RESULTS OF EXPERIMENTS ON THE EFFECTIVENESS OF VARIOUS PRESERVATIVES IN PROTECTING WOOD AGAINST MARINE-BORER ATTACK

Information Reviewed and Reaffirmed

January 1959

No. 1773

FOREST PRODUCTS LABORATORY
MADISON 5, WISCONSIN

UNITED STATES DEPARTMENT OF AGRICULTURE
FOREST SERVICE
In Cooperation with the University of Wisconsin

RESULTS OF EXPERIMENTS ON THE EFFECTIVENESS OF VARIOUS PRESERVATIVES IN PROTECTING WOOD AGAINST MARINE-BORER ATTACK[1]

By

J. D. MacLEAN, Engineer

Forest Products Laboratory,[2] Forest Service
U. S. Department of Agriculture

Purpose of Experiments

Apart from fires, the wood-destroying agencies of the most economic significance are decay, insects, and marine borers. For several reasons, protecting wood against marine-borer attack is, however, far more difficult than protecting it against decay and insects.

This difficulty arises, first, because leaching of the soluble protective constitutents of the preservative or washing out of the preservative oils from marine timbers exposed under water is much more rapid than is usual from wood used for land structures. Secondly, preservative concentrations that will provide satisfactory protection of wood against decay and insects, are entirely inadequate for protecting it against marine borers. Particularly heavy concentrations of preservative are needed in marine timbers not only to help compensate for the more rapid depletion of preservative that results from leaching and washing, but also because the various types of marine borers are resistant to preservative concentrations that are much higher than are needed to protect wood against decay and insect attack. Moreover, many preservatives that are highly toxic to wood-destroying fungi or insects, have little or no effect on marine borers.

The problem is further complicated because different kinds of borers have different modes of attack, so that where more than one kind is present, the activity of one type may hasten or aid the attack of another kind. For example, crustacean borers, such as the Limnoria, Chelura, and Sphaeroma, work largely on the surface wood, while the molluscan borers, such as the Teredo and Bankia (commonly called shipworms), prefer to work in the interior of the timber. The surface attack, in addition to destroying part of the treated sapwood, naturally accelerates the leaching and washing away of preservatives and thus makes the timber more vulnerable to shipworm attack.

---

[1] Presented before the Military Establishment Symposium on Wood sponsored by the National Research Council and the Office of Naval Research, June 16-17, 1949, in Washington, D. C.

[2] Maintained at Madison, Wis., in cooperation with the University of Wisconsin

In addition to the various factors mentioned, results of experiments indicate that although toxicity of the preservative and the ability of the wood to retain it are the essential requirements for protection against decay and insect attack, other preservative constituents in addition to toxics are apparently needed for effective protection of marine structures.

In view of the difficult nature of the marine-borer problem, information is very much needed on the relative effectiveness of various preservatives and on the influence of the variables on the results obtained. It was for the purpose of studying some of these factors that the experiments discussed in this paper were started by the Forest Products Laboratory in 1911.

Method of Test

Arrangements were made to conduct the tests of preservatives in cooperation with the Gulf & Ship Island Railroad and with the Louisville & Nashville Railroad. One group of test specimens was accordingly installed under a wharf of the Gulf & Ship Island Railroad at Gulfport, Miss., and another group was installed under a wharf of the Louisville & Nashville Railroad at Pensacola, Fla. All specimens were bolted to steel frames that were then suspended by chains a sufficient distance under water to avoid any exposure of the wood to the air at low tide.

The tests were continued at Gulfport, Miss., until 1940, when the specimens remaining in the test at that place were removed to Pensacola, Fla. During the course of these experiments the larger number of specimens were in test at Pensacola, partly because of the greater convenience in removing and replacing them when the inspections were made, and partly because borer attack was more severe at Pensacola than at Gulfport.

The last inspection of the test specimens installed at Pensacola was made in December 1946. All specimens remaining were lost during the hurricane that struck Pensacola in the summer of 1947. Data given in this paper therefore summarize the results obtained in tests conducted during a period of about 29 years at Gulfport and during a period of about 35 years at Pensacola.

Shipworms were very active at Gulfport, but both Limnoria and shipworm attacks were very severe at Pensacola. Martesia were also found in some of the specimens installed at Pensacola, but, in general, their attack was quite limited. In some years the borers were less active than in others. This was, apparently, because of a number of variable factors, such as the presence of fresh water resulting from heavy rains, the contamination of the water with sewage or oil from ships anchored in the vicinity of the specimens, and similar temporary unfavorable conditions.

Types of Material Tested

A large proportion of the specimens used were round southern pine sections about 6 inches in diameter and 24 inches long. Some specimens, however, were sawed sapwood pieces about 2 by 2 and 2 by 4 inches in nominal cross section and 18 to 24 inches long. A few specimens of other species were also used in the experiments. In addition, specimens of modified wood of various types were included.

Specimens treated with various preservative oils and other preservatives were added to the experiments from time to time.

Earlier papers[3] discussing the progress of the experiments were published in 1924, 1931, and 1941.

Method of Inspecting Specimens

Inspections were usually made once a year after taking the specimens from the water and removing all shells, growths, and deposits that had collected on their surfaces. Notes were made of the condition of each specimen and of the progress of attack during the year. In tabulating the data, the extent of borer attack on the different pieces was indicated as follows: (1) Sound or slight, (2) medium, (3) severe, (4) very severe, and (5) destroyed.

Some of the specimens in the different groups installed were lost after various periods of exposure because of storms or because of corrosion and failure of such metal fastenings as bolts and supporting chains.

Although the specimens that were lost did not remain in test to destruction, many of them were in test long enough to show fairly definitely the relative effectiveness of the treatment or the relative resistance of the wood in untreated specimens exposed to study the natural resistance of the species.

Results Obtained

Specimens Treated with Various Preservative Oils

Table 1 summarizes the results obtained from specimens installed in the early years of the test. These were treated with coal-tar creosote;

---

[3]MacLean, J. D. Results of Treatment of Piling Specimens Against Attack by Marine Borers. Engineering and Contracting, March 1924; Results Obtained in Marine Piling Experiments. A.W.P.A. Proc. 1931, pp. 287-302; Information Obtained from Marine Piling Experiments on the Gulf Coast. A.W.P.A. Proc. 1941, pp. 101-117.

different fractions of coal-tar creosote; water-gas-tar creosotes; copperized coal-tar creosote; creosote with ferric chloride; coal-tar creosote containing different proportions of naphthalene; copperized crude oil; crude oil and zinc chloride; wood tar; timber asphalt, and Spirittine, a product of the distillation of southern pine. A group of specimens treated with a solution of a byproduct tar in coal-tar creosote was also installed, but a large number of these specimens were lost during the period of test. The results obtained with the creosote-coal-tar solutions, however, indicated that the effectiveness of these solutions was at least comparable to that of coal-tar creosote alone when similar absorptions and penetrations were obtained.

Moderately light absorptions were used in treating most of these specimens, so that the relative effectiveness could be determined more quickly. For the purpose of studying the comparative merits of the different preservatives and the effect of differnet retentions, the absorption for each specimen was plotted against years in test. This method of comparison showed that the following preservatives were the most effective and appeared to be in about the same general class: coal-tar creosote, coal-tar-creosote fraction III, IV, and V, water-gas-tar creosotes Nos. 2 and 3, copperized coal-tar creosote, creosote containing 0.88 percent of ferric chloride, and solutions of coal-tar creosote and byproduct tar.

Table 2 gives the properties of the preservatives used in this series of tests.

Although coal-tar creosote fractions I and II had high toxicity, they were distinctly inferior to the other preservative oils listed. Since these were particularly light fractions, it is probable that they were washed out of the wood more rapidly than the others when in contact with the water. The early failure of the specimens treated with copperized crude oil, with zinc chloride and crude oil, and with Spirittine, showed that these materials were of little value in protecting against borer attack regardless of the absorptions used. Hardwood tar, timber asphalt, and solutions of crude ferric acetate were still less effective.

A comparison of the average absorptions and average number of years in test of specimens treated with creosote containing either copper or ferric cloride shows that when similar retentions of preservative were used, the unfortified creosote oils were about as effective as the fortified creosote.

Results obtained from specimens treated with creosote containing different proportions of naphthalene indicated that increasing the proportion of naphthalene had a tendency to decrease the resistance to borer attack. There were not enough specimens, however, to give definite evidence on this point. One specimen treated wtih creosote containing 50 percent naphthalene had a high retention of 17.02 pounds per cubic foot, which helped considerably to increase the effectiveness of treatment and materially increased the average number of years in test. Laboratory experiments made by Shackell indicated that naphthalene was practically nontoxic to shipworms.[4]

Specimens Treated with Coal-tar Creosotes Containing High Proportions of Tar Acids and Tar Bases Installed in Test at Pensacola, Fla.

Table 3 gives data on results obtained from specimens treated with six different creosotes to study the influence of tar acids and tar bases in protecting wood against borer attack. These specimens were installed at Pensacola. Eight round southern pine specimens were treated with each preservative, which made a total of 48 specimens. Two specimens in each group were lost after being in test nearly 8 years, and two more in each group were lost after being in test nearly 10 years. Three other specimens treated with creosote having a 6 percent tar base were lost later. Table 4 shows the condition of the lost specimens at the time they were last inspected.

It may be noted from the data shown in tables 3 and 4 that the creosotes containing large proportions of tar acids were much less effective than the other creosotes.

Specimens Treated with Various Preservative-oil Mixtures Installed in Test at Pensacola, Fla.

Several groups of southern pine sapwood specimens, 2 by 2 inches in cross section and 18 inches long, were treated with different preservative-oil mixtures and with preservatives fortified with copper in the form of copper oleate or copper resinate. Five specimens were treated with each preservative, and heavy retentions, ranging from about 20 to 35 pounds per cubic foot, were used. A large proportion of these specimens was lost before the tests were completed. Specimens of four groups, however, were in test until they were destroyed. Two other groups had four of the original five specimens in test until they were destroyed. Table 5 gives the results obtained on the six groups.

