Policyholder Service Bulletin_, Employers Mutuals of Wausau, Wausau, Wisc. 1956.

271. "Pole Lines-Inspection of Poles." _Bell System Practices_, Outside Plant Construction and Maintenance, Section G21.315, Standard. Oct. 1931.

272. _Pole Maintenance_. Rural Electrification Administration, Bull. No. 161-4 (E), 441-1 (T). July 1957.

273. Smith, F.W. "Pole Treatment Cuts Line Costs." _Electrical World_, reprint. Sept. 7, 1959.

274. _Standard Method on Inspecting Standing Poles_. Western Wood Preserving Operators' Association. 1961. Unpublished.

275. Stoker, R.S. "X-Ray Pole Inspection." _Proceedings_, Amer. Wood-Pres. Assn., 44, p 298. 1948.

276. _The Story of Osmoplastic--Its Use and Application in Various_

Fields. Osmose Wood Preserving Company of America, Inc., Buffalo, N. Y. 1954.

Treatments for Poles in Service

277. Amadon, C.H. "Groundline Treatment of Standing Poles." Bell Laboratory Records, 22(11), pp 468-471. July, 1944. Rev. Appl. Mycol., 24(7). July 1945.

278. Andrews, J.W., and C.W. Leach. Practices in the Supplemental Field Treatment of Poles. U. S. Steel, Creosote Research. 1956.

279. Blew, J.O. "Evaluation of Groundline Treatments." Proceedings, Wood Pole Institute, Colorado State Univ., Fort Collins, Colorado. June 1960.

280. Carter, M. L. "Manufacturing Procedures and Quality Control of Pole-Aid." Proceedings, Wood Pole Institute, Colorado State Univ., Fort Collins, Colorado. June 1960.

281. "Continuous Pole Impregnation Extends Life from 10 to 15Years." Electrical World, 104, p 17. 1934.

282. Enos, H.A. "Economics of Preservative Treatment of Standing Cedar Poles." Elect. Light & Power, 34(22), pp 128-131. Oct. 15, 1956.

283. Fahlstrom, G.B. "The Osmose Process for Groundline Inspection and Treatment of Poles." Proceedings, Wood Pole Institute, Colorado State Univ., Fort Collins, Colorado. June 1960.

284. Feagens, R.B. "Preventive Pole Maintenance." Proceedings, Wood Pole Institute, Colorado State Univ., Fort Collins, Colorado. June 1960.

285. Financial Survey of Transmission and Distribution Pole Costs and Economic Analysis of the Cobra Process. Cobra Wood Treatment Corp., 124 E. 40th Street, New York 16, N. Y. n.d.

286. "Groundline Preservation of Poles and Posts." Public Works, 68, p 22, New York, N. Y. 1937.

287. Harko, J.F., M.J. Colleary, and H.P. Sedziak. "Results of the Examination of Seven Groundline Treatments and One Butt Treatment on Eastern White Cedar Pole Stubs After Six Years Service." Proceedings, Amer. Wood-Pres. Assn., 44, pp 158-171. 1958.

288. "How IPS Keeps Poles Standing." Floodlight, Iowa Public Service

Co., reprint. June 1958.

289. Hyry, E.C. "Groundline Treatments." Proceedings, Wood Pole Institute, Colorado State Univ., Fort Collins, Colorado. June 1960.

290. Johnson, W.H. "When to Treat Southern Pine Poles." Elect. Light & Power, 38 (17), pp 50-51, 79. Sept. 1, 1960.

291. "Keeping Standing Poles Standing--Indefinitely." Transmission and Distribution, reprint. Oct. 1958.

292. Meyer, F.J., and R.M. Gooch. "Pentachlorophenol Grease for Preserving Poles." Elect. Light & Power, 30, reprint. Aug. 1952.

293. Morgan, H.C. "Preservation of Wood Poles and the Prolongation of Their Service Life by the Oxy-acetylene Scouring and Charring Process." Engineering (London), 141, p 689. 1936.

