WOOD POLE CONFERENCE

sponsored by

School of Forestry, Oregon State College
Forest Research Center, Corvallis, Oregon
General Extension Division, Oregon State System of Higher Education

Campus
Oregon State College
Corvallis, Oregon
March 21 and 22, 1960
WOOD POLE CONFERENCE

PURPOSE

1—To provide information on the properties of wood, its protection, and on its use as poles and crossarms to aid managerial personnel of utilities in their decisions on the installation and maintenance of wood pole lines.

2—To promote open discussion on all aspects of wood pole line structures, their advantages and their problems in order to explore fields of research to satisfy future needs.

CONFERENCE PARTICIPANTS

BLEW, J. O., JR., U. S. Forest Products Laboratory, Madison 5, Wisconsin
BODE, A. T., Bode Inspection Service, 451 A Avenue, Oswego, Oregon
EASTMAN, J. E., Valentine Clark Corp., 2516 Doswell Avenue, St. Paul 8, Minnesota
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HAND, FLOYD, Bonneville Power Administration, P. O. Box 491, Vancouver, Washington
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MILLER, T. R., Joslyn Manufacturing and Supply Co., P. O. Box 2560, Portland 3, Oregon
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STUBKJAER, L. J., Consumers Power, Inc., Corvallis, Oregon
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WOOD POLE CONFERENCE

Room 105 Memorial Union Building
Oregon State College Campus
Corvallis, Oregon

MONDAY MORNING SESSION - MARCH 21, 1960

8:30 A.M. Opening Session, Don Low, Chairman
"Address of Welcome" - A. L. Strand, President, Oregon State College, Corvallis, Oregon

9:00 A.M. Introduction of Keynote Speaker by Don Low
Keynote Address - "Why Have a Wood Pole Conference?"
Gus Norwood, Executive Secretary, Northwest Public Power Association, Inc., Vancouver, Washington

9:45 A.M. Announcements - Adjournment for COFFEE BREAK

LATE MORNING SESSION

Larry Palmer, Chairman

10:00 A.M. "Structure and Properties of Wood" - W. I. West, Head Forest Products Department, Oregon State College, Corvallis, Oregon

11:00 A.M. "Deterioration of Wood and Its Prevention" - R. D. Graham, In charge of Wood Preservation, Forest Research Center, Corvallis, Oregon

12:00 Noon Announcements - Adjournment for LUNCH

Memorial Union Tea Room
WOOD POLE CONFERENCE

MONDAY AFTERNOON SESSION - MARCH 21, 1960

Larry Palmer, Chairman

1:30 P.M. "Thermal Process" - J. E. Eastman, Valentine Clark Corp., 2516 Doswell Avenue, St. Paul 8, Minnesota

2:00 P.M. "Pressure Process" - J. E. Ziegler, McCormick and Baxter Creosoting Co., Portland 8, Oregon

2:30 P.M. Question and answer period on "Thermal Process" and "Pressure Process" - Panel Members: J. E. Eastman and J. E. Ziegler

2:45 P.M. "Production of Treated Crossarms" - T. R. Miller, Manager, Joslyn Manufacturing and Supply Co., Portland, Oregon

3:45 P.M. Announcements - Adjournment for COFFEE BREAK

4:00 P.M. "Production of Treated Poles" - M. R. Knudson, Director of Research, J. Neils Lumber Co., Libby, Montana

5:00 P.M. Announcements - Adjournment of Afternoon Session

MONDAY EVENING SESSION

Jack Goodman, Chairman

6:00 P.M.-6:45 P.M. Social Hour - Benton Hotel

7:00 P.M. Dinner - Benton Hotel

8:00 P.M. Open House - Forest Research Center, R. D. Graham Exhibit Chairman, L. J. Stubkjaer
WOOD POLE CONFERENCE

TUESDAY MORNING SESSION - MARCH 22, 1960

John H. Rixse, Jr., Chairman

8:30 A.M.  "Inspection of Treated Wood Products for Acceptance" -
A. T. Bode, Manager, Bode Inspection Service,
Oswego, Oregon

Question and answer period on preceding topic

10:00 A.M.  Announcements - Adjournment for COFFEE BREAK

10:15 A.M.  "Inspection Program for Wood Structures" - A. H. Hearn,
American Telephone and Telegraph Company,
New York 7, New York

Question and answer period on preceding topic

12:00 Noon  Announcements - Adjournment for LUNCH

Memorial Union Tea Room
WOOD POLE CONFERENCE

TUESDAY AFTERNOON SESSION - MARCH 22, 1960

John H. Rixse, Jr., Chairman

1:30 P.M. "Maintenance Program for Wood Structures" - W. J. O'Neal, Timber Specialist, Electrical Engineering Division, Rural Electrification Administration, Washington 25, D.C.

Question and answer period on preceding topic

3:00 P.M. "Evaluation of Groundline Treatments" - J. O. Blew, Jr., U. S. Forest Products Laboratory, Madison, Wisconsin

3:30 P.M. Announcements - Adjournment for COFFEE BREAK

3:45 P.M. "Evaluation of Top Treatments" - O. Floyd Hand, Chemist, Bonneville Power Administration, Vancouver, Washington

4:15 P.M. Question and answer period on "Evaluation of Groundline and Top Treatments" - Panel Members: J. O. Blew, Jr. and O. Floyd Hand

4:45 P.M. Conference Summary - A. D. Fragall, Superintendent, Outside Division, Portland General Electric Co., Portland, Oregon

5:00 P.M. Announcements - Adjournment of Conference
PLANNING COMMITTEE

DON LOW, Chairman - Department of State-Wide Services, General Extension Division

LOUIS P. GROWNEY, Pacific Power and Light

GUS NORWOOD, Northwest Public Power Association

T. E. LEAF, Pacific Telephone and Telegraph

JACK GOODMAN, Department of Visual Instruction, General Extension Division

BEN LITTLE, Consumers Power, Inc.

ROBERT D. GRAHAM, Forest Research Center, Corvallis

W. I. WEST, School of Forestry, Oregon State College

L. J. STUBKJAER, Consumers Power, Inc.

DON MILLER, Forest Research Center

LARRY PALMER, Pacific Power and Light

JOHN H. RIXSE, JR., Rural Electrification Administration, Washington, D. C.
WHY HAVE A WOOD POLE CONFERENCE?

Keynote address to the Wood Pole Conference, Oregon State College, Corvallis, Oregon, March 21, 1960, by Gus Norwood, Executive Secretary, Northwest Public Power Association

We owe a debt of gratitude to the people and organizations responsible for initiating, planning and promoting this Wood Pole Conference.

We extend our appreciation to the School of Forestry of Oregon State College; to the Forest Research Center, Corvallis, Oregon; and to the General Extension Division of the Oregon State System of Higher Education.

Particular praise is due Don Low, Chairman of the Planning Committee and representing the General Extension Division; to Bob Graham of the Forest Research Center and to John Rixse of the Rural Electrification Administration. Every member of the Planning Committee worked and deserves credit.

Before we adjourn I know we will likewise be indebted to the experts who will put on the actual conference.

A Bridge Between Knowledge and Practice

My function as keynote speaker is to start the building of a bridge between the experts and us laymen. We need a bridge of communication between the technical speakers and the users of wood poles. At our end of the bridge are the problems. At the other end of the bridge we hope is knowledge and the solutions to our problems.
When I wrote Bob Graham suggesting the idea of a bridge between the technical speakers and the practical needs of the utilities, he came back with an admonition that this bridge be constructed of well-treated wood.

Our wood pole conference here in Corvallis is patterned after a similar institute held at the University of Wisconsin June 15, 16 and 17, 1959. One report on the Wisconsin institute makes it clear that more conferences should be held for the exchange of information in the years to come. Much research is needed. After we apply all the available existing knowledge on our utility systems, we must come back, perhaps in two or three years, to re-examine the state of our knowledge and of our practice.

This bridge of communications must be a two-way affair. Furthermore, we need more communications about our failures and problems than we do about our successes.

Now For Some Highlights

1. Boy, Oh Boy, is this a big subject.
2. We should plan now for future wood pole conferences, definitely.
3. The U.S. alone has between 100 and 200 million poles in utility use worth a replacement cost of 25 to 30 billion dollars. This is big business.
4. We have the technical knowledge and ability now to double pole life to about 50 years.
5. Replacement cost of poles in use is about five times the original construction cost. Costs will increase.
6. More research is needed.
The Cedars of Lebanon

Before launching into a discussion of the complex organic nature, the economics, and even the morality of the wise use of wood poles for utilities, I would like to say a few words about the historic and cultural importance of wood poles in the evolution of civilization.

As man evolved from the Stone Age, from cave man existence, he learned to use wood poles to build stockades to capture and domesticate animals. He built the Swiss lake dwellings on wood poles. He used poles for his tents. He used wood poles for the Indian travois. He used poles to support the galleries for mining. Early temples, even the first Parthenon of Athens, were built of wood poles. The totem pole, the flag pole, the ancient forerunners of the Maypole ceremonies reveal the wood pole as a basic art form superceded later by poles of stone, the stone column.

The Cedars of Lebanon were famous throughout the Mediterranean world because man found so many uses for wood poles. Cedar poles were a prized article of commerce - and still are today.

Today, in the United States alone, we use between 100 and 200 million wood poles for the electric and communications industries. Surely we can appreciate the importance of wood poles in modern civilization.

Aesthetics of Wood Poles

A wood pole is highly functional and useful. It is truly an art form if wisely and appropriately used.

I am keenly aware of some public pressure for placing all utility
wires underground. This pressure must be understood and we must not overlook the blame, and we must acknowledge and accept some responsibility for misusing wood poles as ugly obstructions in front of view windows. We must learn to place and use wood poles to achieve maximum function without detracting from the beauty that we all seek in our environment.

Our Wood Pole Industry

The furnishing of wood poles is a basic bread and butter industry of the Pacific Northwest. This means jobs, industry, commerce, more income, and a better standard of living for Northwest residents.

I have seen estimates which indicate that about one half of the total annual income of Oregon is derived directly or indirectly from forest products. With half of the land area of Oregon in timberland, it is to be expected that the forestry industry will always be a significant base for the Oregon economy.

It is a competitive industry with many substitutes for wood under discussion, concrete poles, steel towers, plastic poles, aluminum or steel truss crossarms, steel or concrete stubs.

But the greatest competition is from Southern Yellow Pine. Freight rates, for example, favor the South and hurt the West. We must get in there and pitch for the business for our area.

Then, too, the pole industry has a black eye because of what I call the "disastrous period" of 1946 to 1950 when so many unsatisfactory poles were put in service. We must erase and explain away this black page of wood pole history.
At any rate, this is a two-way street and we in the Pacific Northwest must take a proprietary interest, not only as users of poles but also as a producing region.

**Part of The Conservation Battle**

When we add to the life expectancy of a wood pole we are conservationists. The ideal or test of conservation is to make wise use of our natural resources for the greatest good of the largest number of people for the longest time.

This is the motto of the Forest Service.

The recently published Forest Service report on the Forest Review predicts that by the year 2,000 we must triple our annual output of forest products. One way of achieving this goal is to stretch out the useful life period of the wood we use. Thereby we can help make our nation stronger and more efficient. This helps to meet the ideal of Conservation.

**Life Expectancy of Wood Poles**

Wood is frail. It is subject to decay. It is an organic substance, highly variable and complex. Only in the past century have we significantly learned how to lengthen the life of a wood pole.

When a baby was born in the United States in the year 1900 the life expectancy was only 47 years. Today, due to advances in medical science, it is 70 years, a gain of 23 years.

The life expectancy of wood poles, due to advances in the wood preserving science, is increasing and can be greatly increased. We are learning much about the fungi and insects which destroy wood. We have conducted much research on the strength characteristics of wood.
The Pacific Northwest has a wide range of climatic conditions, hot and cold, wet and dry, heavy and light ice loading, high wind areas, lightning areas and a variety of fungi and insect enemies of wood poles. We have a lot to learn.

We need to develop and use wood pole mortality tables just as insurance companies use mortality tables. The proceedings of the American Wood-Preserver's Association include much data on service records on treated poles. The Bell System and REA, involving about 25,000,000 poles each, are key sources of information as is the Forest Service. Extensive bibliographies and a large technical literature are available as you all know.

What is normal mortality for carefully selected, properly seasoned, incised, treated, inspected and properly handled poles, with on the job treatment of scars, drill holes and gain surfaces and with proper tamping?

Then how can we revise this mortality table by cyclical retreatment?

Fifty Years Is A Reasonable Goal

The article by F. W. Smith of Virginia in the September 7, 1959 issue of Electrical World concludes that retreatment can increase the 30-year life expectancy by 50 to 100%. His goal is 45 to 60 years.

Bob Graham urges that we look forward to a service life of 50 years. Let's think in terms of 50 years service life and let's work for this goal.
The State Of Wood Pole Knowledge

The more you get into this subject the more you feel you are dealing with an iceberg where the known facts are the little part that is visible above the water while the vast volume of the unknown is underneath the surface.

We all know of cases where twin poles, apparently identical and under apparently identical conditions, will have 20 years difference in pole life. Why? We must get the answers.

In preparing for this wood pole conference I mailed a questionnaire November 13, 1959 to consumer owned electric systems of Alaska, Montana, Idaho, Oregon and Washington and to some pole specialists. There were twenty six replies, making up a document twenty eight pages long, single spaced.

Our questionnaire of last November brought in many questions. Apparently we have to place more research on butt rot and top rot. How can we improve inspection for more assurance against incipient heart rot in the new pole? What can we do about cracks and checks?

What about hardness of certain treated poles under very cold weather conditions as this affects climbing conditions?

How can we classify our great number of climatic conditions and tailor our pole program accordingly? Certainly we must shift gears when we cross the Cascades.

Our inspection of standing poles must be improved. Obviously, the hammer and probe method is too superficial. Even the increment borer is not as satisfactory as the brace and bit in the hands of an experienced man.
Mr. George Rivard of Western Utilities Maintenance Company is a strong advocate of supplemental deep drilling to the center of the pole about four feet below ground line into the heart of the pole butt. If a cone of heart rot is located, drastic action is necessary. The usual groundline inspection by boring may take care of 90% of the cases, but for the remaining 10% the deep drilling may pay dividends. Butt rot is a significant problem. How should we treat butt rot?

What about helicopter patrol for inspection of pole tops? Chief Engineer Fred Lehman of Clark County PUD happened to be using a helicopter for a right-of-way survey and then, for the fun of it, the pilot showed him how to patrol line by helicopter. Well, it wasn't fun for Fred. He got a genuine birdseye view of his pole tops. Top rot is a significant problem. How should we treat top rot?

On the other hand, Clark County PUD has a butt treated cedar transmission line with pole tops not only treated but the roof capped with sheet aluminum. The result has been excellent. Should we cap more poles?

What about the relative merits of the various treating methods and the different chemicals? Is a mixture of penta and creosote the best approach? Some companies have shifted from 8 pounds to 10 and 12 pounds retention.

How much sap wood is enough? Should we go to deep incising into the heart wood?

What about better moisture control before treatment?

Should poles be bandaged at the ground line when set?
Wind storms and silver thaws and heavy icing are the ultimate forms of inspection. What are the lessons from storm damage as to dead ending, guying, anchors, corner poles, use of short arms, twisting of angle poles? All these affect pole life. How do you deal with moss?

What kind of wood is bad for certain areas and why? How do you deal with different soils? What precautions are necessary in irrigated areas?

More policing and better specifications are needed. It is alleged that some inspectors have left their inspection hammer with the pole supplier. This defeats the idea of inspection and damages the reputation of the industry.

Utilities can help by improved record systems, stamping poles, putting tags on poles upon retreatment and by utilizing organizations such as the Forest Research Center or the Forest Products Laboratory where information can be pooled.

We should also be open-minded for new ideas and approaches.

Europeans have long experimented with the idea of injecting a poison into a live tree, letting the sap circulate the poison for thorough saturation, for killing the tree and for actually shedding the bark, then after the tree has become seasoned on the stump, cut the tree and use it as a ready treated utility pole.

When I mentioned this idea to my wife, she wondered if we couldn't grow some of these poles in the right place to begin with and thus eliminate transportation and digging holes.

I recommend that we pool our talents and step-up our
communications with the universities and try to lift the standards of performance of wood poles. Especially, we must flag the areas where new or more research is wanted.

Cost of Replacing Wood Poles

My awareness of the high cost of replacing wood poles dates back about ten years when Seattle City Light Superintendent Gene Hoffman told me they had just replaced one 105 foot pole in the downtown area with occupancy by eight utilities at a cost of $1800.

Oscar Blew of the Forest Products Laboratory suggests that the cost of replacement may amount to ten times the cost of the original pole (Paper before APPA E&O Section February 14, 1958).

A survey covering ten Pacific Northwest consumer owned electric systems was reported to the Engineering and Operations Section of the Northwest Public Power Association March 26, 1958 by Ken Lien of Cowlitz PUD and Paul Ousley of Dan Kamphausen Company.

The survey showed the sharp increase in the cost of replacing poles. In 1936-39 the 35 or 40 foot pole cost from $26 to $215 to replace, averaging $65.

In 1940-45 the cost range was $50 to $270, averaging about $100. For 1957 the cost range was $95 to $312, averaging $150 per pole.

Obviously, we should get more cost data in the years to come.

One BPA expert suggests that replacement cost is about five times the original cost of the pole installed.

The Electrical World article of Sept. 7, 1959, based on Virginia experience, uses $100 for original cost and $300 for replacement cost at current prices.
The American Gas and Electric article in the October 15, 1956 issue of the Electric Light and Power grossly understates the economics by comparing retreatment costs to original pole investment cost. Even under these extremely conservative assumptions, the retreatment was fully justified. If the comparison had been made with replacement cost, then the benefit-to-cost ratio might be five times as great.

The Iowa Public Service Company article in the June 1958 issue of Floodlight uses an estimated replacement cost of $125 per pole and then goes on to justify a $16 per pole treatment both at groundline and for the entire pole above ground as paying off if three years is added to pole life. They estimate actual life is extended eight to fifteen years. This is a B/C ratio of four to one.

Some useful data on pole replacement costs has been sent me by John Rixse of REA who is a member of our Planning Committee.

REA borrowers are operating about 1,500,000 miles of line. The poles represent from 25 to 30% of the $3 billion of loans approved.

In December 1959 REA issued a pole replacement cost study based on reports covering seventy three REA borrowers.

For poles 35 foot and shorter forty three borrowers reported 1696 replacements at an average cost of $57. Of this group, 81.7% of the pole replacements ranged from $28.81 to $85.85.

For poles 36 to 49 feet twenty borrowers reported 310 poles with average replacement cost of $97.84 with 88.7% ranging between $56.55 and $154.39. Data are for both energized and de-energized lines.

Twelve borrowers broke down the replacement costs into three
categories: Material 36% (19% to 55%); Labor 36% (22% to 48%); and Miscellaneous 28% (19% to 38%).

Highest cost reported for a pole replacement was $1,035.

The significant figures in the REA data are the average costs of pole replacement of $57 for poles 35 foot and under and $98 for poles 36 foot to 49 foot.

Mr. Rixse also sends some 1958-59 data on the bids made for pole groundline inspection and treatment. To inspect and apply treatment the unit bids ran $3.75 to $6.34 with most bids at $4.00 per pole. To excavate but not treat the bids ran $2.25 to $3.00.

The Ken Lien-Paul Ousley paper makes the case for retreatment being worth from $10 to $15 per year of pole life added - usually 10 years. Two retreatments should add 20 years to pole life at a cost of 60 cents to $1.25 per year. Thus the B/C ratio is about twelve to one in favor of retreatment on a 10 year cycle. The first cycle should start in the 12th to the 30th year, usually 12-14 years west of the Cascades and 15 to 20 years east of the Cascades for butt treated cedar.

Summarizing on the economics of wood poles. Apparently cost for most poles runs $100 to $150 per pole. An added year of pole life is worth about $10. Cost of treatment is $6 to $12 and can add ten years to pole life. The benefit-to-cost ratio is about ten to one. If we get fifty year life we double our pole life, our utilities can provide better service at lower cost, and the Nation saves billions of dollars.

The Morality of Wood Pole Longevity

It was said of the master craftsmen who chiseled the stone images of the Parthenon of ancient Athens that even when their work was for
some virtually invisible and inaccessible nook high in the building, that they nonetheless exercised equal care and exacting devotion to their work of art. They felt that what human eyes would not see the gods would see and would judge.

I once observed the firing of a utility manager over the subject of wood poles. This manager explained why he was setting untreated wood poles for his utility. He had four years to go before retirement. He said the poles would last long enough, at least as long as he was with the utility. He was promptly fired.

The immorality of using untreated wood poles is apparent to anyone. But what about the relative morality of programs which achieve average pole lives of 20, 25, 30, 35, 40, 45 or even 50 years? What will be your score on the poles you set next year?

Is it too much to suggest that perhaps someday we will be able to place a score card on our wood pole programs and give an A grade for achieving pole life of 45 to 50 years, a B grade for 40 to 45 years and a mere C for 35 to 40 years.

Possibly the little extra things we do today will be factors which will encourage or facilitate the achievement of longer pole life in the next generation. Perhaps we will no longer be alive to see whether the full pole life is achieved. We hope the next generation will not look on our handiwork and think of us as a bunch of boomers. Let us take the long range view. Let's look to the future.

Many cathedrals of Europe took over a hundred years to build and have withstood the ravages of time for many centuries. While wood may
never compete with stone for durability, our attitude and our effort can be directed toward achieving the best that is possible.

May I close this keynote address by returning to the symbol of the bridge. Through our joint, cooperative efforts we can all help build a better bridge between knowledge and practice. One of my favorite poems is entitled "The Bridge Builder". Like the old man in this poem we too can strive to do something a little better for those of the next generation who will follow us. The poem reads:

The Bridge Builder
An old man, going a lone highway
Came at the evening, cold and grey,
To a chasm, vast and deep and wide,
Through which was flowing a sullen tide,
The old man crossed in the twilight dim---
That sullen stream had no fears for him;
But he turned, when he reached the other side,
And built a bridge to span the tide.

"Old man," said a fellow pilgrim near,
"You are wasting strength in building here,
Your journey will end with the ending day;
You never again must pass this way.
You have crossed the chasm, deep and wide,
Why build you the bridge at the eventide?"

The builder lifted his old grey head.
"Good friend, in the path I have come," he said
"There followeth after me today
A youth whose feet must pass this way.
This chasm that has been naught to me
To that fair-haired youth may a pitfall be.
He, too, must cross in the twilight dim;
Good friend, I am building the bridge for him."
-- Will Allen Dromgoole

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STRUCTURE OF WOOD*

by

W. I. West

Head, Department of Forest Products

March 1960

School of Forestry
Oregon State College

STRUCTURE OF WOOD

by

W. I. West

INTRODUCTION

The wood pole has served the communications and power industries since their inception. About 7 million new poles are used annually, both for replacements and for extension of these services. Millions of cubic feet of crossarms, bracing, and other wood items are required for completed installations. Seventy-five per cent or more of the poles purchased annually are treated with preservatives prior to installation. The treatment of poles in place is increasing in importance as service age increases.

