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Looking Back at 75 Years of Research in Wood Preservation at the U.S. Forest Products Laboratory

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Introduction

In 1874 Franklin B. Hough was named the first American Forestry Agent for the newly formed Forest Commission with the mission to study forest consumption. In 1880 the Commission was elevated to Division of Forestry status and in 1901 the Division was elevated to Bureau status. Along with this change, Gifford Pinchot was appointed Chief. Now for the first time, special emphasis was put on forest management as it would relate to forest products utilization. This marked the real beginning of Forest Products Research in the field of wood preservation by the U.S. Government. Pinchot appointed Herman von Shrenk (Figure 4) as agent for the Office of Forest Products. His assignment was to initiate studies to show condition, cause, and prevention of decay in railroad ties, which were being used at a rate of 110 million ties / year. The Bureau of Forest was changed to the U.S. Forest Service in 1904. The new Forest Service also got control of the national forests.

The first meeting of the Wood Preservers' Association was held in 1904. Six years later the U.S. Forest Products Laboratory (Figure 1, 2, & 3) was established in Madison, Wisconsin, to conduct research aimed at the wise and efficient utilization of the products from the nation's forest resource. It was not until 1912 that the Wood Preservers' Association changed its name to become the American Wood Preservers' Association (AWPA).

At one of the early meetings of the AWPA, the Director of the Forest Products Laboratory (FPL) listed some of the problems in wood preservation that the Laboratory planned to devote research time to. In the intervening years, the AWPA has been a consistent supporter of the FPL and has received much help in return. Since the FPL has just celebrated its 75th Anniversary, the present meeting seemed to be an opportune time to review some of the Government and industry-supported research that had taken place over the years. When possible, we will access the improvements which have been achieved and to consider measures to solve the many problems that still remain.

This paper will deal mainly with research at the FPL since that is the subject most familiar to the authors. There will be limited references to the literature. It is assumed that the reader has access to the AWPA Proceedings, and most of the references to papers published in other journals. The authors regret that limitation on their time prevents them from recognizing the many excellent papers by earlier investigators and from mentioning the countless contributions and practical observations made by producers and users of treated wood.

Beginning of Research at FPL

In 1910 the FPL was established in Madison, Wisconsin, with McGarvey Cline (Figure 5) as the first Director. The FPL was organized into various sections or divisions, each concerned with a major line of investigation and each area under the supervision of an experienced Division Chief. The first four divisions in the organization were: Wood Preservation, Timber Tests, Wood Chemistry, and Wood Technology. These four original divisions were soon increased to eight with the new areas being: Engineering, Pathology, Wood Distillation, and Pulp and Paper. The first chief of the section of Wood preservation was F. M. Bond. It was recognized that

Howard F. Weiss was the most experienced wood preservation expert when the Laboratory started, but his experience was needed in administration. Weiss became as Assistant Director under McGarvey Cline at the time of the Laboratory opening.

Ernest Bateman (Figure 14) was one of the first employees at FPL back in 1910 who was placed in charge of the section of Wood Chemistry. He was later to have a very distinguished career in Wood Preservation research.

Clyde Teesdale succeeded Bond as the Wood Preservation Section Chief in 1917. At the time the United States found itself involved in World War I which necessitated a profound revamping of wood preservation research. Wood preservation was set aside and activities such as adhesives, moisture-proof coatings, and propeller manufacturer were the primary duties of the wood preservation staff, which had swollen to 71 members during this war time activity. Teesdale, assisted by George Hunt, was in charge of these war-time activities.

In 1919, George Hunt (Figure 8) became Chief of the Wood Preservation section. In the 1920's under his guidance, the wood preservation division expanded into several new areas of research. These were glues, plywood, laminated construction, and wood finishing. The wood preservation work was divided into two general areas of activity, processing technology and chemistry of wood presenatives. Hunt was primarily concerned with the methods of applying preservatives, while Bateman and his assistants devoted much of their time to the chemistry of wood preservatives investigating the relationship between viscosity of preservatives and its penetration into wood in response to various treating conditions. One of Bateman's assistants was Roy Baechler, who joined the Laboratory in 1922 in the chemistry division, also assisting J. D. McLean in the wood preservation division.

The division of plant pathology of Washington, D.C. established a project in Madison during this time. This group had the responsibility to investigate the fungi that were responsible for decay of wood. R. H. Colley headed up this group which continued to be administered from Washington and occupied quarters in a building near the Forest Products Laboratory. Their facilities for toxicity testing were used extensively by Bateman's group.

During this period, the Directorship of the Laboratory saw some changes also. Howard Weiss (Figure 6) was Director from 1913 to 1917. Carlile P. Winslow (Figure 7) succeeded Weiss and served as the Director until 1946 which spans two World Wars and countless trials and tribulations. The Laboratory went from a staff of 80 in 1919 to the largest organization in the world devoted to research on utilization of wood and related products with a staff of nearly 700 in 1945,

The following is the list of all the FPL Directors to the present:

McGarvey Cline	1909-1912
Howard Weiss	1912-1917
Carlile P. Winslow	1917-1946
George W. Hunt	1946-1951
J. Alfred Hall	1951-1959
Edward G. Locke	1959-1966
Herbert O. Fleischer	1966-1975
Robert L. Youngs	1975-1985
John R. Erickson	1985-Present

Experiments in wood preservation were one of the first research activities in the Bureau of Forestry (the forerunner to the U.S. Forest Service), beginning in 1902. Wood preservation research at the FPL made significant gains from 1910 to 1917, both in fundamental and practical research. Prior to the establishment of the Madison laboratory, the preservation work was confined largely to demonstrations and some field tests. There was considerable cooperation with railroads, mining companies, and utility companies. The main preservatives were creosote and zinc chloride. The Madison laboratory turned its attention to field tests, fundamental studies, and demonstrations of wood preservation. During these early years, some of the fundamental studies involved chemical, physical, and toxic qualities of various wood preservatives and investigations to improve the processes of preservation. The Laboratory still has an active study dating back to 1910 which deals with the performance of treated and untreated wood and bears the title, "Service Records on Treated and Untreated Fence Posts."

In 1910, there were some 70 treating plants in the United States. The field testing was essential to solving a pressing problem in the lack of standardization of preservative and preservative processes and to assist the consumer who is faced with a perplexing problem of uncertainty as to just what preservative to use which would yield the best performance for the end use intended. To alleviate some of the confusion, the FPL undertook exhaustive tests on a number of commercial creosotes and other preservatives in order to classify them as to quality. At the same time, the wood preservation researchers were dealing with various treatment processes to improve preservation penetration. This, we might add, is a problem which still seems to be with us today.

Cooperative projects with various companies constituted a large part of the FPL wood preservation work in the form of field testing and help in the design of wood preservation plants. The FPL could take significant credit for wood preservation expansion of some 70 treating plants in 1910 to over 100 plants in 1915. With preservative testing and research to the physical and chemical requirements of wood preservation, the industry was placed on a sound scientific basis.

The Forest Products Laboratory has been an active participant in matters of AWPA since the beginning. One measure of contribution is the number of published research papers. The AWPA has published over-1100 papers since 1905. Of these, 220 or 20% of the papers were by FPL authors. Also important is the continuous involvement staff from FPL have had in the technical committees of the association.