294. O'Neal, W.J. "Supplementary Treatment of Poles (Groundline and Pressure Retreatment)." Proceedings, Eastern Wood Pole Conference, State Univ. Col. of Forestry, Syracuse Univ., Syracuse, New York, pp 80-87. Sept. 1961.

295. Packer, F.W. "Groundline Treatment of Standing Poles." Electrical World. 110, pp 1434-1435. 1938.

296. Panek, E. "Results of Groundline Treatments One Year After Application to Western Redcedar Poles." Proceedings, Amer. Wood-Pres. Assn., 56, pp 225-235. 1960.

297. Panek, E., J.O. Blew, and R.H. Baechler. Study of Groundline Treatments Applied to Five Pole Species. For. Prod. Lab., U. S. Dept. of Agri., Rpt. No. 2227, Madison, Wisc. Aug. 1961.

298. "Protection of Wood Poles; Oxy-acetylene Testing, Scouring, and Preservation Process." Electrician (London), 126, p 360. 1941.

299. "Sand-Creosote Collar Protects Wood Poles." Electrical World, 108, p 72. 1937.

300. Sanders, J.W. "Pole Life Extended by Injection Inoculation." Electrical World, 111, pp 399-400. 1939.

301. Speaker, J. "Portable Unit Applies Preservative to Wooden Pole Checks and Cracks." Electrical South. 39(10), p 77. Oct. 1959.

302. Tierney, F.P. and G.H. Lund. "Utilitity Pole Control." Proceedings, Amer. Wood-Pres. Assn., 56, pp 86-92. 1960.

303. Tobey, H.M. "The Characteristics and Application of Pol-Nu."

Proceedings, Wood Pole Institute, Colorado State Univ., Fort Collins, Colorado. June 1960.

304. "Treat Groundline, Eliminate Termites." Electrical World, 111, p 725. 1939.

305. Wentling, J.P., and committee. "Groundline Treatment of Poles in the Line." Proceedings, Amer. Wood-Pres. Assn., 40, pp 139-142. 1944.

306. Wentling, J.P., and committee. "Groundline Treatment of Poles in the Line." Proceedings, Amer. Wood-Pres. Assn., 41, pp 39-43. 1945.

307. Wentling, J.P., and committee. "Groundline Treatment of Poles in the Line." Proceedings, Amer. Wood-Pres. Assn., 43, p 125. 1947.

Related References

308. Aaron, J.R., and K. Wilson. "Soft-rotting Fungi in Timber." Wood (London) 20 (5), pp 186-189. May 1955.

309. Andrews, J.W., S.N. Buco, and P. O'Brien. "The Study of a Creosoted Pole after Twenty-three Years in Service." Progress Report on Applied Research Laboratory Project 7.3-103. 1954. Proceedings, Amer. Wood-Pres. Assn., 51, pp 68-74. 1955.

310. Androc Pole-Check Service. Androc Chemical Co., 7301 W. Lake Street, Minneapolis 26, Minn. n.d. Advertisement.

311. Angel, H.W., V.F. Hribar, and W.A. McFarland. "Experiments in the Use of High Vacuums and Wetting Agents in the Preservative Treatment of Green Douglas Fir Lumber." Proceedings, Amer. Wood-Pres. Assn., 44, pp 324-335. 1948.

312. Ashbaugh, F.A. "Relation Between Quality and Pole Service Life." Proceedings, Amer. Wood-Pres. Assn., 48, pp 328-334. 1952.

313. Atwell, E.A. Red-Stain and Pocket-Rot in Jack Pine; Their Effect on Strength and Serviceability of the Wood. Dept. of Mines and Resources, Circ. 63, Canada. 1948.