Many of the problems arising during preparation, reduction, drying, treating, manufacture and service life of wood products may be related directly to wood's structure (anatomy) and wood-moisture relationships. Difficulties encountered with wood can be reduced greatly through an understanding of its structure, properties and natural durability. This paper concerns primarily the conifers (trees with needle or scale-like leaves), popularly called softwoods.
STRUCTURE OF WOOD

Wood is a complex cellular material that has reached a high state of development. The cell walls are composed of cellulose and lignin upon which have been deposited residues of the physiological processes of the once living cells. This residue is referred to as "extractives". The type of cell, their size, shape, arrangement, wall thickness, and wall openings vary with species. Considerable variation occurs within a species and even within a tree as a result of heredity and growing conditions. Although softwoods are similar in their cellulose (60%) and lignin (30%) content, there is wide variation in amount and nature of their extractives.

Gross structure

Examination of a section of a softwood log (Figure 1) reveals the central wood portion surrounded by bark. 'Outer bark' serves to protect inner tissues from mechanical injury and desiccation; 'inner bark' conducts food manufactured in the leaves and dissolved in water to living cells in the cambium and outer part of the wood cylinder. If bark is left attached to felled timber it often promotes attack by fungi, stain, and insects.

The wood portion in most species is differentiated readily into 'sapwood' and 'heartwood' regions. Both are constructed basically of long, slender, fiber-like cells (tracheids, hereafter called fibers) oriented parallel to the longitudinal axis of the tree. Narrow bands of tissue, denoted as 'wood rays', extend through the inner bark towards the pith perpendicular to the tree's axis. Wood rays serve to conduct manufactured food solutions horizontally from the inner bark to living cells in the outer sapwood. Rays are numerous and represent planes of weakness which
contribute to surface checking as the barked pole, or flat-grained lumber, dries in seasoning.

The cambium is a uni-cellular layer of tissue immediately between inner bark and sapwood. During the growing season of each year, in our temperate climate, cambium adds to outer sapwood and inner bark through cell division. Increase in diameter growth is accomplished through production of new longitudinal wood fibers, new wood rays, and continuation of those rays already present. Not all rays originate at the pith center; as tree diameter increases rays are added concomitant with fibers to maintain a uniform system for distribution of food. Once begun, rays continue to develop throughout the life of the tree (unless cambium is injured) and function as conductive and food-storage tissue; storage of food is necessary to hold the tree over the dormant period of the year.

Fibers in the outer sapwood are physiologically active in conducting water from the ground to leaves in the crown for use in manufacture of food and its distribution. Sapwood universally is light in color, is characterized by high initial moisture content (Table 1), is not resistant to attack by insects and fungi, but is permeable to liquids and can be more readily seasoned or penetrated with preservatives than can heartwood of a species. As circumference increases with succeeding growing seasons, the inner sapwood undergoes a transition to heartwood, conductivity of fibers and rays decreases, extractives are deposited, and slight anatomical changes take place.

Heartwood ranges from a very light color through shades of brown, to deep reddish-purple, depending upon species as influenced by the nature and quantity of extractives. These include many types of organic compounds
such as tannins, dyestuffs, gums, resins, and other substances soluble and insoluble in neutral solvents (water, alcohol, and benzene). Many of these substances are toxic in character and are present in sufficient quantity in some species to cause the heartwood to be recognized for its high durability; i.e., cedars, juniper and redwood. Hemlock and true firs (sometimes called 'sapwood trees') show little or no contrast in color between sapwood and heartwood because of the small amount of extractives present; heartwood of these species is classed as nondurable. Color is not always an indicator of heartwood durability; for example, Port-Orford-cedar and Alaska-cedar have light-colored, but durable, heartwood. Light-colored western redcedar heartwood is believed to include a higher concentration of toxic extractives than will the dark wood present in many old-growth trees*. Although extractives contribute to


heartwood durability, they are believed to play a part in reducing its permeability to liquids. Whether sapwood is higher, equal to, or lower in strength than heartwood is related to influencing factors to be discussed. When a tree is felled, sapwood initially may be of greater weight than heartwood because of its high moisture content; this may or may not hold true when wood from both regions is dried to comparable moisture content.

To differentiate sap- and heartwood where distinction is not obvious, pH indicators may be used. A 0.04 per cent solution of bromcresol green in 50 per cent ethanol has been found useful with Douglas-fir. The
indicator solution is adjusted to a pH of 7.0 with dilute sodium hydroxide. Sapwood remains green, while heartwood turns a pale orange to yellow when indicator is applied by atomizer, or flowed over the surface.

One item concerning the cambium should be noted. Often poles and piling that have been hand-peeled in the spring and stacked for air drying may be difficult to treat with preservatives. This may be associated with collapse of newly-formed fibers to form a surface glaze. Mechanical debarkers usually eliminate this obstacle.

The new band of fibers added to the tree's wood cylinder during a growing season is called an annual ring. This layer is a continuous covering of wood in branch, stem and roots as long as all members are alive. Upon close scrutiny, each annual ring can be seen to include two regions—an inner, light-colored zone and an outer, dark-colored zone—referred to respectively as springwood and summerwood. Color differentiation lies in the springwood being porous to facilitate water movement and low in density—while summerwood is high in density and less porous as its primary purpose is strength, with conduction of minor importance. The period of annual ring development, which extends from early spring to some time in the fall depending upon climate, is followed by a dormant period.

The pith (Figure 1) is of no major importance other than to serve as a specialized region for food storage directly behind terminal buds of the elongating stem and branches. However, the first few annual rings surrounding the pith are likely to be different in structure when compared to subsequent growth. This region of early growth is referred to as juvenile wood and, if large in area, can exhibit undesirable properties. Depicted in Figure 1 are planes (A, B, C) and directions (D, E, F) employed in studying or describing wood.
Microscopic anatomy

The anatomical structure of a typical conifer is illustrated in Figure 2. Fibers comprise 90-93 per cent of the wood volume; the remaining largely is ray tissue. Wood fibers are organized in orderly radial rows with ray tissue scattered here and there to form an interconnecting system cemented together with lignin. Visible cell walls are basically cellulose, which consists of long-chain molecules oriented more or less parallel to the long axes of the fibers.

The small openings in ray cells and doughnut-like structures in the radial walls of fibers are porous spots (pits) to facilitate moisture movement. A tree moves several barrels of water daily from the ground to the crown via the sapwood, especially during the growing season. When inner sapwood undergoes transition to heartwood, a slight structural change develops in the pit membrane to block-off and reduce moisture movement. Infiltration of extractives also assists this blocking to reduce permeability of heartwood in most softwood species. Extractives which line cavities and penetrate cell walls further affect permeability; heaviest extractive concentration usually occurs in ray cell cavities.

Springwood is characterized by fibers with thin cell walls and large cavities; the zone is porous, light in color, soft, and weak in strength. In the summerwood, fibers have decreased in radial dimension and have heavier cell walls and smaller cavities to form a band of tissue parallel with the annual ring (tangentially) which is darker in color, harder and stronger than springwood. The tangential dimension in a given radial row of fibers remains fairly constant within a growth layer. In normal growth, the transition from springwood may be more or less abrupt (Douglas-fir, western larch, lodgepole and ponderosa pine), or may be gradual (spruce, hemlock, white pine and sugar pine). Variations occur in fiber diameter
and length, fiber shape (rectangular or hexagonal), ratio of summerwood to springwood in respect to ring width, and ratio of cell-wall thickness to cavity size. These variations are reflected in average values for specific gravity for different species as indicated in Table 1. Specific gravity usually is expressed as weight of oven-dry wood for a unit volume of wood at a specified moisture content. It is a valuable criteria of wood strength, shrinkage, and other properties.

Wood fibers are slender, closed cells tapering at both ends. They are organized to overlap cells above and below by one-quarter to one-third their length, with pits concentrated in this area. Is there any wonder wood exhibits a high strength-weight ratio when it is formed from minute cylinders which are among the strongest of geometric shapes? The length of these fibers is about 100 times their tangential diameter. Average fiber lengths vary from 3 to 5 millimeters. If a Douglas-fir fiber were blown up to permit a man to walk its length, he would be in a tube about two blocks long and pit openings would appear as portholes about one foot in diameter. A one-inch cube of Sitka spruce has been said to contain about 10 million fibers.

Scattered longitudinal openings called resin canals are found in pine, spruce, larch and Douglas-fir as normal features. They may appear in other woods in localized areas in response to injury. Such canals are lined with specialized resin-secreting cells, which add to the extractive content. They join with horizontal canals in some wood rays to form a canal system.

**Growth-strength relationships**

Strength values in bending (modulus of rupture) in relation to specific gravity for western pole species are shown in Table 1. There is a decided
contrast between western redcedar and larch, or Douglas-fir, in both values. What is the variation to be expected within a species? Variations encountered in a recent study of young-growth Douglas-fir are presented in Figure 3. Similar relationships are evident in other species.

As has been mentioned, specific gravity is a measure of oven-dry wood substance (including extractives) as determined by characteristics of cells of springwood and summerwood. Rate of growth (rings to an inch) and percentage of summerwood are accepted visual indicators of specific gravity. The following statements summarize growth-strength relationships in softwoods:

1. Juvenile wood in the immediate vicinity of the pith often includes annual rings of fast growth, and summerwood is not clearly defined; usually such wood is low in specific gravity.
2. At any given height in a tree, specific gravity increases with age, assuming a uniform decrease in width of annual ring, as long as springwood volume decreases and summerwood remains relatively constant in succeeding rings. Local environmental fluctuations (rainfall or release from competition through death or removal of adjacent trees) may alter ring width-summerwood ratios at any age.
3. Specific gravity decreases with height in a tree. Heaviest wood is near the base.
4. Occasionally wood appearing to have suitable rate of ring growth and percentage of summerwood is below normal in specific gravity because fibers exhibit a low ratio of cell wall to cavity. A rapid, practical means of non-destructive testing is needed for structural wood materials. Increment cores taken from questioned items may furnish many quick, indicative answers.
5. Wide ring development, with summerwood apparently comprising 50 per cent or more of ring width, should be examined carefully for presence of compression wood. Compression wood is formed most commonly in softwood trees growing on steep slopes, to counteract gravity and maintain an upright position. Ends of logs show the pith to be off-center with eccentric, wide rings on one side (downhill side of the tree). Summerwood is abnormally high in percentage and lacks the luster of normal wood. Although often heavier than average wood of a species, compression wood is low in strength and exhibits abnormal shrinkage.

6. With decrease in ring width to 30-40 rings to an inch or more in a given tree, specific gravity may become erratic or decline as compared with earlier material with 6-20 rings to an inch material.

7. Slope of spiral grain increases in a tree with age. In lumber and poles, spiral grain and other fiber distortions (knots) are controlled through limiting specifications.

8. The terms yellow fir and red fir* are used often in describing wood from Douglas-fir. Yellow fir customarily is described as "narrow-ringed, fine-grained, quite uniform-textured, moderately soft and easily worked, and yellow or pale reddish-yellow." The outer portion of a large, old-growth log would be representative. Red fir is "characterized by wider rings with a wide band of dense, reddish summerwood which is responsible for its
orange-red or deep-red color; it is coarser grained and more uneven-textured than yellow fir, also stronger and more refractory under tools." Heartwood of young-growth trees, or central portion of old-growth, would be considered typical.

9. Except for outermost sapwood (new cells), wood is comprised of dead tissues. As long as a dead tree is sound, free of decay, stain, insects and serious drying degrade, the wood is comparable in quality to wood from living trees at the same moisture content.

Wood-moisture relationships

The woody portion of a living tree constantly is fluxed with water, which is confined within the cell walls as 'bound' water and to the cell cavities as 'free' water. The water content of sapwood is much greater than that of the heartwood (Table 1). Western hemlock often exhibits localized wet pockets; butt logs of western redcedar, redwood, sugar pine and some true firs frequently are very high in moisture content. The total water content of a tree remains reasonably constant.

Moisture content of wood is expressed as a ratio of the weight of water to the weight of oven-dry wood, usually reported in per cent. The weight of water in wood varies with specific gravity of the wood. To illustrate: one cubic foot of freshly cut Douglas-fir having a specific gravity of 0.45 contains 28 pounds of wood substance, but a cubic foot of unseasoned western redcedar (specific gravity of 0.31) contains 19 pounds of wood substance. If the moisture content of both woods was 60 per cent, Douglas-fir would contain 16.8 pounds of water while cedar would contain 11.4 pounds of water to a cubic foot.
Wood dries through evaporation of moisture from its surface. Water from the interior of the wood reaches the surface by capillary movement of water and by movement of water vapor through cell cavities, pits and cell walls of fibers. Except for pine species, wood rays appear to be of minor importance. Sapwood, though usually at a much higher moisture content than is heartwood, dries more rapidly because of its greater permeability. Rate of water removal from end grain may be from 10 to 20 times faster than that from side surfaces. Conversely, penetration of liquids into wood usually is many times faster along the grain than across the grain.

During drying, the free water from cell cavities and intracellular spaces is lost first. The moisture content at which all free water has been removed is called the 'fiber saturation point' which is about 30 per cent. Further drying removes bound water from its close association with the cell-wall components (principally cellulose) to cause the walls of those cells involved to shrink, or attempt to shrink. The cell-wall components of fibers, comprising the bulk of wood substance, normally are oriented more or less parallel to the longitudinal axes of softwood fibers. With loss of water from between these cell-wall components, as wood dries below the fiber saturation point (FSP), most shrinkage occurs primarily perpendicular to the long axis of each fiber. From 90 to 93 per cent of softwood is comprised of fibers paralleling the length of poles or lumber. Almost all shrinkage occurs, therefore, at right angles to the length of poles or lumber. Longitudinal shrinkage usually is exceedingly low (0.1-0.2 per cent).

Wood does not shrink uniformly. Tangential shrinkage (parallel to annual rings) is about one and one-half to two times the radial shrinkage
(across the annual rings), as noted in Table 1. Unequal shrinkage is the cause of distortions in lumber and timbers, as pictured in Figure 4. In poles, tangential shrinkage builds up stresses that soon exceed the tensile strength of wood perpendicular to the grain, and cause checks to develop along radial planes of weakness, such as wood rays and knots. Surface checks in poles, or lumber, are instigated with a rapid rate of surface drying. During the early stages of drying, surfaces are restrained from shrinking by the wet underlayers of wood, so checks formed during this period may increase in depth and width as drying progresses.

How much wood shrinks in cross section is related directly to size of piece considered, specific gravity, and amount of bound water removed below the fiber saturation point. In Table 1 are noted average values for shrinkage of various pole species. Values for shrinkage to be expected with variations in specific gravity are illustrated in Figure 5. As wood is hygroscopic in nature, it will pick up moisture and swell, especially where exposed to the weather, or in contact with the ground.

Due to strengthening of cell walls and increased concentration of wood substance in a decreased volume due to shrinking, most strength properties increase with drying below the fiber saturation point. In structural lumber (joists, planks, posts and timbers), the increase in strength with drying may be offset by severe checking and other seasoning defects--collapse, honeycomb. Checking in poles does not seem to materially reduce strength.

Other properties of wood are improved with drying; resistance to fungi and many insects increases with a decrease in moisture content below 20 per cent; as wood dries it improves in gluability, machining and finishing properties; conductivity of electricity and heat decreases.
Abnormal longitudinal shrinkage occurs from compression wood, juvenile wood, wood abnormally light in weight for the species, spiral grain, and localized misalignment of fibers in the vicinity of knots. Such shrinkage results in lengthwise distortion (twist, bow, crook), and tension failures with seasoning of lumber and crossarms. Compression wood in poles can be a serious factor if present in quantity near the surface, due to low strength properties and development of tension failures—separation within fibers to form breaks at right angles to the pole axis.

Compression failures are interior, fine-lined buckling of fibers perpendicular to the length of poles or timbers caused by high winds in a stand of timber, falling trees over obstacles, or from rough handling where submitted to sudden severe bending.

Impregnation of wood with liquid solutions, as in preservation and pulping, is related to the structural features of wood and is influenced greatly by the chemical extractives. The relative ratings of penetrability for western pole species are included in Table 1. Sapwood is much more permeable than is heartwood. The sapwood of some species, such as the pines, is much easier to penetrate with liquids than is the sapwood of others, such as Douglas-fir. Incising, which exposes end grain, has increased greatly the treatability of heartwood of some woods and has improved the uniformity of treatment. Drying of wood is essential, not only to facilitate penetration of preservatives, but also to prevent formation of checks after treatment.

The reader can obtain more detailed information on structure and properties of wood from the sources of information listed in the Appendix.
CONCLUSION

In the final analysis, wood is a versatile material from which thousands of products have been produced to serve society, and from which untold numbers of products will be made in the future. An understanding of wood structure will help solve many of the problems confronting supplier and users of wood products.
APPENDIX

Sources of Information

   Wood Preservers' Association. 819 Seventeenth St., N. W.,
   Washington 6, D. C.

   Box 2010, University Station, Madison 5, Wisconsin.

3. Oregon Forest Research Center, P. O. Box 571, Corvallis. See List
   of Publications.

   Handbook 40, U. S. Department of Agriculture. ($0.40 cash).

5. Textbook of Wood Technology, Vol. I and II. Brown, Panshin and

6. U. S. Forest Products Laboratory, Madison 5, Wisconsin; consult
   Bibliographies No. 177--Growth, Properties and Identification of
   Wood; No. 200--Mechanical Properties and Structural Uses of
   Wood and Wood Products; No. 446--Seasoning of Wood; No. 508,
   Fungus Defects in Forest Products; No. 704, Wood Preservation.

   Agriculture. ($2.00 cash).

   New York, N. Y.

* Superintendent of Documents, U. S. Government Printing Office,
  Washington 25, D. C.
Table 1. Some Average Values for Physical Properties of the Major Western Pole Species.

<table>
<thead>
<tr>
<th>Species</th>
<th>Sapwood Thickness</th>
<th>Green Moisture Content</th>
<th>Specific Gravity</th>
<th>Weight^1</th>
<th>Fiber Stress^5</th>
<th>Shrinkage^6</th>
<th>Duralibility^7</th>
<th>Penetraibility^8</th>
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<tbody>
<tr>
<td></td>
<td>Inches</td>
<td>%</td>
<td></td>
<td>Ib.</td>
<td>Ib.</td>
<td>%</td>
<td></td>
<td></td>
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<tr>
<td>Douglas fir</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Coast</td>
<td>0.75-3.0</td>
<td>115</td>
<td>37</td>
<td>0.45</td>
<td>39</td>
<td>34</td>
<td>7400</td>
<td>4.0</td>
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<td>Intermountain</td>
<td>0.50-1.75</td>
<td>154</td>
<td>34</td>
<td>0.41</td>
<td>38</td>
<td>32</td>
<td>7400</td>
<td>3.3</td>
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<tr>
<td>Lodgepole pine</td>
<td>0.50-2.5</td>
<td>120</td>
<td>41</td>
<td>0.38</td>
<td>39</td>
<td>29</td>
<td>6600</td>
<td>3.6</td>
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<tr>
<td>Ponderosa pine</td>
<td>2.00-3.5</td>
<td>148</td>
<td>40</td>
<td>0.36</td>
<td>45</td>
<td>28</td>
<td>6400</td>
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<td>Western redcedar</td>
<td>0.20-1.4</td>
<td>249</td>
<td>58</td>
<td>0.31</td>
<td>27</td>
<td>23</td>
<td>5600</td>
<td>1.9</td>
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<tr>
<td>Western larch</td>
<td>0.50-1.30</td>
<td>119</td>
<td>54</td>
<td>0.51</td>
<td>50</td>
<td>39</td>
<td>8100</td>
<td>3.4</td>
</tr>
</tbody>
</table>

1 Account for most pole production in Western United States.

2 Moisture content in percent = \( \frac{\text{weight of water}}{\text{oven-dry weight of wood}} \times 100 \). 'Green' refers to newly cut timber condition.

3 Specific gravity = \( \frac{\text{oven-dry weight of wood}}{\text{weight of equal volume of water}} \); values cited are based upon volumes taken with wood in green, swollen condition (maximum volume) and are employed to compare species.

4 Weight per cubic foot includes wood substance, extractives and water; moisture content (MC) should be cited.

5 Fiber stress refers to maximum bending strength or modulus of rupture (MOR).

6 Shrinkage is related to change in dimension expressed as a percentage of green dimension: R - Radial, T - Tangential, V - Volumetric.

7 Relative resistance of heartwood to attack by insects and fungi: 1 - high, 2 - moderate, 3 - low.

8 Relative penetrability of heartwood to liquids: 1 - easy, 2 - moderately difficult, 3 - difficult, 4 - very difficult.
Figure 1. Gross structure of a log.
Figure 2. Drawing of a small cube of softwood. (Courtesy of U. S. Forest Products Laboratory).
Figure 3. Relationship of modulus of rupture to specific gravity in young-growth Douglas-fir. (Factors related to variation in specific gravity of young-growth Douglas-fir. M. D. McKimmy. O.F.R.C. Bulletin 8).
Figure 4. Tangential shrinkage is about twice as great as radial shrinkage, which results in distortion and checking.
Figure 5. Relationship of shrinkage to specific gravity (oven-dry weight and unseasoned volume). (Courtesy U. S. Forest Products Laboratory).
CAUSES AND PREVENTION OF DETERIORATION IN WOOD*

by

Robert D. Graham

March 1960

Forest Products Research
OREGON FOREST RESEARCH CENTER
Corvallis

CAUSES AND PREVENTION OF DETERIORATION IN WOOD

by
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Wood poles and crossarms are exposed continually to deteriorating effects of weather and to attack by plants, insects, and animals that utilize wood both for food and for shelter. Man, himself, contributes in no small part to destruction of these products.

That this deterioration can be retarded is readily apparent in the increased serviceability obtained by treating wood products with preservatives. Formerly, 15-20 years of service were considered acceptable, but users now anticipate 35 years, and look forward to 50 years. Basic to accomplishment of this goal is understanding of the causes of wood deterioration.

CAUSES OF DETERIORATION

Decay fungi

Decay of wood is caused by simple forms of plant life called fungi. Lacking chlorophyll, fungi are unable to manufacture their own food, so they utilize starches, cellulose, and lignin of complex plants. Fungi develop from microscopic spores that germinate and form strands of cells (hyphae) that eventually develop into extensive root-like systems (mycelia) within or on the
wood (Figure 1). New spores form either within the hyphae or on aerial structures from which they are released by the millions.