Wood Preservation Research at FPL Between World War I and World War II

As mentioned above, service tests were among the first projects to be started. A fundamental study of the various factors affecting results obtained in pressure treatments was started by J. D. MacLean (Figure 15) in approximately 1920. This comprehensive investigation extended over many years. In addition to experiments made with the pilot-plant cylinder at Madison, MacLean visited treating plants operated by several railroad companies and collected data on the effect of several treating variables, including species, on the absorption and penetration of preservatives. The results of this investigation were summarized in the document, "Preservative Treatment of Wood by Pressure Methods", U.S. Department of Agriculture Handbook 40, revised in 1960.

In the Chemistry Division, Bateman had started the chemical and physical properties of different types of commercial creosotes. The results were published in U.S. Department of Agriculture Bulletin 1036 (October 20, 1922).

In the early 1920's, Bateman and C. Henningsen started a series of theoretical studies entitled '"A Theory of the Mechanism of the Protection of Wood Preservatives." Eight papers were presented at subsequent AWPA annual meeting beginning in 1920.

At the 1930 meeting, G. M. Hunt and T. E. Snyder of the Bureau of Entomology and Plant Quarantine published an installation report describing four sets of 2x4x18-inch specimens that were prepared at Madison and treated with various preservatives. One set each of the specimens was sent to four tropical areas that were known to be heavily infested with termites. These were inspected periodically for a number of years.

Toxicity of Chemicals to Fungi

In 1922, R. H. Baechler (Figure 18) reported for work at FPL and was assigned to assist E. Bateman. It had been planned to start an investigation of the effect of the molecular structure of organic compounds on their toxicity to wood-destroying fungi. The practical objective was to find chemicals which could be dissolved in low-cost petroleum oils to form oil-type preservatives. The project was extended to include water-borne chemicals in later years. This was considered a continuous project for an indefinite period, despite interruptions which in some cases lasted for several years. By means of the agar-flask technique, determinations were made of the minimum concentrations required to prevent the growth of *Fomes annosus.* In a paper giving data on a large number of chemicals at the 1937 AWPA meeting, Bateman and Baechler stated that "Of all the chemicals that were found to kill our test organism, tetrachlorophenol and pentachlorophenol were the cheapest sources of toxic action." It was further reported that 3 percent and 5 percent solutions of each chemical had been used to treat sets of one hundred southern pine fence posts which were installed in the Forest Service test site in Mississippi.

Three members of the FPL staff were involved in papers presented at the 1941 AWPA meeting. Hunt and Snyder presented the 12th Progress Report on the International Termite Tests. R. M. Wirka gave a detailed account of the start of the Mississippi fence post study with data obtained after approximately three years. This ultimately proved to be the first of the series of many progress reports on these tests. R. H. Baechler presented data on the resistance to leaching and the decay protection of various precip itates formed in wood by double diffusion.

A Glance at the U.S. Wood-Preserving Industry in 1922

During Baechler's break-in period, Bateman discussed the basic principles of wood preservation and also the nature and objectives of FPL projects relating to the subjects. During these talks, Bateman mentioned some features of the current wood preserving industry.

At this time the treatment of crossties dominated the industry. It comprised approximately 90 percent of the total volume of wood treated. Most treatments were made in plants owned by railroad companies, although a trend had started toward the sale of treating plants to companies whose sole business was the production and sale of treated wood items.

Next to sawn crossties, bridge timbers accounted for the largest total volume of sawn wood that was treated. Efforts had been made to convince the railroad companies that it would be profitable to treat lumber prior to its use in the construction of railroad cars. For many years these efforts met with little or no success. The total volume of lumber that was trated at this time did not justify its inclusion in statistics on wood treatment.

The total volume of wood in the form of poles treated in 1922 was small but an upward trend had started. Up to this time, naturally-durable species, such as chestnut and the cedars, were available in sufficient quantities to fill the needs of pole users. However, supplies of chestnut poles were shrinking as the result of the ravages of the chestnut blight. At the same time, readily accessible stands of the cedars were becoming harder to find. It was easy to foresee that before long it would be necessary to use poles of nondurable species that required preservative treatment in order to yield satisfactory service life. The year 1922 could be considered the beginning of this trend.

Another trend that was noticeable at this time related to the type of preservative used to treat crossties. Because of its low cost, zinc chloride had been favored over creosote by many who recognized the superiority of creosote for this use. However, annual statistics had shown that the percentage of crossties treated with creosote and creosote-tar solutions was increasing. In 1922, creosote and its solutions had overtaken zinc chloride according to the statistics published in the following year.

In retrospect, it might have been said that creosote-petroleum solutions were in a transition stage. Correspondence with users of treated wood indicated a gradual increase in the number of crossties treated with such solutions. Several years later, creosote-petroleum solutions were included in the statistics on wood presentation.

Wood Preservation Research During World War II

Importation of creosote from Europe was suspended during the war and for several years after peace was declared. The supply of domestic creosote did not meet the demand. Information on substitute materials was urgently needed. In the face of this situation, research in wood preservation declined sharply. Inspections of material in field tests were reduced to a minimum. The search for new knowledge of wood preservation was at a low ebb.

At FPL most of the personnel that had been engaged in wood preservation research were transferred to projects of immediate military importance. For example, Baechler was shifted to the wood-hydrolysis project in the Chemistry Division. This project consisted of experiments to develop the most efficient procedure for hydrolyzing chipped wood with dilute mineral acids in order to obtain hydrolysates that could be neutralized and fermented to ethyl alcohol. Required for the production of synthetic rubber and other materials, ethyl alcohol was in short supply throughout the war. The process that was developed was practical under wartime conditions. It was not competitive in cost with other methods of producing alcohol after peace was declared. Baeclder also investigated a number of domestic and foreign species to ascertain their suitability for use in chemical engineering construction.[1]

From World War II to Vietnam

The declaration of peace was soon followed by abrupt changes in the research program of FPL. In each division, some projects that had been suspended for the duration of the war were not resumed. In addition, several new projects appeared on the program. A few of these expanded quite rapidly and commanded the time of a small group of staff members. While some new studies were completed in a relatively short time, others were very active for extended periods after which they were either terminated or continued at a low rate. The fluctuations in the emphasis on different projects often reflected changes in the nation's economy.

Assistance to the Rural Electrification Administration

A rapid increase in the construction of power lines by the Rural Electrification Administration (REA) presented many technical problems. Some involved the treatment of poles and crossarms on which REA sought the advice of FPL. J. O. Blew (Figure 19) and coworkers participated in the development of specifications for the treatments. They also compared the relative effectiveness of a number of formulations for groundline treatments. An extensive program of service tests was started. Ultimately, REA greatly expanded its technical staff in the Washington, D.C. office, whereby, its need for assistance by FPL greatly decreased.