314. Babbitt, J.D. "On the Diffusion of Adsorbed Gases Through Solids." Canadian Jour. of Physics. 29, pp 437-446. 1951.

315. Barmack, B.J. "Dentistry Saves Wood Poles, Stops Pole-top Heart Rot." Electrical World, 136(3), pp 112-113. 1951.

316. Becker, G. "Organic Solvent Preservatives in Germany." Timber Technology, pp 592-596. Dec. 1958.

317. Behr, E.A., D.R. Briggs, and F.H. Kaufert. "Diffusion of Dissolved Materials Through Wood." Jour. Phys. Chem., 57, pp 476-480. April 1953.

318. Bowen, J.W. "Preserving Timber Underground; Use of Dinitrophenol." Chemical Age, 51, p 153, London, England. 1944.

319. Bridge Cook, W. "Recent Systems of Polypore Classification." Lloydia, 12, pp 220-227. 1949.

320. Bridgewater, M.M. "New Practice Saves Poles Threatened by Termites." Electrical World, 100, p. 693. 1932.

321. Browne, F.L. "Water-Repellent Preservatives for Wood." Architectural Record. pp 131-133, reprint. Mar. 1949.

322. Browne, F.L., and R.A. Zabel. "Adsorption and Penetration of Oil-soluble Wood Preservatives in Dip Treatments--a Summary of Progress." Jour. For. Prod. Res. Soc., 4(2), pp 101-103. Apr. 1954.

323. Burr, H.K., and A.J. Stamm. Diffusion in Wood. For. Prod. Lab., U. S. Dept. of Agri., Rpt. No. 1674, Madison, Wisc. Mar. 1956.

324. Campbell, W.G., and S.A. Bryant. "Determination of pH in Wood." Nature, (London), 147(3725), p 357. 1941.

325. Carlin, B. "Locating Internal Defects." Amer. Gas Assn. Monthly, 29(9), pp 391-392. 1947.

326. Cartwright, K.St.G. "The Relation Between Field and Laboratory Work in Mycology." Trans., Brit. Mycol. Soc., 22, pp 222-238. 1939.

327. Cartwright, J.B., D.W. Edwards, and M.J. McMullen. "Sterilization of Timber with Methyl Bromide." Nature (London), 172, pp 552-553. 1953.

328. Clark, J.W. "Comparative Decay Resistance of Some Common Pines, Hemlock, Spruce, and True Firs." Forest Science, 3 (4), pp 314-320. Dec. 1957.

329. The Cobra Process for the Preservation of Wood Poles. Cobra Wood Treatment Corp., 124 E. 40th Street, New York 16, N. Y. n.d. Advertisement.

330. Color Tests for Differentiating Heartwood and Sapwood of Certain Oaks, Pines, and Douglas-fir. For. Prod. Lab., U. S. Dept.

of Agri., Tech. Note No. 253, Madison, Wisc. 1954.

331. Computed Thermal Conductivity of Common Woods. For. Prod. Lab., U. S. Dept. of Agri., Tech. Note No. 248, Madison, Wisc. Dec. 1952.

332. Determining the Moisture Content of Wood. For. Prod. Res. Institute, Tech. Note No. 19, Laguna, Phillipines. May 1961.

333. Dice, J.W. "Location of Internal Defects by Super-Sonics." Instruments, 19(12), pp 718-722. Dec. 1, 1946.

334. Diller, J.D., and S.W. Huang. "Further Results on the Vertical Advance of Two House Decay Fungi in Artificially Infested Timbers." Phytopathology, 46, p 467. Aug. 1956.

335. Duncan, C.G. Soft-rot in Wood, and Toxicity Studies on Causal Fungi. For. Prod. Lab., U. S. Dept. of Agri., Madison, Wisc. 1960.

336. Duncan, C.G. Wood-Attacking Capacities and Physiology of Soft-rot Fungi. For. Prod. Lab., U. S. Dept. of Agri., Rpt. No. 2173, Madison, Wisc. 1960.