Most fungi cannot grow in wood that is saturated with water or buried deep in the ground, because of resultant limited air supply, or in wood that has a moisture content of less than 20 per cent, based on oven-dry weight of the wood. They develop best at temperatures from 70 to 90 F, but some can continue to grow at temperatures from slightly above freezing to 120 F. Low temperatures inhibit their growth, but rarely kill them. They can be killed by heating wood to temperatures of 150 F for two hours, or 170 F for one hour; sterilized wood may be subject to reinfection, however.

Decay fungi, in utilizing the constituents of cell walls in wood, cause changes in color, luster, and strength; marked reductions in strength can occur before discolorations become noticeable. Cellulose and lignin are utilized in different proportions. White rots leave mainly cellulose, but brown rots leave largely lignin. Once established, fungi can destroy normally resistant adjacent wood. Some fungi are capable of transporting water from moist areas for long distances through thick mycelial strands to attack wood that otherwise would be considered safe from destruction.

The great range of conditions under which fungi will grow, the large number of species, and their wide distribution are
indicative of difficulties encountered in preventing and controlling their attack. Major emphasis should be placed on prevention of attack by decay fungi.

**Termites**

Termites are small, primitive, but highly specialized insects living in well-developed colonies and having several forms or castes. A colony, which may contain several thousand members, consists of the egg-laying queen, a king, soldiers, winged reproductives, and numerous workers. Protozoa in the digestive tract of the termite break down the ingested particles of wood into simpler products that can be assimilated by the termite. Cellulose and related compounds are the principle food sources.

During favorable periods of the year, usually late summer and fall, winged reproductives emerge from the colony, swarm into the air for short flights, alight and lose their wings, then tunnel into wood where they mate and begin a new colony. During the flying stage, termites frequently are confused with winged ants, but are identified readily by the uniform width of their bodies in contrast to the constricted "waist" of the ant (Figures 2, 3).

Termites are found throughout the United States, where they attack virtually all species of wood, including species such as cedar and redwood, with durable heartwood. Three types are common to the western states.
Subterranean termites. Earth-dwelling termites (about one-fifth inch long) are the most destructive and widespread. They range from southern California, north into British Columbia, and east into Idaho. Although they nest in the ground, characteristically they construct mud tunnels, either free-standing or over intervening materials, to reach wood well above the ground.

Dry-wood termites. Extensive damage is caused by dry-wood termites in southern California and Arizona. They are not uncommon in northern California and have been reported as far north as Washington. One writer comments that, in southern California, nearly every walnut tree containing dead branches has dry-wood termites. Since these termites establish colonies in sound, dry wood, and require no contact with the ground, they are difficult to control. Adults are about 0.3 inch long.

Damp-wood termites. Ranging from southern California north into British Columbia, damp-wood termites are most destructive in humid coastal regions. They require moist conditions for growth, need not be in contact with the earth, and usually are associated with decaying wood. Adult termites vary from 3/8 to over 3/4 inch in length and are the largest in the United States.

Carpenter ants

Large (½ inch long), black, or reddish-black carpenter ants (Figure 3) are a major destructive agent of cedar
poles and attack nearly all woods. They excavate large cavities, particularly in decaying wood, for shelter and nesting purposes, but expel the wood particles, which accumulate in mounds as a characteristic sign of their presence. Unlike termites, wood is not their source of food.

The colonies have well-developed castes consisting of workers and reproductives. Winged reproductives emerge in the spring to start new colonies.

Weathering

Weathering is the gradual breakdown of wood due to combined action of wind, rain, and changing temperatures. Frequently, weathering is accompanied by decay. In areas of wind-blown sand, erosion of wood may be quite rapid. Alternate wetting and drying cause dimensional changes that result in minute, but extensive, fractures of the wood surface, which facilitate losses of preservatives by leaching and evaporation. Depletion of oil-type preservatives frequently is much greater above ground than below ground, but decay conditions are much less severe above ground. Old treated poles in service should be given supplemental treatments before being reset to greater depths, or prior to increases in grade. Some companies make a practice of re-treating poles that have been stored for 3 years or more, as well as old poles to be re-used.
Fire

During combustion, wood first loses moisture (to 212 F), some constituents begin to volatilize (200 F), inflammable gases are produced (300 F) that begin to flame (400 F), then charcoal forms and glows (700-950 F). Treatment of wood with oil-type preservatives reduces the fire resistance until volatile components have evaporated. After weathering for a year, the fire resistance of treated wood approaches that of sound wood and is much greater than that of decayed wood, which ignites at much lower temperatures than does sound wood.

Systems for reducing the flammability of wood-trestle bridges treated with oil-type preservatives have been studied for several years. The latest method includes phosphorus-halogens in the treating solution. Such systems appear promising, particularly at retentions normally used for the treatment of poles.

Checking after treatment

Poles treated at high average moisture contents continue to season in storage or in service until they approach a moisture content in equilibrium with that of the surrounding atmosphere. Resultant shrinkage can cause extension of seasoning checks past the treated zone into the untreated core (Figure 4). Such checking can be most damaging with large poles, in poles stored
in a horizontal position, to species with thin sapwood, in species with nondurable heartwood, in moist regions, and in areas of high hazard from termites.

Data on moisture distribution (Figure 5) indicate that large poles in the Corvallis area approach an equilibrium moisture content of about 12 per cent. In addition, seasoning appears to be virtually a one-way process, for only the outer \( \frac{1}{4} \) inch of treated poles increases in moisture content during our wet winter months.

Information is needed on relationships of moisture content to shrinkage in sound material to permit incorporation of realistic requirements for moisture content in pole specifications. Seasoning to comparatively low moisture contents before treatment may mean more and larger checks, but also will produce a more serviceable product. Strength of poles, as shown by recent tests reported by American Society for Testing Materials, is reduced very little, if at all, by large checks. Some users consider large checks a safety hazard and impose restrictions on their width. Since the modern view of safety is that accidents may be lessened by avoiding unsafe conditions and practices, an industry-wide study to determine the true role of checks as a climbing hazard merits consideration.
Man

Frequently man is wood's worst enemy, largely because of lack of knowledge about the products he uses, or failure to pass information on to others. Failure to anticipate emergencies or future needs causes expediencies in which specifications are waived, and substandard products may be placed in use.

Value of the best preservative treatment can be lost completely by one careless act during inspection or handling of treated products. Such acts include:

- Use of tongs or peavies on side surfaces of poles, particularly in the ground-line area.
- Making cuts or holes in treated products and leaving these areas untreated.
- Failure to plug holes made by increment borers during inspection of new poles, or of poles in service.
- Inspection of poles in service with prods, or other puncturing devices.

PRESERVATIVE TREATMENTS

Nature provided the heartwood of some trees, notably cedar, chestnut, and redwood with chemicals that made these woods resistant to attack by wood-destroying organisms. Man injects
chemicals to protect wood, not only against organisms, but against weathering and fire as well.

**Preservatives**

Chemicals used to protect wood should be toxic to wood-destroying organisms (but reasonably safe to man and other higher animals) and should be stable for extended periods of time, noncorrosive to metal, and not harmful to wood strength.

Oily, or oil-soluble preservatives such as creosote, and pentachlorophenol in heavy petroleum carriers have been used most widely for poles and crossarms. They provide protection against weathering and give some degree of dimensional stability by reducing water absorption. A recent development is creosote plus 2 per cent pentachlorophenol for southern pine poles, which permits use of low retentions as a means of preventing bleeding.

Water-borne preservatives, which depend on chemical reactions in the wood to form almost insoluble toxic compounds, are used to some extent. The treated wood is clean and can be painted after the wood dries. The main objection to their use is that increased electrical conductivity may be associated with salt-type chemicals. The validity of this objection is debated by some users, who consider the chemicals to be of minor importance and the presence of water of major importance in changes in electrical resistance of wood.
Objectives

For maximum serviceability, wood must be penetrated uniformly to a depth that will prevent exposure of untreated wood in normal use, must retain sufficient preservative to provide protection for extended periods of time, and must be dried to a moisture content that will prevent extension of checks past the penetrated zone. The penetrated zone serves both as a protective barrier and as a reservoir of preservative.

Penetration. Penetration of preservative in poles is limited almost entirely by thickness of the sapwood, which may vary from a minimum of ½ inch in western red cedar and western larch to as high as 3 inches in Douglas-fir. Depth of sapwood in Douglas-fir, for example, is about uniform within a tree and increases with mid-point diameter (Figure 6). Sapwood is easier to penetrate than is heartwood. As it has little resistance to attack by decay fungi, most of the sapwood should be penetrated in thin-sapwood species. Spur marks that penetrate into untreated sapwood may cause shell rot behind the treated zone that, once established, may extend into the heartwood.

Incising is the key to successful preservation of lumber and timbers that are predominately heartwood. Numerous incisions facilitate longitudinal penetration of preservative, yet weaken
wood only slightly (5-10 per cent). Penetration in heartwood is limited largely to depth of the incisions. Longitudinal penetration in Douglas-fir heartwood has been found to vary with geographic location in Oregon. Heartwood from western Oregon, though varying widely in longitudinal penetration, is much less difficult to treat than is heartwood from eastern Oregon, which is uniformly difficult to treat. This situation is believed to exist throughout the range of Douglas-fir on the Pacific Coast.

**Retention.** As used in treatment specifications, retention may refer either to retention of preservative based on total volume of wood in charge, or to concentration of preservative in the treated zone or portion of this zone. Although a charge of poles may be treated to average retention of eight pounds a cubic foot, retentions of individual pieces vary greatly due to proportion of sapwood, depth of penetration, moisture content, and specific gravity of the wood.

Concentration of preservative in the treated zone, which varies among poles as well as within poles, decreases with depth of penetration, so is highest near the surface. Final steaming and vacuum cycles are used to reduce the concentration in the outermost layer of sapwood to prevent bleeding. Since half, or less, of the volume of poles of western species is sapwood,
concentrations of preservative in the treated zone must be high to meet the requirement of eight pounds to a cubic foot of wood in a charge, as shown by the following table:

<table>
<thead>
<tr>
<th>Sapwood or treated volume (Per cent)</th>
<th>Preservative in sapwood or treated zone Lb/cu ft</th>
</tr>
</thead>
<tbody>
<tr>
<td>100</td>
<td>8</td>
</tr>
<tr>
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**Result-type specifications.** The present trend to "result-type" specifications that require minimum concentrations of preservative in the treated zone provides a good estimate of effectiveness of the treatment. Such concentrations can be compared directly with those found necessary by laboratory tests to protect wood against decay fungi. The minimum concentrations found necessary to prevent decay (called threshold retention) in small blocks of pine sapwood treated with several preservatives, then artificially weathered and tested against five important decay fungi, are as follows:
Since threshold retention varies both with preservative used and with fungi present, much higher initial concentrations are needed to provide for losses during service and to protect wood for long periods of time.

Fortunately, the high concentrations actually obtained in sapwood of most western woods are well above those required to protect wood against fungal attack. Evidence to date in treated Douglas-fir, western larch, and western red cedar poles indicates that deterioration of wood in the treated zone is extremely rare. Failures are due almost entirely to deterioration of untreated tops, or to heart rot near the ground line as a
result of exposure of untreated wood after treatment.

The exception may be lodgepole pine, in which failures due to decay in the treated portion have been reported. These failures were attributed both to use of substitute preservatives during and following World War II and to low retentions. The latter reason appears more valid, because sapwood in lodgepole pine is easily impregnated and, unlike most other western woods, can be penetrated deeply, while low concentrations of preservative in the treated zone are possible. These low retentions also may be attributed to placing emphasis on clean treatments at the sacrifice of good service. Result-type specifications will help prevent such incidents in the future.

CONCLUSION

Preservative treatments have shown that they can effectively prevent wood deterioration for prolonged periods of time. Western woods with their comparatively thin sapwood pose a challenge, but there is reason to believe that, through cooperation of the user and supplier, treated wood products from these species can attain an average service life of 50 years or more without early failures caused by deterioration.

Knowledge of the causes and prevention of wood deterioration will enable consumers to appraise specifications under which
treated wood products are purchased, to anticipate problems that may arise from wood products now in service, and to evaluate the wide variety of chemicals and treatments intended both for new poles and for poles in service.

Research is necessary to find improved ways of seasoning wood to specified moisture contents, of preventing checking, and of obtaining increased penetration and improved distribution of even more effective preservatives in wood.
Figure 1. Growth characteristics of decay fungi highly magnified.

A. Egg-shaped germinating spores from which hyphae have begun to develop.
B. Young mycelium from single spore.
C. Portion of mycelium showing cellular structure of hyphae.

Figure 2. Worker (left) and soldier of western subterranean termite.

From *Termites and Termite Control*, Kofoed et al., University of California Press, 1934.
Figure 3. Worker and winged reproductive carpenter ants. Note constricted "waist". From *Carpenter Ant Control*, Extension Circular 627, Oregon State College.
Figure 4. Dark-colored area of decay within light-colored untreated heartwood at base of seasoning checks on top of round crossarm with completely penetrated sapwood.
Figure 5. Moisture distribution two feet above ground in 13 creosoted Douglas-fir poles after 9 years' service near Corvallis, Oregon.
Figure 6. Douglas-fir sapwood depth and volume.
The purpose of this Wood Pole Conference is to provide pole users and producers with a clear picture of the factors and problems involved in getting poles from the stump to the power or telephone line.

Pole users have long held increased service life as their goal and it should be the object of all treating plants to satisfy this requirement. At present there are two generally accepted processes used to treat poles with preservative. One is the pressure treatment, which is commonly employed on various species of pole timbers in any state of seasoning. The second is the Thermal Process which is used on those pole species with relatively thin sap-woods, and which have been previously air seasoned.

You have, no doubt, heard about the pressure treatment and we wish to point out that there is no magic in the word "pressure" nor is there any magic in the pressure process. It is a good process, it has its place, and it most certainly should be used on certain pole species and other wood products. This does not mean, however, that a pressure treatment is the only process that should be applied to poles.

The Thermal Process, as we know it today, utilizes thermal expansion and atmospheric pressure rather than mechanically applied pressure for good results. Excellent treatments obtained by the Thermal Process are actually due to the temperature differential between hot and cold preservatives properly applied for certain lengths of time. The Thermal Process is not a non-pressure process; the term non-pressure should only be applied to the
application of a preservative without pressure, namely, brushing, spraying or dipping.

Let us describe the Thermal Process as it is applied, let's say, to the full length treatment of Western Red Cedar Poles.

First, air seasoned poles are inspected and must adhere to the American Standard Association's Specification 05.1 for timber quality and measurements. (E. E. I. Specification TD-100 calls for an average moisture content not exceeding 30%, with moisture contents between 12% and 26% preferred.) They are then measured to determine their actual class and length and this classification is hammer stamped or branded on each pole. Next, the poles are roofed, gained and bored to the user's specifications. All poles are incised at the ground line which insures uniform penetration and greater retention of preservative in that vulnerable area where decay is most prevalent. The incised section is usually three feet in length extending one foot above and two feet below the ground line, but can be increased to satisfy the setting requirements of the individual user. This incising also retards subsequent checking after the poles are treated.

The poles may or may not be machine shaved above the incised area, depending upon the customer's desire. We at Valentine Clark Corporation advocate that all poles be machine shaved for the following reasons: #1 - Full length shavings allow a more thorough job of inspection of the pole in the white, and the operation will disclose hidden defects which otherwise would go undetected; #2 - Shaving above the ground line to deliberately reduce the sapwood on thicker sapwood poles in itself is a decay inhibitor; #3 - Shaving prepares the surface of the pole to receive preservative treatment; #4 - Shaving definitely improves the appearance of a pole and since our Northwest species do not have large overgrown knots (especially in the top section of the pole) shaving is not detrimental to the strength, nor does it cause splintering
of the wood fibers.

The poles are now ready for treatment and are placed in long tanks that are equipped with steam coils or heat exchangers for heating and maintaining the temperature of the preservative. When full, the tank covers are closed and secured to overcome the buoyancy of the poles and hot preservative is introduced into the tank until the poles are completely submerged.

The hot treatment or cycle is maintained above 190°F and below 235°F for at least six and up to sixteen, twenty or even twenty-four hours depending upon the weather and condition of the pole. These extended hot cycles are necessary during cold winter weather when both the poles and tanks are cold, or when the poles have recently been wet by rain or snow. During the hot cycle, a substantial portion of air within the sapwood is displaced by thermal expansion and by the movement of vapor that may be produced from any moisture in the wood. Thus, since some moisture may be driven out of the wood, additional seasoning of the pole is accomplished.

At the end of the hot cycle, the hot preservative is pumped off the poles and is quickly replaced by cold preservative, which ranges from 90°F to 150°F. As the wood cools, thermal contraction of the air or condensation of vapor within the wood cells creates a partial vacuum into which atmospheric pressure forces preservative. The cold cycle is maintained for at least two hours and up to six, eight or even ten hours depending again upon the species of wood and its condition.

We have samples on display here today showing the cross-section of certain pole species. In general, those species of southern pine with the small heartwoods and thick sapwoods should be treated by the Pressure Process. The pressure process as applied to poles is generally an "empty cell" treatment. Those species with larger heartwoods and thinner sapwoods are being successfully treated by the Thermal Process and should be so treated. The
Thermal Process, as applied to the thinner sapwood pole, is a full cell treatment; that is, the wood cells are filled with preservatives, thus, giving greatest absorption and retention of preservative resulting in maximum protection, especially in the ground line area.

This is a brief outline of the Thermal Process as applied to air seasoned poles and as you can see, there is not much that can go wrong in the processing and treating of poles by this method. Plants are simple, consisting of storage and treating tanks, with necessary valves and piping, steam coils or heat exchangers and thermometers. Most important is the fact that there is nothing which will bring about a strength reduction in the wood such as steaming or mechanical pressure cycles.

The Thermal treating industry made an early switch wholly or in part to pentachlorophenol and helped popularize that preservative. It proved to be a most sensible move as the viscosity of the petroleum solvent is lower at cold bath temperatures so that penetration and retention were improved accordingly. Cleaner poles have also resulted.

Concerning retention, it has been customary for the user of poles to specify pressure treatment according to gauge readings; such as 6 pounds, 8 pounds or 10 pounds per cubic foot. That meant that in the purchase of an 8 pound treatment, the entire charge in any one cylinder was given 8 pounds of preservative per cubic foot of timber but did not guarantee the retention in any given pole and it has been found that the retention varies in different poles in the same charge from as low as 2-1/2 pounds to 13 pounds. It is apparent what might happen to the 2-1/2 pound pole and what the surface condition of the 13 pound pole might be.

Ever since the inauguration of pentachlorophenol as a pole preservative, poles treated by the Thermal Process have been tested at the ground line immediately after treatment for penetration and the increment boring
cores assayed for retention. We understand that the Pressure treaters are now following the example of the Thermal treaters and before many years they too will require that the poles be assayed after treatment for retention instead of relying on plant gauge readings.

For many years the American Wood Preservers' Association did not have a specification for the full length Thermal treatment of cedar poles. The delay prompted users to take action which resulted in the T & D (Transmission and Distribution) Committee of the Edison Electric Institute writing their own specification. Because of this priority, their Specification TD-100 is more widely used today than the long delayed AWPA C8-58 Specification, even though they are quite similar. The TD-100 Specification offers two classes of treatment. The Standard, Class S, Treatment is intended for use under conditions where the rate of destruction by insects or fungi is normal or average as may be found in the regions with moderate humidity and temperature conditions during the warm seasons. The Extra, Class X, Treatment is intended for use under conditions where climate is especially favorable to insect and fungus attack. The results of both treatments performed in accordance with the Specifications are usually judged on the basis of retention of preservative by the wood expressed as pounds per cubic foot and the depth of penetration as expressed in inches or per cent of sapwood depths. Whether the Standard or Extra treatment is supplied depends wholly upon the pole consumer as he is the one who must judge whether or not service conditions warrant the added protection of Extra preservative.

Occasionally, the question is raised as to whether or not present treating specifications are adequate. We believe the answer is "yes" and base it on the fact that nearly 100% of all Thermal treating is done under the E.E.I. Standard rather than E.E.I. Extra treatment. This would indicate that even though an extra treatment is available, most pole users find they
are receiving what they want and need from the Standard Treatment.

The records of the results of Thermal treatments speak for themselves. Committee T-8's report to the American Wood Preservers' Association this year showed detailed penetration and analytical retention data on Lodgepole pine poles which would be difficult for any other commercial process to better. Of 1,258 poles tested, 97.9% were full sapwood treated in the ground line area. From that sample, 535 poles were tested at the midpoint and 94.4% of those were full sapwood treated. The reports of Committee 5-5-2 of the American Wood Preservers' Association proceedings for 1947 and 1948, and the reports of Committee T-8 in their proceedings from 1949 through 1958 provide information on the Thermal process treatment of western red cedar, western larch, lodgepole pine, Coast Douglas fir, and intermountain Douglas fir. No other group can point with such pride to the written record.
The field of wood preservation dates back to at least the 1700's, the pressure process being introduced and patented in Europe in 1838. During these 100 years many things have been learned and new applications developed, the most notable being the Boulton, or boiling under vacuum, method of reducing the moisture content of material to be treated. Max Rueping devised the "empty cell" process which allows adequate retention of preservative and still produces a relatively clean, dry product. These processes have been improved and standardized by the American Wood Preservers Association which dates back to 1911. Treating specifications are based on A.W.P.A. recommended practices, which have been prepared by the mutual efforts of governmental research agencies, users and producers. Adequate scientific methods of incising both sawn and round stock have been and are being developed. Incising allows better and more uniform distribution of the preservative and tends to control the distribution and magnitude of seasoning checks. Modern methods of preframing prior to treatment have been developed enabling the purchaser to procure a product that requires little or no field cutting that would rupture the treated zone thereby reducing the value of the treatment. Power machine pole shavers (or peelers) are marketed that produce a uniform product pleasing in appearance.

Before we discuss the pressure process we will describe the various pieces of equipment used.
Tram Car

Steel, four wheeled, with arms on each side to hold the material to be treated. Runs on tracks in the retort.

Retort

Horizontal, round steel pressure vessel up to 9' in diameter and up to 180' long. Insulated to retain heat. Built to rigid specifications to withstand pressure to P.S.I.

Rueping Tank

Similar to retort. Mounted above retort and interconnected by pipes.

Pressure Measuring Tank (PMT)

Usually vertical round steel pressure vessel. Calibrated to show exactly how much preservative used. Connected to retort.

Air Pressure Tank

Tank used to store air at approximately 90# PSI.

Condenser

To convert moisture vapor to liquid.

Condensate Collecting and Measuring Tanks

Small steel tank used as name indicates.