Results obtained with these small specimens showed that creosote and water-gas tar, and mixtures containing large proportions of these two preservative oils, gave the best results. Crude oil and mixtures containing very large proportions of crude oil were of little value even with the heavy retentions used. Specimens containing crude oil were generally the first ones attacked.

In most cases the specimens treated with crude oil or with mixtures containing a large amount of crude oil were destroyed by shipworms. Most of the other specimens were destroyed by *Limnoria*.

---

[4] Shackell, L. F. The Comparative Toxicity of Coal Tar Creosote and Creosote Distillates and of Individual Constituents for the Marine Borer Xylotrya. A.W.P.A. Proc. 1915, pp. 233-247.

Douglas-fir Piling Sections Installed in Test at Pensacola, Fla.

In 1919 six sections, cut from three piles that had been in service about 29 years in the Oakland Long Wharf in San Francisco Bay[2] were installed in test at Pensacola. One section of each pile was taken from the water line, and one section was taken from the mud line. These specimens were furnished by the Southern Pacific Railroad Co.

All of these sections were free from borer attack at the time they were placed in test at Pensacola, and no attack was evident at Pensacola until the pieces had been in test about 2 years. After this period a few Limnoria were noted in scattered areas on the surface. The areas attacked gradually extended over the entire surface as the time of exposure lengthened.

Three of the specimens were lost between the 1929 and 1930 inspections, two from one pile and one from the water line of another pile. These specimens had shown Limnoria attack to a depth of about 3/8 inch from the side surface when they were last inspected in 1929, or 10 years after they were installed at Pensacola. Two sections from another pile, which were lost between the 1932 and 1933 inspections, had shown Limnoria attack to a depth of 3/8 to 1/2 inch at the time they were last inspected in 1932, or about 13 years after they were installed in test at Pensacola. The remaining section from the mud line of the third pile was removed in December 1946 and sawed lengthwise for one-half its length to determine the condition of the interior. It is shown in figure 1 after having been exposed to borer attack at Pensacola for more than 27 years, following 29 years in service in San Francisco Bay, or after a total life of 56 years. Unfortunately, the reason for the exceptionally long life of these piles has not been discovered.

For a few years after these sections were placed in test at Pensacola, the two end surfaces were covered with tar coatings and metal sheathing, since the untreated heartwood was exposed on these surfaces. Later the effort to protect the end surfaces was discontinued because of the difficulty of making this surface protection entirely effective. Although Limnoria had destroyed the surface wood to a depth of about 3/4 inch, it may be noted from figure 1 that the remaining treated sapwood was still sound. All deterioration of the treated sapwood of these specimens was apparently the result of Limnoria attack, but the untreated heartwood was attacked by shipworms, as shown in figure 1.

The discussion of the condition of the piles removed from the Oakland Long Wharf, which is published in the 1920 Proceedings of the American Wood Preservers' Association, gives the following data for the pile section shown in figure 1, based on creosote extractions from the treated wood when the pile was removed.

Radius of section, 5.4 inches.
Radius of unpenetrated portion, 3.88 inches.
Creosote oil in treated wood 20.71 pounds per cubic foot.
Creosote oil based on entire area of cross section, 10.00 pounds per cubic foot.

---

[2] A discussion of piling removed from this wharf is given in Railway Review, August 9, 1919, p. 202, and in the A.W.P.A. Proc. 1920, pp. 148-178.

Specific gravity of extracted oil at 38° C., 1.0796.
Specific gravity of fraction from 235° to 315° C. at 38° C., 1.0550.
Specific gravity of fraction from 315° to 355° C. at 38° C., 1.1270.
Tar acids, 3.3 percent.
Residue above 355° C., 21.30 percent.

The preservative used was an English creosote oil.

These piles were said to have been air-seasoned before treatment, and they were treated by the full-cell process with an average retention of 14.17 pounds per cubic foot.

Specimens Treated with Mixtures of Paraffin Containing Copper Iodide and Arsenious Iodide, Creosote and Paraffin, and Creosote and Montan Wax, Installed in Test at Gulfport, Miss., and at Pensacola, Fla.

In order to determine whether waxes would have an important effect in retarding the leaching of creosote or other chemicals, southern pine sapwood specimens 2 by 4 by 24 inches in size were treated with (a) paraffin alone, (b) paraffin containing 1 part copper iodide by weight, (c) paraffin containing 1 part arsenious iodide by weight, (d) 25 percent creosote and 75 percent paraffin, and (e) 50 percent creosote and 50 percent paraffin.

Three groups of southern pine sapwood specimens, 2 by 4 by 24 inches in size, were treated with mixtures of A.W.P.A. grade 1 creosote and montan wax. Each group also contained two southern pine specimens about 6-5/8 inches in diameter and 24 inches long. Specimens impregnated with the montan-wax mixtures were treated and furnished by the Montan Company, Inc.

Table 6 shows the results obtained with these mixtures.

Results obtained from the specimens treated with both paraffin and montan wax showed very clearly that increasing the proportion of paraffin or montan wax in the mixture decreased the resistance to borer attack.

Results Obtained with Creosote Fortified with Carbazole, Dinitrochlorobenzene and Dinitronaphthalene

The fifth interim report of the Special Committee of the Institution of Civil Engineers to Investigate the Deterioration of Structures in Sea Water (London, Eng., 1925) stated that the effectiveness of coal-tar creosote against marine-borer attack appeared to be improved when fortified with the organic compounds, carbazole, dinitrochlorobenzene, and dinitronaphthalene.

In order to obtain data on this subject a total of 56 southern pine sapwood specimens, about 2 by 4 by 24 inches in size, were treated with creosote alone and with creosote containing 2.5 percent and 5.0 percent of each of the three compounds. The average absorptions of the preservatives ranged from more than 17 to about 32 pounds per cubic foot.

A large proportion of the specimens were lost after they had been in test from 4 to 8 years, but the degree of attack noted at the different inspections indicated that fortifying creosote with these chemicals made no significant improvement in the resistance of the preservative to borer attack.

Longleaf Pine and Coast Douglas-fir Specimens Treated with Coal-tar Creosote

Six longleaf pine and 12 coast Douglas-fir specimens about 6 inches in diameter and 24 inches long were treated with coal-tar creosote to compare the results obtained with the two species. While the sapwood of southern pine is much more easily treated than the sapwood of Douglas-fir, it is possible that woods that are more resistant to penetration may also be more resistant to leaching and washing. This may help account for the high resistance of the Douglas-fir specimens cut from piling that had been in service in the Oakland Long Wharf in San Francisco Bay. Unfortunately, the Douglas-fir specimens that were available for treatment had much thinner sapwood than the longleaf pine specimens, so that comparable penetrations and absorptions could not be obtained. Table 7 shows the absorptions obtained, the average depth of sapwood, and the condition of the specimens when last inspected in the case of those that were lost before the pieces were destroyed. The average number of years in test is also shown for the specimens that were destroyed. Six of the Douglas-fir specimens were incised to a depth of 3/4 inch before treatment, and six were treated without incising.

It may be noted from table 7 that the sapwood depth of the Douglas-fir specimens ranged from about 0.15 inch to 0.40 inch, while the sapwood depth of the pine specimens ranged from 0.90 inch to 1.20 inches.

The pine specimens were treated by the open-tank hot-and-cold-bath method in an attempt to avoid getting particularly heavy absorptions in comparison to those obtained in the Douglas-fir pieces. All Douglas-fir specimens were pressure-treated by the full-cell process. The thin sapwood of the Douglas-fir pieces, however, made it impossible to get as heavy absorptions in this wood as were obtained in the pine specimens. Practically complete sapwood penetration was obtained in both groups of specimens.

Four of the six incised specimens of Douglas-fir were in test until destroyed by borer attack, and the number of years in test ranged from 15 to 22. These specimens had absorptions varying from nearly 10.5 pounds to about 12.5 pounds per cubic foot. The average sapwood depth was 0.15 inch in two specimens and 0.20 inch in the other two. One of the unincised specimens that had a low absorption of 7.5 pounds per cubic foot, was destroyed after 5-1/2 years in test. Another unincised specimen was destroyed after 15-1/2 years in test. This latter piece would doubtless have been in test somewhat longer if it had not had a groove worn through the treated wood surface caused by rubbing against a wharf timber that was in contact with it.

Two of the longleaf pine specimens were destroyed after 22 and 24 years, respectively. These had absorptions of about 16.7 and 19.7 pounds per cubic foot, and a sapwood depth of 0.90 and 0.95 inch, respectively.

Notwithstanding the much thinner sapwood and lower absorptions in the Douglas-fir specimens, the resistance of this wood to borer attack compared well with that obtained with the longleaf pine.

Mixtures Containing Creosote and Organic Arsenic Compounds

A group of pine specimens (probably *Pinus sylvestris*) that were treated in Germany with coal-tar creosote fortified with various organic arsenic compounds, was furnished by the American Wood Impregnation Corp. These specimens were all installed at Pensacola, Fla. Table 8 gives information on the absorptions, chemicals and concentrations used, and on the results obtained. Since the creosote retentions were only about 6 to 7 pounds per cubic foot, they were too low to give very effective protection. In the concentrations and retentions used, none of the arsenic compounds appeared to improve the effectiveness of the creosote.

Mixtures of 50 Percent Coal-tar Creosote and 50 Percent Coal Tar

A total of 18 round southern pine specimens were treated with a mixture of 50 percent coal-tar creosote and 50 percent coal tar. These specimens were treated and contributed by the Gulfport Creosoting Company. Eight of the specimens were placed in test at Gulfport, and 10 were installed at Pensacola. Table 9 shows the absorptions obtained in the individual specimens and the condition of the specimens when last inspected.

It may be noted that after 14.9 years four specimens showed slight attack, four showed medium attack, and only one showed severe attack. Two specimens were removed when last inspected, to be sawed and photographed. These are shown in figure 2. The photograph shows that attack was confined to the untreated interior heartwood portion of both specimens, but that the sapwood showed very little attack after 14.9 years in test.

Although the end surfaces were penetrated to some extent at the time of treatment when the ends were left exposed, as in the case of most of these test specimens, the bottom surface was usually the region where attack was first noted. This naturally would not occur in a driven pile, since the lower end would be protected from direct contact with the water.