Nonpressure Treatment of Fence Posts

As a branch of the U.S. Department of Agriculture, the Forest Service had long been encouraged to investigate potentially practical methods for treating fense posts on the farm. At the 1904 World's Fair in St. Louis, Herman von Schrenk, a Forest Service employee at the time, demonstrated the creosoting of fence posts in an open tank. During early years at FPL, experiments were made on the treatment of fence posts in open tanks. A virtual boom in such experiments occured in southern forestry schools during the years following World War II. This coincided with a change in the agricultural economy of the South in which many farmers were replacing the growing of cotton with the raising of cattle. More

[1] Baechler, R. H. Wood in Chemical Engineering Construction, For. Prod. Res. Soc., 1954, Preprint 566.

fences were needed and, since the abundant southern pine lacked resistance to decay and termites, low-cost preservative treatments seemed to be a practical answer.

A project to develop a simple, nonpressure treatment of fence posts was started at each forestry school in the south. Their interest was not confined to simple methods that could be used on the individual farm, but also, methods that would be practical for use in small plants that could be operated either by private enterprise, by cooperative groups, or by counties.

The conferences held at southern Forestry Schools were attended by FPL persomel, who conducted similar experiments in Madison. J. O. Blew and coworkers tried soaking the posts in a solution of penta in fuel oil of low viscosity. Their results agreed in a general way with those obtained in the south. The presence of biological attack that developed during seasoning influenced the uptake of the solution. Absorption of preservatives varied over a wide range—from amounts that were too low to give good protection, to amounts that were excessive from the standpoint of cost. Blew, et. al., experimented with the end-steeping of posts in aqueous solutions of chemicals. Most hardwoods absorbed smaller amounts than did pine, and in those hardwoods that seemed to be fairly well treated, subsequent field tests showed poor resistance to decay and termites.

Baechler and Roth investigated the applicability of double diffusion, both by complete immersion of the posts and by standing them upright in barrels. Pine posts treated in tanks by double diffusion and installed in the Mississippi test plot, prior to the war, were showing excellent results. (Several small post-trating plants using some version of the basic method have now been in successful operation for over thirty years.)

The '"standing-in-barrels" procedure offered the advantage of requiring only low-cost equipment (used oil drums). Several combinations of chemicals were tried. After about five years' exposure, the results seemed quite promising, the main cause of the few failures being top decay. Some modifications in the method aimed at reducing this difficulty were under consideration when the project was interrupted by work of higher priority. These experiments were not resumed as the interest in such treatments had declined with changes in domestic agricultural economy. In pioneering times, the typical, small American farm was quite self sufficient. The combination of factors such as the development of the automobile, the improvement of roads, and availability of cheap motor fuel, in effect, brought the shopping center closer to the farm. This reduced the incentive for many do-it-yourself activities on the farm, including the treatment of fence posts. This illustrates another point. Because of the lack of a completely reliable, short-time test to evaluate a new material or method for wood preservation, the practical potential of a new idea may be affected adversely by changes in the nation's economy.

Assay of Treated Wood

As was mentioned previously, most preservative treatments in the country during the early days were made in plants operated by railroad companies. Since the producer and user were the same, there was little need for either specifications or for methods to check the quality of treatment. With the development of commercial wood treating, the producer and ultimate user of the treated wood were no longer the same. This lead to a need for detailed specifications. For many years such specifications covered penetrations of the preservative as shown by borings. Retentions were generally based on the readings of tank gauges before and after treatment. It was known that this method of determining the retention for a charge was subject to considerable error. Purchasers of treated wood, therefore, looked toward a method based on the analysis of borings from the treated wood. A few experiments along this line were made at the Bell Telephone Laboratories, prior to the war, with inconclusive results. In the early 1950's a manufacturer of creosote financed a study at FPL to ascertain the feasibility of such a method.

A parallel project was conducted at the Bell Telephone Laboratories. The results obtained on creosoted pine poles at both Laboratories were fairly encouraging and gradually led to the use of the method in commercial treatments. Later the FPL studied the method for use on heavily creosoted marine piling and on lumber treated with both water-borne preservatives, and oil-type preservatives.

From this early beginning, results-type specifications are now common place in industry. There are only a few commodities which are not tested for preservative retention by chemical assay after treatment. The most common of these products is railroad ties.

The Evaluation of Wood Preservatives in the Laboratory

As new preservatives were being developed it became apparent that faster methods of evaluating these systems were needed. Early work by John Leutritz, Reg Coney (Figure 25), Audrey Richards (Figure 24) and Catherine Duncan (Figure 27) was very important in the development and standardization of the Laboratory soil-block test method. This system

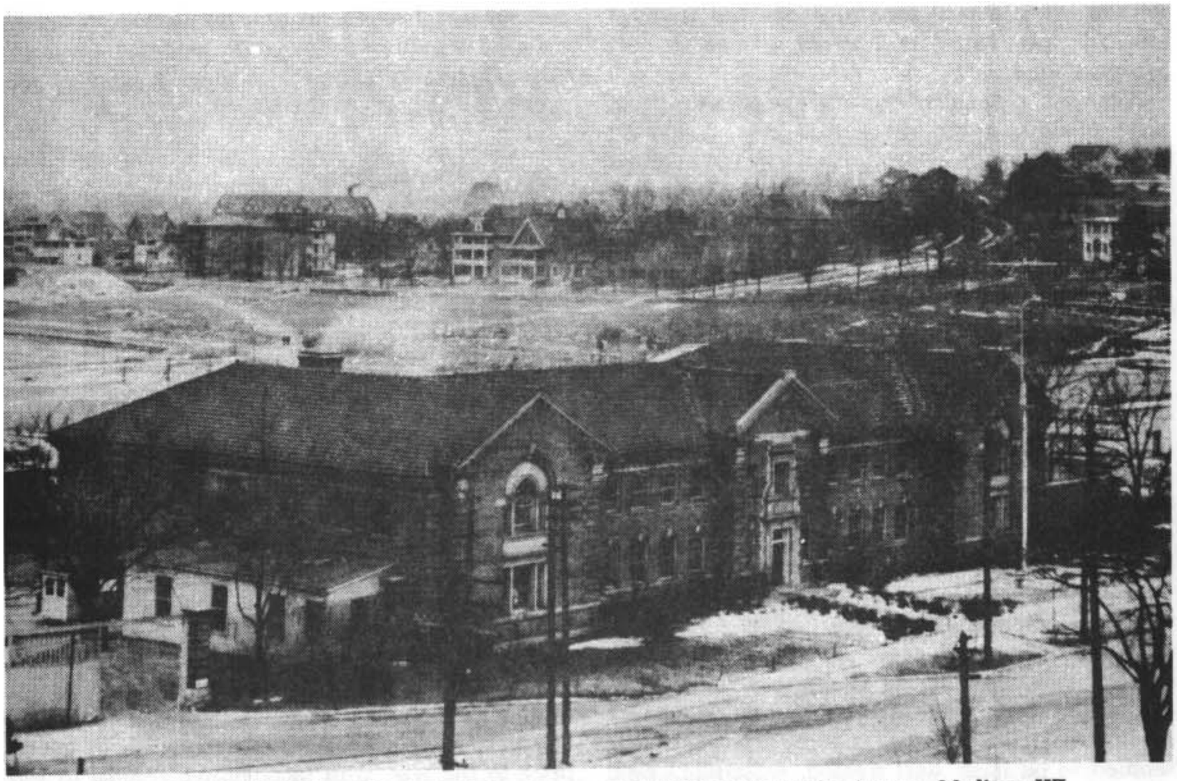

Figure 1.—Original Forest Products Laboratory erected 1910 on University Avenue, Madison, WI.