PRESSURE TREATING CYCLE

A charge, or quantity of poles, (all of approximately same moisture content and same approximate size) is placed on tram cars, put into the retort and retort door sealed. Poles are usually seasoned by the Boulton process. Boultonizing is circulation of hot preservative (180°F - 220°F) over the poles, through a heat exchanger (to maintain
preservative at desired temperature), through Rueping tank and back to retort. During this time a continuous vacuum of about 24" of mercury is maintained on the Rueping tank, lowering the boiling point of the water from the poles. The retort is continuously full of preservative with a small amount in the Rueping tank. The moisture vapor from the poles reaching the Rueping tank is boiled away from the preservative, drawn out of the Rueping tank and discharged in the condenser, liquified and sent to the condensate collecting tanks where the quantity is recorded. As this process continues, moisture is removed from the poles to an ever deeper level. The treating engineer has precalculated the amount of moisture to be removed from the poles to reach an optimum moisture content. This is done by measuring the moisture content prior to placing charge in retort, computing the cubic content and surface area of wood in charge, then computing amount of moisture to be removed to bring the poles to approximately 20% average moisture content in the sapwood and outer layers of heartwood. When moisture collected approximates 1/10 of 1# per cubic foot of wood per hour, the material has reached approximately 20% moisture content.

When Boultonizing is complete, the retort is emptied of preservative, usually pumped to the Rueping tank. The next step is the air press. Approximately 20# PSI of air is applied to the poles in the retort and held for about 30 minutes. The air penetrates the sapwood of the poles. It is important that the air remain trapped in the poles until the end of the oil press. At the end of the 30 minutes, the retort is refilled with preservative, being careful not to break the air press.
The oil press is now started. A precalculated amount of preservative is pumped from the pressure measuring tank into the wood at pressures up to 150 PSI and at temperatures from 180° to 210°F. The amount of preservative forced into the retort is in excess of the contract gallons or final net retention. When the oil press is complete the pressure in the retort is returned to atmospheric pressure by venting. As the pressure is lowered, the air trapped in the poles forces the free oil in the wood cells out of the poles. This is known as "kick back" and is the reason an excess amount of preservative is used during the oil press.

Following the oil press is an expansion bath. This is a repeat of the original Boulton cycle usually at 220°F, 20" - 24" vacuum and lasts one to two hours. This again heats and expands the air in the poles, forcing more free oil from the wood cells. At the completion of the expansion bath, the retort is again emptied.

A final vacuum is drawn directly on the poles to clean off any excess free oil.

This completes the normal cycle.

If the poles are going to a hot dry area or if the customer desires an unusually clean dry product, two more steps may be taken.

1. A steaming period at about 235°F that lasts from one to two hours. This again expands the air in the wood cell forcing still more free oil to the surface.

2. A second final vacuum removes excess oil and cleans up the poles.

The result of the foregoing process is an empty cell treatment where
only the cell walls retain preservative. The retention is at least the minimum stipulated in the order. The empty cell treatment allows much deeper penetration for a given amount of preservative.

The empty cell process is used primarily under standard conditions. These are poles, piling in fresh water and land, lumber, etc. The full cell process is used for lumber and piling in salt water and sometimes for foundation piling under buildings and grain elevators.

The full cell process differs from the empty cell process as the name implies. The cell walls and cells are full of preservative. Higher net retentions such as 12# - 14# per cubic foot, are required to accomplish this. Full cell treatment can not be made clean or dry as there is always free oil in the cells that tends to come to the surface.

In treating with the full cell process, the material is Boultonized or seasoned in the same way as empty cell process. There is no air press. After seasoning, oil is pressed into the material and this is followed with a single final vacuum.

To summarize, the pressure process consists of a series of carefully controlled steps by which wood is seasoned or conditioned to prepare it for treatment, impregnated under pressure to obtain the optimum penetration and concentration of preservative consistent with use conditions, and cleaned by heat and vacuum.
INTRODUCTION

Crossarms have been in use almost since the first telephone lines were constructed in 1878. Yet many people are not familiar with either the word crossarm, its meaning, nor the many sizes and lengths commonly in use today. A crossarm is the structural support attached to the pole to carry the wires of a telephone or electric system. The strength of these pieces of wood is of primary consideration and their lasting quality is the secondary consideration most important to the user.

The smallest arm being manufactured in quantity is the $3\frac{3}{4} \times 4\frac{3}{4} - 18''$ crossarm used by the Rural Telephone Association. Also in the picture are $3\frac{1}{2} \times 4\frac{1}{2} - 8'$ and $3\frac{3}{4} \times 4\frac{3}{4} - 10'$ which are very commonly used on electric distribution lines.

Transmission crossarms in use today may range from $3 \times 10 - 25'$ to $4 \times 8 - 40'$ or $8 \times 8 - 42'$, and numerous requests have been received recently for crossarms up to 65' in length. As higher voltages are used, greater lengths and larger cross-sections will be required or changes in design will be made to provide spacings needed.

ESSENTIALS OF MANUFACTURING

Crossarms are manufactured from any wood that has sufficient structural strength. Common woods in use today are Southern Pine, Douglas Fir, and to some extent West Coast Hemlock. Practically all crossarms on the West Coast are of Douglas Fir because of its superior strength qualities and resistance to decay when compared to other wood species.
Since only a small portion of a log can be cut into the grade of material suitable for crossarm manufacture, practically all of the wood used in crossarm manufacturing today is purchased from sawmills in the rough sizes that can be surfaced to standards established by the industry. The most commonly used standards are those of the Edison Electric Institute or the Rural Electrification Administration, and the numerous specifications issued by utilities which closely approximate those of EEI.

The standards so established determine the method of manufacture of crossarms. These basic essentials require material of high structural strength, thoroughly seasoned, bored to meet various needs, shaped to provide a roof for ease of pulling wire over the top of an arm when in position, and treated to provide added life in areas where either severe weather or insect infestation is prevalent. To conform with such specifications, every manufacturer must perform essentially the same functions.

SEASONING OF CROSSARM STOCK

On receipt of a car of lumber purchased for crossarms, the manufacturer must sort and carefully grade the material. Grading at this point eliminates the major portion of the unusable material included in every shipment of stock to the manufacturer. Particular attention is given to density, size and location of knots, and slope of grain. Further, the material must be stickered with thin pieces of wood to provide air space between adjacent pieces to accomplish proper drying of the material. Stock may be dried either by air drying under covered storage or loaded into kilns where more rapid drying may take place under controlled temperature and humidity conditions.

Thorough seasoning requires that the piece of wood be dried throughout so that the outer surface is not more than 5\% different in gradient from the inner one-half. The average moisture content should be between 12 and 20 percent. This is the requirement of practically all specifications.
governing the subject to prevent both honey comb, with its serious strength reduction, and further severe shrinking or surface checking of the material. To accomplish such a rigid specification is a long process and when done by air drying requires from 90 to 180 days in this area. When kiln dried, it takes from 12 to 15 days on distribution sizes.

REASONS FOR DRYING

It must be apparent to all that considerable costs are involved in preparing materials for drying, in the form of labor and expense of kiln drying or the incident capital investment costs for the time consumed in air drying. It certainly would not be done unless the reasons therefor justified the expense. So one might properly ask, what are the reasons for this operation and its added expense? Let us examine a chart from USDA Handbook #72, page 314, fig. 70, showing characteristic shrinkage and distortion as affected by the direction of the annular ring growth. The circumference or tangential shrinkage is about double the diameter or radial. Lengthwise shrinkage is negligible. Note the varied results from drying. Some of the most obvious answers to the question are: (1) It provides for better fitting of the hardware on a piece of wood that is little subject to change. (2) When drilled for wood pins, the pin-hole sizes do not shrink causing tension around the dry pins which occasionally results in full length splitting of an unseasoned piece of wood. Also, (3) when wood is properly dried, the fungi which cause decay are killed or their growth is retarded sufficiently to materially increase the life of the piece of wood.

But some of the less obvious reasons for drying are probably more important than the foregoing. The strength of a piece of wood when green is much reduced when compared to its dry strength. For example, the U. S. Forest Products Handbook #72, page 75, shows that the strength of green Douglas Fir in compression is only approximately 50% of its dry strength.
And in shear, it is approximately 80%.

Secondly, a piece of wood that is surfaced green to a given net size, which engineers have computed to be necessary for supporting the load for which a particular crossarm has been designed, will shrink materially when the moisture gradient in the piece of wood has equalized to the weather conditions in the area where the crossarm is used. Green Douglas Fir has a fiber saturation point of approximately 30% moisture content. In most areas of the United States, wood will eventually dry to between 10 and 18% moisture content. If one assumed that the average would become 15% moisture content, the shrinkage which would occur in that piece of wood is approximately 4%. So from a crossarm surfaced green to 3-3/4 x 4-3/4, you could expect to get a crossarm only 3-6/10 x 4 1/2. It is obvious that the buyer of green crossarms is getting a much smaller piece of wood than the buyer of thoroughly seasoned material. If the strength of the larger piece of wood is required, the crossarm ordered green should be one-quarter inch larger initially than the size of the dry crossarm required.

When properly kiln dried, Douglas Fir can be more readily treated to obtain a better distribution of preservative in all pieces of a given treatment charge. We have carefully observed the results obtained from treating (1) unseasoned or green stock which has been Boultonized prior to treatment, (2) thoroughly air dried to comply with EEI Specifications, and (3) kiln seasoned material to conform with EEI Specifications, always with better uniformity of treatment obtained from using kiln dried stock. Also the treatment is cleaner and has far less tendency to "bleed" during the period of storage at the plant. (No laboratory tests have been made by us to confirm these observations.)
SURFACING, TRIMMING & BORING

To continue with manufacturing operations, once the stock is dry, it is surfaced and further grading and trimming are required to remove all strength-reducing defects which may become apparent. The crossarm blank resulting is then graded and stuck to determine its adaptability to a given customer's specifications to assure that all permissible defects do not fall in critical areas which would materially reduce the strength of the crossarm. The quality of the final product is determined by the skill and thoroughness of these gradermen.

The boring and branding operation is done by mechanical means and is quickly accomplished once the machine has been set in operation. Untreated crossarms are loaded directly into the cars from this operation.

TREATING CROSSARMS

Crossarms should be treated whenever the expected life of the crossarm is less than the expected life of the pole to which it is attached, whether the reason be for decay, weathering or possible insect damage. Not all pieces of wood in a treating cylinder will be treated alike even though from the same general growth area and seasoned in a similar manner. A treatment of 6# of preservative per cu. ft. means only that the average retention is 6# per cu. ft. with individual pieces having more oil and others less than the average. (Some surfaces may have no more than 1/16" penetration from a 6# or 8# treatment.) Incised material has had uniform surface perforations made into it so that these openings will provide easier access for treatment --only by this method can the treater be certain all surfaces will accept a given depth of treatment.

When crossarms are to be treated, whether incised or not incised, the usual procedure is to place them on trams with thin strips of wood, such as lath, separating the crossarms in layers to permit a free flow of
preservative around each piece.

Many customers request independent inspection of their crossarms prior to treatment as well as after. This may be done ahead of the boring machine or as placed on the trams.

The retorts are filled with all tram loads possible and treatment given in accordance with the customer's request. Final inspection is made after treatment.

LOADING OUT

Only a few years ago, all distribution crossarms were loaded into box cars piece by piece and unloaded in a similar manner by the customer. This method is still widely used.

With the advent of small fork lift equipment being used to offset high labor costs, new methods of loading have been instituted. Bundled crossarms loaded on flat cars have become popular. No standard package can be devised to fit the various sizes of railway equipment in service today, therefore packages should be designed to fit the car within reasonable limits. The ends on flat cars must be rigidly braced, the end bundles must tilt toward the center, and successive tiers must be set back from car ends. Secure strapping of individual bundles and straps around all bundles in a tier are necessary to assure the safe arrival of the car at its destination.

Long length transmission structures with necessary hardware attached require careful bracing and ample separation between structures. The long lengths make loading easier.

Some users with crane equipment in their yards request bundled loads in gondola cars. Others with unloading docks and very small fork lifts which are readily maneuvered inside a box car request bundled crossarms loaded in such equipment. The latter must use short crossarms to permit loading crosswise inside a box car.
TRANSMISSION CROSSARMS

The same basic considerations apply to manufacturing the larger transmission crossarm. Thorough seasoning of these large sizes is even more important than in distribution sizes, for shrinkage is in direct proportion to volume, thus enlarging the defects. Hardware fitted to green or partially seasoned wood soon becomes loose; seasoning checks will develop which will extend beyond the depth of preservative treatment with the result of not only weakening the structural strength but also impairing the effectiveness of the preservative in these checks. The larger the piece of wood, the longer the time required in seasoning.

While some use crossarms for transmission in lengths less than 20 feet long, the trend is toward higher voltages with the wider spacings between conductors which use longer crossarms. There are sufficient sawmills capable of cutting timbers to 42 ft. long, but not all such sawmills have logs of the quality needed to cut long length timbers in volume. Lengths of 32 ft. or less are quite available if the sawmill is given reasonable time to select appropriate logs. There are still a few mills able to cut 60 to 85 ft. timbers but the volume is very limited and the cost extremely high. The transmission crossarm manufacturer cannot buy timbers in multiples of the lengths needed, so to render service on small requirements he must carry eight to ten cross-sections in the various lengths used. When spacings between conductors are more than 20 feet, the transmission structure design must either be changed to other than the H-Frame Structure or laminates substituted for solid timbers.

Laminates can be constructed to meet any spacing requirement, have been thoroughly kiln dried for stability, and treat satisfactorily. The major problem for laminates to overcome is price. The multiple operations, high labor cost, the expense of glue and the cutting away of material resulting
in considerable scale waste of wood used offset the lower material cost.

Pole type crossarms have been tried and are being used today but thus far have not proven themselves. The service records are unimpressive. The problems of seasoning and treatment of round materials offer real challenges to the industry.

Considerable publicity was recently given the use of tubular aluminum and steel tubes as substitutes for pole type crossarms. This test line was built in 1959, therefore cannot answer the test of time. It is built in an area of infrequent electrical storms where the impulse insulation value of wood was given little consideration, nevertheless, this experiment is of interest to the wood fabricator.

Wood's most logical solution for wide spacings on electrical circuits probably rests with the engineer who can redesign the structures permitting the use of readily available sawn timbers in place of either laminates, poles or metal substitutes.

FACTORS INFLUENCING CUSTOMER COSTS

Standard specifications recognize the need for a variety of sizes, lengths, and types of treatment which the manufacturer prepares to furnish. Also, differences in pinhole sizes and their location in the crossarm are expected and welcomed by the producers. These differences permit better utilization of stock, thereby reducing over-all costs.

Non-standard specifications either in the grade or size of material or type of treatment disrupt manufacturing procedures with resulting cost increases. Some examples of customer requests which increase cost are as follows: (1) smaller knots or fewer knots than standard, (2) A lower moisture content than standard, (3) A more rigid slope of grain requirement, (4) A net size either larger or smaller than standard, (5) Particular restrictions upon spike knots, spike knot cavities, and knot holes,
(6) Rigid loading specifications on size of packages.

Another quite common experience, requested on transmission particularly, is for quick shipment on items not regularly stocked in such quantities, if stocked at all. This results in the crossarm manufacturer paying a premium to some friendly sawmill who is willing to assist him and too often the sawmill must waste a portion of the log in filling his commitment, so gains little even though a premium price is received.

SUMMARY

Structural strength is the primary purpose for which a crossarm is designed. The length of service it will render depends greatly upon how thoroughly the functions of selection, drying and treating are performed by the manufacturer. The cost of crossarms is the initial cost installed divided by the years of service—-the labor expense of replacing a crossarm is many times the cost of material. The use of treated quality crossarms is economy on the part of the utility.
"A NECESSARY RELATIONSHIP"

The part which wood has played in industry exhibits endless ramifications. The part it plays calls for all types of cooperation and all kinds of engineering, beginning with the tools used by the Forester and extending to the use of the finished product -- whether it be a home or a pole. Basic changes are taking place in the engineering and economics of the use of wood which affects both the producing and the consuming industries. As a result, engineering in the use of wood, forest management, and methods of wise and complete utilization must continue to be coordinated to an even higher degree than that in the past.

Of great importance in this coordination is the balancing of the supply of forest raw material with the consumption and demand of forest products. The trend in recent years in the use of wood for poles has been to utilize more and more what the forest is growing and to utilize species that were at one time considered to be secondary species. Many of these formerly unused species have now found themselves in the position of being a primary pole timber. We are continuing to find the need to utilize other species to aid in pole supply and to help alleviate the shortage in periods of peak demand. It is quite possible that an increasing percentage of poles will be produced in coming years from species not formerly used in large quantities, or species that are not used at all at the present time.

There appears to be an increasing demand for larger poles, 40' and longer. This results possibly from a trend toward joint usage. Also, we find a tremendous increase in the demand for small poles, poles 18' through 22' in length and with a top diameter limitation of 5 to 6". The increase in the use of these smaller poles is due primarily to the ever-growing popularity of the rigid-pillar type of construction. This type construction is sometimes referred to as "pole frame construction," and
we find it used quite extensively in farm buildings. Pole frame con-
struction is not new. It was used many years ago by cutting poles from
nearby wood lots and placing them in the ground without preservative
treatment of the wood. Because of this market, along with the demand
created by expansion of rural telephone lines, the availability of small
material of this nature has increased and made possible the use of poles
as cross arms or spar arms.

Still greater demands will be created if the prediction is true that
the need for power in the United States will double every ten years.

Before we concern ourselves too much about whether or not this in-
creasing demand will cause pole material to be in short supply, and before
we consider what is being done to prevent a short supply situation from
developing, it might be well to ask, "Will we experience a continuing need
for the wood pole?"

The demand for the wood pole might be reduced by the installation of
some communication lines underground and greater use of steel towers
where clearance requirements are greater than 40 feet, but I believe the
producers of the wood pole feel confident that there will be a continuing
need for their product. I know of no substitute material available at the
present time, or that might be available in the very near future, that has
as many attributes, economically or inheritably, as the wood pole for use
in construction of telephone, power, and communication lines.

Some advantages of wood for poles are:

1. Wood is abundant and universally available.

2. Wood is adaptable, workable with simple tools, easily climbed,
   and is pleasant to the touch.

3. Wood has a high fatigue resistance, is light in weight in com-
   parison to other construction materials, and when compared to
other materials has a high strength-to-weight ratio.

4. Wood has a good electrical resistance factor.

5. Wood will give long, satisfactory service life when proper measures are taken to protect it from its natural enemies.

In addition, wood is unusual in that it is the only renewable natural resource in an era of diminishing natural resources. It can be expected that the forests could provide wood poles in quantities and sizes to meet the requirements of the foreseeable future if we learn to use the tools of industry, along with good forest management practices, and thus be more capable of satisfying the need for this product. A feeling of optimism would be justified in the fact that proper harvesting is the best possible means of insuring a continued, permanent timber supply.

Assuming we are reasonably correct in our opinion that there will be a continued need for the wood pole, it would seem logical that those people in charge of the management of our country's timber resources, along with the pole manufacturer, the pole user, and those people responsible for writing specifications for the wood pole, should continue their cooperative relationship in efforts towards making certain that the wood pole will be available for continued use.

It is not our intent, as pole manufacturers, to itemize the field of responsibility for agencies or persons other than ourselves. We feel a responsibility in this matter, however, in that we manage timber and manufacture treated products. In accepting this responsibility, there are many different phases of pole manufacture that are important to us.

One of the most important considerations is that of the formulation of the proper specification for the wood pole. Throughout the entire history of the use of wood, we find that those craftsmen who built the houses, the ships, the wagons, and other things of wood, learned many things about
this material. They became quite familiar with its strength characteristics, its workability, its suitability for various jobs, and the differing characteristics of various species of wood. The results of their experiences, handed down from father to son, were used for devising rules for design and construction with wood. Unavoidably, then, as know-how was passed along from master to apprentice, some of the lessons learned from experience were lost. Learning became mechanical, and rules and specifications replaced reason.

For a long time, people and organizations wrestled with the problems involved in constructing a better transmission or distribution line. At the very outset of the pole industry, it seemed as though the judgment and experience of the line construction foreman controlled the acceptance of the pole. This was all right as long as there was adequate supply of timber handy to the lines that were being built. As communication lines extended, they began developing territories or areas where these poles were not so readily available. Eventually, it evolved to the point that the development of specifications rested largely in the hands of utility engineers. There was considerable pulling and hauling, and there was a time when "specifications" was almost a frightening word because those on the production end could not see the sense or justification, merits or what have you, to some of the requirements the engineers wrote into the specification. Handicraft customs collided with Machine Age demands. Up until this time, the producer accepted little responsibility towards a proper pole specification.

Even now a large proportion of the wood that is treated commercially is treated under purchasers' specifications. Sometimes these specifications are the general specifications developed by various associations, and in other cases the purchaser develops his own specification and puts into them the provisions that he considers important. Frequently, whatever the
source, the specification fails to protect the purchaser or contains provisions that are actually harmful to the wood or unnecessarily increase the cost of treatment.

Only in recent years has the problem of the development of a proper pole specification been systematically attacked. Actually, it was most difficult to solve the problem until people well versed in the various branches of science were brought together and organized so as to facilitate free exchange of information for the creation of an acceptable set of standards. All the factors, such as the strength of the wood, its durability, proper methods of seasoning, the influence on strength of defects such as knots and checks, methods of framing and treatment and installation, and a multitude of other problems and practices had to be studied. The evaluation of these factors called for the specialized knowledge of the engineer, the wood technologist, chemist, and the pathologist. Organizations, such as the American Wood Preservers Association, the American Society for Testing Materials, and the American Standards Association, and research laboratories, such as the Forest Products Laboratory at Madison and here at Oregon State, are making valuable contributions towards solutions to their problems. Cooperative relationships of this nature will make possible the development of a wood pole specification that will be beneficial to the user and the producer, and be of such a nature that it will contribute to a wider and better utilization of our forest raw material.

In order to be better informed and more able to contribute constructively to the formulation of a specification for wood poles, industry is carrying on many different research projects to study the various aspects of pole production and manufacture.

The problem of pole supply is being studied in our own operations in cooperation with the Forest Utilization Service at Missoula, Montana. We
are initiating studies to determine whether or not it is possible to grow and manage forests in such a manner that we could grow a tree with the ideal characteristics for use as a wood pole. Over 500 study plots will be incorporated in this study; and within these plots the individual trees will be studied in relation to their crown structure, their foliage pattern, branching habits, bark characteristics, general conformation, sapwood depth, growth rate pattern, and specific gravity. The type of soil that the tree is growing in, the type of vegetation that surrounds the tree, and an analysis of the stand type, which includes an analysis of site, exposure, aspect, etc., will all be studied. It is hoped that the data accumulated will show that certain characteristics, or a particular combination of situations, will be associated with that tree that has the ideal characteristics for a pole. As a result of this study, we hope it will be possible for private industry to establish on its own forest holdings a well-rounded pole management program so as to enable it to offer a continuing supply of poles.