Seven of the specimens treated with this creosote-tar mixture were lost during the period of test, and four of the seven were lost at Pensacola during the first year after they were installed. If the remaining specimens had not been lost at the time of the 1947 hurricane, they would probably have been in serviceable condition for several years longer.

Specimens Treated with Celcure Installed in Test at Pensacola in 1939

Table 10 gives data on the absorptions and the results obtained with sawed southern pine specimens, about 1-5/8 by 3-5/8 by 24 inches in size, that were treated with different retentions of Celcure. These specimens were treated and furnished by the Celcure Southern Corp, and were placed in test in Pensacola, Fla., in June 1939. In the total of 28 specimens that were installed, 21 were all sapwood and 7 contained varying amounts of sapwood and heartwood.

The first group of seven sapwood specimens, having an average retention of 0.779 pound of dry salt per cubic foot, were destroyed after an average period in test of about 3.6 years.

In the group of seven sapwood specimens having an average retention of 1.41 pounds of dry salt per cubic foot, the specimens were destroyed after an average period in test of 5.1 years.

One specimen in the group of seven sapwood specimens having an average retention of 2.52 pounds of dry salt per cubic foot, was removed to be sawed and photographed after being in test 6.5 years. This specimen showed medium attack at the time it was removed. The other six specimens in this group also showed medium attack when last inspected 7.5 years after they were installed.

The seven specimens having varying amounts of heartwood had an average retention of 0.66 pound of dry salt per cubic foot and an average period in test of 3.6 years before they were destroyed.

These results indicate that even when very heavy retentions are used, this preservative is much less effective than either the coal-tar creosotes or the creosote coal-tar solutions for protecting wood against marine borers. It must be borne in mind that the creosote retentions used in these experiments were, in general, considerably lower than those commonly specified for commercial treatments. These lower retentions of preservative oils were used so that the relative effectiveness of the preservatives could be compared without waiting for a long period of time. There are, of course, some cases when only a limited period of protection against borer attack is needed, and under such conditions this preservative salt with retentions of possibly 1 pound or more per cubic foot might be useful. Figure 3 shows sections of some of the Celcure-treated specimens and their condition after various periods in test.

Results Obtained with Untreated Foreign Woods

Specimens of several foreign species that have been claimed to have good natural resistance to borer attack, were included in these experiments.

Specimens of the following untreated woods were placed in test at Pensacola: greenheart (Ocotea rodioei), manbarklak (Eschweilera spp.), basra locus (Dicorynia paraënsis), arc wood (Tabebura spp.), and massaranduba (Minusops spp.).

There were four heartwood specimens of greenheart about 6 by 6 by 24 inches in size, and these all showed attack by Martesia a short time after they were installed. They were finally destroyed by the Martesia after being in test about 11 years, but they showed only slight evidence of attack by Limnoria or shipworms during this time.

Three heartwood specimens of manbarklak about 1-1/2 by 1-1/2 by 14 inches in size were in test for 3 years, but they were lost when a hurricane hit Pensacola in 1926. These specimens were entirely free from borer attack of any kind at the time they were last inspected.

Four heartwood specimens of massaranduba and four of arc wood that were about 2 by 4 by 18 inches in size were destroyed by shipworms within a period of 3 years.

There were originally three heartwood specimens of basra locus placed in test at Gulfport and three at Pensacola. Two of the specimens at Gulfport and one at Pensacola were lost during the first year of test. The remaining specimen at Gulfport was destroyed within 4 years.

A second specimen at Pensacola was missing when the second inspection was made, and the third specimen was destroyed within 7 years. While this wood appears to have some natural resistance to borer attack, these tests indicated its resistance to be low in comparison to that of creosoted wood. This species has been tested at other localities, from where similar results have been reported.

Untreated Southern Pine Specimens Containing Copper and Steel Nails

It has been known that wood impregnated with rust from steel or iron nails has shown very considerable resistance to marine-borer attack. In 1929 the writer had an opportunity to examine some piling that had just been taken out of a pier at Charleston, S. C. A number of these piles were untreated southern pine that had steel nails driven around the circumference from a few feet below the mean water line to a little above the high-tide line. These were ordinary roofing nails spaced about 1/2 inch each way. The piles were said to have been driven about 6 years before they were removed.

The portion of the piles below the nails had been destroyed by shipworms, but there was no indication of borer attack on the part in which the nails were driven. The wood in the portion containing the nails was sound and had a dark color from the iron stain.

In order to study the relative protection afforded by steel and copper nails, four heartwood southern pine specimens, about 2 by 4 by 24 inches in size, were studded with copper nails and four others were studded with steel nails, spaced 1/2 inch each way in the four sides and in the end surfaces. Two specimens of each group were placed in test at Gulfport and two at Pensacola. The two specimens with copper nails in test at Gulfport were destroyed by shipworms in 2 years, while the two copper-nail specimens at Pensacola were destroyed within 4 years. Some of the live shipworms in these specimens were completely surrounded by what appeared to be copper corrosion products, but the presence of this material did not seen to affect their activity.

The steel-nail specimens at Gulfport showed a slight amount of end-surface attack after 1 year in test, but this did not extend to any appreciable depth and did notappear to increase after the first year. The steel-nail specimens at Gulfport were split open after they had been in test for 3 years, and were found to be sound except for the slight amount of end attack. One of the steel-nail specimens at Pensacola was lost after being in test for 6 years, and the other was lost after being in test for 13 years. These specimens also showed only a very small amount of end attack when they were last inspected.

Two untreated round southern pine specimens, about 6 inches in diameter and 24 inches long, were later installed at Pensacola. These had steel nails placed 1 inch each way over the surface and ends. Before they were placed in test they were submerged for a short time in a dilute sulphuric-acid bath to start corrosion. One specimen was in test for 5-1/2 years, and the other was in test for 6-1/2 years. Although the outer surface showed severe attack, the interior was sound when the specimens were removed. Figure 4 shows the interior of the specimen that was in test for 6-1/2 years. It may be noted that this split section shows practically sound wood at the interior. In an earlier installation of untreated round pine specimens that had nails similarly driven in the sides and ends, the preliminary acid bath was not used and the pieces were destroyed during the first year of test. If the nails were well-rusted or corroded before the specimens were installed, it seems reasonable to expect that the nails would afford good protection for a fairly long period.

Specimens Treated with D.D.T. Installed in Test at Pensacola, Fla.

Five southern pine sapwood specimens, 2 by 4 by 18 inches nominal dimensions, were pressure-treated with 1.25 percent D.D.T. (dichloro-diphenyl trichloroethane) in Stoddard solvent (0.39 pound dry salt per cubic foot). These specimens showed slight to medium attack after being in test 1 year.

Four other specimens of the same kind were treated with 2.7 percent D.D.T. in Stoddard solvent (0.86 pound dry salt per cubic foot). These specimens also showed slight to medium attack after being in test 1 year.

If the specimens treated with this chemical had not been lost with the others in test at Pensacola, they would probably have been destroyed within 2 years.

Specimens Painted with Bakelite Antifouling Paint Installed in Test at Pensacola, Fla.

Five untreated southern pine sapwood specimens (2 by 4 by 18 inches nominal dimensions) were painted with three coats of Bakelite antifouling paint No. AF-11. These showed light to medium attack after 3 years of exposure.

A second group of five specimens of the same kind were painted with three coats of Bakelite anitfouling paint No. AF-12. These were all destroyed within 2 years.

Five untreated control specimens installed at the same time were found destroyed at the first inspection made 1 year after they were placed in test.

Specimens Treated with Chlorinated Phenols

Table 11 shows the results obtained with chlorinated phenols. One group of eight southern pine sapwood specimens (nominal dimensions 2 by 4 by 18 inches) was treated with 3 percent pentachlorophenol plus 2 percent of ortho-dichlorophenylphenol (by weight) in No. 2 fuel oil. These specimens had an average retention of 17.4 pounds of solution per cubic foot. All specimens were destroyed during the first year of test.

A second group of the same kind of specimens was treated with 5 percent pentachlorophenol (by weight) in No. 2 fuel oil. These specimens had an average retention of 20.2 pounds of solution per cubic foot, and the average period in test before they were destroyed was 1.3 years. It is probable that specimens such as these that are destroyed in a relatively short time, as in the first year or two, are destroyed earlier than indicated since the inspections are made only once a year. Specimens destroyed even as early as the first 2 or 3 months after they are placed in test would necessarily be recorded as in test 1 year, while more frequent inspections might show the treated pieces were little, if any, more resistant to borer attack than untreated wood.

These results indicate, however, that fuel oil containing the chlorinated phenols in the proportions used are of little value in protecting wood against marine borers.

Treatments with Copper Naphthenate and with Phenyl Mercury Oleate

Table 12 gives data for specimens treated with copper naphthenate and with phenyl mercury oleate, including the absorptions, the preservative concentrations, and the average number of years the specimens were in test before they were recorded as destroyed. These specimens were all southern pine sapwood with nominal dimensions of 2 by 4 by 18 inches. One group of five specimens was given a one-coat brush treatment with a copper naphthenate solution containing 2 percent copper metal, and a second group of five specimens was given a similar brush coating with a copper naphthenate solution containing 3 percent copper metal. The average period in test for the first group was about 1.7 years, and for the second group about 1.4 years.

Four groups of five specimens each were given empty-cell pressure treatments with solutions containing copper-metal concentrations of 0.286, 0.572, and 0.863 percent. Specimens in one of these treatments had an average absorption of 31.3 pounds of solution per cubic foot, in which the copper-metal content was 0.863 percent. Even with this heavy treatment, it may be noted from the table that the specimens averaged less than 3 years in test before they were recorded as destroyed.

It should also be borne in mind that the figures showing the number of years in test are probably somewhat high, since specimens may be destroyed several months before the annual inspection is made.

Figure 5 is a photograph showing the type of borer attack on different specimens treated with various absorptions and solution concentrations of copper naphthenate, as given in table 13.