337. Eades, H.W. "Differentiation of Sapwood and Heartwood in Western Hemlock by Color Tests." For. Prod. Jour., 8(3), pp 104-106. 1958.

338. Fleischer, H.O., and L.E. Downs. Heating Veneer Logs Electrically. For. Prod. Lab., U. S. Dept. of Agri., Rpt. No. 1958, Madison, Wisc. 1953.

339. Goldstein, I.S., W.A. Dreher, E.B. Jeroski, J.F. Nielson, W. J. Oberly, and J.S. Weaver. "Wood Processing--Inhibiting Against Swelling and Decay." Indust. & Engin. Chem., 51(10), pp 1313-1317. 1959.

340. Graham, H.M., and E.F. Kurth. "Constituents of Extractives from Douglas Fir." Indust. & Engin. Chem., 41, p 409. 1949.

341. Graham, R.D., and E. Wright. "Stronger Spray Cuts Pole Rot." Electrical World, 152(4), p 60. Jul. 27, 1959.

342. Growth of the British Columbia Shipworm. Fisheries Research Board of Canada, Progress Reports of the Pacific Coast Stations, No. 105. Feb. 1956.

343. Hartley, C., R.W. Davidson, and B.S. Crandall. Wetwood, Bacteria, and Increased pH in Trees. For. Prod. Lab., U. S. Dept. of Agri., Rpt. No. 2215, Madison, Wisc. April 1961.

344. Hartman, E.F. "Localized Pressure Treatments." Proceedings,

Amer. Wood-Pres. Assn., 17, pp 440-463. 1921.

345. Hatfield, I. "Further Experiments with Chemicals Suggested as Possible Wood Preservatives." Proceedings, Amer. Wood-Pres. Assn., 28, pp 330-340. 1932.

346. Hawley, L.F. Wood-Liquid Relations. U. S. Dept. of Agri., Tech. Bull. 248. 1931.

347. Hines, E., G.B. Fahlstrom, and R.S. Stoker. "Migration of Penta in Spray-Treated Cedar Poles." Elect. Light & Power, 34 (4), pp 102-105. Feb. 15, 1956.

348. Houtman, J.P.W., and others. "Colloidal Solutions for Timber Preservation." Timber Technology, 64(2200), p 87. Feb. 1956.

349. Humphrey, C.J., and C.A. Richards. Railroad Tie Decay--The Decay of Ties in Storage, Defects in Cross Ties Caused by Fungi. Amer. Wood-Pres. Assn., Washington, D.C. 1939.

350. Kajanne, P. "A Rapid Method for Moisture Determination." Paperi ja Puu--Papper och Trä, 39(8), pp 391-398. 1957.

351. Karpov, V.L., Y.M. Malinsky, V.I. Serenkov, R.S. Klimanova, and A.S. Freiden. "Radiation Makes Better Woods and Copolymers." Nucleonics, 18(3), pp 88-90. Mar. 1960.

352. K-Ban--Groundline Treatment Bandage. Chapman Chemical Co., Memphis, Tenn. 1957. Advertisement.

353. Keer, G.A. "Protection of Wood Against Moisture Changes." Wood (London), 21(4), pp 130-131. Apr. 1956.

354. Kenaga, D.L., and E.B. Cowling. "Effect of Gamma Radiation on Ponderosa Pine." For. Prod. Jour., 9(3), pp 112-116. Mar. 1959.

355. Kingston, L.H. "Shave, Spray Standing Poles to Combat Shell-Rot." Electrical World, reprint. Sept. 2, 1944.

356. Kluczycki, K. "The Toxicity of Some Wood-Preservatives and Insulators to Fungi and the Method of Its Testing." Acta Microbiol. Polon., 1, pp 223-256. 1952. (In Polish with English summary.)

357. Krause, R.L. "Iron Stain from Metal Fastenings May Accelerate Decay in Some Woods." Jour. For. Prod. Res. Soc., 4(2), pp 103-111. 1954.