The species that we intend to manage under a scientific management program would be Lodgepole Pine, Western Larch, and Douglas Fir.

Lodgepole Pine is well suited for the production of medium and small size poles. It is probably one of the most interesting commercial woods of the western United States that has historically been used as a pole. Nearly all the Northwestern Indians living adjacent to the Rocky Mountains used the small saplings of this species for their teepee poles because the trunk, or bole, is uniformly round, straight, and possesses very little taper. The Blackfeet, the Crow, the various tribes of the Salish Nation, the Nez Perce, and many other Indian tribes used this tree. Since the Indians' homes were also called lodges, the species became known as Lodgepole Pine. The wood is moderately soft, has a medium fine texture, is light in weight, and very receptive to preservative treatment. The
technical name, *Pinus Contorta*, meaning contorted pine, was apparently established on the basis of a different variety of Lodgepole Pine. This variety seems to grow at a higher altitude, is slower grown, is stunted, has a lower specific gravity, and apparently has higher proportions of compression wood and spiral grain. The species has an admirable history for use as a pole, with records dating back as far as 1910.

Western Larch, the species we intend to manage primarily for pole production ranges in the high valleys and mountain slopes of southeastern British Columbia, northern Montana, northern Idaho, and western Washington. Its technical name is *Larix Occidentalis*, and it is the largest and most massive of North American Larches. Because there are variations of Larch, the Western Larch growing in northern Idaho and western Montana should not be confused with other Larches. The trees reach their greatest development and greatest commercial importance in the Inland Empire where they sometimes form pure forests of limited extent. Their straight trunks grow ordinarily to a height of from 100 to 180 feet and a diameter of 3 to 4 feet. The tapering trunks are clear of branches for 60 to 100 feet or more, while the crown is very open and carries comparatively few, small, horizontal branches. They are a distinctive forest tree in that they are conifers but are not evergreens. They lose their leaves every fall, their branches becoming bare in winter and in the spring putting forth new foliage. Their loss of foliage each year is probably one of the reasons for their slow growth, their high ring count per inch, and their high age at maturity. The exceedingly thick bark of old and of half-grown trees is a most important protection against fire. Very many large trees bear evidence of having passed through a number of destructive forest fires without damage to their vitality. The wood is clear, reddish-brown, heavy, and fine-grained, commercially valuable for construction timbers as well as poles. It is a very durable wood in an unprotected
state, differing greatly in this respect from wood of the Eastern Larch. It is known as a straight-grain wood because the wood is comparatively free from spiral grain and entirely free from interlocking grain. Western Larch is heavier than the majority of softwoods as well as one of the strongest.

In addition to studying ways and means of managing forest lands to produce poles, we have spent considerable time in studying factors that influence the stability of a pole in line. This is also referred to as "twisting." In evaluating stability of a pole, it seems to be the general consensus of opinion that the straightness, or lack of straightness, of grain in a pole is a major consideration. For more than three years, we have had under study 62 test poles which have been installed in such a manner as to give us information on stability. Incorporated in this study are Western Larch, Douglas Fir, and Lodgepole Pine. The test poles are either air seasoned to an equilibrium moisture content or boultonized or retort seasoned. Preservative treatment is either butt treated or pressure treated. Poles with a constant degree of spirality of grain, as well as poles with a varying degree of spirality, have been incorporated in the study. The various test poles of each species were matched to the other species as to degree of constant spirality in a single pole, as to varying degrees of spirality within any single pole, and as to left and right hand spiral.  

This study is still underway; consequently, it is too early to be able to say what the results will be, but there are certain suggestions from the progress of the study to date. For instance, it seems very possible that rate of growth is related to direction of spirality. Each species of

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1 For purposes of this study, a left or right hand spiral is identified as follows: Standing at the base of the test pole and sighting along its long axis, if the grain deviates to the left, it is a left hand spiral; and, correspondingly, a deviation to the right is a right hand spiral.
poles could have its own optimum rate of growth, and any variation from this optimum rate could produce a spirality either left or right. It is suggested that the occurrence of spirality is no greater in one species than in another when considering pole size timber. It is suggested very strongly that pressure treatment stabilizes any pole in which spiral grain is present. It is suggested that all species are equally stable or equally unstable, dependent upon the degree of grain deviation. It is suggested that a fairly substantial percentage of poles that are now being rejected by standard specifications because of excessive grain deviation can safely be accepted and would prove to be very stable when installed. If this latter suggestion proves to be true, and specifications are changed accordingly, it could mean a savings to the pole producer, and this savings could be reflected in the cost of poles to the consumer. It also makes possible one more step towards greater and better utilization of our forest resources.

The carpenter and the apprentice long ago found that wood needs to be seasoned to rid itself of its moisture before it is used. If this is not accomplished prior to the time the wood is put into use, the moisture will leave subsequently of its own accord, and the wood will shrink and move in place. It is equally true that the condition of a wood pole prior to treatment has a great bearing on the success of the preservative treatment to follow and the service life of the pole installed in line. We believe that proper conditioning prior to treatment contributes greatly towards stability in line as well as the prevention of after-checking and the resultant exposure of untreated wood, which makes the pole vulnerable to the attack of decay-producing organisms.

Our studies in methods of seasoning wood poles are of fairly long standing. In cooperation with the Forest Products Laboratory, studies were conducted on the air seasoning of Lodgepole Pine. Our objectives
were to establish the most ideal method of stacking poles for air seasoning so as to obtain rapid and uniform drying. In addition, we attempted to season the poles to a moisture content that would be most ideal for subsequent preservative treatment and to develop the checking pattern that would be most desirable in the utility pole. The checking pattern should be such that the checks will be numerous. The combination between checking pattern and moisture content will be a preventative for after-checking. The studies were so successful in achieving our objectives that at one time we had 100,000 poles committed to air seasoning.

However, air seasoning is a very slow process and is far from precise. Large inventories are required with a corresponding high investment. It is difficult to forecast the market for poles so that the proper size and length will be in the air seasoning yard and available for manufacture and shipment at the proper time. If it were possible for the consumer to award contracts for purchase of poles six to eight months prior to the first delivery date, this problem in operation of an air seasoning yard could be greatly alleviated.

Because of these difficulties, we were stimulated to find other means of seasoning poles prior to preservative treatment. Retaining the same two primary objectives as those in the air seasoning study -- that of proper moisture content and proper checking pattern, a method of controlled seasoning was developed. This method is a procedure whereby a complete retort charge of pole material is placed in a chamber in which temperature and humidity are controlled. Seasoning is conducted so as to produce an ideal checking pattern and a moisture content that is ideal for preservative treatment and subsequent satisfactory service life.

The method of controlled drying developed is most encouraging and to date is proving to be more successful than we had believed possible. Moisture contents and moisture gradients have proven to be most satis-
factory, and checking patterns developed have been equal, and in many cases superior, to that developed in air seasoning. Our criterion of proper seasoning has been a moisture content at or near 22% at a depth of 1-1/4 inches, development of a multitude of fine hair-checks over the entire surface of the pole, and the prevention of rupture checks. There are other benefits from controlled seasoning in that uniformity of treatment throughout the year is improved because material entering the retorts is uniform as to wood temperature, moisture content, and checking pattern, and we are no longer confronted with the problems associated with variables of weather or ice and snow.

It is our considered opinion that economy of production in our operations dictates that the seasoning of poles in the retort should be curtailed as much as possible. This conclusion is reached not only on the basis of economy, but also on the basis of which procedures produce the most desirable results in Inland Empire species.

The next step in pole manufacture, framing, has received considerable attention from the pole producers. Automatic framing and tram loading machines that make possible a fairly economical operation for accomplishing the most frequent type of pole framing have been developed by our organization and others. We are still confronted, however, with the many other variations in framing patterns. Each of these requires the changing of dies, jigs, tools, etc. in the framing operations. The loss of production time as a result of these changes can be a serious penalty to the pole manufacturer. Ideally speaking, it would be a great boon to the pole producer if such a thing as standard framing could be developed.

The final step, preservative treatment, is also one on which a great deal of time and effort has been spent. Mother Nature did not see fit to confer immunity to decay upon the principal construction timber species
that grow in such vast quantity in the United States. Therein is the reason for the existence of our widely-spread but little publicized wood preserving industry. It has been said that wood preservation must be considered the oldest industry of all because Noah preserved the hull of his Ark with pitch.

The methods now in use for injection of preservatives by pressure processes are the result of technical research and also of the accumulation of nearly a century of world experience in wood preservation. Much improvement has been made in recent years so that it is practical for purchasers to obtain adequately treated timber that can be depended upon for long life even under the most severe conditions of exposure.

In the last few years many organizations, including our own, have been attempting to evaluate the advantages or disadvantages of a result type specification. By result type specification we mean a specification that is applied to a finished product. As far as possible the specification would cover the finished product rather than minor details of the manufacturing process. It would clearly define the methods that will be used in judging the quality of the finished product. With this type specification, it would be the treaters' responsibility to use his own initiative, imagination, and ability to the best advantage so as to comply with the requirements.

In formulating a result type specification, an important question that must be answered is, "How shall the retention of preservative be specified?" Many have felt that retention should be specified in terms of pounds of liquid preservative, or pounds of dry chemical preservative, retained in the treated area. Others feel it should be a retention specified in a certain zone within the treated area. Much work has been done within the committee structure of the American Wood Preservers Association
and also by many individual treating operations on this phase of result specifications.

All that I have said can be summed up in saying that the successful and satisfactory service life of wood, like any other product, is dependent to a great extent upon a proper specification and manufacture in accordance with this specification. In developing the specifications or improving old specifications, there should be a relationship of cooperation and thorough understanding between the purchaser and the producer to be sure that the requirements of the specification are reasonable and can be fulfilled. Cooperation of this nature would help standardize specifications, would be an aid in establishing quality control methods of operations, and would be a major step towards better understanding between consumer and producer, and mutual benefits would be found in a quality product.

Through the cooperation of engineers, wood preservers, and wood researchers, we have made great progress in the last 100 years towards a better understanding of wood as an engineering material and in developing practical and effective methods of protecting it from its numerous destructive enemies. Continuing this cooperative relationship in further research for the development of better specifications for better products, and in organizing wood pole conferences such as this for the free exchange of ideas and information, will insure additional progress for unlimited years to come.

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INTRODUCTION

Greater emphasis is continually being placed on treated wood products for longer service life and greater utility value. With the introduction and acceptance of a larger number of preservatives, greater demands are being made for the type of preservative for specific uses by users of treated materials. Users of large quantities of lumber, poles, piling, crossties and crossarms are continually searching for ways and means to get longer life and greater returns from their investment. Railroads, the users of the largest volume of treated wood, invest a tremendous sum of money each year in treating crossties, piling for docks and bridges, poles for telegraph and telephone lines, and lumber for car and bridge construction. Utilities have invested huge sums in treated poles and crossarms and are expanding their operations with the construction of transmission and distribution lines throughout the country. Piling for docks, wharfs and foundations are needed in increasing quantities.

With the upward trend of prices for forest products and the search for the best protection over the greatest period of time purchasers are taking a closer look at the materials installed in their operations and are asking (1) Which is the best preservative for my purpose, (2) What concentration is consistent with the mechanical life of the structure, and (3) Am I getting my money's worth in proper treatment, required retentions and penetrations, and quality of raw material which I purchase? The first two questions will, of course, be decided after consulting with technical authorities, treating
plant personnel and their own engineering staff. The third question constitutes the basis of this paper and shall be discussed in detail under appropriate divisions during our inspection procedure.

Having decided the first two points in question, the purchaser wants assurance that he is getting the proper product with the required end results. He himself is not well versed in the techniques involved in determining such results nor is he aware of the variables existing in the raw timber products, in treating processes, in depth of penetration and retention of preservative. He does, however, demand and expect the finished product to conform to his specifications in all respects and, being uninformed himself, engages an authority in this field who can represent him at the supplier's yard or plant and can follow through on all details of production and treatment. Independent inspection performed on a competent and impartial basis assures the purchaser conforming material and the supplier a satisfied customer. Besides, many plant operators welcome an independent inspector for his assistance in eliminating extra time and expense in processing non-conforming material and his ability to check all details of operations, a procedure not possible by plant employees without the additional expense of hiring trained personnel.

The routine for inspecting poles and crossarms will be described under the following headings:

A. Poles
   a. Untreated
   b. Treated

B. Crossarms
   a. Untreated
   b. Treated
A. Poles
   a. Untreated

   Before proceeding with the actual processing of an order all
details and specifications set forth by the purchaser must first be
thoroughly scrutinized, making sure they are adequate and complete
and that the inspector is in agreement with the supplier on all points.
As will be explained later, some specification exceptions may be
stated on the order so it must be fully understood exactly what the
customer desires in order to avoid misinterpretations, delay, and
wasted material. Any additions should be written in or amendments
added to the order.

   Quality control is an important phase in a pole plant and reflects
to a great extent the level at which a product is maintained through­
out the operations. This control begins with the man in charge of
production and carries through the peeling operations, classification
and storage procedures, manufacturing, handling and treating, and
results in placing the plant in a low, average or high quality bracket.

1 Size. Most poles are purchased under the ASA (American Standards
Association) tables for size under the proper species, classes
and lengths having been determined by the engineering force for
load requirements and clearances. This size, as you undoubtedly
all know, is based on the minimum circumference permissable at a
point 6' from the butt and the circumference at the top. If either
measurement is less than given in the table the pole falls into
the next smaller class. The butt size usually governs since pole
taper normally is less than the table figures.

   A 6' steel tape, coiled to conform with the contour of the
pole and graduated in inches, is used to measure circumferences.
This is usually done when poles are dogged down on skids for framing or when a skid load of finished poles is offered for inspection. An experienced inspector can pick out the poles that are near the minimum size, measure them and judge the adjacent ones by comparison.

Some utilities require that the pole after treatment meet the designated table size. In such cases an allowance of ½" to 1" oversize must be allowed for shrinkage. The ASA Specifications do not specify a green or seasoned dimension so it should be stated on the order from the customer. Some quite serious complaints have come from field engineers because the delivered poles were under the Table size. This point should be clarified in the next ASA publication.

Maximum top sizes are specified by some utilities to reduce weight and conserve cargo space. One specification reads "tops not more than 28% greater than the minimum specified," others "not more than 2" over the Table figures." Some will allow tops to be no more than two sizes larger. Such restrictions give the customer a more uniform product but impose penalties on the supplier by increasing sorting and handling costs.

Extremely large butt sizes are avoided by including a clause in the specifications limiting the maximum to not more than 7" over the specified minimum. When inspecting poles for size, large poles are easy to spot and to measure for specification limits.

(2) Peeling. Machine peeled poles are now supplied by all treating plants since most poles are received as "barkies." However, the ASA Specifications do not mention machine peeling so the order
should specify what is desired. Some machines give better results than others and some operators are more skilled in turning out smooth poles by virtue of accurate setting of peeler blades and delicate manipulation of controls. The inspector should call the supervisor's attention to poles showing "barber pole" and "wheel gouging" and suggest that adjustments be made.

(3) **Sweep.** When measuring a pole for size it can also be judged for sweep. Sweep, or bow, is defined as a deviation from a straight line. It is measured by stretching a steel tape from the surface of the pole at the ground line to edge of the pole at the top. According to the ASA the distance from the pole to the line shall be not greater than 1" for each 6' of length between these points. When poles have sweep in two planes or in two directions in one plane, a straight line connecting the mid-point at the ground line with the mid-point at the top shall not at any intermediate point pass through the surface of the pole. To eliminate poles having hooked butts and excessive sweep, some utilities specify that the above measurements be made from the top to the edge of the extreme butt.

(4) **Crook.** Crook means an offset along the length of the pole or a localized deviation. In fir it is often caused by a snow break where the terminal leader is broken and a lateral shoot takes its place. This frequently causes a serious weakness due to diverted grain or twist at this point or to decay contained inside. Poles showing localized swelling or unnatural growth must be closely examined for defects.

(5) **Length.** Before a pole is framed it must be measured for length. Defects in the butt or top are usually cut off at this time.
The butts can be squared and the top cut to the required roof slope. Splits, shake and decay can be readily detected at this time and the pole rejected or cut to the next shorter length on the order. Defects caught at this time eliminate further time and expense in framing operations. The allowance of 3" under and 6" over length on short poles and 6" under and 12" over on poles 50' and over gives some flexibility in framing and in cutting out defects.

(6) Knots. Rejections because of knots are ordinarily caused by the sum total of their diameters exceeding specification limits. Since fir has a tendency to send its lateral branches out in whorls around the tree, it is common to find too many knots in the same 1' section which weakens the pole. Only careful search and a watchful eye will enable one to detect these groups of knots. Some engineers consider knots to have such a weakening effect that they limit the sum total of knot diameters in a foot section to 5". This eliminates nearly all poles except those grown in dense and favorable site stands and makes production more difficult.

"Sucker" knots are a source of much dispute and confusion since they are not usually mentioned in the specifications. These knots do not extend outward from the bole of the tree at right angles as normal knots do, but grow upward at an angle and eventually reach the surface some distance from the source. They frequently cause an irregularity in the shape of the tree and cause serious weakness in a pole, or they may be associated with decay and worm infestation. If the wood fibres are intergrown and the knot is not large for the size of the pole, no serious harm is done. However, if the knot is encased in bark, is of considerable
size, and causes distortion of growth for some distance in the wood, the pole should be rejected.

Poles produced in certain areas have been found to contain black, pitchy knots $\frac{1}{2}$" and $\frac{3}{4}$" in size but on close examination prove to be soft and contain decay. A section cut out of this pole and split with an axe will disclose decay to the pith. When such poles are found with evidences of soft, black knots, a knife blade used as a probe will readily disclose the nature of the knot. Preservative treatment will not cure this condition.

Western Red Cedar poles must be closely examined for Western Cedar borers. This is mentioned here since infestation of the pole comes through the branches, consequently when the knots are trimmed their galleries are exposed and can be readily seen. The larva enter the pole and dig galleries which often are so numerous that a honeycomb effect results. Such poles are seriously weakened and subject to decay.

(7) Decay. Decay is not permitted in Douglas Fir poles so the butt and top surfaces must be carefully examined. Should unsound wood appear, the pole is usually cut back to the next shorter 5' length. Incipient decay is frequently found in the heartwood in pole toos in the form of bluish discoloration—the darker the color the greater the breakdown of wood fibers. Only the lightest discoloration should be allowed.

Saprot, which is not permitted, is caused from cutting dead timber or leaving "down" timber too long in the woods after falling. Serious disintegration of the wood fiber takes place which no preservative treatment can cure. Saprot or "burned" spots often occur in stock piles where the pole comes in contact with a skid
or separating pieces. Moisture collects at such junctions and decay results if stock is left in storage too long. These particular spots should be closely examined and if advanced decay is present, the pole must be rejected. Relative to decay, this may be the place to put extra emphasis on good storage and yarding practices. Poles should be yarded, peeled and placed on substantial storage skids as soon as possible. Poles left on the ground will show signs of decay in a relatively short time and may be lost completely, whereas if placed on treated storage skids they will begin to season immediately. Such practices provide much better "housekeeping" conditions.

Cedar poles will be acceptable if the area of decay does not exceed 10% of the butt surface and extends no more than 2' up the pole. Probing with a steel rod will provide some indication of the extent of decay.

(8) Crossbreaks. Poles are often cracked during falling operations in the woods by impact with a stump, rock or irregular terrain. Such cracks are very difficult to spot in green poles and it is necessary to slowly go over the piece and watch for fiber breaks in the top section, especially around knots. After some air seasoning cracks are easier to find but it is noteworthy that many cracked poles are not found until after treatment when inspecting for checks and bursts.

(9) Scars and Catfaces. These defects are prohibited in most specifications because they are associated with decay, worms and insufficient sapwood for satisfactory treatment. They are not permitted in the ground line area in any event. Depressions in the surface of the pole from other causes may be permitted if sufficient sapwood remains.
(10) Compression Wood. This abnormal wood is not permitted in the outer 1" of the pole since it shrinks excessively lengthwise and often causes the outside shell to peel off making climbing hazardous. These abnormally wide and dark growth rings are conspicuous on cross sections.

(11) Sapwood. The thickness of sapwood is not mentioned in the ASA Specifications and as a result has caused many serious complications. Poles purchased under this specification must specify that on Douglas Fir the sapwood minimum is 3/4" since this is the part of the pole that is impregnated, serves as protection for the heartwood, and must meet a minimum of 3/4" of preservative penetration. The ASTM Specifications state that the sapwood on piling cannot be less than 1" in thickness and it is our opinion that this clause is equally important for pole specifications.

Poles containing thin sapwood can be detected by watching for signs of reddish heartwood around knots, in areas where peeler blades have cut through the sapwood and where framing shows the depth of sapwood. Unless these poles are rejected when untreated they may pass without notice after treatment when samples of only twenty poles are taken from each charge.

(12) Framing. Framing a pole means cutting flat surfaces and drilling holes at prescribed points for the attachment of crossarms, cross-bracing, transformer racks, guys and other hardware necessary for line installation. Since all utilities have their own requirements in this respect it is very important that details be shown on the order and sizes and dimensions double checked. The roof may be flat, a single cut of 15 degrees or more or a two slope roof of 90 or 120 degrees. Mortise or slab gaining is usually
designated but utilities use certain variations of these in width, length, depth of cut, and location on the pole. The sizes of holes vary and some orders may require three different sizes in the same pole.

When framing is done on skids or in machines it is very important to observe that no change in position has taken place which will throw the gains out of alignment. "Sighting boards" should be used to check this detail of parallelism. Some poles require framing at 90° with the face and some joint use poles are framed every 90° around the stick so greater skill and attention is necessary to check these details. The inspector must be on the alert to catch any variations by making frequent measurements of spacing and bit sizes, and to make sure that all framing is done at the proper locations. Machines occasionally get out of adjustment or breakages occur that will cause ruined poles unless the difficulty is soon discovered and corrected. The inspector should also observe that the hole is in the exact center of the gain and also in the center line of the pole diameter as well as noting that framing is on the face of the pole.

(13) Branding. This operation is done for proper identification of the pole and to serve as a reference spot when setting in the hole on the line. In addition to the information prescribed in the ASA specifications for branding, the order must state at what distance from the butt this mark shall be applied and if additional data is required, such as the company initials. It must state if burn branding is required or if aluminum discs are acceptable.
The distance from the butt to the brand is usually ten feet on small poles and 14' on poles 55' and longer. Some utilities specify the distance as 6' above the ground line as designated in the ASA tables. Others require a 12' distance on all poles. The same brand burned in the pole on its face is also required on the face of the butt by some utilities, while others need only the class and length, stamped with a hammer.