Table 12 shows that nearly all of the specimens treated with phenyl mercury oleate were destroyed within the first year of test. The only specimens that were in test more than a year, were those treated with a solution to which was added 16 percent water-repellent solids.

These results indicate that phenyl mercury oleate and copper naphthenate offer no appreciable resistance to marine-borer attack.

Preservatives Found to be of Little or Very Limited Value for Protection Against Marine Borers

Tables 14 and 15 show data on completed or nearly completed tests of the materials that were found to be of little or very limited value for protection against marine borers. These tables also list various preservatives that were tested in these experiments, but the results of which are not included in the previous tables.

Results of Tests on Plywood Panels Bonded with Different Types of Adhesives and Having Different Veneer Thicknesses

Table 16 shows the results obtained with plywood panels bonded with different adhesives and having different thicknesses of veneer (table 17) when exposed to marine-borer attack.

The results show that none of the plywood specimens had high resistance to borer attack. The best results were obtained with panels made of veneer 1/100 inch thick. Four of the five specimens made with this veneer were in test for an average period of 2-1/2 years, and one showed medium attack when last inspected after 4 years of exposure. Veneer of this thickness usually absorbs a large amount of glue, which doubtless helps retard borer attack, while the thicker veneer has a large volume of unimpregnated wood.

Figure 6 shows yellow-poplar specimens, described in table 17, that were destroyed after being in test 1 year.

Tests Using Staypak

Table 18 shows the results obtained with staypak (a heat-stabilized wood). These specimens, 1/2 and 1 inch thick, 4 inches wide, and 18 inches long, were made of cottonwood, maple, and yellow birch veneer and were glued with phenolic-resin glue. The average time in test before the specimens were destroyed was only 1.5 to 2 years, which indicates that staypak has relatively low resistance to marine-borer attack.

Treated Plywood

One group of five specimens of Douglas-fir plywood was given a pressure treatment with Celcure, in which the retention of dry salt was 1.35 pounds per cubic foot. A second group of five specimens was also treated with this preparation, in which a heavy retention of 2.80 pounds of dry salt by cubic foot was obtained. The dimensions of the specimens were 5/8 by 4 by 18 inches.

All specimens were sound when last inspected 2 years after they were placed in test.

A group of five control Douglas-fir specimens was found destroyed at the first inspection made 1 year after they were placed in test.

Acetylated Plywood

Five specimens of six-ply acetylated yellow birch plywood 0.4 by 3.5 by 15.75 inches in size, which had been acetylated to the extent of 17.8 percent acetyl content, showed slight to medium attack after 2 years in test.

The control yellow birch specimens were destroyed during the first year in test.

Impreg, Compreg, and Papreg

Table 19 gives data on yellow-poplar impreg and compreg plywood and papreg specimens that were installed in December 1942. These had been in test 4 years when the last inspection was made before the specimens were lost. This table also gives data on cottonwood compreg plywood of different densities. The surfaces of the latter specimens were bronzed with a bronze powder

The cottonwood specimens were installed in December 1943 and had been in test 3 years when last inspected.

The impregnating resin used for both the yellow-poplar and cottonwood plywood was phenolic resin, and the veneer was glued with phenolic-resin glue. The papreg was impregnated with approximately 35 percent phenolic resin.

It may be noted from table 19 that some of the impreg specimens and one of the papreg specimens were showing slight to medium attack but that all of the compreg specimens were sound after 3 and 4 years of exposure.

Summary and Conclusions

1. Among the various preservatives used in these experiments, the most effective were the higher-boiling creosote oils and creosote fractions, the higher-boiling water-gas-tar creosotes, and solutions of coal tar in coal-tar creosote.

While it is recognized that the high-boiling creosotes are less toxic than the low-boiling, they still apparently contain an amount of the toxic constituents sufficient to give good protection. Their greater permanence apparently makes them more effective than the low-boiling oils with higher toxicity. It is also possible that these higher-boiling oils contain substances that, although not necessarily toxic, are nevertheless repellent to the borers. The protection afforded by the iron stain that infiltrates the wood from rusted nails or bolts illustrates how materials commonly recognized as nontoxic can have a very important influence on the degree of borer attack.

2. Creosotes containing high percentages of light distillates or tar acids were found to be much less effective than creosotes low in tar acids or containing high proportions of tar bases. Although Shackell's tests[6] showed that the tar acids were generally highly toxic to marine borers, the lower permanence of the light oils and tar acids in contact with water probably accounts for the lower effectiveness of these constituents.

3. The results of these tests showed very conclusively that the most effective treatments were obtained with heavy retentions and deep penetrations. The first point of borer attack was commonly noted where penetration was more shallow than at other regions of the specimen surface. Permanence is markedly dependent on these two factors. Heavy retentions insure deeper penetrations and also furnish a reserve supply of preservative to help compensate for leaching and washing over a considerable period.

4. No important improvement in resistance to borer attack was evident when creosote was fortified with chemicals such as copper salts, organic or inorganic arsenic compounds, carbazole, dinitronaphthalene, dinitrochlorobenzene, ferric chloride, or high percentages of naphthalene.

5. The resistance of creosote to borer attack was decreased by the addition of paraffin or montan wax, and the decrease in resistance was more or less in direct proportion to the decrease in the amount of creosote in the mixture.

6. Quite a large number of both soluble and insoluble preservative salts were used in these experiments, but none has shown promise of offering protection for more than limited periods. Even when the best of these were used in very heavy retentions, they were far less effective than the coal-tar creosote commonly used for treating marine timbers.

It has been the opinion of some of those interested in the marine-borer problem that poisonous salts containing chemicals, such as copper, arsenic, and the like, that are insoluble in water but soluble in animal digestive fluids, should give good results. Although such salts have been used in these experiments, they have been ineffective against marine borers. This would suggest that possibly the digestive fluids of the borers do not have chemical substances that will make the salts toxic.

While none of the preservative salts nor the resins used in modified wood gave evidence of reasonably long-time protection such as that afforded by coal-tar creosote or creosote coal-tar solutions there are some that would very likely prove useful where creosote cannot be used and a limited period of protection is acceptable, such as in some kinds of boat hulls.

---

[6] Shackell, L. F. Marine Borers from the Wood Preservers Standpoint. A.W.P.A. Proc. 1916, pp. 124-131.

7. Petroleum oils afforded very little protection against borer attack, even when heavy retentions were used. Solutions of creosote and petroleum became less effective as the proportion of creosote in the mixture was reduced.

8. Results of these experiments showed that Limnoria will attack treated wood that effectively resists shipworm attack. There is no question that where the Limnoria are active it is much more difficult to protect wood against these borers than it is to protect it against shipworms. Furthermore, since the Limnoria attack the surface wood, they accelerate leaching and washing out of preservatives so that shipworms are able to enter the timber earlier than would be possible if the Limnoria attack had not occurred.

It was also observed in these experiments that when Martesia are present, these borers can enter heavily treated wood that is well-protected against the shipworms.

9. There are some users of marine piling who believe that marine-borer attack is chiefly confined to the portion of the timber near the water surface. This, however, is not the case, for Limnoria, shipworms, and Martesia were all found active as far as the mud line in creosoted piling that had been removed from a Pensacola Wharf. This distribution of borer attack has also been observed in piling installed in other localities.

10. In the course of these experiments it was noted that the intensity of borer attack was affected both by the season of the year and by the presence of sewage or fresh water in the vicinity of the test specimens. In some years abnormally heavy rains apparently reduced the borer activity by lowering the salinity of the water. The presence of sewage was also found to retard their activity. It would be difficult to say whether it was the sewage or the water in which the sewage was carried that was responsible for the effect of this material.

All borers were apparently more active in the warm months. This is to be expected, since it is well known that marine timbers exposed in tropical waters are under particularly severe conditions of service because of the greater activity of borers in these warmer regions. The intensity of borer attack and the type of borers that are present may vary widely, depending on the location.

11. A mistake commonly made is to draw conclusions from relatively short-time tests. Some preservatives may be so ineffective that only a few months time in test will demonstrate that they are entirely unsuitable for use in protecting wood against marine borers. On the other hand, there are preservatives that may show good results for a period of 4 or 5 years or longer, after which the wood may start to deteriorate very rapidly. For this reason, several years may be required to show the relative value of preservatives that have a fair degree of resistance to borer attack.

Specimens are also sometimes placed in test where borer attack is only mild or is more or less erratic. Tests under such conditions can be very misleading, for they are not comparable to conditions where borer attack is severe and where even the most effective preservatives may not furnish protection for a long period of time.

12. Control specimens are commonly installed with specimens under test, but in many cases specimens treated with a standard coal-tar creosote could be included to advantage. Since coal-tar creosote is recognized as a standard preservative for marine piling, the creosoted specimens would help furnish a yardstick for measuring the effectiveness of the preservative under test. Groups of creosoted specimens containing two or more different retentions might be desirable for the purpose of comparison.

Suggestions for Further Study of the Marine-borer Problem

The following suggestions are offered for further study of the marine-borer problem.

1. Continue the search for more effective preservatives and investigate methods that might help retard loss by leaching and by washing away of protective constituents of preservatives now used.

2. Make extensive study of service records of piling installed in localities where marine borers are particularly active, and give particular attention to cases of early failure or unsatisfactory service, and also to installations that have given outstandingly good results.

3. Compile information on various mechanical protections that have been used. This should include data on results obtained, cost, where used, service period, advantages and disadvantages, and the like.

4. Collect data on results obtained from untreated piling made from woods that have more or less natural resistance to marine-borer attack, such as greenheart.

5. Determine whether some species, when treated, give better results than others similarly treated.

6. The information obtained in past and present experiments should save a considerable amount of exploratory work in future investigations, but there is need for an extensive program of study in this field to find more effective methods of protecting wood against marine-borer attack.

Table 1.--Specimens installed at Gulfport, Miss., and Pensacola, Fla., in 1911, 1912, 1914, and 1915

(All treated specimens were southern pine about 6 inches in diameter and 24 inches long.)