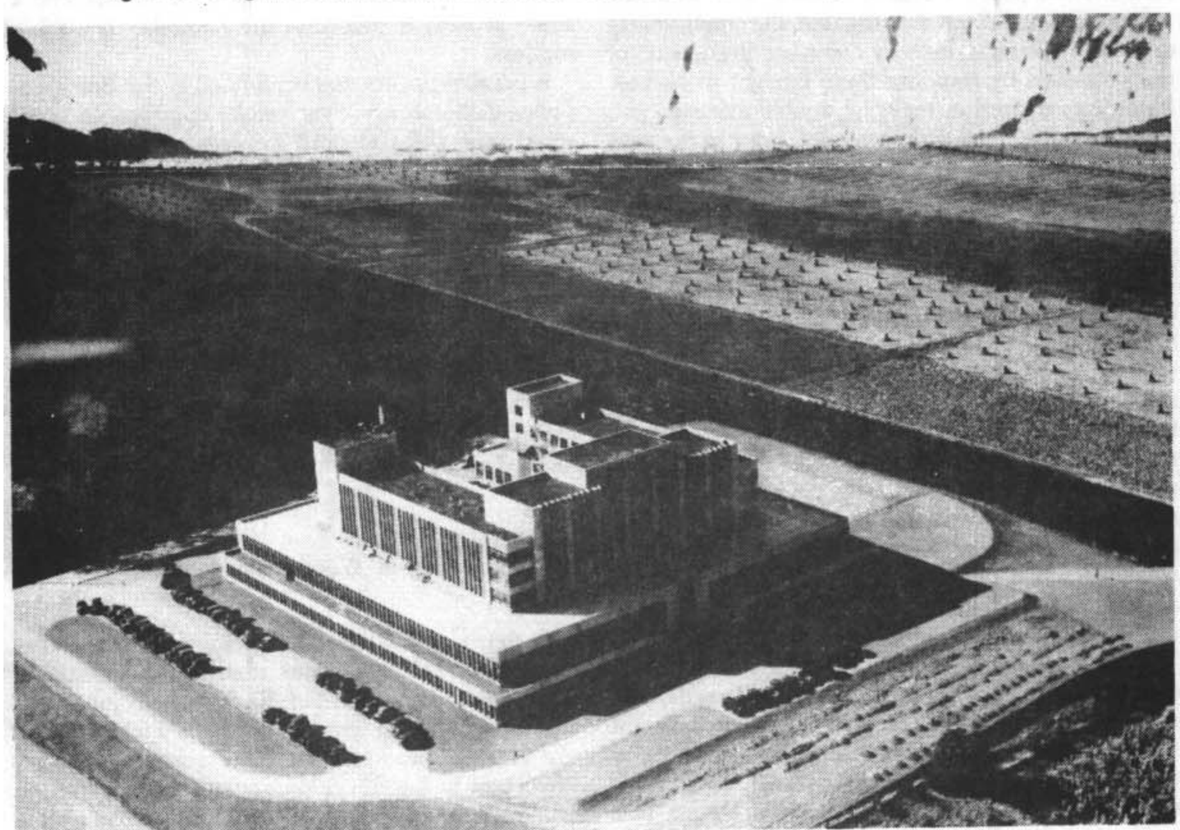

Figure 2.—Forest Products Laboratory built by the U.S. Government on the University of Wisconsin Campus 1932.

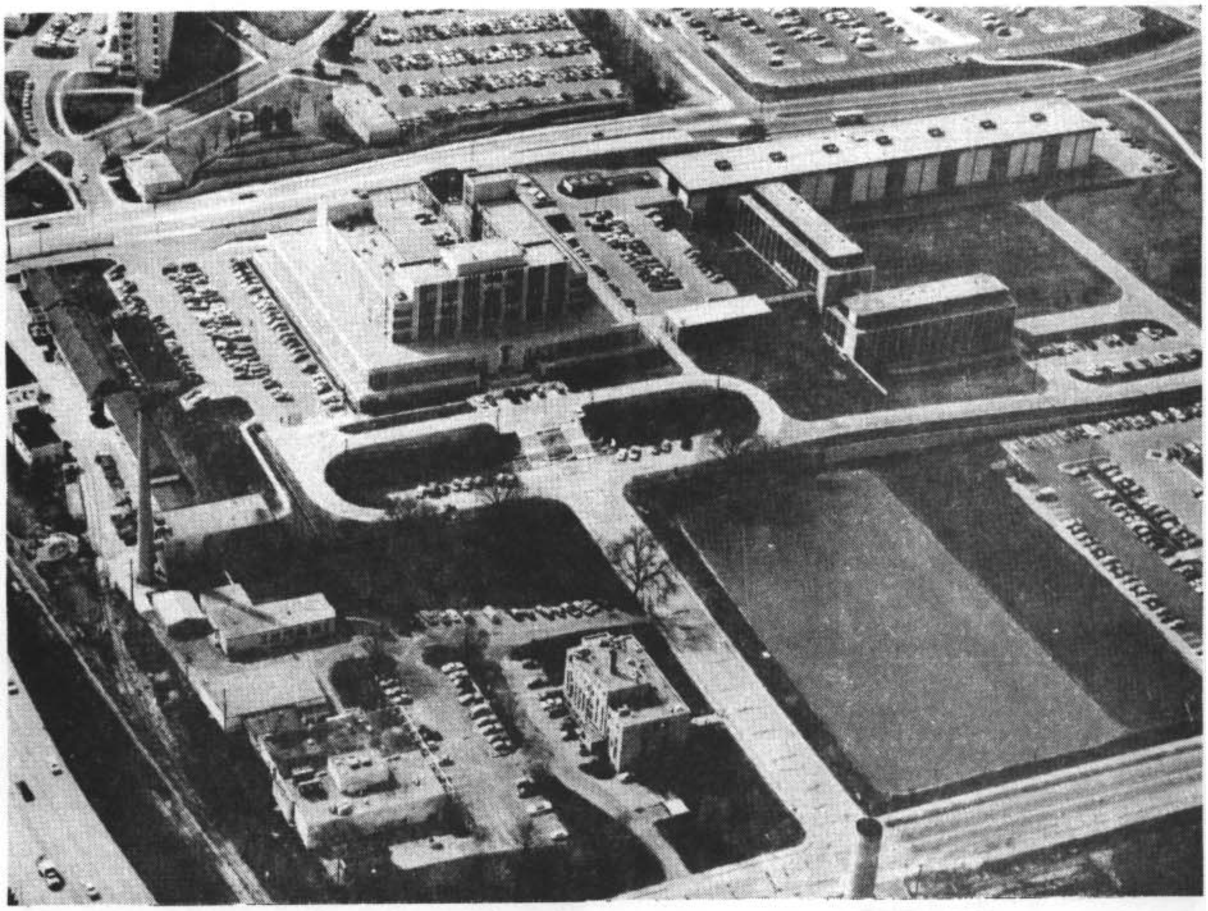

Figure 3.—U.S. Forest Products Laboratory complex, Madison, Wisconsin 1985.