After a pole is set in the line the brand serves as reference for the records so it should be carefully and neatly done and accuracy is of the greatest importance. Frequent changes in class and length on mixed orders require repeated checking for corresponding changes in the brands. It must also be observed that the branding on the butts checks with the branding on the face and that butt brands are changed on cut-backs.

(14) Spiral Grain. All specifications covering poles and piling contain a restriction on the amount of spiral or twist permissible. The ASA is very liberal in this respect and causes little concern in Douglas Fir poles. However, most utilities have difficulties with poles twisting their installations out of alignment so specify one complete twist in 30 feet or ½ twist in 15 feet. In green poles spiral grain is more difficult to detect than in seasoned stock, but by carefully observing growth and fiber characteristics the twist can be traced. Since the twist may be in the top, butt or for the full length, it is necessary to examine the entire pole. The common practice is to follow the grain from a designated spot to a point 180° from this point and measure the distance along the axis of the pole. If the distance is less than that permitted on the order, the twist
is excessive and the pole is rejected.

(15) Incising. Machines of various types have been designed to incise round material the entire length, normally in conjunction with peeling operations, the contention being that a better checking pattern will develop, seasoning is speeded up and treatment is facilitated. This operation should not cause excessive pulling of fibers or roughing up of the surface.

When incising cedar poles and fir poles for treatment by the thermal process all inner and outer bark must be removed from the area 2' below and 1' above the ground line before incising. The location of this 3' area must be checked.

b. Treated

After a charge of poles has been treated in the retort and transferred to the yard it is advisable to make a preliminary inspection before removing them from trams. Due to mechanical difficulties in operations, underestimating the condition of untreated poles, or severe penetration requirements the results may not be satisfactory and the operator may wish to retreat the charge. Time and expense can be saved by getting this decision as soon as possible.

(1) Inspecting For Penetration.

Group A. When following the AWPA (American Wood-Preservers' Assoc.) procedure for determining penetration of preservative poles are selected at random around the outside of each tram load. Twenty pieces, representative of the size and length contained in the charge, are selected and numbered. A core is taken from each pole with an increment borer and placed in a tray designed for this purpose.
Measurement with a steel scale graduated in .10 inch will determine if the pole meets penetration requirements and the pole is marked accordingly. If 18 of the 20 borings meet requirements the charge as a whole shall be accepted but those non-conforming are marked for retreatment. If 16 or 17 meet penetration requirements each pole shall be bored and only those meeting the requirements shall be accepted. If less than 16 borings meet requirements the entire charge shall be rejected.

**Group B.** Poles in this group measure 37.5 inches or more in circumference 6′ from the butt and each pole must be bored to determine the penetration depth with only those accepted which meet the specifications. When bored before unloaded from trams, a crayon mark on the end of the pole identifies it as conforming (straight mark), retreat (R), or reject (#). These poles need not be bored later on skids. The balance of the poles can then be bored and appraised when spread out on skids, and those shipped which are marked as conforming.

(2) **Inspection For Treatment**

**Eight Pound Retention or .40 Pounds**

Treatments on this specification require a minimum of 3/4" penetration with creosote or creosote-solutions or with an oil-borne preservative such as pentachlorophenol, the assumption being that it requires 8 pounds of oil or .40 pounds of pentachlorophenol in a 5% solution to attain this result in the charge as a whole. When boring poles, a spot should be selected approximately midway between the butt and the top being careful to avoid checks, knots, shake, holes, and incisions as they influence penetration results. The boring
tool shall be directed toward the pith and bored deep enough to include all the sapwood. On some stock this may measure 2½ and 3 inches. Care should be exercised to not lose part of the boring when extracting it from the bit. The treated portion is now measured and recorded and if 3/4" or more it conforms for penetration. Those rings where only the summerwood portion is treated are also measured providing there are no intervening untreated rings in the measured portion. Those cores showing a high moisture content underneath the treatment should be rejected on the basis of the poles being too vulnerable to seasoning and checking through the treated area when in line.

When in doubt about the core being truly representative of the pole a second core should be taken on another quarter of the circumference. It is our practice to measure the depth of sapwood in addition to the depth of preservative and to record this on the report for the benefit of the customer. By comparison, it will give him not only the measurements on penetrations he received but the total sapwood present, and the percent of untreated sapwood.

Under this classification we can also include poles treated under the Standard Table of Specification TD-100, Edison Electric Institute. Cores are taken for analysis on the first 12 conforming borings and analyzed as will be described later under Analysis. Under this Table cores from the incised butt section must measure 5/8" minimum and average ½" on 6 of the above conforming poles at the mid-points. The procedure is the same as on pressure treated fir when
boring for penetration conformance. Measurements are recorded on the first 20 poles but we bore the charge 100% in the incised areas and non-conforming poles are retreated and re-inspected.

Ten Pound Retention or .50 Pounds

Poles ordered under this treatment require penetration of 3/4" minimum and 85% of the sapwood up to a maximum of 1-5/8". These penetration requirements are being requested on an increasing number of orders for added protection and increased service life, especially for poles in the larger sizes.

Penetration tests for this requirement must be carefully performed since total sapwood depth is involved and the line of demarkation between sapwood and heartwood must be definitely determined. The change in color and wood fiber characteristic is normally distinguishable in poles treated green but is more difficult to detect on air seasoned stock. The ease with which the increment borer enters the wood is a good indication of the seasoning condition since dry poles require a considerably greater pressure to twist the bit to the required depth. On poles seasoned in the retort there will normally be some of extra heavy sapwood which do not season out and the lack of surface checking is an indication of insufficient seasoning and treatment. Since it is necessary to remove moisture to below the fiber saturation point to allow the preservative to penetrate, shrinkage will take place as indicated by longitudinal checks. Moisture blocks the movement of oil beyond the outside inch unless the seasoning is continued to bring the moisture of all the sapwood down below 30%. The result of piece inspection shows that the poles with thick sapwood and
few annual rings per inch are the ones requiring retreatment. Where difficulty is experienced in determining the depth of sapwood, the core can be treated with a methel orange solution, which will color the sapwood yellow and the heartwood red.

Poles of unequal seasoning as those rafted in the water will show a "dry" side on the upper surface and wet on the remainder. This "dry" side is deceiving because it is seemingly case hardened on the surface with large quantities of water underneath, and the seasoning cycle normally employed will not season this side as readily as the wet side. The trapped water underneath does not permit the preservative to enter this portion of the pole, although the rest of the pole may be well treated. Rafted poles can be distinguished by the water line marks and cores should be taken from the upper or "dry" side to determine minimum penetration.

Poles treated under the Extra Table of Specification TD-100, Edison Electric Institute, require that each pole when bored in the ground-line incised section must have a minimum of $3/4"$ of penetration and an average of $1/2"$ penetration at the mid-points on the set of test cores. To assure each pole being sufficiently treated we bore each one at the ground line and record the first 20 measurements on the records.

Butt-treated cedar poles are tested in a similar manner by taking 20 cores out of a vat loaded from the incised ground-line section. If treated according to AWPA Specifications the depth of penetration shall be not less than $1/2"$, unless the sapwood depth is less than $1/2"$, in which case complete sapwood penetration must be obtained. All poles in Group B must be bored and
only those conforming to requirements shall be accepted. Group B are poles whose 6' from butt circumference is 40" or more.

Poles are usually spread out on skids for inspection to speed up the operation and facilitate loading. This provides adequate space for boring each pole and appraising its physical condition. Except for quantities of small poles which are uniformly seasoned and treated, it is our practice to bore each piece and marking those not conforming. Because the hole leaves exposed untreated wood it is imperative that each hole be plugged with a treated dowel so each hole is marked either with a circle to indicate acceptance or with an R to indicate retreats. It is mandatory that all holes be plugged before other operations are started or work proceeds on another skid. The presence of a crayon mark locates the hole to be plugged, which is a big help when rain fills it and is a check when marking the ends for the loading crew.

(3) Inspection for Physical Condition.

After poles have been bored to determine penetration conformance, each piece is scrutinized for its physical condition by rolling it completely over with a peavy. It is examined for damage during handling, falling breaks around knots, excessive checking and internal bursts. Considerable difficulty has been experienced from bursts which occur during the treating cycle and leave the pole unusable. This feature occurs almost exclusively in poles which have had no previous air seasoning and is most common in poles and piling of larger sizes, showing on the surface as fiber ruptures or many times as only a hair line check with a slight sheer.
A slight wedging of the check with a shingling hatchet will disclose checking or burst to the very center of the stick. A cross-section will show a star-shaped checking pattern from the pith to the outside surface and, in many cases, it will fall apart into two or three pieces. This is a serious loss to the suppliers. If not found at the plant, it may split open during subsequent handling operations. It would constitute a hazard to linemen and to passing traffic and its service life would be short because of checking through the treated area, exposing white wood.

Since some charges of poles and piling contained a high percentage of burst pieces we have adopted a policy of "sounding out" every stick with a shingling hatchet to assure soundness. A well seasoned and treated pole will have a natural ring when struck with the flat end of a hammer or hatchet. Repeated taps from end to end will tell what the internal condition is like. Burst pieces will sound dead or hollow and close examination will expose the check nearly unfailingly, sometimes near the tops, sometimes in the center or butt section. Many theories have been voiced as to the causes of this internal failure but no one has found a method to predetermine the pieces which will fail during treatment. Opposing forces of shrinkage and swelling in wood fibers has been given as one reason but it has been demonstrated that charges well seasoned by boiling under vacuum will show better results than the same material not as efficiently seasoned and undergoing the same pressure cycle. The speed with which moisture is removed during seasoning and the
maximum pressure attained during the pressure period are no doubt contributing factors.

(4) Analysis. A constant check should be maintained on the preservatives at each plant in cooperation with the chemist or person responsible. With plants treating with as many as seven different solutions, it is imperative that no mixing or diluting takes place and that the minimum standard set up by the Association be maintained. Laboratory analysis on working stock at regular intervals will give assurance that proper controls are enforced.

Analysis of pentachlorophenol content in poles treated under Specification TD-100 is done by the lime-ignition method as set up by the AWPA under Standard A5-58. When taking borings out of the first 12 conforming poles, extreme care should be taken not to lose any portion off the end of the core. Each core is measured for depth of treatment and thickness of sapwood which are recorded on the report to the customer. The outer ½" is then cut off and placed in the prepared crucible for analysis. We have never found an analysis near the minimum limits permitted in the EEI Specifications.
B. CROSSARMS

a. Untreated

Included under this category are distribution arms purchased under TD-90 of the Edison Electric Institute, DT-5B and PE-16 of the REA, Heavy Duty Douglas Fir Crossarms under TD-92 and Heavy Duty Douglas Fir Braces under TD-93.

Inspection of arms for quality and grade is performed at the supplier's manufacturing plant on the finished product. Piece inspection is necessary for all four sides and the ends must be seen and examined for exceptions not permitted in the specifications. Short arms are usually placed on saw horses and turned by hand while longer and heavier arms are inspected during the process of manufacturing or shipping. A modern and progressive plant will have screened the stock carefully and eliminated obvious non-conforming pieces before drilling the holes.

Since many orders contain exceptions to the standard specifications, all details should be checked with the supplier to avoid errors and misinterpretations, and all requirements should be noted on the prints. With the aid of an electric moisture meter, all moisture content requirements can be readily checked and recorded. The most common defects are crossgrain and knots which reduce strength. The size and location of knots is very important, especially in the top center section and in pin and bolt holes. When stacked in piles the arms are examined on the ends for annual ring requirements, prohibited heart centers, compression wood, splits and shake and non-conforming pieces marked out. During handling operations all surfaces are inspected for non-conforming features such as decay, shake and splits. Scant pieces are noted by lack of surfacing.
The finished size, position and diameter of holes bored, roofing, chamfering and easing of edges, incising, if permitted, should be initially and frequently checked against the specifications. Hot iron branding on one face is required for identification and must contain the manufacturer's designation, year manufactured, code letters for preservative used and DF for Douglas Fir. All accepted arms are stamped with the inspector's individual brand.

b. Treated.

An analysis of the preservative used for treatment must be made to assure its conformance with specifications. Modern plants are equipped with complete laboratories and personnel to make complete records. Preservative treatment can be by either creosote or pentachlorophenol with either the pressure process or the thermal method.

After the charge has been withdrawn from the retort or taken out of the vat, it is bored for penetration. Cores are taken from no less than 5% but in no case less than 20 pieces. These cores are taken parallel to the pin holes to determine the amount of end penetration. On standard arms the penetration must be complete at a distance 1\(\frac{1}{2}\)" from the hole. On a 4# pressure treatment the penetration must be complete at a distance of 2" from the hole, 2\(\frac{3}{4}\)" for 6#, and 3" for an 8# treatment. Side penetration must be 3/16" but more may be specified in some instances.

All ends should be examined for checks or splits which may have developed during treatment. Surfaces should be clean and dry and it is important that they remain so. An examination should be made of the entire charge as a whole for damaged pieces from other causes.

Retention of preservative should be calculated and details of all treating cycles recorded, together with contents of the charge,
penetrations and results of final inspection. The material accepted is then branded with the inspector's individual hammer. Copies of reports are distributed as specified with one copy for the supplier for his information and guidance.
Conclusions.

There has been considerable concern within the ranks of some utilities in recent years in regard to decay appearing in pressure treated poles because of checks opening up and exposing untreated wood to decay producing organisms and termites. Poles installed in areas of high temperatures and low humidity are especially vulnerable to continued seasoning and severe checking. This has been the prime reason why some people advocate seasoning to a lower moisture content, either artificially in the retort or by air-seasoning before treating.

It is a well known fact that before green sapwood can be successfully impregnated with an oil preservative, artificial seasoning must continue until the moisture content has been reduced to a point well below fiber saturation. Shallow penetration results from relatively short seasoning cycles. Average penetration requires more seasoning time while full sapwood penetration requires extra long seasoning cycles.

To assure poles of longer service, a greater percentage of the sapwood needs to be treated. To get deep penetration, sufficient moisture must be removed. Then it follows that with a specification requesting 85% of the sapwood to be treated up to 1-5/8" or 1-3/4", poles must be well seasoned to a considerable depth to attain that penetration. This greatly minimized checking of poles in service.

It has been our experience that the less the seasoning the greater the percentage of retreats. It has also been noted that adequately seasoned charges contained fewer burst pieces, somewhat compensating for longer treating cycles.

We would advocate the practice that every pole, no matter what size, be bored in the ground line area. This is the most vulnerable part of the pole and needs the greatest protection. Cores taken from this area showing
85% of the sapwood treated would certainly have maximum protection from checking and decay. Concentration would be of minor importance, since Douglas Fir sapwood treated to that depth would contain considerable more preservative than the threshold point. Some objections have been heard regarding boring holes in the ground line area since some holes may not get plugged. If the practice of marking each hole with a crayon is followed and no operations permitted until plugging is finished we cannot see any dangers involved.

Besides boring each pole we recommend that each piece be thoroughly tested for soundness by sounding with a hammer or hatchet. A surprising number of bursts and checks are uncovered in this manner. It is important for the customer to know the results he is getting in each shipment. A record of at least 20 cores with depth of penetration, thickness of sapwood and per cent of sapwood treated would be valuable information.

With the great investment that utilities have in poles and the tremendous cost involved in making replacements, it seems necessary that they take steps to lengthen the life by employing means to assure conformance of each piece. The small cost per pole added by inspection is repaid many times by lower replacement costs.

We have studied these conditions for some time and it is the writer's experience, over 32 years in the wood preserving industry, that more concern is currently being expressed in this field than ever before. Competent and experienced independent inspection plays an important role in this field and gives added assurance that all of the specification requirements are met at a very low cost per pole.
MAINTENANCE INSPECTION OF
WOOD POLE LINES
A. H. Hearn
Engineer, American Telephone and Telegraph Company

1. NEED FOR PERIODIC INSPECTIONS

The inspection of poles is essential to the maintenance of the aerial plant in serviceable condition and enables the replacement of defective poles before they deteriorate below the minimum strength requirements. From general experience, routine periodic inspection of all poles in the plant by regularly assigned inspectors has been shown to be a desirable and economical procedure when considered over a period of years.

The failure of a pole which has deteriorated below the minimum strength requirements usually means interruption of service and, if the pole carries power wires, a hazard to the public. Decayed poles are often the starting point of line breaks in which a number of poles may go down under storm loading conditions. Lost time or even fatal accidents are of too frequent occurrence because a deteriorated pole breaks while a man is working on it.

With relatively short span construction the wires or cable suspension strand will often support a pole completely rotted off at the ground line. As the length of span increases the support of adjacent poles decreases. Therefore, with the present trend toward longer spans, the necessity for periodic inspections assumes greater importance.

It is considered advantageous to have pole inspection work supervised by the plant engineer so that required pole work may be coordinated with planned additions, rearrangements, relocations or removals of existing plant.

2. INITIAL INSPECTION AND REINSPECTION

In the past, the age when an initial inspection of a pole should be made depended upon the resistance to decay and insect attack of the species of pole timber involved. This in turn depended largely upon whether the pole was given a preservative treatment before installation and upon the type of such treatment.

At the present time practically all poles going into plant are treated full length either by a pressure process or by the thermal (hot and cold bath) process. The specified retentions of preservative varies for the different species but is based on the relative sapwood thicknesses so that retentions in the treated wood are essentially equivalent. Requirements for the depth of penetration of the preservative also varies for the different species of pole timbers depending on their sapwood thickness, but are such that protection of the sapwood is essentially equivalent for all species. As a result, it may be assumed that all poles regardless of species will perform comparably when set in similar locations. Therefore, theoretically the scheduling of periodic inspections should be the same for all species.
Experience, however, has shown that the incidence of early failures and the rate of deterioration varies with geographical location due to variations in climatological factors. For example: test posts in the Gulfport, Mississippi test plot start to decay earlier and the decay progresses more rapidly than in posts, cut from the same poles and treated simultaneously, which have been placed in the Chester, New Jersey test plot. The two climatological factors which appear to be most closely correlated with the performance of poles in line are average rainfall and the length of the growing season. The growing season is considered the number of days between the last killing frost in the spring and first killing frost in the fall.

Taking these two factors into account, namely rainfall and growing season, the Transmission and Distribution Committee of the Edison Electric Institute has adopted the following:

GUIDE FOR DETERMINATION OF YEAR IN WHICH FIRST POLE INSPECTION SHOULD BE MADE IN ANY SPECIFIC LOCALITY

<table>
<thead>
<tr>
<th>*Average Annual Precipitation (Inches)</th>
<th>Year of Service in Which First Inspection Should be Made</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>*Average Length of Frost-Free Period *Average Length of Frost-Free Period *Average Length of Frost-Free Period</td>
</tr>
<tr>
<td></td>
<td>More Than 250 Days 150 to 250 Days Less Than 150 Days</td>
</tr>
<tr>
<td>50</td>
<td>12 15 18</td>
</tr>
<tr>
<td>30 to 50</td>
<td>15 18 21</td>
</tr>
<tr>
<td>Less than 30</td>
<td>18 21 24</td>
</tr>
</tbody>
</table>

*Based on information from local Weather Bureau or other local sources.

As stated in the title the foregoing is proposed as a guide only. For any given area there are a number of other factors which must be considered. These include:

(a) The temperature range. How many days during the year is the temperature in the optimum range for the growth of decay organisms? How many days in the year is the temperature so low that fungi and insects are dormant?

(b) Is the precipitation spread out over the year or does it fall mainly during a short period? How much of it is snow? If it occurs mainly during a short period is this when the temperature is low or high?

(c) Is an area in which there is little precipitation irrigated?
For example: using only average annual precipitation and the length of the frost-free period as the criteria, the Gulf Coast Area and the East Coast of Washington, Oregon and Northern California would fall in the same category and an initial inspection would be made in 12 years. A study of the U. S. Weather Bureau reports, however, shows that the average summer precipitation (June through August) ranges from 10 to 22 inches along the Gulf Coast whereas for the coastal belt of Washington, Oregon and Northern California the range is from one to 8 inches. Also the average annual temperature is 20 degrees higher in the Gulf Coast Area than along the Northwest Coastal Area. This would mean that there are more days in the former area when conditions are favorable for decay. Taking these modifying factors into consideration, it may be assumed that if poles set along the Gulf Coast should be inspected 12 years after installation, inspection of poles set along the Northwest Coastal Area should be inspected 18 years after installation.

In the last analysis, however, the scheduling of inspections, both initial and subsequent reinspections, should be based on local experience tied in with local climatic conditions.

3. CAUSES OF DETERIORATION

3.1 Decay - The major cause of deterioration of wood in use is decay or rot. Decay is caused by low forms of plant life called fungi. The vegetative stage of fungi consists of minute threads which grow within the cells of the wood. These secrete enzymes which break the wood substance down into compounds which can be used by the fungi for food. The toadstools or brackets often found on decayed material are the fruiting bodies in which spores or seeds are produced.

3.11 There are 3 types of decay found in poles, namely:

(a) Internal decay, called hollow heart by pole inspectors, in the deep sapwood species such as southern pine, ponderosa pine and red pine is usually found in untreated sapwood because of poor or irregular penetration of the preservative. In these species it may extend the full length of the pole under a ring of treated wood, it may be confined to the lower portion of the pole, or it may occur in pockets or streaks at any place in the pole because of moisture pockets in the wood resulting from uneven seasoning or water or air pockets in the treating cylinder.

In the shallow sapwood species, such as lodgepole pine, Douglas fir, the cedars and western larch, internal decay may occur in a ring of untreated sapwood or may be in the heartwood. In areas with high humidity the decay may be present the full length of the pole. More commonly, particularly heartwood decay, is found in the lower portion of the pole, often entirely below ground line.

Rot in the top is often found in butt-treated or untreated poles but is not common in full length treated poles because of heavy end penetration of the preservative.
(b) External decay, usually called rotten butt by pole inspectors, is found at or below ground line. The distance below ground line at which it is most severe varies with soil moisture conditions and type of soil. This type of decay starts at the surface and progresses toward the center of the pole. In the untreated cedar and chestnut poles, originally used to support utility wires, this type of decay was almost universal. Allowances were made in selecting the size of new poles for a constant annual decrease in circumference.

External decay is also found in treated poles because of inadequate retention of preservative. It is more prevalent in poles treated during the past 25 years than in poles previously treated, probably because of reductions in retention and other steps taken to produce clean, non-bleeding poles. It may extend around the entire circumference of the pole or may be confined to pockets or streaks along checks. Because the rate of deterioration varies with the residual retention and distribution of the preservative estimates of the rate of future circumferential decrease can not be made as was done for the untreated cedar and chestnut poles.