Preservative	Number of specimens installed	Number of specimens lost	Specimens destroyed: Number	Specimens destroyed: Average absorption	Specimens destroyed: Average time in test	Location of test specimens
				Lb.per cu.ft.	Years	
Fraction I creosote	12	1	11	8.9	6.1	Gulfport and Pensacola
Fraction II creosote	12	2	10	6.8	6.0	Do.
Fraction III creosote	12	3	9	8.6	9.6	Do.
Fraction IV creosote	12	4	8	10.1	11.9	Do.
Fraction V creosote	12	2	10	9.7	15.8	Do.
Coal-tar creosote No. 1	12	3	9	11.7	13.6	Do.
Water-gas-tar creosote No. 3	4	1	3	6.7	10.3	Gulfport
Hardwood tar	4	....	4	11.9	1.8	Do.
Timber asphalt	4	....	4	10.0	1.5	Do.
Copperized crude oil	8	....	8	10.6	3.2	Gulfport and Pensacola
Copperized coal-tar creosote No. 2	4	....	4	11.6	13.5	Pensacola
Creosote No. 2 with 0.88 percent ferric chloride	4	....	4	17.7	15.9	Do.
Water-gas-tar creosote No. 2	4	....	4	6.1	7.5	Do.
Water-gas-tar creosote No. 1	4	1	3	7.1	6.3	Do.
Zinc chloride and crude oil	4	1	3	21.4 oil 1.97 dry salt	3.6	Do.
Spirittine	4	1	3	8.5	3.6	Do.
25 percent by-product tar 75 percent coal-tar creosote	8	5	3	9.9	10.4	Gulfport and Pensacola
50 percent by-product tar 50 percent coal-tar creosote	8	6	2	9.6	14.1	Do.
75 percent coal-tar creosote No. 2,25 percent naphthalene	8	3	5	9.1	10.0	Do.
50 percent coal-tar creosote No. 2,50 percent naphthalene	8	2	6	10.5	12.4	Do.
5 percent solution of crude ferric acetate	2	....	2	.648 dry salt	1.2	Do.
13 percent solution of crude ferric acetate	4	....	4	3.04 dry salt	2.8	Do.

Z M 84871 F

Table 2.--Properties of preservatives used in series of 1911 to 1915

Preservative	Specific gravity at 60° C.	Amount distilled -- Hempel column: To 170° C.	170° to 205° C.	205° to 255° C.	255° to 295° C.	295° to 320° C.	Above 320° C.	Highest temperature reached	Residue	Loss	Remarks
		Percent	Percent	Percent	Percent	Percent	Percent	° C.	Percent	Percent	
Coal-tar creosote No. 1	1.048	.....	11.0	35.9	14.8	12.4	.....	320	25.8	0.1	....
Fraction I	.934	28.6	34.8	27.0	.....	.....	.....	225	8.1	1.5	Collected between 0° and 205° C.
Fraction II	1.003	.9	8.1	76.4	10.5	.....	.....	287	4.0	.1	Collected between 205° and 250° C.
Fraction III	1.045	.2	.5	29.2	43.8	11.3	8.8	337	5.8	.4	Collected between 250° and 290° C.
Fraction IV	1.088	.....	.....	1.4	21.7	31.5	23.1	335	22.5	.1	Collected between 290° and 320° C.
Fraction V	1.15	.....	.....	.....	2.4	7.7	38.6	360	51.2	.1	Residue above 320° C.
Water-gas-tar creosote No. 1	.995	.....	6.9	39.4	29.0	5.0	11.7	350	7.6	.4	Water-gas tar distillate
Water-gas-tar creosote No. 2	1.042	.....	5.5	20.7	17.5	10.0	23.9	360	21.9	.5	Water-gas tar distillate
Water-gas-tar creosote No. 3	1.058	.....	4.9	2.9	9.3	10.5	36.9	350	35.0	.5	High-boiling water-gas-tar distillate oil
Hardwood tar	1.195	27.0	3.1	20.9	10.0	.....	.....	244	46.8	2.2	A tar product from distillation of hardwoods. Contained 24 percent water.
Timber asphalt	1.063	.....	.....	.....	17.9	30.5	27.1	345	20.2	4.3	A residuum of petroleum
Copperized oil	.937	.....	.....	.....	19.4	20.7	30.82	358	17.5	3.6	To 340° C. contained 10 percent saponifiable oil removed before distillation At 340° to 358° C. contained 0.34 percent copper.
Spirittine	1.006	.....	22.1	13.2	4.4	.....	.....	295	56.9	3.4	A product of the distillation of southern pine.
Creosote from which five fractions were distilled	......	2.0	7.0	43.0	16.0	4.5	.....	315	27.6	.9	Analysis by retort method contained 0.9 percent water
Coal-tar creosote No. 2	1.071	.....	1.2	31.7	14.5	15.2	.....	360	36.9	.5	Contained some undistilled tar.
75 percent coal-tar creosote No. 2 and 25 percent crude naphthalene	1.063	.....	.5	40.8	11.0	12.1	.....	330	35.1	.5	....
50 percent coal-tar creosote No. 2 and 50 percent crude naphthalene	1.064	.....	.5	46.8	10.0	12.4	.....	330	30.0	.3	....
75 percent coal-tar creosote No. 2 and 25 percent by-product tar	1.108	.....	2.6	24.5	12.7	12.8	.....	330	46.9	.5	....
50 percent coal-tar creosote No. 2 and 50 percent by-product tar	1.139	.....	1.6	18.7	9.3	13.1	.....	330	56.8	.7	....
Crude oil	.873	[1]1.0	[2]16.5	[3]17.0	.....	[4]17.0	34.8	365	.....	.....	....
Zinc chloride solution (at 20° C.)	1.048	.....	.....	.....	.....	.....	.....	.....	.....	.....	....
Creosote ferric chloride mixture	......	.....	.....	.....	.....	.....	.....	.....	.....	.....	Percent ferric chloride in mixture, 0.88
Copperized coal-tar creosote	......	.....	.....	.....	.....	.....	.....	.....	.....	.....	Percent copper in mixture, 0.879
Copperized crude oil	......	.....	.....	.....	.....	.....	.....	......	.....	.....	Percent copper in mixture, 0.654

[1]To 190° C.
[2]190° to 275° C.
[3]275° to 300° C.
[4]300° to 320° C.

Z M 84872 F

Table 3.--Specimens treated with six different creosotes to compare the effect of tar acids and tar bases. Installed at Pensacola, Fla., in 1918

Preservative	Specific gravity at 38° C.	Number of specimens in test	Number of specimens lost	Specimens destroyed: Number	Specimens destroyed: Average absorption	Specimens destroyed: Average time in test
					Lb. per cu. ft.	Years
English creosote	1.015	8	4	4	15.6	14.5
Coal-tar creosote	1.08	8	5	3	20.9	24.5
Creosote - A.R.E.A. specification	1.055	8	4	4	20.0	27.0
Creosote having 17 percent tar acids	.99	8	4	4	20.9	14.6
Creosote having 37 percent tar acids	1.01	8	4	4	21.7	14.3
Creosote - A.R.E.A. having 6 percent tar base	1.06	8	7	1	17.0	18.7

Table 4.--Data on specimens lost after various periods in test

Preservative	Specific gravity at 38° C.	Specimen No.	Absorption	Date when last inspected	Time in test when last inspected	Degree of borer attack when last inspected
			Lb. per cu. ft.		Years	
English creosote	1.015	407	13.2	Feb. 1928	9.7	Very severe
		405	15.1	Feb. 1926	7.7	Severe
		406	17.1	Feb. 1926	7.7	Slight
		403	24.0	Feb. 1928	9.7	Severe
Creosote	1.08	415	16.7	Feb. 1928	9.7	Medium
		414	18.3	Feb. 1926	7.7	Slight
		411	20.9	Feb. 1928	9.7	Medium
		413	23.2	Feb. 1926	7.7	Severe
		412	18.3	Feb. 1937	18.8	Severe
Creosote A.R.E.A. specification	1.055	423	14.6	Feb. 1928	9.7	Medium
		421	14.7	Feb. 1926	7.7	Severe
		419	23.8	Feb. 1928	9.7	Medium
		422	25.3	Feb. 1926	7.7	Slight
Creosote having 17 percent tar acids	.99	429	13.9	Feb. 1926	7.7	Severe
		427	21.3	Feb. 1928	9.7	Very severe
		430	21.4	Feb. 1926	7.7	Medium
		431	24.1	Feb. 1928	9.7	Very severe
Creosote having 37 percent tar acids	1.01	439	16.7	Feb. 1928	9.7	Very severe
		437	18.8	Feb. 1926	7.7	Severe
		438	19.8	Feb. 1926	7.7	Medium
		435	22.6	Feb. 1928	9.7	Very severe
Creosote, A.R.E.A. having 6 percent tar bases	1.06	442	15.5	Feb. 1937	18.8	Severe
		447	17.4	Feb. 1928	9.7	Very severe
		446	18.1	Feb. 1926	7.7	Medium
		443	26.1	Feb. 1928	9.7	Severe
		445	26.3	Feb. 1926	7.7	Medium
		448	23.5	Feb. 1932	13.7	Medium
		444	18.0	Feb. 1932	13.7	Medium

Table 5.--Southern pine sapwood specimens treated with various preservative-oil mixtures. (Specimen dimensions 2 by 2 inches in cross section and 18 inches long)

Original number of specimens	Number of specimens lost	Preservative used	Net retention of preservative	Average time in test before specimens were destroyed
			Lb. per cu. ft.	Years
5	None	50 percent crude petroleum oil and 50 percent water-gas tar containing 1 percent copper in form of copper oleate	35.5	9.3
5	None	50 percent crude petroleum oil and 50 percent water-gas tar	31.4	9.7
5	None	Crude petroleum oil containing 1 percent copper in form of copper oleate	26.5	3.7
5	None	Crude petroleum oil	30.2	3.4
5	1	Coal-tar creosote containing 1 percent copper in form of copper resinate	32.5	9.6
5	1	10 percent fraction I creosote, 90 percent water-gas-tar creosote containing 1 percent copper in form of copper oleate	35.2	9.9

Table 6.--Southern pine specimens treated with paraffin and montan-wax mixtures. (Sawed specimens were all sapwood.)