Figure 4.—Herman von Shrenk

Figure 5.—McGarvey Cline
FPL Director, 1909–1912

Figure 6.—Howard Weiss
FPL Director, 1913–1917

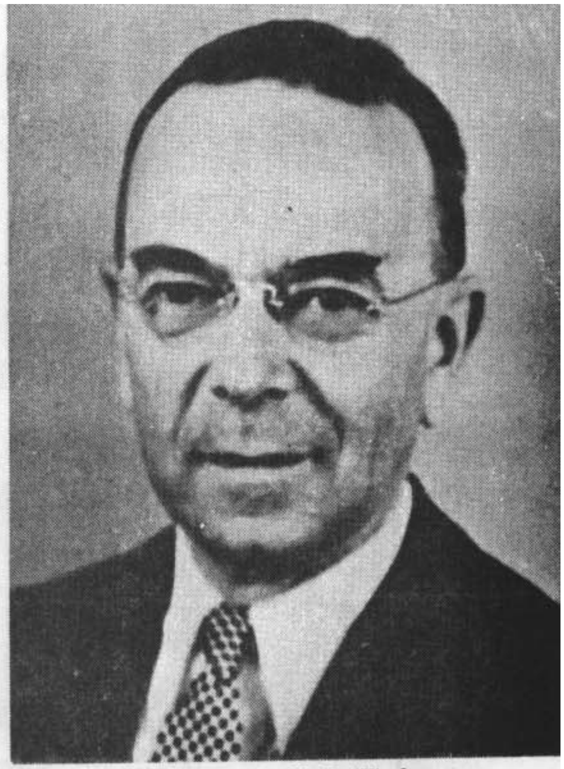

Figure 7.—Carlile P. Winslow
FPL Director, 1917–1946

Figure 8.—George M. Hunt
Chief of Wood Preservation Section, 1919–1946 and FPL Director, 1946–1951

Figure 9.—J. Alfred Hall
FPL Director, 1951–1959

Figure 10.—Edward G. Locke
FPL Director, 1959–1966

Figure 11.—Herbert O. Fleischer
FPL Director, 1966–1975

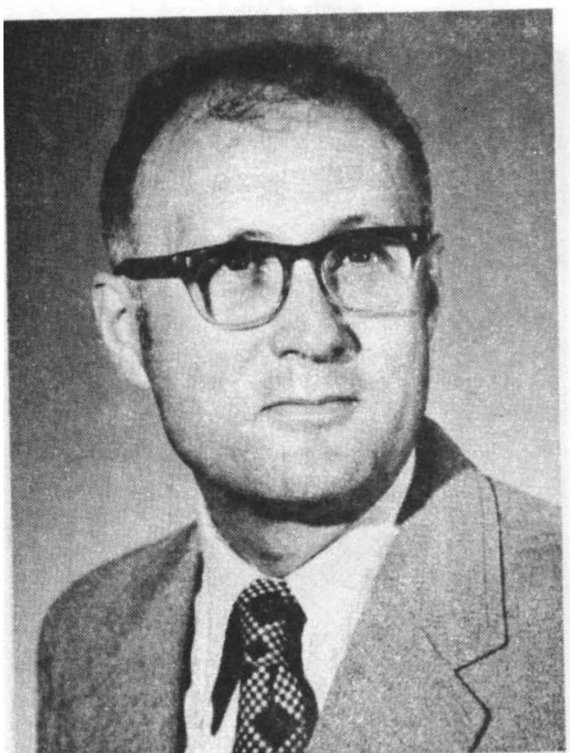

Figure 12.—Robert L. Youngs
FPL Director, 1975–1985

Figure 13.—John R. Erickson
FPL Director, 1985–Present

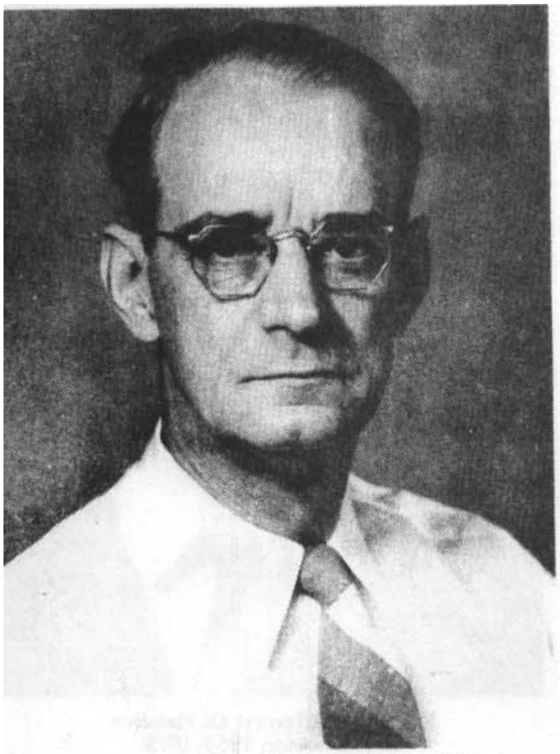

Figure 14.—Ernest Bateman, 1910–1937
One of the first employees at FPL and became Chief of the Wood Chemistry Section.

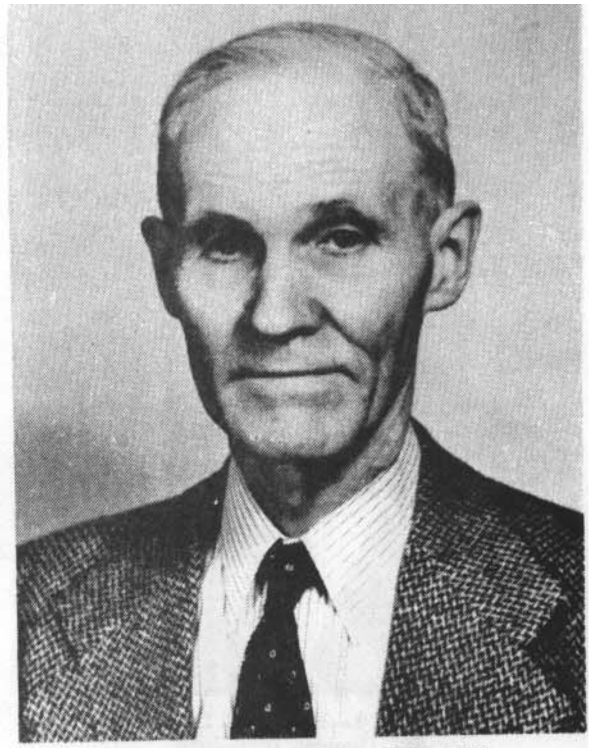

Figure 15.—J. D. MacLean, 1920–1955
Conducted many fundamental studies on pressure treatments of wood.