(c) Shell Rot - This type of decay, usually found in butt-treated cedar poles, is confined to the sapwood in the aerial section. It is generally found under a paper-thin shell of sound wood too dry to decay. Because of the shallow sapwood of cedar poles (average 0.5 inch) and because of the excess amount of wood in the upper portion of the pole, the loss of the sapwood above ground line does not affect the utility of the pole from a strength standpoint. Shell rot is a safety hazard to workmen climbing the poles and in the advanced stage does make the poles unsightly.

3.2 Insects - The most common type of insect damage found in poles is caused by termites. Termites are of two types - the subterranean type, which has been found in all of the original 48 states and an aerial type found in southern Florida and in Southern Arizona, New Mexico and California. The subterranean type, which lives in the ground and feeds on the wood, is, particularly in the northern part of the country, usually associated with decay. Their presence is confined to the below ground portion of the pole or at most a few feet above ground line. The aerial termites, which both live in the pole and feed on the wood, may be found in any part of the pole above ground line and will also attack crossarms and insulator pins.

Carpenter ants and carpenter bees live in the wood but get their food elsewhere. Their channels and galleries, which may be present anywhere in the above ground portion of a pole, are often extensive enough to materially weaken the pole. They are more often found in decayed wood than in sound wood and are seldom found in full length treated poles.

Damage by the larvae of the round and flat-headed borers may be rather extensive but usually occurs in untreated poles in storage in the woods and poles so damaged are rejected before treatment.
Surface channeling or shallow galleries caused by the larvae of bark beetles do not materially affect the strength of a pole. They are, however, indicative that the poles have been stored too long in the woods with the bark on and under conditions favorable for decay.

3.3 Woodpeckers - There have been a number of theories advanced to explain why woodpeckers attack poles. Unless there are insects present, such as carpenter ants or bees, or the woodpecker wishes to build a nest most of the theories have proven fallacious. For example, one popular theory has been that the hum of the wires made the birds think insects were present. Why then do they attack a freshly treated pole, newly set, before any attachments have been made? Woodpecker damage is of two types - the large window-like holes with an arched top made by the pileated woodpecker and the small round holes made by the smaller woodpeckers.

3.4 Mechanical Damage - This type of damage may be caused by lightning, split tops, road-grading or farm machinery, snow plows, automobiles, trucks, or even by young George Washingtons trying out their new hatchets. Lightning may remove a shallow slab from or may split or shatter the top of a pole. Splits in the top are the result of expansion and contraction because of moisture changes. As a rule they are not serious unless in a plane which will loosen through bolts or other hardware. They may, however, expose untreated wood to decay. Road-grading, farm machinery and snow plows may gouge out the lower part of poles, often sufficiently to impair their strength seriously. Poles hooked by car or truck bumpers, particularly at filling stations or loading platforms or in alleys, may be seriously damaged. Poles hit by motor vehicles may appear undamaged on casual inspection but may be cracked in the upper part as a result of the impact. If so, these poles are a serious safety hazard as they may break later under an unusually low load such as may be imposed by a man working on them.

4. METHOD OF INSPECTION

A complete inspection of a pole would include in addition to the inspection of the poles and crossarms, the inspection of all attachments to the pole. Is the tension and sag of the wires or cable correct, is the hardware corroded, are the guys slack, what is the condition of the anchor rods, etc.? Since, however, this institute is interested primarily in the timber, discussion will be confined to poles and crossarms.

4.1 TOOLS

The tools needed for pole line inspection are:

(a) A hammer or hand ax for sounding the pole and driving increment borer plugs. The ax is preferable as it can be used for chopping brush or roots at the base of the pole, but some Companies object to the ax as a safety hazard.
(b) An increment borer for determining the internal condition of the pole. Some inspectors use a 3/8-inch wood bit but the increment borer core, being in one piece, gives a better indication of preservative penetration and shell thickness.

(c) A shovel for excavating around the ground line.

(d) A blunt prod for determining the presence and extent of decay below ground line.

(e) A tape for measuring circumferences.

(f) A six-inch scale for measuring shell thickness, depth and width of decay pockets.

(g) Climbers so that the inspector may examine suspicious areas above ground line.

Optional tools are:

(a) A digging bar if the ground is hard or frozen.

(b) Binoculars for observing upper part of pole.

(c) A wide-bladed, long-handled chisel for removing external decay.

In addition, the inspector will need plugs for plugging increment borer holes and the necessary forms for recording his findings.

4.2 INSPECTION OF POLES

4.21 Above Ground Inspection

Examine all poles, guy stubs and pole braces on all sides for visible defects or suspicious areas. When necessary, climb to the level of any damage that is out of reach from the ground for further examination and testing using the sounding tool (hammer or hand ax), increment borer or pole prod as described later.

Note: All holes made with the increment borer in poles which are not condemned should be plugged with tight fitting treated or heartwood locust plugs.

The most common visible defects or external indications of internal defects are:

(a) Split tops or through checks in the tops. These are not generally serious enough to justify condemnation unless they are located in a plane so that attachments will be loosened.

(b) Lightning damage. This is cause for condemnation only if the upper part of the pole has been badly shattered or split.
(c) Unusual checking, shrinkage or discoloration at the top of a pole. These may be indicative of top rot and the top should be checked with a pole prod.

(d) Unusual checking such as a number of small checks in a localized area, possible accompanied by shrinkage of the pole surface, wet spots, or shrinkage along seasoning checks. These may indicate the presence of internal decay. Such areas should be checked by sounding with the hammer or hand ax supplemented by increment borings.

(e) Woodpecker holes. These should be checked with the prod for depth, extent of hollowing out of the pole and their possible association with decay and insect damage. If decay or insect damage is suspected an increment boring should be taken below the center of the hole for confirmation. Unless they are associated with decay or insect damage, or the pole has been hollowed out for nesting purposes or they are sufficiently numerous in a short section to materially reduce the cross-sectional area, woodpecker holes are not cause for condemnation of a pole. Enlargement of unused bolt holes orwidening of seasoning checks should be ignored.

(f) Cross breaks or cracks. As previously discussed these are actual breaks across the fibers of the wood and are a safety hazard. They are generally the result of an impact load imposed during handling or by a motor vehicle after erection. They may be caused by the whipping of the wires or strand as the result of an automobile hitting a pole several spans away. Any poles so cracked should be condemned. Do not confuse the lifting of the fibers around knots due to uneven shrinkage caused by the exposure of end grain during machine shaving with cracks.

(g) Insect damage. Sawdust or dross in checks in the upper part of the pole may be indicative of the presence of aerial termites. Sawdust in checks or on the ground at the base of the pole is indicative of the presence of carpenter ants or bees in the upper part of the pole. Mud-filled checks near the base of the pole are indicative of subterranean termite activity. The extent of damage should be determined by sounding and by increment borings.

(h) Rotten knots. The extent of damage should be determined by prodding and an increment boring taken below the center of the knot to determine if internal decay (heart rot) is present. If the decay is confined to the knots it is not cause for condemnation as in calculating strength knots are considered as holes.

(i) Mechanical damage caused by road or farm machinery, automotive vehicles, etc. This type of damage is cause for condemnation if the residual effective circumference of a pole has been reduced below that required to support the load on the pole.
After the observation of a pole for visible defects sound each pole to determine if internal decay is present. This is done by striking the pole lightly but sharply at closely spaced intervals, both vertically and circumferentially, from the ground line to the height a man can reach with a hammer or the back of a hand ax. A decaying pole sounds dull or hollow and in some cases the wood will give under the impact of the blow. A pole free from decay sounds clear and solid, and the hammer usually rebounds noticeably when the pole is struck sharply and squarely. Other conditions such as a wet surface near the ground line due to high soil moisture, shakes in the pole near the surface, wide checks, heavy concentrated loads and guards over riser cables may change the sound of a solid pole. Care must be taken not to mistake the altered sound due to these or other causes for the sound associated with internal decay. An increment borer core should be taken in all cases where testing with the hammer indicates the pole is not solid or where there is doubt in the inspector's mind about the internal condition of the pole.

When the increment boring indicates that the pole is decaying, additional sounding and boring tests should be made to determine the extent, circumferentially and vertically, of the decay and the thickness of the shell of sound wood.

4.22 Below Ground Inspection

If the above ground line portion of the pole is sound or if the defects found are not sufficient to necessitate replacement, the below ground line section of the pole should be examined for external decay, termite damage and internal decay. In some cases the external decay may be at the ground line and can be detected by prodding without excavation. The decay may even extend above ground line under a thin shell of sound wood and be detected in the sounding test. In general, however, the maximum decay will be below ground and an excavation should be made around the base of a pole to expose the below ground line surface. The excavation should be to the depth which local experience indicates that the maximum decay will occur. The depth will vary depending on the level of the water table and the type of soil. In loosely packed sandy or gravelly soils the decay will be at a greater depth than in hard-packed clay soils. As an example: in poles set in the edges of wheat fields near Pendleton, Oregon the maximum decay was just below ground line. In the more arid area near Baker, Oregon maximum decay occurred two feet or more below ground line.

Examine the exposed below ground section with a dull pole prod for the presence, extent and depth of external decay. This type of decay may be general around the circumference of a pole, may be in pockets or only along checks.

Note: Do not strike the pole with a heavy pointed bar or other sharp tool that might cause damage or perforate the treated wood to the extent that decay organisms may gain entrance to untreated wood.
If decay is present the residual circumference of the sound wood should be determined. If decay is general this can be done by scraping away the decayed wood with a chisel or hand ax, taking care not to remove any sound wood, and measuring the remaining circumference. It can also be done by determining the average depth of decay and making deductions from the circumference measured just above the decay. The width around the circumference and the depth of decay pockets should be measured and appropriate circumferential deductions made.

In the determination of the extent of decay pockets care should be taken not to chop away sound wood to expose them. If they are enclosed determine their extent by sounding or boring.

Bore all poles below ground line for the presence and extent of internal decay. If external decay is not present determine the minimum shell thickness for calculation of residual strength. If both external and internal decay are present the pole should be condemned.

4.3 CONDEMNATION OF DECAYING POLES

Now that a pole has been inspected and found in a decaying condition should it be condemned or is there enough sound wood left to support the imposed load and should it be left in line until at least the next inspection period? This decision is usually based on the adequacy of the residual sound wood at the point of greatest decay, generally in the ground line section, to support the load on the pole under storm loading conditions and taking into account the fiber stress of the species of pole timber and the safety factor for the class or grade of the line.

For practical purposes tables may be made up showing minimum required circumferences for each class or grade of line and for each species of timber based on the storm load on the wires, cables and other attachments on the pole, the distance from center of load to ground line and span length. Tables can also be made to show deductions in circumference for different types of decay.

As a general rule poles with hollow heart which have a shell thickness less than two inches should be replaced. In poles with a shell thickness of two inches or more deductions from the measured circumference of sound wood will vary with the circumference of the sound wood and the thickness of shell. For example: if a pole is 35 inches in circumference and the shell thickness 2.0 inches 3 inches would be deducted from the measured circumference. For the same pole deductions for a 2.5-inch shell would be 2 inches, a 3.5 or 4.0 inch shell 1 inch and for 4.5 inch or thicker shells no deduction.
For enclosed pockets, which may occur either above or below ground, deductions are based on thickness of shell over the pocket and depth of pocket. For example: a pole having a 30-inch measured circumference, a minimum thickness of shell of 2 inches and a pocket 5 inches deep is equivalent in strength to a solid pole having a circumference of 1 inch less or 29 inches.

Deductions for exposed pockets are based on horizontal width and depth of the pockets. For example: a pole with a measured circumference of 30 inches and an exposed pocket 4 inches wide and 3 inches deep will be equivalent in strength to a solid pole having a circumference of 5 inches less or 25 inches.

In poles having external decay below ground line around the entire circumference, the decay may be scraped away and the residual circumference measured or deductions, based on the average depth of decay, made from the measured circumference above the decay. In the latter case, for practical purposes, the deduction is 6 times the depth of decay.

4.4 INSPECTION OF CROSSARMS

While it is often possible to detect defects in crossarms from the ground, such as splitting, warping, bowing and sometimes decay, in general it is advisable to climb the pole so that the top surfaces of the arms may be examined. The most severe checking, with possible loosening of pins usually occurs in the top surfaces and, especially in untreated crossarms, decay frequently occurs under the shoulder of the pins. The pins should also be examined for the presence of decay and in areas where aerial termites are present for damage by these insects.

4.5 SAMPLE INSPECTIONS

Sample inspections are valuable for determining the condition of the plant as a whole. They may also be applied to specific lines or age groups of poles to determine whether or not there is sufficient deterioration to justify inspection of all of the poles in the line or age groups. They are measures of average quality level and do not take the place of routine inspections. Sample inspections to be valid must follow the rules laid down by the statisticians very closely. A sampling system, based on random numbers and for which every pole in the plant had to be assigned a number, has been used successfully by some of the Bell System Companies for evaluating their plant for rate case purposes. This plan has been published by the Osmose Company of America and for information by the Transmission and Distribution Committee of the Edison Electric Institute.

Other methods for sampling the pole plant are being used by some Companies. For example, one Company inspecta a one-mile section of pole line selected at random. If the incidence of decay is high the entire line is inspected. If the incidence of decay is low inspection of the whole line is deferred. Other Companies sample every tenth pole. While these methods do not have the sanction of the statisticians they seem to work out fairly well in practice.
EVALUATION OF GROUNDLINE TREATMENTS

By

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Introduction

Groundline applications of wood preservatives to standing poles are not new; some procedures have been in use for 40 years for untreated poles. The Cobra Process was developed in Germany about 1920, and the Anig Process was employed in Sweden at about the same time. In 1927 and 1932 the Anaconda Copper Mining Company developed and patented applications of arsenic trioxide in dry and paste form to poles and posts. The Osmose Process originated in Germany about 1930, United States patents were first issued on it in 1934, and the Osmoplastic treatment was applied experimentally in 1936. Several groundline treatments for untreated standing poles were described by Wentling in the report of the Committee on Poles, Non-Pressure Treatment in the 1942 Proceedings of the American Wood-Preservers' Association.

Tests on Anaconda groundline applications on posts and poles were started by the Forest Service in 1926 in Montana, and similar work was

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1 To be presented at the Wood Pole Conference, Oregon State College, Corvallis, Oregon, March 21-22, 1960.

2 Maintained at Madison, Wisconsin, in cooperation with the University of Wisconsin.
began on lodgepole pine posts in 1929 at Madison, Wis. In 1941 southern pine posts, treated at the groundline and on top with Osmoplastic, were installed by the Forest Products Laboratory at the Harrison Experimental Forest in Mississippi. Various groundline applications to poles have been tested on standing untreated poles of northern white-cedar, western redcedar, and chestnut by the Bell Telephone Laboratories, the Canadian Forest Products Laboratory, and by telephone and power companies in the United States and Canada. Results of these studies varied but, in general, have shown the treatments to be beneficial, and in most cases to add several years to the life of the untreated posts and poles. In Mississippi, the southern pine posts treated with Osmoplastic are estimated to have an average life of 12 years as compared with 3 years for untreated control posts. Anaconda groundline applications have in some cases more than doubled the life of untreated lodgepole pine posts in Wisconsin and have furnished somewhat less protection to posts and poles in Montana, presumably because the drier conditions in Montana are less favorable to the diffusion of the preservatives in the wood than in Wisconsin. Service records showing the beneficial results of Osmoplastic groundline application to standing, untreated chestnut and western redcedar poles are published in Proceedings of the American Wood-Preservers' Association for 1945 and later. Amadon reported in the Bell Laboratories Record that a sodium fluoride-creosote application increased the life of

the untreated poles by about 6 years. Harlan and others of the Canadian Forest Products Laboratories reported on seven groundline applications in the 1948 Proceedings of the American Wood-Preservers' Association. On the basis of the examination of cedar stubs in service for 6 years, Harlan concluded that all applications but one were effective in inhibiting decay at the groundline for a period of 6 years. Chisholm and Suggitt of the Ontario, Canada, Hydro-Electric Power Commission concluded that after 16 years' field experience with six groundline applications to untreated cedar poles, from 6 to more than 13 years of additional service was provided.

About 10 years ago the promotion of groundline applications for standing treated poles began. Interest in such applications was stimulated, on the part of pole users, through a number of premature failures on poles treated during and for the 2 to 3 years after World War II. During this period shortages in standard preservatives and pole supplies had been accompanied by the wide use of new and improved preservatives and species. Some of these premature pole failures are continuing to show up but, with improvements in pole treatment specifications, the situation appears much less serious than it did several years ago. There is still room for improvement in preservative and treating specifications.

The application of groundline treatments to treated poles has been suggested and used also in cases where poles are removed and reinstalled.

where soil has been excavated from around the groundline zone for inspection or other purposes, and where changes in grading have resulted in a change in the original groundline of the poles. It is felt by some, although apparently without conclusive evidence, that there is a serious depletion of preservative at this critical groundline zone of the pole in such cases. If such is actually the case, common sense would seem to indicate a need for "booster" treatment to replace the depleted preservative. There is some evidence to indicate, however, that preservative depletion below the groundline of poles is much less than is commonly supposed, and much less than the loss in the part of the pole exposed above ground.

Assuming there is a need for supplementary treatments on standing treated poles, it does not logically follow that the improved pole serviceability of untreated cedar and chestnut poles can be expected when such applications are made on treated poles, particularly on poles of other species and characteristics. Because of the increasing number of groundline applications now promoted for treated poles and the very limited experience with such treatments, the Forest Products Laboratory, in cooperation with others, started a study in 1957 to answer the more important questions about supplemental treatment of treated poles.

Evaluating Applications to Treated Poles

A groundline treatment for previously treated poles is somewhat difficult to evaluate. First of all, it cannot be determined accurately from a treated pole how much service life remains when the supplemental
groundline treatment is applied. In the end, the performance or life of a pole with two treatments might be attributed to one or the other, or to a combination of both treatments. An evaluation of the groundline treatment is possible, however, by comparing -- under similar exposure conditions -- the performance of a large number of treated poles with groundline treatment with similarly treated poles without groundline treatment. Such a study, however, is difficult to make and would probably require many years to complete. In beginning a study on the evaluation of several groundline applications, it was reasoned that such a treatment should meet certain prerequisites. Different products might be compared therefore on the basis of the results of tests designed to answer several pertinent questions.

**Prerequisites for Groundline Treatments**

A groundline preservative treatment for standing treated poles, in addition to being reasonable in cost of application, should function as follows:

1. Be applicable to the commonly used pole species.
2. The preservative should penetrate the previously treated sapwood to sufficient depth and in sufficient quantity to protect the wood. In the case of thin sapwood species such as western redcedar, western larch, and possibly Douglas-fir and lodgepole pine, improved pole service may also depend on preservative penetration into the heartwood.
3. The protection provided should be for a long enough period to justify the cost of the groundline treatment.
(4) The treatment should be applicable to poles installed in different areas and under different conditions of soil and climate.

(5) The groundline treatment should definitely add to the life of the treated pole to which it is applied.

Test Procedures

With cooperators, plans for field tests were developed in 1957 around the above-mentioned prerequisites and the work was started.

Locations.—As mentioned earlier, the performance of a groundline treatment with arsenic was apparently influenced by moisture conditions present where the pole is installed. Some difference due to moisture in the soil and wood might be expected also with an oil-borne preservative such as pentachlorophenol, which is commonly used in groundline preservative formulations. In order to determine the possible influence of moisture, test locations were selected in three areas of varying rainfall. The Harrison Experimental Forest, Saucier, Miss., has an average annual rainfall of approximately 60 inches and a 276-day growing season; it was selected as a moist area and one particularly favorable to decay and insect attack. The Forest Products Laboratory, in cooperation with the Southern Forest Experiment Station, conducts many of its field tests at this location. A second installation was made at Madison, Wis., which receives about 30 inches of precipitation yearly. The third location was at Fort Collins, Colo., where there is an average precipitation of 14 inches; this site was made available through the cooperation of the Rocky Mountain Forest and Range Experiment Station and Colorado State University.
Soil-moisture determinations were made at each test station when the groundline treatments were applied and moisture determinations are made at various times on the pole stubs.

**Species and initial pole treatments.**—The more commonly used pole species, southern pine, western redcedar, Douglas-fir, lodgepole pine, and western larch, were selected. It was considered desirable to have sections of stubs in test, taken wherever practicable from poles that had been in service for some years. This was done in the case of 50 stubs from pressure-creosoted southern pine poles that had been in service in Mississippi for approximately 20 years, and 75 stubs from butt-creosoted western redcedar poles that had been in service from 16 to 34 years in the Chicago, Ill., area. These stubs from treated poles, along with untreated stubs for control purposes, were installed with several groundline treatments at the Mississippi test station.

Due to the difficulty in obtaining old treated poles of all five species for each of the three test areas, it was decided to use freshly treated 6-foot-long stubs; these were pressure treated with retentions as low as would be consistent with obtaining deep sapwood penetration, in an effort to simulate the condition of older treated poles. The pressure treatment was with coal tar creosote for the most part; this avoided analytical complications later for fluorides and pentachlorophenol components in the groundline preservatives to be used. In one case, however, the lodgepole pine stubs, that were to be groundline treated with a fluoride-containing formulation and analyzed only for fluoride, were pressure treated with 5 percent pentachlorophenol in petroleum oil.
In addition to the tests on pole stubs, the Forest Products Laboratory has cooperated with one of the utility companies in Illinois in a study of several groundline applications to butt-creosoted western redcedar poles in service outside of Chicago.

Inspection and analytical work.--The treatments involved inspection and analytical work in the tests for evaluating groundline treatments and can be summarized as follows for the various installations:

(1) Western redcedar butt-creosoted poles in service in Illinois.--Treatments involved are Cobra, Mycotox, Osmoplastic, Pol Nu, Woodtreat A, and Pole-Tox. Borings were taken from representative poles for fluoride or pentachlorophenol determination in two sapwood zones and three heartwood zones after 1 year and after 2 years.

(2) Western redcedar stubs from untreated and butt-treated poles removed from Illinois. Stubs in test in Mississippi.--Treatments involved are Cobra, Mycotox, Osmoplastic, Pol Nu, and Woodtreat A. Representative stubs were removed 1 year after groundline application; disks were cut from the groundline area, for fluoride and pentachlorophenol determinations and for soil-block tests, in two sapwood zones and in three heartwood zones. Borings were taken 2 years after treatment for fluoride and pentachlorophenol determinations in five zones.

(3) Pressure-treated stubs of five species at Madison and Fort Collins and of two species in Mississippi.--Treatments involved are Cobra, Osmoplastic, Pol Nu, Woodtreat A, and pentachlorophenol-sodium fluoride (also Androc at Madison on one species and pentachlorophenol at Madison and Fort Collins on one species). Borings were taken after 3 months and
1 year for fluoride and pentachlorophenol determinations in the outer one-half inch, second one-half inch, and next inch. All stubs were removed after 2 years and disks cut for fluoride and pentachlorophenol determinations in three zones. Stubs will also be used to check results of borings versus disks and to compare chemical determinations below and above the groundline.