Preservative	Specimen dimensions	Number of specimens placed	Net retention of preservative	Average time in test before specimens were destroyed	Remarks
	Inches		Lb. per cu. ft.	Years	
Paraffin	2x4x24	3	17.7	2.0	In test at Pensacola.
Paraffin containing 1 part copper iodide by weight	2x4x24	3	18.1	---	Attacked by shipworms during first year. Specimens lost after first inspection. In test at Pensacola.
Paraffin containing 1 part arsenious iodide by weight	2x4x24	3	18.4	2.0	In test at Pensacola.
25 percent creosote and 75 percent paraffin	2x4x24	3	11.7	5.0	In test at Pensacola.
50 percent creosote and 50 percent paraffin	2x4x24	3	12.1	5.3	In test at Pensacola.
70 percent montan wax 30 percent A.W.P.A. grade 1 creosote	2x4x24	8	19.0 to 38.8	(1)	4 specimens in test at Gulfport. 4 specimens in test at Pensacola.
	About 6-5/8 diameter x 24	1	24.1	---	Lost after 13 years. Very severe attack when last inspected. In test at Gulfport.
		1	26.2	11.0	In test at Pensacola.
60 percent montan wax 40 percent A.W.P.A. grade 1 creosote	2x4x24	8	21.7 to 30.9	(1)	4 specimens in test at Gulfport. 4 specimens in test at Pensacola.
	About 6-5/8 diameter x 24	1	24.7	---	In test at Gulfport. Lost after 14 years. Showed very severe attack when last inspected.
		1	24.9	14.0	In test at Pensacola.
50 percent montan wax 50 percent A.W.P.A. grade 1 creosote	2x4x24	8	18.0 to 27.7	(1)	4 specimens in test at Gulfport. 4 specimens in test at Pensacola.
	About 6-5/8 diameter x 24	1	28.0	---	In test at Gulfport. Lost after 5 years in test. Showed slight attack in 5 years.
		1	28.4	---	In test at Pensacola. Nearly destroyed when last inspected after 21 years in test.

[1] Many of the sawed specimens treated with creosote and montan-wax mixtures were lost during the period of test, but most of them were in test a sufficient time to show the relative effectiveness of the different mixtures.

Table 7.--Longleaf pine and coast Douglas-fir specimens treated with coal-tar creosote

Specimen number	Absorption	Average depth of sapwood	Installed at	Condition when last inspected
	Lb. per cu. ft.	Inches		
				Longleaf pine specimens (About 6 inches in diameter and 24 inches long)
P-1	26.26	1.20	Gulfport	Lost after 17-1/2 years in test. Showed medium attack when last inspected.
P-2	16.67	.95	Pensacola	Destroyed after 24 years in test.
P-3	14.65	.90	Pensacola	Lost after 16-1/2 years in test. Showed medium attack when last inspected.
P-4	19.73	.90	Gulfport	Destroyed after 22 years in test.
P-5	17.74	.90	Gulfport	Lost after 5-1/2 years in test. Sound when last inspected.
P-6	19.13	1.20	Pensacola	Lost after 11-1/2 years in test. Showed medium attack when last inspected.
				Coast Douglas-fir specimens (About 6 inches in diameter and 24 inches long)
DF-1[1]	13.05	.40	Gulfport	Lost after 8-1/2 years in test. Sound when last inspected..
DF-2[1]	11.80	.20	Pensacola	Lost after 4-1/2 years in test. Sound when last inspected.
DF-3[1]	10.81	.15	Gulfport	Destroyed after 15 years in test.
DF-4[1]	12.53	.20	Gulfport	Destroyed after 16 years in test.
DF-5[1]	10.38	.15	Pensacola	Destroyed after 17 years in test.
DF-6[1]	12.02	.20	Pensacola	Destroyed after 22 years in test.
DF-7	7.50	.20	Pensacola	Destroyed after 5-1/2 years in test.
DF-8	12.78	.40	Gulfport	Lost after 3-1/2 years in test. Sound when last inspected.
DF-9	12.92	.45	Pensacola	Lost after 2-1/2 years in test. Sound when last inspected.
DF-10[2]	12.20	.40	Gulfport	Destroyed after 15-1/2 years in service.
DF-11	12.37	.30	Gulfport	Lost after 3-1/2 years in test. Sound when last inspected.
DF-12	12.79	.30	Pensacola	Lost after 4-1/2 years in test. Sound when last inspected.

[1] One of six specimens incised to depth of 3/4 inch. Other specimens were not incised.

[2] This specimen had a grove worn through the treated surface caused by rubbing against the edge of a wharf timber. Shipworms entered the exposed untreated wood.

Table 8.--Specimens treated with creosote fortified with organic arsenic compounds. Specimens obtained from Germany and installed at Pensacola, Fla., in February 1927. (Pine specimens (probably *Pinus sylvestris*) about 6 inches in diameter and 15 inches long)

Arsenic compound	Concentration in creosote	Absorption immediately after treatment		Date recorded as destroyed	Remarks
		Creosote	Arsenic compound		
	Percent	Lb. per cu. ft.	Lb. per cu. ft.		
P--Aminophenylarsinoxide	0.048	6.7	0.0032	Feb. 1934	
P--Aminophenylarsinoxide	.482	7.2	.0035	Mar. 1930	
P--Dimethylaminophenyl-arsinoxide	.243	6.8	.0163		Missing 1929 inspection (sound 1928)
P--Dimethylaminophenyl-arsinoxide	.486	6.7	.0327		Missing 1928 inspection
P--Oxyphenylarsinoxide	.037	7.0	.0026	Feb. 1934	
P--Oxyphenylarsinoxide	.112	6.3	.0071	Feb. 1932	
Chinolinarsentartrate	1.490	6.5	.0967		Missing 1929 inspection (slight attack 1928)
Strychninarsentartrate	1.000	7.1	.0071	Mar. 1933	
Coal-tar creosote	....	7.0	....	Feb. 1934	

Table 9.--Specimens treated with 50 percent coal-tar creosote and 50 percent coal-tar. Installed in 1932 (Southern pine specimens about 5 inches in diameter and 24 inches long)

Specimen number	Placed in test at	Absorption of preservative	Conditions of specimens when last inspected
		Lb. per cu. ft.	
TC-1	Pensacola, Fla	22.0	Slight attack. In test 14.9 years.
TC-2	......do........	22.0	Medium attack. In test 14.9 years.
TC-3	......do........	27.2	Do.
TC-4	......do........	25.0	Do.
TC-5	......do........	20.2	Severe attack. In test 14.9 years.
TC-6	......do........	23.3	Missing 1933 inspection.
TC-7	......do........	20.0	Do.
TC-8	......do........	22.7	Do.
TC-9	......do........	13.6	Do.
TC-10	......do........	23.3	Slight attack. In test 14.9 years.
TC-11[1]	Gulfport, Miss.	25.0	Do.
TC-12[1]	......do........	24.3	Removed 1946 to photograph. (See fig. 2)
TC-13	......do........	23.8	Missing 1940 inspection. Sound 1939.
TC-14[1]	......do........	25.7	Removed 1946 to photograph. (See fig. 2)
TC-15[1]	......do........	26.4	Slight attack. In test 14.9 years.
TC-16	......do........	24.2	Missing 1940 inspection. Sound 1939.
TC-17	......do........	25.7	Missing 1934 inspection. Sound 1933.
TC-18[1]	......do........	21.2	Medium attack. In test 14.9 years.

[1] One of five specimens at Gulfport removed to Pensacola following the 1940 inspection. None of the specimens installed at Gulfport showed any evidence of attack at the time they were removed to Pensacola in 1940.

Table 10.--Specimens[1] treated with Celcure installed at Pensacola, Fla., June 1939
(Dimensions 1-5/8 by 3-5/8 by 24 inches)

Specimen No.	Percent sapwood in specimens	Absorption of solution reported	Net retention of dry salt	Time in test before recorded as destroyed	Condition of surviving specimens when inspected after 7-1/2 years in test	Remarks
		Lb. per cu. ft.	Lb. per cu. ft.	Years		
C-1	100	35.19	0.755	3.5	....	Solution 2.146 percent
C-2	100	35.69	.766	3.5	....	made according to the
C-3	100	36.18	.776	3.5	....	following formula:
C-4	100	36.18	.776	4.5	....	$CuSO_4$ $5H_2O$......5 lb.
C-5	100	36.56	.784	3.5	....	$Na_2Cr_2O_7$ $2H_2O$...5 lb.
C-6	100	37.17	.798	3.5	....	80 percent commercial
C-7	100	37.17	.798	3.5	....	acetic acid....1.16 lb.
						Water 54-1/2 gals.
						454.8 lb.
Ave.		36.31	.779	3.6		
C-8	100	42.38	1.40	4.5	....	Solution 3.3 percent
C-9	100	42.63	1.41	5.5	....	made according to the
C-10	100	42.75	1.41	4.5	....	following formula:
C-11	100	42.75	1.41	4.5	....	$CuSO_4$ $5H_2O$...7.84 lb.
C-12	100	43.00	1.42	6.5	....	$Na_2Cr_2O_7$ $2H_2O$..7.84 lb.
C-13	100	43.00	1.42	6.5	....	80 percent commercial
C-14	100	43.12	1.42	3.5	....	acetic acid...1.16 lb.
						Water.....450.66 lb.
Ave.		42.80	1.41	5.1		
C-15	20	12.39	.41	2.7	....	
C-16	20	14.88	.49	2.7	....	
C-17	30	18.22	.60	2.7	....	
C-18	40	21.69	.72	2.7	....	
C-19	40	22.30	.74	4.5	....	
C-20	40	23.54	.78	3.5	....	
C-21	50	27.39	.90	6.5	....	
Ave.		20.06	.66	3.6		
C-22	100	37.17	2.435	....	Medium attack	Solution 6.55 percent
C-23	100	37.42	2.451	Removed to photograph	.....do......	made according to the
						following formula:
C-24	100	37.79	2.475	....	.....do......	$CuSO_4$ $5H_2O$...15.68 lb.
C-25	100	38.54	2.524	....	.....do......	$Na_2Cr_2O_7$ $2H_2O$ 15.68 lb.
C-26	100	38.66	2.532	....	.....do......	80 percent commercial
C-27	100	39.29	2.574	....	.....do......	acetic acid...1.17 lb.
C-28	100	39.41	2.521	....	.....do......	Water......445.30 lb.
Ave.		38.33	2.51			

[1]All specimens were treated by the Celcure Southern Corporation, at its plant, and the treating data were reported to the Forest Products Laboratory.