358. Liese, W., and H. Von Pechmann. "Experiments on the Effect of Soft-rot Fungi on Wood Strength." Forstwissenschaftliches Centralblatt, 78(9/10), transl. 1959.

359. Lindgren, R.M. "Permeability of Southern Pine as Affected by (Trichoderma) Mold and Other Fungus Infection." Proceedings, Amer. Wood-Pres. Assn., 48, pp 158-174. 1952.

360. Lindgren, R.M., and E.C.O. Erickson. "Decay and Toughness Losses in Southern Pine Infected by Peniophera." For. Prod. Jour., 7(6), pp 201-204. 1957.

361. Lindgren, R.M., and G.M. Harvey. "Decay Controls and Increased Permeability in Southern Pine Sprayed with Fluoride Solutions." Jour. For. Prod. Res. Soc., 2(5), pp 250-256. Dec. 1952.

362. Lindgren, R.M., and E. Wright. "Increased Absorptiveness of Molded Douglas-fir Posts." Jour. For. Prod. Res. Soc., 4(4), pp 162-164. Aug. 1954.

363. Livingston, K.W. "The Effects of Species, Diameter, and Density of Wood on Absorption of an Oil Solution of Pentachlorophenol by Fence Posts With the Cold-soaking Method." Ala. Acad. Sci. Jour., 21/22, pp 43-45. Feb. 1952.

364. MacLean, J.D. Effect of Moisture Changes on the Shrinkage, Swelling, Specific Gravity, Air or Void Space, Weight and Similar Properties of Wood. For. Prod. Lab., U. S. Dept. of Agri., Rpt. No. 1448, Madison, Wisc. 1952.

365. MacLean, J.D. "Studies of Heat Conduction in Wood--", "I. Results of Steaming Green Round Southern Pine Timbers." Proceedings, Amer. Wood-Pres. Assn., 26, pp 197-219. 1930. "II. Results of Steaming Green Sawed Southern Pine Timbers." Proceedings, Amer. Wood-Pres. Assn., 28, pp 303-330. 1932. "III. Temperatures in Green Southern Pine Timbers After Various Steaming Periods." Proceedings, Amer. Wood-Pres. Assn., 30, pp 355-373. 1934.

366. MacLean, J.D. "Temperatures and Moisture Changes in Coast Douglas-fir." Proceedings, Amer. Wood-Pres. Assn., 31, pp 77-103. 1935.

367. Mark, R., and B.M. Zuckerman. "Reinforced Plastics as Protective Coatings for Wood." For. Prod. Jour., 8(7), pp 25A-26A. Jul. 1958.

368. Marsh, P.B. "A Test for Detecting the Effects of Micro-organisms and of a Microbial Enzyme on Cotton Fiber." Plant Disease Reporter, 37(2), pp 71-76. 1953.

369. Maruzzella, J.C., D.A. Scrandis, J.B. Scrandis, and G. Grabon. "Action of Odoriferous Organic Chemicals and Essential Oils on

Wood-Destroying Fungi." Plant Disease Reporter, 44(10), pp 789-792. Oct. 15, 1960.

370. Miller, D.G. "Sonic Detection of Blisters for Plywood and Other Bonded Materials." Wood (London), 25(2), pp 57-60. Feb. 1960.

371. Moisture Meters. Western Pine Association, Res. Note No. 5.231. 1953 (rev. 1960).

372. "Non-destructive Testing." Prod. Eng., 17(12), pp 137-138. 1946.

373. Oliver, A.C. Use of X-Rays in the Detection of Teredo in Wood. The Timber Development Assn., Test record B/TR/2, London. 1959.