(4) Stubs from pressure-creosoted 20-year-old southern pine poles installed in Mississippi.--Treatments involved are Androc, pentachlorophenol solution (with and without sodium fluoride), Pol Nu, Osmoplastic, Woodtreat A, Cobra, Barrett, and Mycotox. Stubs are to remain in test and be inspected periodically, but borings were taken from eight treatments for fluoride and pentachlorophenol determinations after 1 year. It was impracticable to attempt to differentiate between the original creosote in the poles and that applied in the Barrett groundline treatment.

(5) Untreated green southern pine stubs at Mississippi.--Treatments include those in (4) plus Wood Preserva, Pentaplastic, and an FPL formulation of pentachlorophenol, sodium fluoride, borax, boric acid, and chlordane. This installation will remain undisturbed until failure of the stubs.

Results to Date

The results in the cooperative tests are not yet available for distribution. A paper on the "Results of Groundline Treatments One Year After Application to Western Redcedar Poles" (installations (1) and (2) above) will be presented by Edward Panek of the Laboratory next month at the annual convention of the American Wood-Preservers' Association. These results will be discussed here on an informal basis, as will the results to date in installation (3). Table 1 shows the results from borings taken,
after 1 year, from eight treatments on the 20-year-old, pressure-creosoted southern yellow pine poles in Mississippi.

On the basis of soil-block tests on pine the threshold, or quantity of preservative necessary to inhibit decay, is between 0.1 and 0.2 pound per cubic foot for pentachlorophenol and approximately 0.2 pound per cubic foot for sodium fluoride. It will be noted from table 1 that all but one of the four applications analyzed for pentachlorophenol was above the threshold in the outer one-half inch, only one of the four was above the threshold in the second one-half inch, and all were below the threshold in the second inch.

Of the four applications for which sodium fluoride determinations were made, two showed above-threshold quantities in the outer one-half inch but none reached the threshold beyond this zone.

These results apply only to the conditions of this particular installation. The results on butt-treated western redcedar poles in Illinois and on stubs in Mississippi do, however, follow a similar pattern. The results do not, of course, show that the life of all treated poles in service would be benefited through application of a preservative at the groundline. If a large quantity of preservative is already present from the original treatment, the addition of more preservative to the outer zone of the pole would be of doubtful value.

It is the pole with either a limited quantity of preservative present or the beginning of surfacc decay that would probably be most helped by the "booster shot" or supplementary groundline treatment.
Table 1.—Results of analyses of boring samples taken 1 year after application of groundline treatments to old creosoted southern yellow pine pole stubs in test on the Harrison Experimental Forest, Saucier, Miss.

<table>
<thead>
<tr>
<th>Groundline treatment</th>
<th>Pentachlorophenol</th>
<th>Sodium fluoride</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>lb. per cu. ft.</td>
<td>lb. per cu. ft.</td>
</tr>
<tr>
<td>Androc</td>
<td>0.810</td>
<td>0.015</td>
</tr>
<tr>
<td>Pentachlorophenol solution</td>
<td>0.012</td>
<td>0.009</td>
</tr>
<tr>
<td>Pol Nu</td>
<td>0.950</td>
<td>0.350</td>
</tr>
<tr>
<td>Woodtreat A</td>
<td>0.320</td>
<td>0.033</td>
</tr>
<tr>
<td>Cobra</td>
<td>0.099</td>
<td>0.084</td>
</tr>
<tr>
<td>Mycotox</td>
<td>0.260</td>
<td>0.100</td>
</tr>
<tr>
<td>Osmoplastic</td>
<td>0.410</td>
<td>0.130</td>
</tr>
<tr>
<td>Pentachlorophenol solution: plus sodium fluoride</td>
<td>0.022</td>
<td>0.018</td>
</tr>
</tbody>
</table>

Assumed wood density (38 pounds per cubic foot) to calculate retention of pentachlorophenol and sodium fluoride.
Evaluation of Pentachlorophenol
Spray Treatment of Standing
Western Red Cedar Power Poles

by

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Bonneville Power Administration
January, 1960

U. S. Bonneville Power Administration
Portland, Oregon
In cooperation with
State of Oregon
Forest Research Center
Corvallis, Oregon
ACKNOWLEDGEMENTS

The author wishes to express his appreciation to Mr. Myron Nowak of Bonneville Power Administration for his diligent, accurate work in selection, preparation, and analysis of some 700 samples for penta, and to Mr. Robert D. Graham of the State of Oregon Forest Research Center for his advice, counseling, and general planning of the work that makes up this presentation.
EVALUATION OF PENTA POLE TOP TREATMENT IN WESTERN RED CEDAR POWER POLES

The application of pentachlorophenol-petroleum solutions to the above-ground portions of butt-treated western red cedar poles has received widespread acceptance in the utility industry. The treatment of the ground line area of standing poles with various wood preservatives has been common practice for many years, both in this country and abroad. However, it was not until the early 1940's that any appreciable number of poles were top spray treated.

The credit for pioneering the spraying of standing poles is given to Henry W. Graeber of the Northern States Power Co. of Minneapolis, Minnesota. In the latter part of the 1940's the commercial application of penta to standing wood poles, as we know it today, was started. Since then a number of companies have entered the field of pole top treating.

The increasing cost of materials and labor involved in replacing decayed poles has provided the principal impetus for prolonging the serviceable life of poles. If it can be assumed that various ground-line treatments will extend the life of a pole, it becomes necessary to preserve the above-ground section of the pole so that it will endure an equivalent time. A number of claims, assumptions, and plain guesses have been made concerning the additional life to be expected from the use of pole top treatments. These have ranged up to twenty years and, in some instances of greater optimism, to thirty
It is, of course, not a simple matter to determine the added life gained by treatment. Many variables affecting the durability of treatment have not been fully studied and climatic conditions, such as temperature and rainfall, will introduce factors of a local nature.

Some companies and utilities are conducting investigations to determine the effectiveness of spray treating poles. Hines, Fahlstrom, and Stoker\(^{(1)}\) reported the distribution of penta in four spray treated western red cedar poles both as to depth in sapwood and migration of the preservative down the pole. Their studies were also directed towards determining the rates of loss of preservative in different sections of the poles due to leaching and weathering.

The ratios of penta concentration between the outer and inner sapwood layers and between the top and bottom sections of poles have been studied and reported by Enos\(^{(2)}\). By deriving such information he has been able to establish standards for preservative concentration and retentions that assure his company of getting enduring protection of poles from decay.

The Bonneville Power Administration started treating western red cedar transmission poles in 1956. These had been placed in service in 1940 and were showing considerable deterioration of the sapwood. It was hoped that in addition to extending the useful structural life of the poles, an extra benefit would be obtained by keeping them

\(^{(1)}\) Edward Hines, George B. Fahlstrom, and Richard S. Stoker "Migration of Penta in Spray Treated Poles"--Electric Light & Power, February 15, 1956

\(^{(2)}\) H. A. Enos, "Economics of Preservative Treatment of Standing Cedar Poles"--Electric Light & Power, October 15, 1956, P.128-131
in condition suitable for climbing. This, in itself, could yield tangible profits since, under increasingly stringent safety regulations, the decayed sapwood would ultimately have to be shaved from the poles at considerable expense. Our specifications at that time called for a solution of 6% by weight of pentachlorophenol in No. 2 fuel oil. The retention required was 0.25 pounds of penta per cubic foot of sapwood, calculated as being in the outer one-half inch. The tops of the poles were to be double sprayed. Three borings were to be taken at each of three locations—below the top of the poles, at the midsection, and above the creosote at the butt. The samples at each location were to be taken 120° apart around the pole. Moisture content at the time of spraying was to be below 30%. One pole in each mile was to be sampled.

The contractor was required to take the samples between two weeks and thirty days after spraying and to furnish results of the analyses. After the first year, our laboratory also ran penta analyses on samples taken by our lineman inspectors. This was done as a check on the contractor and to determine the time at which the preservative concentration reached stable values. It was found in comparing our work with that of the contractor that our results generally showed a lower concentration of preservative. We attribute this in part to the earlier sampling by the contractor before the preservative was stabilized in the wood.

In 1956 and 1957 about 3500 poles were sprayed with the 6% solution. During this period questions were raised concerning the
degree of effectiveness of the treatment. In order to find answers to these questions a cooperative study involving the Administration and the State of Oregon Forest Products Research Center was undertaken. The results of work reported by R. D. Graham and Ernest Wright(3) consisted of pathological studies and chemical analyses of the inner sapwood of both penta sprayed and unsprayed western red cedar poles in service. It was noted by the authors that living fungi were cultured on agar slants from the inner sapwood of all unsprayed poles and from 75 to 90 percent of the sprayed poles. Decay fungi were cultured from the inner sapwood of from 70 to 83 percent of the sprayed poles. Fungal development in samples from unsprayed poles was rapid, occurring in five to seven days, while in the sprayed poles the development was slow--occurring in 23 to 28 days.

In the 16 poles sampled for the study the average penta content was 0.16 pounds per cubic foot of actual sapwood. There was little significant difference between the penta retentions in poles sprayed five years prior to sampling and those treated two years before sampling. It is quite possible that the poles sprayed five years before had, originally, a higher penta content. These poles had been in service 25 years before treatment while the poles of the two-year group had been in service 15 years. It has been recognized that higher preservative retentions are possible in sapwood showing advanced decay over that of relatively sound sapwood.

While it was concluded that the spray treatment greatly inhibited the growth of fungi in culture it was noted that "fungus growth occurred at penta retentions as high as 0.28 pounds a cubic foot in the inner 0.5 inch of sapwood". Such fungi could be classed as tolerant of penta, however there is no certainty that they are wood destroying.

As a result of the work by Graham and Wright, it was their recommendation that we increase the penta concentration in the spray solution to 10% with a retention requirement of 0.4 pounds per cubic foot in the entire sapwood. It was also recommended that further work be done in studying the distribution of penta in wood with the hope that a minimum retention of 0.15 pounds per cubic foot in the inner sapwood could be realized by increasing the concentration of penta in solution.

The Administration adopted the recommendations with a minor modification as noted below. Starting in 1958 and continuing through 1958, over 5000 poles were treated with a 10% penta solution. The specifications required a retention of 0.4 lbs/cu ft of penta calculated in the outer 0.5 inch of sapwood in a minimum of 90% of the poles treated. A maximum of 10% was allowed to be below 0.4 lbs/cu ft but required to be above 0.25 lbs/cu ft. The exception to the Graham and Wright recommendation was that the 0.4 lbs/cu ft retention be calculated as being in the outer 0.5 inch instead of the entire sapwood. These values, of course, are not the same except where the sapwood is 0.5 inch in depth. This
is a necessary expedient since it is difficult to determine sap-
wood depth in decayed poles, particularly under field sampling
conditions.

In the spring of 1959 a study, as outlined by Graham, was
started to gain further information concerning:

(1) The distribution of penta in the sapwood of western red
cedar poles as a function of time.
(2) The possibility of obtaining 0.15 pounds per cubic foot
of penta in the inner sapwood using a 10% solution.
(3) The time required for penta retention values to sta-
bilize for purposes of sampling.

PROCEDURE

In the summer of 1959 three groups of ten poles each,
from two separate 115-kv lines, were chosen for test. One group
contained six poles from the older line and four from the newer
line giving two principal groups of sixteen and fourteen, respec-
tively. These lines were located in the Willamette Valley between
Oregon City and Salem. One line had been in service 16 years and
one 19 years prior to treatment. The poles were sampled at periods
of four hours, one week, four weeks, and sixteen weeks after spray-
ing.

The samples consisting of 4" x 4" blocks cut with a chisel
from sapwood and containing a small amount of heartwood were taken
from the north side of the poles above the creosoted butts. They
were chosen from relatively sound wood, as free as possible from
checks and decay. After removal of the sample, the cavity was painted with a pine knot sealer in order to eliminate bleeding of the preservative that might alter subsequent adjacent samples. At the 16-week sampling period, in addition to samples from the north side of the butt, samples were also taken on the south side of the butt and five feet below the top of the pole on the north side. All samples were wrapped in aluminum foil and sent to the laboratory for analysis. Previous to the 4-hour sampling period the moisture content of the wood was determined in \( \frac{1}{4} \)-inch increments in depth and a sample of the spray solution was obtained (Table I).

Within 24 hours after sampling, the specimens were sawed into approximately 1" x 1" square blocks with the third dimension including all of the sapwood and a small amount of the heartwood. The sapwood depth was measured and recorded for purposes of calculation. The blocks were cut into \( \frac{1}{4} \)-inch increments with a knife blade, squared up, and the dimensions determined with a micrometer. Analysis was made by the lime ignition method according to AWPA A-6.

Duplicates were taken of all samples at the 16-week period and sent to the State of Oregon Forest Research Center to be tested for viable fungi in the inner sapwood. This work was done by R. D. Graham and Ernest Wright and consisted of splitting the wood blocks and removing pieces of wood from the inner sapwood with sterile chisel forceps and implanting them on malt agar slants. Cultures were incubated for at least one month. If one of the duplicate
slants made for each block showed signs of fungal growth, the block was denoted as having fungi present.

RESULTS

An examination of analyses indicates pronounced differences in the preservative retention and distribution characteristics between the two lines chosen for study. The averages of preservative retentions for different positions are given for two lines in Table II. The total retention for the older poles is higher on the north side at the butt and top; however, on the south side of the butt it is significantly lower. One explanation would be that the sapwood on the south side of the poles is more highly weathered in the older poles and the added absorptive properties lessen the downward migration rate of preservative. The total penta retention is higher in the older poles as would be expected. It is interesting to note that the average retention of penta in the inner sapwood at the top of the older poles on the north side, the position at which we would consider it most difficult to attain a satisfactory concentration, exceeds slightly the assumed toxic threshold value of 0.1 lb/cu ft. The sixteen-year-old poles average 0.087 lb/cu ft in this position, leading to the conclusion that something should be done to increase the concentration of penta in the tops of the poles. One way to accomplish this would be to triple-spray rather than double-spray the tops.

The depth of sapwood, particularly if relatively sound, is a limiting factor in obtaining a toxic retention value in the inner
sapwood. We have found the curve obtained by plotting retention against depth to be exponential (see Figure 2). In the case of the nineteen-year-old poles the equation is \( Y = 0.93 \times (X)^{-1.5} \) where "\( Y \)" is concentration in lbs/cu ft and "\( X \)" is in increments of \( \frac{1}{4} \) inch. Applying this equation to the nineteen-year-old poles, the concentration of 0.1 lb/cu ft is found to be at slightly over one inch in depth. A different exponential equation, \( Y = 0.93 \times (X)^{-2} \), applies to the sixteen-year-old poles and in this case the toxic threshold is found at about the three-quarter-inch depth.

Data relating to the average concentration of preservative in depth in the sapwood as a function of time are compiled in Table III. These data are plotted in graph form in Figure 1. As previously noted, this information was obtained from samples taken at stipulated intervals from the north side of the poles above the creosoted butts. Figure 1 illustrates that the nineteen-year-old poles reach a stable penta retention in the outer \( \frac{1}{4} \) inch within four weeks, maintaining this level to the final sixteen-week sampling. The second \( \frac{1}{4} \) inch shows a gradual, steady increase in retention from the one-week sampling to the sixteen-week period, while the third \( \frac{1}{4} \)-inch retention value is virtually constant from the four-week to the sixteen-week sampling.

The sixteen-year-old poles show considerable increase in retention in the outer \( \frac{1}{4} \) inch of sapwood between the four- and sixteen-week sampling periods. The second \( \frac{1}{4} \) inch shows a gradual increase in retention after the four-week period, paralleling the curve
for the second \( \frac{1}{4} \) inch of the nineteen-year-old poles. As in the case of the third \( \frac{1}{4} \) inch of the nineteen-year-old poles, the third \( \frac{1}{4} \) inch in this age group shows little change in retention after the four-week sampling.

It is to be expected that the older poles would absorb more preservative—and such is the case here—but it is intriguing that while the second and third \( \frac{1}{4} \)-inch sections of each series absorb at parallel rates respectively, the outer \( \frac{1}{4} \)-inch sections of the two age groups bear no relation to each other. In the case of the sixteen-year-old series, additional samples would have to be taken to find the point at which the curve will flatten out.

While the data in Table II is not as complete as we would like, it does indicate that we have been able, in both age groups, to achieve an average of better than 0.15 lbs/cu ft retention in the inner sapwood.

The results of culture tests on samples at sixteen weeks from sixteen poles of the nineteen-year-old group and four of the sixteen-year-old group were reported by Graham and Wright as follows:

<table>
<thead>
<tr>
<th></th>
<th>Fungi Present</th>
</tr>
</thead>
<tbody>
<tr>
<td>Top, north</td>
<td>75%</td>
</tr>
<tr>
<td>Butt, North</td>
<td>40%</td>
</tr>
<tr>
<td>Butt, south</td>
<td>35%</td>
</tr>
</tbody>
</table>

1. A much greater percentage of cultures from the top of poles contained fungi than did cultures from 4 to 5 feet above the ground (butt).

2. Growth of fungi in culture, with but few exceptions, was slow and weak.
3. Although no attempt was made to identify the fungi present, there appeared to be only four species present. Only one was a decay fungus.

4. Very few of the 120 cultures made contained decay fungi and only one culture contained vigorous growth.

5. Fungal growth, with but one exception, was always associated with the implanted wood indicating that there was little or no contamination during transfer.

"These findings parallel previous results except that more cultures contained decay fungi in the earlier work(3). The spray treatment appears to have reduced greatly the population of fungi in the inner sapwood of cedar poles and to have inhibited the growth and development of decay fungi in particular."

CONCLUSIONS

It is apparent that an average preservative retention of 0.15 lbs/cu ft of sapwood can be attained in the inner sapwood of poles of the age groups studied using 10% penta solutions.

The results of the present study show that we are exceeding the penetration and retention requirements for AWPA specification C8 covering cedar poles treated by the full length thermal process. This specification calls for a retention of 0.30 lbs/cu ft in the unincised area and a penetration only for the incised area of "---not less than one-half inch, in which case complete sapwood penetration must be obtained."

The distribution of preservative in the sapwood as a function of time indicates that, for specification purposes, a retention value of preservative in the inner sapwood could be established. This value could be set at 0.15 lbs/cu ft.
It was noted that in poles in the age groups studied—that is those older than 15 years—the sapwood decay had advanced to a considerable degree. To derive full benefit from a pole top treatment poles should be sprayed at or before the fifteen year service period. This would probably require triple-spraying the tops to be sure of obtaining the 0.15 lbs/cu ft retention in the inner sapwood.

We feel that the pole spray treatment is an effective means of prolonging the life of butt-treated poles. In the past we have estimated a ten year extension of life. This has been made on the basis of limited experience and with limited or inadequate data which was available. In the light of present experience and with the information we have been able to derive from the use of 10% solutions, the ten year extension of usable life can be considered as more certain. In addition, the present policy of ground line inspection previous to top treating will eliminate the unsound poles thus lowering the replacement curve. Besides the savings gained from extended life there is the additional saving gained from the climbing inspection made during treating. Such an inspection would normally have to be made at some expense by our own crews.

There is a possibility, which has not yet been fully explored, that butt-treated cedar poles could be used instead of full length thermal process treated poles. After some years of service, when all seasoning and checking had taken place, the poles could then be sprayed in place, resulting in more complete protection.
by preserving the exposed heartwood.

The information gained in the present study points out the need for further data of a specific nature. These should include:

1. A determination of the fungi strains responsible for pole top and ground line decay in the Pacific Northwest.

2. The establishment of toxic thresholds of penta for these wood destroying fungi above ground.

These are not easy problems to solve, but answers to them would contribute greatly to the understanding of the deterioration phenomena of wood poles.
**TABLE I**

Preservative Concentration and Moisture Content of Wood at Time of Treatment

<table>
<thead>
<tr>
<th>Group</th>
<th>Water Content of Wood</th>
<th>Preservative Conc. % Penta</th>
</tr>
</thead>
<tbody>
<tr>
<td>Group 1</td>
<td>10-12.5</td>
<td>8.63-9.08</td>
</tr>
<tr>
<td>Group 2</td>
<td>11</td>
<td>9.87-10.07</td>
</tr>
<tr>
<td>Group 3</td>
<td>11</td>
<td>10.37-10.53</td>
</tr>
</tbody>
</table>
### TABLE II

Penta Retention in Two Lines  
Sixteen Weeks After Spraying  
With 10% Solution  

Lbs/Cu Ft of Total Sapwood

<table>
<thead>
<tr>
<th></th>
<th>Base, North</th>
<th>Base, South</th>
<th>Top, North</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total</td>
<td>0.388</td>
<td>0.548</td>
<td>0.715</td>
</tr>
<tr>
<td>Inner Sapwood</td>
<td>0.073</td>
<td>0.162</td>
<td>0.338</td>
</tr>
<tr>
<td>Spread in Inner Sapwood</td>
<td>0.000</td>
<td>0.000</td>
<td>0.026</td>
</tr>
<tr>
<td></td>
<td>0.270</td>
<td>0.274</td>
<td>0.746</td>
</tr>
</tbody>
</table>
## TABLE III

Penta Concentration by $\frac{1}{4}$" Increments
At Different Sampling Periods in Two Lines

Samples from North Side at Base

<table>
<thead>
<tr>
<th>$\frac{1}{4}$&quot;</th>
<th>4-Hr. Period</th>
<th>1 Week</th>
<th>4 Week</th>
<th>16 Week</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>16-Yr.</td>
<td>19-Yr.</td>
<td>16-Yr.</td>
<td>19-Yr.</td>
</tr>
<tr>
<td>1</td>
<td>.654</td>
<td>.668</td>
<td>.635</td>
<td>.690</td>
</tr>
<tr>
<td>2</td>
<td>.072</td>
<td>.104</td>
<td>.088</td>
<td>.214</td>
</tr>
<tr>
<td>3</td>
<td>.018</td>
<td>.056</td>
<td>.053</td>
<td>.150</td>
</tr>
</tbody>
</table>
Figure 1

Preservative penetration of sapwood

Pounds/ft. x 1000

\[
\text{Preservative penetration of sapwood}
\]

- 1st 1/2" 19yr poles
- 1st 2/3" 16yr poles
- 2 1/2" 16yr poles
- 2 1/2" 19yr poles
- 3 1/2" 19yr poles
- 3 1/2" 16yr poles

Weeks

0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17

Figure 1
PENTA CONCENTRATION BY \( \frac{1}{2} \)" INCREMENTS FOR 16 WEEK SAMPLES

Figure 2

- 19-yr. old poles
  \[ y = 0.93(x)^{1.5} \]
- 16-yr old poles
  \[ y = 0.93(x)^{-2} \]

Penta lbs/cu ft Sapwood

\( \frac{1}{2} \)" Increments
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