Z M 84874 F

Table 11.--Southern pine sapwood specimens treated with chlorinated phenols (Nominal dimensions 2 by 4 by 18 inches)

Specimen No.	Absorption of solution	Time in test before recorded as destroyed
	Lb. per cu.ft.	Years
Specimens treated with 3 percent pentachlorophenol plus 2 percent 2-chlororthophenylphenol (by weight) in No. 2 fuel oil		
C-1	17.9	1.0
C-2	18.0	1.0
C-3	16.8	1.0
C-4	18.2	1.0
C-5	17.0	1.0
C-6	17.0	1.0
C-7	16.8	1.0
C-8	17.2	1.0
Ave.	17.4	1.0
Specimens treated with 5 percent pentachlorophenol (by weight) in No. 2 fuel oil		
C-9	22.9	1.0
C-10	22.9	1.0
C-11	23.8	1.0
C-12	23.5	1.8
C-13	22.8	1.8
C-14	23.3	1.8
C-15	22.9	1.0
C-16	17.5	1.0
C-17	17.5	1.0
Ave.	20.2	1.3

Table 12.--Southern pine specimens treated with copper naphthenate and phenyl mercury oleate. (Specimens all sapwood. Nominal dimensions 2 by 4 by 18 inches.)

Preservative and treatment	Number of specimens in average	Average absorption of solution	Concentration[1]	Average time in test before recorded as destroyed[2]
		Lb. per cu. ft.	Percent	Years
Copper naphthenate				
Brushing, 1 coat	5	0.79	2.000	1.7
Brushing, 1 coat	5	.79	3.000	1.4
Pressure, empty-cell	5	12.1	.286	1.8
Pressure, empty-cell	5	11.3	.572	1.8
Pressure, empty-cell	5	10.5	.863	2.2
Pressure, full-cell	5	31.3	.863	2.8
Phenyl mercury oleate				
3-minute dipping	5	1.6	.4	1.0
3-minute dipping	5	1.1	[3].4	1.0
18-hour cold soaking	5	2.7	.4	1.0
18-hour cold soaking	5	5.0	[3].4	1.0
Pressure, empty-cell	5	6.0	.4	1.0
Pressure, empty-cell	5	6.1	[3].4	1.0
Pressure, full-cell	5	26.5	.4	1.0
Pressure, full-cell	5	26.0	[3].4	2.0

[1] The concentration for the copper naphthenate is that of the copper metal in the preserving solution; for the phenyl mercury oleate, that of the entire preservative.

[2] The average life is probably less than shown because inspections were made only once a year.

[3] Treating solution contained 16 percent water-repellent solids.

Table 13.--Specimens treated with copper naphthenate in test at Pensacola, Fla., February 1942 to November 1943

Specimen No.	Method of treatment	Copper in concentrated solution	Absorption: Concentrated solution	Absorption: Copper metal
		Percent	Lb. per cu. ft.	Lb. per cu. ft.
1[1]	Brush, 1 coat	2.000	0.82	0.016
2	......do.......	2.000	.82	.016
3	......do.......	2.000	.66	.013
4	......do.......	3.000	.82	.025
5	......do.......	3.000	.99	.030
6	Empty-cell	.286	12.00	.034
7	......do.......	.572	11.20	.064
8	......do.......	.572	11.80	.067
9	......do.......	.572	11.40	.065
10	......do.......	.863	11.70	.101
11	......do.......	.863	7.90	.068
12	......do.......	.863	9.20	.079

[1] Contained about 12 percent heartwood.

Table 14.--Oils, tars, and oil mixtures found to be of little or limited value for protection against marine borers

Preservative	Nominal dimensions of specimens	Number of specimens installed	Number of specimens lost	Specimens destroyed: Number	Specimens destroyed: Average absorption	Specimens destroyed: Average time in test	Location	Remarks
	Inches				Lb. per cu. ft.	Years		
Hardwood tar[1]	About 6 diam. and 24 long	4	None	4	11.4	2.1	Gulfport, Miss.	....
Copperized crude oil (0.34 percent copper)	....do....	4	None	4	10.0 Oil 22.9	2.0	Gulfport, Miss.	....
Zinc chloride and crude oil	....do....	4	1	3	Dry salt 0.97	3.6	Pensacola, Fla.	....
Copperized crude oil[1] (0.654 percent copper)	....do....	4	None	4	11.3	3.5	Pensacola, Fla.	....
Spirittine (Proprietary preservative)	....do....	3	None	3	8.5	3.6	Pensacola, Fla.	....
Timber asphalt	....do....	4	None	4	10.0	1.5	Gulfport, Miss.	....
Paraffin	2x2x24	3	None	3	17.7	2.0	Pensacola, Fla.	....
1 part copper iodide and 100 parts paraffin by weight	2x2x24	3	....	....	18.1	.....	Pensacola, Fla.	All attacked by shipworm first year. Lost after first inspection.
1 part arsenious iodide and 100 parts paraffin by weight	2x2x24	3	None	3	18.4	2.0	Pensacola, Fla.	....
Mercurized solution. Proprietary preservative	2x2x24	6	....	....	12.4	.....	Pensacola, Fla.	Attacked by shipworm first year. Lost after first inspection.
Crude-tar acids chlorinated to about 31 percent chlorine content. Diluted with 9 parts petroleum oil to 1 part chlorinated tar acids	2x4x24	8	....	....	....	.....	Gulfport, Miss. and Pensacola, Fla.	Specimens at Gulfport destroyed first year. Destroyed during second year at Pensacola.

[1]Properties shown in table 2.

Z M 84876 F

Table 15.--Organic and inorganic preservatives found to be of little or limited value for protection against marine borers

Preservative	Nominal dimensions of specimens	Number of specimens installed	Number of specimens lost	Specimens destroyed: Number	Specimens destroyed: Average absorption	Specimens destroyed: Average time in test	Location	Remarks
	Inches				Lb. per cu. ft.	Years		
13 percent solution crude ferric acetate	About 6 diam. x 24 long	4	None	4	3.04 dry salt	2.8	Gulfport, Miss. and Pensacola, Fla.	....
5 percent solution crude ferric acetate	....do....	2	None	2	.648 dry salt	1.2	......do......	....
Copper carbonate solution	....do....	6	None	6	25.5	1.0	......do......	....
Arsenic -- dry salt		1		1	Dry chemical placed in holes bored along axis	1.0	Pensacola, Fla.	All destroyed first year.
Lead nitrate -- dry salt	....do....	1	None	1				
Sodium fluoride -- dry salt		1		1				
Copper orthoarsenite and copper fluoride[1]	2x4x24	8	None	8	.45 dry salt	....	Gulfport, Miss. and Pensacola, Fla.	Specimens at Gulfport destroyed first year. Specimens at Pensacola destroyed during second year.
Copper orthoarsenite and copper aceto-arsenite[1]	2x4x24	8	2	6	0.65 dry salt	.....	......do......	Specimens at Gulfport destroyed first year. Specimens at Pensacola destroyed during second year.
Zinc-meta-arsenite[1]	2x4x24	8	2	6	.65	....	......do......	Do.
Barium carbonate[1]	2x4x24	8	4	4	1.0 dry salt	....	......do......	Do.
Sulphur[2]	2x4x24	3	None	3	Impregnated with melted sulphur. Absorption not determined.	1.0	Pensacola, Fla.	....
Celcure	1-5/8 x 3-5/8x24	28	None	21	See table 10	See table 10	......do......	....
Chlorinated phenols	2x4x18	8	None	8	See table 11	1.0	......do......	....
		9		9		1.3		
Phenyl mercury oleate	2x4x18	20	None	20	See table 12	1.0	......do......	....
Phenyl mercury oleate with 16 percent water-repellent solids	2x4x18	20	None	20	See table 12	2.0	......do......	....
Copper naphthenate	2x4x18	30	None	30	See table 12	Max. 2.84	......do......	....

[1] Specimens treated and furnished by the Western Union Telegraph Co., New York.

[2] Specimens treated and furnished by Texas Gulf Sulphur Co.

Z M 84875 F

Table 16.--Results obtained with untreated plywood panels made from yellow-poplar veneer of different thicknesses, using different types of adhesive. (Dimensions of panels about 3/8 by 4 by 18 inches)

Adhesive	Veneer thickness	Number of plies	Number of specimens in test	Average time in test before destroyed	Remarks
	Inch			Years	
High-temperature-setting phenolic-resin film glue	1/100	31	5	2.5 for 4 specimens	1 showed medium attack after 4 years
	1/32	11	5	1.0	....
	1/16	5	5	1.0	....
Hot-setting melamine-resin glue	1/100	31	5		1 slight attack 4 medium attack
	1/32	11	5	2.0	....
	1/16	5	5	1.0	....
Hot-setting urea-resin glue	1/32	11	5	1.0	....
	1/16	5	5	1.0	....
Cold-setting urea-resin glue	1/32	11	5	1.0	....
	1/16	5	5	1.0	....
Intermediate-temperature-setting phenolic-resin glue	1/32	11	5	1.0	....
	1/16	5	5	1.0	....