374. O'Neil, W.J. Tests on Treated Fence Posts. Mo. Agr. Expt. Sta., Bull. 612. Jan. 1954.

375. Partridge, A.D. "Fumigants Kill the Oak Wilt Fungus in Wood." For. Prod. Jour., 11(1), pp 12-14. Jan. 1961.

376. Pearson, S.J. "It Pays to Treat Tops of Standing Poles." Elect. West. 110(4, ptI), p 97. Apr. 1953.

377. Peyton, A.H. "Treat Poles When Reset to Prolong Life." Electrical World, 134(15), pp 130, 138. 1950.

378. Pol-Nu. Chapman Chemical Company, Memphis, Tenn. 1958. Advertisement.

379. Price, E.A.S. "Correlating Laboratory and Field Tests on the Behaviour of a Wood Preservative Towards Soft-Rot." Wood (London), 22(5), pp 193-196. May 1957.

380. "Radioactive Isotopes in Timber Preservation Studies." Bell Laboratories Record, 28(6), pp 249-251. 1950.

381. Radiography in Modern Industry. Eastman Kodak Co. 1957.

382. Rodrigues, V.J.M. "Preliminary Notes on a Method of Identifying Woods by Means of NaOH." Forestry Abstracts, 12(2), p 185. 1950.

383. Roth, L.F. "Climatic and Structural Conditions that Favor Attack by Wood-destroying Fungi." Pest Control, 24, pp 30, 32, 34-35. Jan. 1956.

384. Savory, J.G. "Role of Micro-fungi in the Decomposition of Wood." Rec. Annu. Conv. Brit. Wood Pres. Assn., pp 3-35. 1955.

385. Scheffer, T.C. and F.L. Browne. "Tests of Some Superficial Treatments of Exposed Wood Surfaces for their Protection

Against Fungus Attack." Jour. For. Prod. Res. Soc., 4(3), pp 131-132. June 1954.

386. Scheffer, T.C., and A. Van Kleeck. "The Decay Resistance of Wood Impregnated with Fire-retarding Ammonium Salts." Proceedings, Amer. Wood-Pres. Assn., 41, pp 204-211. 1945.

387. Schmidt, H. "The Effect of X-rays on Wood-Destroying Insects." Holzforsch. u. Holzverwert., 13(1), pp 8-11, reprint. 1961.

388. Schmitz, H. "Studies in Wood Decay. III.--The Toxicity of Western Yellow Pine Crude Oil to Lenzites saepiaria." Jour. of Ind. & Eng. Chem. 14(7), p 617, reprint. 1922.

389. Shiio, H., T. Ogowa, and H. Yoshihashi. "Measurement of the Amount of Bound Water by Ultrasonic Interferometer." Jour. Amer. Chem. Soc., 77(19), pp 4980-4982. Oct. 1955.

390. Shrinking and Swelling of Wood in Use. For. Prod. Lab., U. S. Dept. of Agri., Rpt. No. 736, Madison, Wisc. 1952.

391. Simeone, J.B. "Pole Deterioration by Wood Destroying Insects." Proceedings, Eastern Wood Pole Conference, State Univ. Col. of Forestry, Syracuse Univ., Syracuse, New York, pp 15-22. Sept. 1961.

392. Smith, D.N. "Preservation and the Permeability of Wood." Timber Technology, 66(2231), pp 460-461, 463, 464. Sept. 1958.

393. Spalt, H.A. "The Sorption of Water Vapor By Domestic and Tropical Woods." For. Prod. Jour., 7(10), pp 331-335. 1957.

394. Stamm, A.J. "The Effect of Inorganic Salts Upon the Shrinking and Swelling of Wood." Jour. Amer. Chem. Soc., 56, p 1195. 1934.

395. Stamm, A.J., and W.K. Loughborough. "Thermodynamics of the Swelling of Wood." Jour. Physical Chem., 39, pp 121-132. 1935.

396. Stamm, A.J., and W.H. Petering. "Treatment of Wood With Aqueous Solutions; Effect of Wetting Agents." Indust. & Engin. Chem., 32(6), 809. 1940.