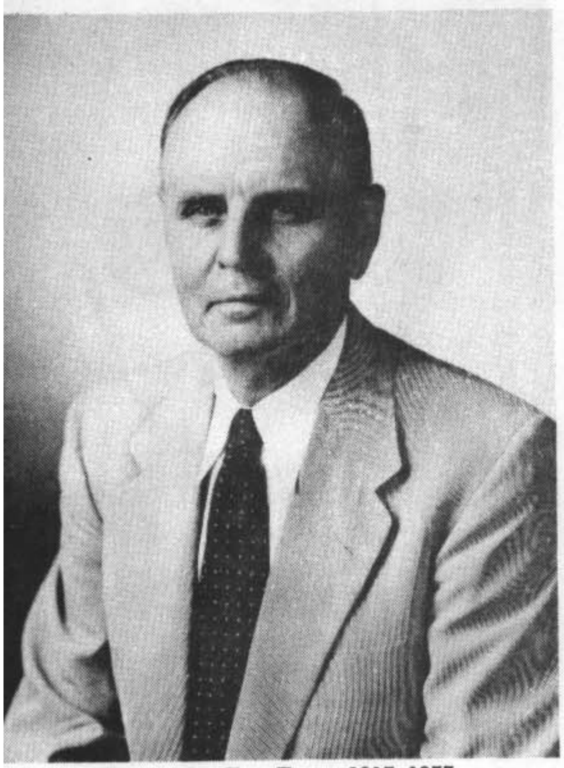

Figure 16.—Tom Truax, 1915–1955
Chief, Wood Preservation Research 1944–1955.

Figure 17.—Ralph Lindgren, 1950–1963
Division Chief, Wood Preservation Research 1955–1963.

Figure 18.—R. H. Baechler, 1922–1970
Preservatives Section 1955–1963
Project Leader, Wood Preservation Research 1963–1967

Figure 19.—J. O. Blew, 1941–1970
In Charles Wood Preservation Treatment Processes 1955–1963

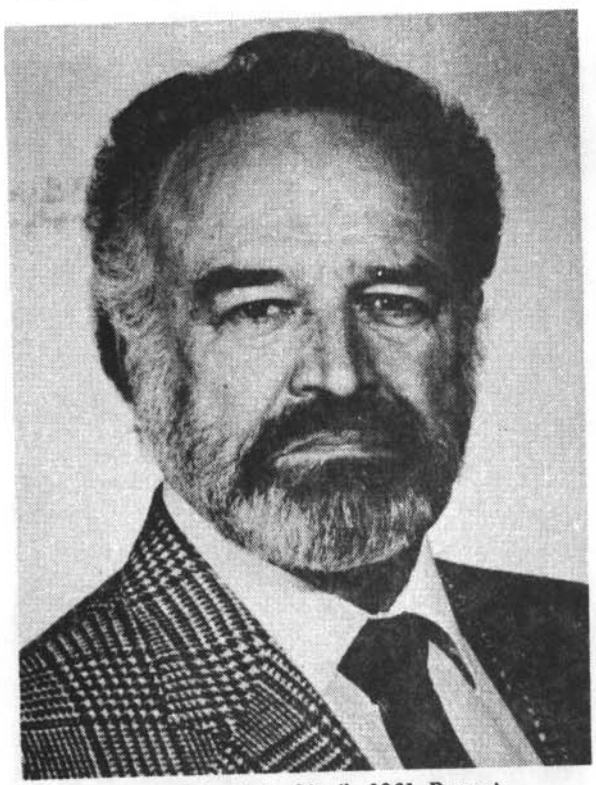

Figure 20.—L. R. Gjovik, 1961–Present
Project Leader Wood Preservation Research 1967–1972

Figure 21.—G. J. Hajny, 1938–1979
Project Leader Wood Preservation Research 1972–1978

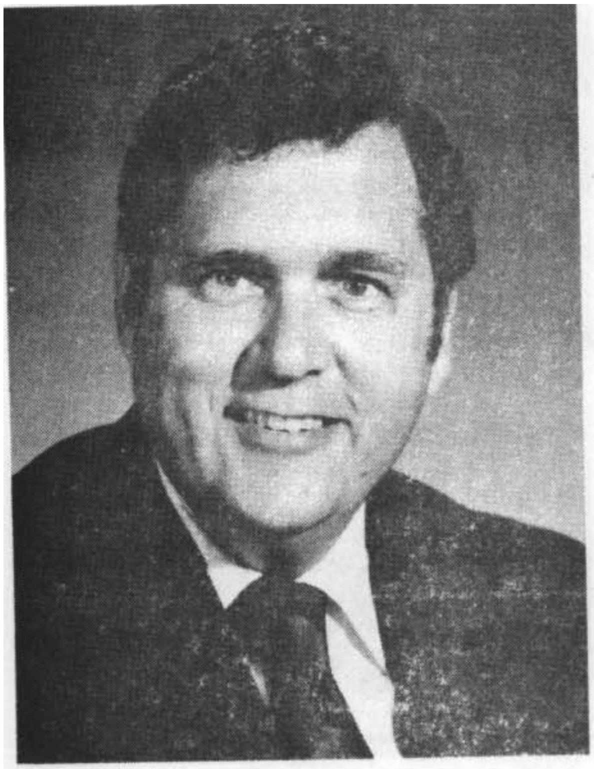

Figure 22.—R. C. De Groot, 1976–Present
Project Leader Wood Preservation Research 1978–Present

Figure 23.—R. Wirka, 1919–1942
Research Specialist—Wood Preservation

Figure 24.—Audrey Richards, 1917–1955
Head of the Division of Plant Pathology 1928–1951

Figure 25.—Reg Colley, 1921–1928
In charge of Division of Forest Pathology

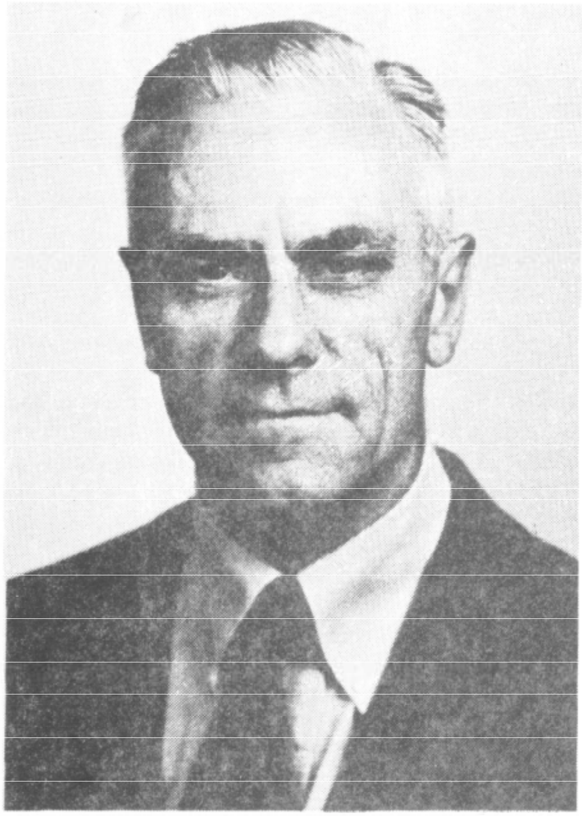

Figure 26.—T. C. Scheffer, 1930–1970
In charge of Wood Biodeterioration Research 1955–1963, Project Leader Forest Products Pathology Research 1963–1970

Figure 27.—Catherine Duncan, 1944–1968
Research Specialist in Forest Products Pathology

permitted a rapid screening of candidate wood preservatives and allowed the comparison of different preservatives. The 1950's saw a series of such published evaluations in AWPA by Duncan and her co-workers.

The Deterioration of Wood in Cooling Towers

For many years FPL had received occasional inquiries regarding the deterioration of wood in cooling towers. An increase in the frequency of such inquiries was observed shortly after World War II. Investigators in England had reported the finding of organisms in British cooling towers. That differed in nature from true basidiomycete wood destroyers.

In view of the fact that towers in this country were built of redwood, a naturally durable species, it was at first assumed that the deterioration of the wood was due mainly to the chemicals in the water. In many towers, the water was maintained at a fairly high pH to combat corrosion of heat exchangers and other steel equipment. Furthermore, it was suspected that in some towers, chlorine, used in an algaecide, was used at concentrations harmful to the wood.

However, as many samples of deteriorated wood from towers were studied in the Laboratory, it was found that practically all showed biological deterioration. Samples from the nonflooded parts of towers showed the presence of typical basidiomycete wood destroyers. Approximately ten basidiomycete fungi, both white- and brown-rots, were isolated from domestic cooling towers. They were isolated from the structural members which were not constantly wet.

Samples from slates in the flooded portions of towers were free from attack by basidiomycetes. However, many showed surface attack by different organisms designated as soft-rot fungi. They cause a softening of the surface and a gradual loss of cross section, especially in the case of thin slats. It seemed obvious that so long as it was impractical to change the treatment of the water appreciably, it was advisable to use wood treated with a leach-resistant preservative in the construction of towers. This is now a routine practice and the problem of premature decay of wood in cooling towers has virtually disappeared.[2]

As has been mentioned, a branch of the Division of Plant Pathology with headquarters in Washington, D. C., was established in Madison to work in cooperation with the Forest Products Laboratory. This group made many contributions to the science of wood preservation. Their participation in the development of the soil-block method has been mentioned. A paper on soft-rot fungi by Duncan in the 1960 AWPA Proceedings called attention to the role of these organisms, especially in the surface decay of hardwoods under wet conditions. These organisms were also found to decay leached redwood slats in the flooded parts of cooling towers. Lindgren published a paper in the 1952 Proceedings on the "Permeability of Southern Pine as Affected by Mold and Other Fungus Infections."

Dual Treatment of Marine Piling

At the time when the first railroads were built in this country, little thought was given to a preservative treatment of the crossties. Wooded areas were being cleared for agriculture and wood was very cheap. Also, species with a fair degree of natural durability were abundant in many areas and the service life of untreated ties was considered satisfactory as a rule.

On the other hand, untreated pilings driven in coastal harbors were subject to rapid deterioration by several types of organisms called "marine borers". In some harbors, untreated pilings were destroyed in less than a year. Some form of protection was essential and many were tried.

The principal scourge of piling in the colder American harbors were several species of *terdo.* They penetrated a pile in the form of tiny embryo which grew to worm-like forms in the interior and were, therefore, termed "ship worms".

An entirely different type of marine organism, called *Limnoria,* became established in small tunnels on the surface of the wood. Smaller than a grain of rice, they are extremely prolific and gradually honeycombed the surface of a pile. They were especially destructive in warm harbors.

The papers discussing the marine borer problem in the early Proceedings of the AWPA dealt mainly with *teredo.* Although, occasional references to *Limnoria* may be found, construction engineers and wood preservation specialists seemed to be concerned mainly with preventing attack by *teredo.* Several explanations suggest themselves. The growth of *Limnoria* is relatively slow except in tropical or subtropical harbors. Many of our first harbor structures were build along our northern coasts.

It had been found in Europe that a thorough impregnation with coal-tar creosote gave excellent protection against *teredo.* Later, experiments showed that while the adult *teredo* were resistant to creosote, the embryo were extremely susceptible to its toxic action. These facts pointed to two precautions, namely, to avoid mechanical damage to the heavily-creosoted, outer layers and to avoid the attachment of untreated bracing.

As more and more creosoted piling was used in warmer harbors, it became evident that even when treated with high retentions of creosote, such pilings were quite vulnerable to destruction by *Limnoria.* A species called *Limnoria tripunctata,* commonly found in the warmer harbors, was especially destructive.

Experiments on *Limnoria,* grown in the Laboratory and exposed to many different chemicals, showed that *Limnoria* are quite susceptible to copper. This pointed to a procedure that became known as the dual treatment. It comprised a pressure treatment with an aqueous solution of copper and arsenic compounds, whereby a precipitate of very low solubility was deposited in the wood. After the wood so treated was seasoned, it was pressure treated with creosote.

When wood specimens of various sizes were treated in the manner described and exposed in harbors infested with both *toredo* and *Limnoria,* they showed excellent resistance to both types of marine borers. A number of commercial charges of piling were treated and seasoned.

When the pilings were transported to several harbors and driven, it was found that the treatment had embrittled the wood. This unfortunate side effect plus the added cost and the need for more lead time more or less nullified the usefulness of the dual treatment for most purposes.

The foregoing experience illustrates the frustrating disappointments with which the researcher must learn to live.

Studies of Coal-Tar Creosote

Importation of coal-tar creosote from Europe was suspended abruptly at the beginning of World-War II, and was not resumed to a normal rate for several years after peace was declared. Since the American wood-treating industry had depended upon importation for nearly one-third of the creosote used, a shortage of creosote soon developed. For several rea-

[2] Causes and Prevention of Decay of Wood in Cooling Towers, by R. H. Baechler, J. O. Blew and Catherine Duncan, presented at the Petroleum Mechanical Engineering Conference, Kansas City, Mo., Sept. 26-27, 1961.

sons, the domestic producers of creosote were able to increase their output only to a limited extent and the use of substitute materials increased. There was also an increase in rumors concerning fraudulent practices used to extend the supply of creosote.

At the same time, there was an increase in the demand for certain chemicals which were normally present in creosote, especially naphthaline and low-boiling tar acids. These were being removed in increasing amounts. Questions arose as to the preservative value of the remaining creosote. The producers declared that these chemicals had been removed in variable amounts for many years with no apparent effect on the effectiveness of the creosote as a wood preservative.

To obtain some information which would help to answer these controversial questions, a cooperative research project was started in 1948. The participants were: (1) two domestic producers of creosote, (2) an importer of creosote, (3) a commercial wood-treating company, (4) the Forest Products Laboratory and, (5) the Wm. F. Clapp Laboratory. After the project was underway, it was expanded to include tests on 3/4-inch stakes by the Bell Telephone Laboratory, the Allied Chemical Corp., and the Koppers Wood Preserving Division. The organization and objectives of the project were covered in a paper by R. H. Baechler, et.al., presented at the 1950 AWPA Convention.

To summarize the findings on field and marine tests, the first results were obtained from marine tests on small treated panels exposed in two harbors. Relatively low retentions were used in order to accelerate the results. The data were erratic so that only a few conclusions were possible. A 70-30 creosote-tar solution was somewhat superior to straight creosote and definitely superior to a 70-30 creosote-petroleum solution. There was no consistent pattern in the effectiveness of the eight creosotes that had been distilled from the same tar. Creosote distilled from a high-temperature, coal-tar were definitely superior to a creosote distilled from a vertical-retort tar.

The next tests to be reported on were made on 3/4-inch, pine sapwood stakes treated with the original oils that were not designated as the "1948 co-operative creosotes". The stakes were exposed in two southern plots. In a report by Coney, et al., in the 1962 AWPA Proceedings, the authors discussed in considerable detail the sources of experimental error in field tests. The depreciation curves indicate that as a general trend, high-residue and medium-residue oils perform somewhat better than low-residue oils.