397. Stamm, A.J., and H. Tarkow. "Dimensional Stabilization of Wood." Jour. of Phys. and Colloid. Chem., 51, pp 493-505. 1947.

398. Stearns, J.L., and C. Hartley. "Physico-Chemical Methods for Wood Diagnosis." Jour. For. Prod. Res. Soc., 2(4), pp 58-61. 1952.

399. Suckling, E.E., and W.R. McLean. "Sonic Images." Acoust. Soc. Amer. Jour., 29(1), pp 146-148. Jan. 1957.

400. Sussex, I.M., and others. "Extraction and Biological Properties of an Anti-fungal Fraction of Woody Plant Tissues." Botan. Gaz. 121(3), pp 171-175, reprint. Mar. 1960.

401. The Use and Maintenance of Moisture Meters. Western Pine Association, Res. Note No. 4.4111. 1953 (rev. 1959).

402. Weaver, J.W., E.B. Jeroski, and I.S. Goldstein. "Dyes for Preserving Wood." For. Prod. Jour., 9(10), pp 372-374. Oct. 1959.

403. Weaver, J.W., E.B. Jeroski, and I.S. Goldstein. "Toxicity of Dyes and Related Compounds to Wood-destroying Fungi." Applied Micro-biology, 7(3), pp 145-149. 1959.

404. Winebrenner, L.I. "The Place of Water Repellents in the Preservative Field." For. Prod. Jour., 5(2), pp 146-148. Apr. 1955.

405. Young, H.C., and J.C. Carroll. "Decomposition of Pentachlorophenol When Applied as a Residual Pre-emergency Herbicide." Agronomy Journal, 43, pp 504-507. 1951.

406. Zabel, R.A. "Decay Resistance Variations Within Northeastern Forest Tree Species." Proceedings, N.E. Forest Tree Impr. Conf., 3, pp 13-17. 1956.

APPENDIX

RECOMMENDATIONS FOR THE INSPECTION OF TREATED POLES IN SERVICE

Report of Committee 7-7 - Pole Service Records, H.A. Haenseler, Chairman. Proceedings, American Wood-Preservers' Association, Vol. 36, pp 175-177. 1940.

1. GENERAL

1.1 The following methods are recommended for the inspection of pressure-treated and non-pressure-treated poles in service.

1.2 Tools. Tools used in the inspection of poles in service should be of a type which will minimize injury to sound wood. Increment borers or small-diameter wood bits, preferably the former, should be used for determining the internal condition of the pole. Tools for prodding and removing decay should be as light as practicable, so as to prevent unnecessary damage to sound wood. The use of heavy pointed bars for probing and heavy tools for cutting should be avoided as these may open deep wounds in the pole and thus greatly shorten its life.

2. INSPECTION PROCEDURES

2.1 Inspection procedures will depend largely on the species of the pole and the kind of treatment. In general, however, the inspection of a pole should include:

(a) Visual examination from roof to ground.
(b) Sounding to locate internal decay.
(c) Examination below the ground line where there is reason to suspect decay or other serious defect in that section of the pole.
(d) Boring where internal decay is suspected.
(e) Exploration of decay or other serious defect found on pole, to determine extent of damage.

2.2 Examination Above Ground--Visual. Each pole should be examined visually on all sides from roof to ground, for any defect or condition which may make the pole unserviceable. The pole surfaces should be observed carefully for evidence of decay or insect attack, and for defects, such as hollow knots, woodpecker holes, splits, cracks, and splintered or crushed wood. When necessary, poles should be climbed to inspect defects that may be serious but cannot be examined satisfactorily from the ground.

2.3 Sounding. Each pole should be tested for internal decay by tapping or striking the pole with a broad-headed hammer or other tool which will not damage the timber. The pole should be sounded around its circumference, from the ground to a point preferably as high as can be reached conveniently.