In a paper summarizing the results of tests by FPL on treated posts and 2x4-inch stakes, the effects of the size and shape of the test specimen as well as the exposure conditions were again dramatically demonstrated. The performance of stakes treated to retentions of 8 pcf. was excellent in Wisconsin, but hardly acceptable in Mississippi. The removal of naphthalene and tar-acids from the creosote had no serious effect on the preservative value.

There was a large spread in the distillation patterns of the eight creosotes distilled from the same parent tar. However, the variability in service life of the 2x4-inch stakes treated with these oils was surprisingly small with the exception of oils No. 1 and No. 12. These creosotes were very high in distillage to 235° and give relatively poor protection.

The fact that the rate of depletion of creosote from treated wood was influenced by climatic factors as well as the size and shape of the specimen was widely recognized. There was more tendency to overlook a third factor, namely, the normal position of the wood product in service. In products that were used in a vertical position, for example, poles, posts and piles, there is a gradual downward movement of creosote. Many who were aware of this phenomenon were unaware of the magnitude of it. In the 1950 Proceedings of AWPA, J. W, Andrews, S. N. Buco, and P. O'Brien described an experiment in which the amount of residual creosote was determined in samples removed from a southern pine pole that had been in service for 23 years after being treated in a charge that retained 8.6 pcf. of creosote. After removal, the pole was sectioned and samples removed from different locations were extracted with hot toluene and pyridine. A sample from just above ground line yielded 14.8 pcf., whereas, a corresponding sample from the approximate middle of the air section yielded only 4.8 pfc.

In a paper presented by Coney, et.al., at the 1980 AWPA Convention, data were given comparing the index of condition of round posts and 3/14-inch stakes treated with various oils. When a low-residue creosote (see), was compared with several high-residue creosotes, the results obtained with stakes differed considerably from the results obtained with posts. In the stake tests, the high-residue creosotes were distinctly superior, but in the post tests, showed little difference.

Acknowledgement

The authors want to thank the Association for allowing them to present this history of wood preservation research at FPL. The publication by Charles A. Nelson "History of the U.S. Forest Products Laboratory (1910-1963)" was very helpful in establishing dates and places for the report. Our photographic staff supplied all the personnel photos for this paper.

Discussion

W. S. McNamara: Lee, I think you have done an excellent job reminding the Association of the work the Forest Products Laboratory had done for the Association and the work done serving industry in general over the past seven decades. The question I would like to ask, not so much to you Lee, but to the Association in general, is what is going to happen over the next seven decades. We currently have an industry group working through the National Forest Products Association that reviews the programs in research on wood preservation and biodegradation at the laboratory. It is particularly important that we do this at this time because of the entire thrust of the Federal budget is a reduction in government services. We have just seen the services that have been provided by government to the wood preserving industry. The positive services! I want to assure members that the Forest Service is responsive to industry comments in directing priorities of the Forest Products Laboratory research in wood preservation. I ask members of the Association to use this vehicle, to communicate their desires for research that is suggested to be performed at the laboratory and also to protect things of interest to us, particularly the longterm test plots that we find so valuable. If we don't continually make our case year by year to do this, and keep our priorities well spelled out to the management of the Laboratory and the Forest Service, we are going to loose contributions of the Forest Products scientists. To participate in this committee, simply slip me a business card while we are at the meeting, I'll see you get the information as to where and when the committee meets. It is usually one week around the fist of April in Madison. It provides you with an excellent chance to meet with the scientists and learn firsthand what is going on there and, most importantly, to provide industry input to support and assign priorities to the research work conducted at the Laboratory. I will appreciate any response of any member of the American Wood-Preservers' Association. I assure you it is important to keep wood preservation research alive and well.

Mr. Gjovik: Thank you, Bill. I would just like to say that early on, the Forest Products Laboratory was very responsive to industry requests and before 1930 there were seven to ten members on Committees of this Association and they responded to requests.

The Industry / Forest Products Laboratory interchange of ideas and researchable problems is not something new. It has been a long-standing program; sometimes formal, sometimes informal. Current budget restraints may require certain research areas to be curtailed. What Bill says is true, and I urge you to join his committee and help out with the program review.

W. C. Kelso Jr.: Lee, I want to first congratulate you on the excellent review of the history of the Forest Products Laboratory. I want to make two comments, they are not derogatory, but number one I think you missed one important person—Catherine Duncan. The second comment is I want to congratulate you of all the people you showed on the screen you were the only one up to this date that has been able to grow a beard.

MR. Gjovik: Thank you, Bill, the omission of Catherine Duncan is an oversite and will be corrected. The beard is to cover up a bad case of the uglies.

Dr. Nicholas: Our next speaker is Andy Baker. Andy is an engineer in the Energy and Chemicals program at the U.S. Forest Products Lab in Madison. He has a degree in Chemical Engineering from the Univ. of Wisconsin and his current research interests are in wood combustion, Wood Hydrolysis and Corrosion of Metals in contact with wood. He has been working on this program for the last 15 years. His talk will be on Metal Corrosion in Treated Wood. Andy.

(Editors' Note: Mr. Baker gave an interesting review of "Metal Corrosion in Treated Wood").

Discussion

Joe Morgan: J. H. Baxter has test results on chemonite treated wood artificially wet wood in an accelerated test and baths after 38 years in service in Portland, Oregon. Our tests show initial rapid reaction with Zn galvanizing which slows as the ammonia evaporates and almost stops after a couple of years.

These bolts may look rusty, but tensile strength tests show breaking strengths at or above the rated strengths.

Could you comment on this in light of your test results.

Mr. Baker: I guess I can't really comment too much on that because the exposure conditions are probably much different. The corrosion rate would tend to decrease with time and the amount of decrease depends on the exposure conditions. Could you say more about the exposure?

Mr. Morgan: We have one set of tests results in an artificial accelerated test for guardrail stock where we artificially wet the material on a daily basis for about one hour. Also we have some test bolts that were pulled out of some utility poles after 38 years service which look fairly bad but they were tested for strength and all tested about 100 percent of rated strength. I have plenty of information on that if you would like to see it.

MR. BAKER The exposure you have is much different from that I have. You have water washing over the surface of the guardrail, and the other was just exposed to weather. That is quite a bit different from the exposure to soil burial and 100% Rh that I used. I don't think there is a serious problem with the galvanized hardware on utility poles because in most areas there are sufficient dry periods to inhibit the corrosion. As you found, there was corrosion but not enough to effect the bolt strength. It would have *been* better to test the complete bolted joint.

DR. NICHOLAS: Our next speaker, Bruce Johnson, is known to many of us having presented papers for the Association in prior years. Bruce is a research scientist at the U.S. Forest Products Lab in Madison. He has a BS degree in wood science and technology from the U. of Mass. His MS and Ph.D. in wood science are from the U. of Wis. in Madison. His current research interests include protection of wood in the marine environment. His first paper to AWPA in 1970 dealt with the effect of terrestrial microorganisms on the structure and permeability of wood. His topic today is Soft-Rot of Presevative-Treated Southern Pine in a Marine Environment. Bruce.

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