2.4 Examination Below Ground Line. Poles should be examined below the ground line in all cases where there is reason to suspect decay or other faulty conditions in that section of the pole. In this inspection, sufficient earth should be removed from around the pole to permit examination at the point where decay will probably be maximum. Maximum decay will usually occur at a depth of 4 to 12 in. but in dry, porous soils it may be at a greater depth, and in wet locations it may be at or above the ground line. The excavated portion of the pole should be examined visually and tested by careful sounding for evidence of decay or insect attack. Particular care should be taken to examine conditions at deep checks, as decay may originate at these openings into the pole.

2.5 Boring. One or more borings should be taken at each point on a pole where visual examination, sound test, or other evidence indicates probable interior decay. Ordinarily, the exploratory boring should be directed, as nearly as practicable, in a horizontal plane and towards the center of the pole.

2.6 All holes bored in poles for inspection purposes should be fitted with tight-fitting wooden plugs, except in cases where poles are recommended for replacement. The plugs should be of creosoted wood, or of untreated durable heartwood approved by the pole owner.

2.7 Exploring Defects. If decay or other defect is found which may make the pole unserviceable in the above or below-ground section, the defect should be explored to determine its extent and probable effect on the serviceability of the pole. External decay pockets should be explored by prodding or by careful removal of wholly decayed wood, and internal decay should be explored by sounding and boring to determine the extent of unsound wood.

2.8 Removing Decayed Wood. Completely decayed wood may be removed from poles to determine the limits of decay but partially decayed wood, that is, wood which is decaying but still retains a considerable amount of its original strength, should be allowed to remain. Sound wood should not be chopped away or otherwise mutilated, to reveal the extent of decay.

2.9 Woodpecker and Knot Holes. Where decay is suspected in woodpecker holes or hollow knots, the affected section should be examined by sounding and by boring or prodding. Borings, if taken, should include one directly below the center of the damage.

2.10 Inspection Precautions. A break in the protective layer of treated wood around a pole may shorten the life of the pole materially. Care should be taken in excavating, backfilling and other inspection operations, to avoid needless injury to the treated wood. These precautions are particularly desirable where the pole has a thin shell of treated wood.

3. SPECIAL PROCEDURES

3.1 The comments which follow should be considered as broad generalizations and the procedures suggested should be changed to accord with local experience.

3.2 Pressure-Treated Creosoted Poles. Wood that has been impregnated with creosote can be expected to show high resistance to decay and insect attack. As a general rule, therefore, decay in poles that have been pressure treated with creosote will start in untreated wood underneath the exterior treated layer. This decay may be fully enclosed, or partially exposed at season checks. It may occur in any section of the pole but will be found most frequently in the vicinity of the ground line. If untreated sapwood is present in the pole, the decay may progress fairly extensively through this before damaging heartwood. The inspection of pressure-treated creosoted poles should, therefore, be directed largely to detecting the presence and extent of decay and untreated sapwood that may exist underneath the treated surface.

3.3 Non-Pressure-Treated Creosoted Poles. Where poles have been treated with creosote by a non-pressure method (hot bath followed by a cold bath), decay in the treated section will usually start and progress as indicated for pressure-treated poles. In the treated section of these poles, inspection should be directed largely to detecting the presence and extent of wholly or partially concealed decay. In the untreated top section, inspection should include examination for sapwood decay.

3.4 Owing to deeper and more uniform penetration, cedar poles that have been incised prior to treatment will generally show stronger resistance to decay in the ground section than non-incised cedars. For this reason, inspection below the ground line may usually be omitted on incised cedars for several years after this inspection operation is desirable for non-incised poles.

3.5 Insect Damage. Dirt-filled checks around the base of a pole, or an unusual sound or loss in resiliency of the wood when sounding around the pole, may be due to termites. Particles of wood resembling sawdust at the base or in checks of a pole, may be evidence of carpenter ants. Small openings into the pole may indicate the presence of wood-destroying insects or their larvae. Where these indications of insect infestation are found, special effort should be made to ascertain if damage has occurred.

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