Table 17.--Description of yellow-poplar plywood specimens in test 1 year

Specimen No.	Thickness of plies	Number of plies	Adhesive
	Inch		
1	1/32	11	High-temperature-setting phenolic-resin film glue
2	1/16	5	High-temperature-setting phenolic-resin film glue
3	1/16	5	Hot-setting melamine-resin glue
4	1/32	11	Hot-setting urea-resin glue
5	1/16	5	Hot-setting urea-resin glue
6	1/32	11	Cold-setting urea-resin glue
7	1/16	5	Cold-setting urea-resin glue
8	1/32	11	Intermediate-temperature-setting phenolic-resin glue

Table 18.--Results obtained with staypak (heat-stabilized wood) (Specimen dimensions 1/2 and 1 by 4 by 18 inches)

Species	Number of plies	Number of specimens	Specific gravity	Average time in test before destroyed	Remarks
				Years	
Yellow birch	20	5	1.36	1.5	....
Yellow birch	32	5	1.33	2.0	....
Maple	16	5	1.36	2.0	....
Cottonwood	12	5	1.32	1.4	....
Cottonwood	12	5	1.33	2.0	Bronzed faces
Cottonwood	12	5	1.32	2.0	Compreg faces

Table 19.--Results obtained with impreg and compreg yellow-poplar plywood in test 4 years (installed in December 1942) and with cottonwood specimens (installed in December 1943) (Dimensions of yellow-poplar specimens, 3/8 by 4 by 18 inches; of cottonwood specimens, 1/2 by 4 by 8 inches).

Material		Number of plies	Thickness of plies	Specific gravity	Resin content	Number of specimens	Condition when last inspected in 1946 after 4 years in test
			Inch		Percent		
Impreg	Yellow-poplar	5	1/16	0.63	30	5	Some practically sound and some showed medium attack
Impreg	Yellow-poplar	5	1/16	.58	15	5	3 specimens were eliminated because they were broken. 2 remaining showed slight attack
Compreg	Yellow-poplar	11	1/16	1.24	30	5	All sound
Compreg	Yellow-poplar	11	1/16	1.18	15	5	All sound
Papreg					35	5	4 sound and 1 showed medium attack
Compreg, bronzed faces	Cottonwood	6	1/8	.79	33	5	All sound
Compreg, bronzed faces	Cottonwood	11	1/8	1.36	33	5	All sound

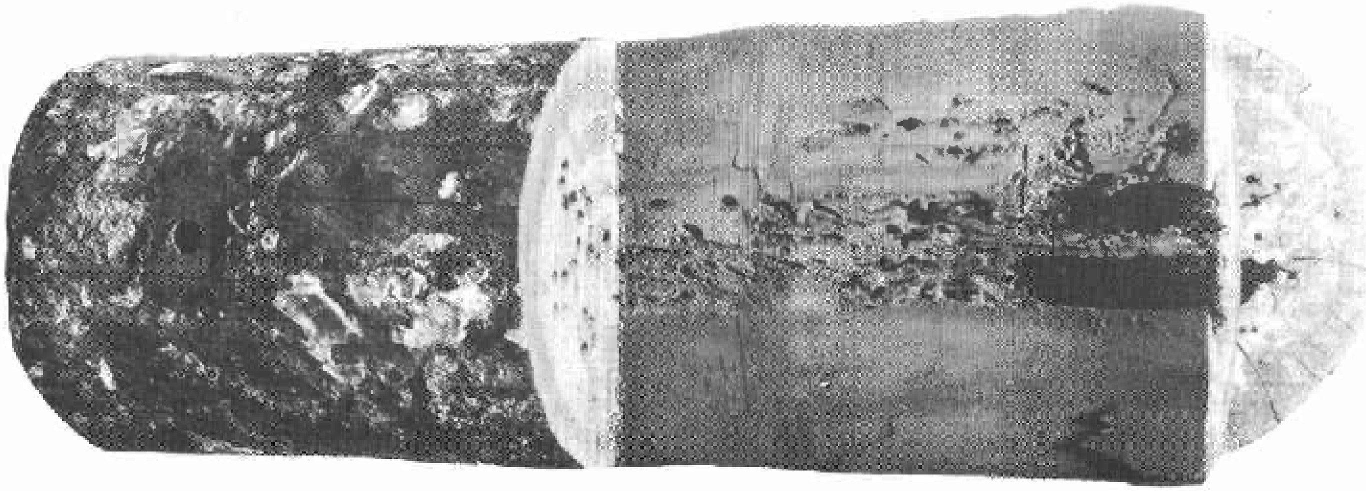

Figure 1.--Douglas-fir section cut from mud line of pile that had been in service in the Oakland Long Wharf in San Francisco Bay for 29 years. This pile section was later installed in test at Pensacola, Fla., in 1919 and was removed in 1946, after 27 years in Pensacola harbor. Although the treated sapwood had been destroyed by Limnoria to a depth of about 3/4 inch, the remaining sapwood was still sound, as may be noted from the sawed surface.

Z M 51554 F

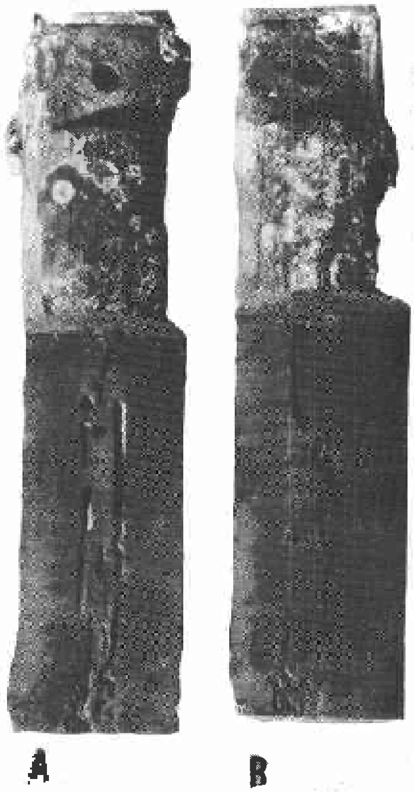

Figure 2.--Specimens treated with 50 percent creosote and 50 percent coal tar. In test 14.9 years. Specimen A had absorption of 24.3 pounds per cubic foot. Specimen B had absorption of 25.7 pounds per cubic foot.

Z M 81228 F

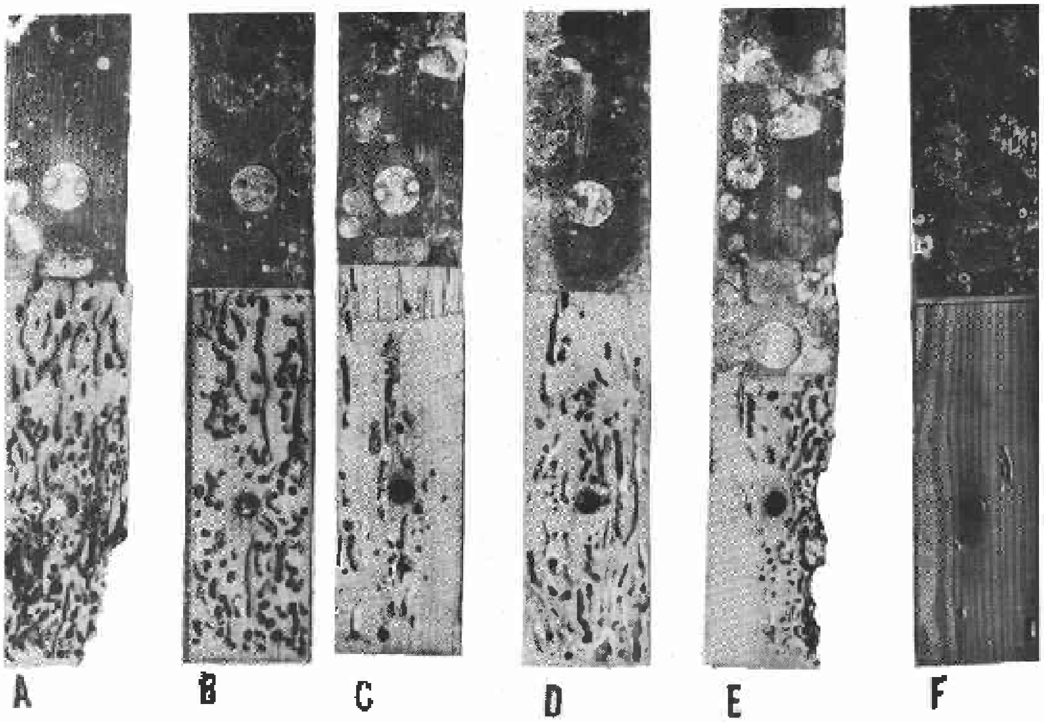

Figure 3.--Celcure-treated specimens. Specimen E had 60 percent heartwood. All other specimens had 100 percent sapwood. A, Absorption, 0.766 pound of dry salt per cubic foot; destroyed after 4.5 years. B, Absorption, 1.42 pounds of dry salt per cubic foot; destroyed after 4.5 years. C, Absorption, 1.41 pounds of dry salt per cubic foot; destroyed after 4.5 years. D, Absorption, 1.41 pounds of dry salt per cubic foot; destroyed after 4.5 years. E, Absorption, 0.74 pound of dry salt per cubic foot; destroyed after 4.5 years. F, Absorption, 2.435 pounds of dry salt per cubic foot; showed medium attack when removed after 6.5 years in test.

Z M 81227 F

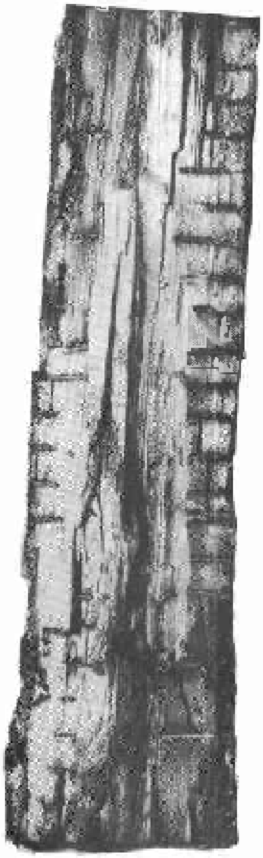

Figure 4.--Untreated southern pine specimen, about 6 inches in diameter and 24 inches long, that had steel nails spaced 1 inch apart each way on circumference and in ends. Specimen was in test at Pensacola, Fla., for 6-1/2 years. After nails were driven, the specimen was placed in a dilute-acid solution to start corrosion of nails so that rust could penetrate the surrounding wood.

Z M 81229 F

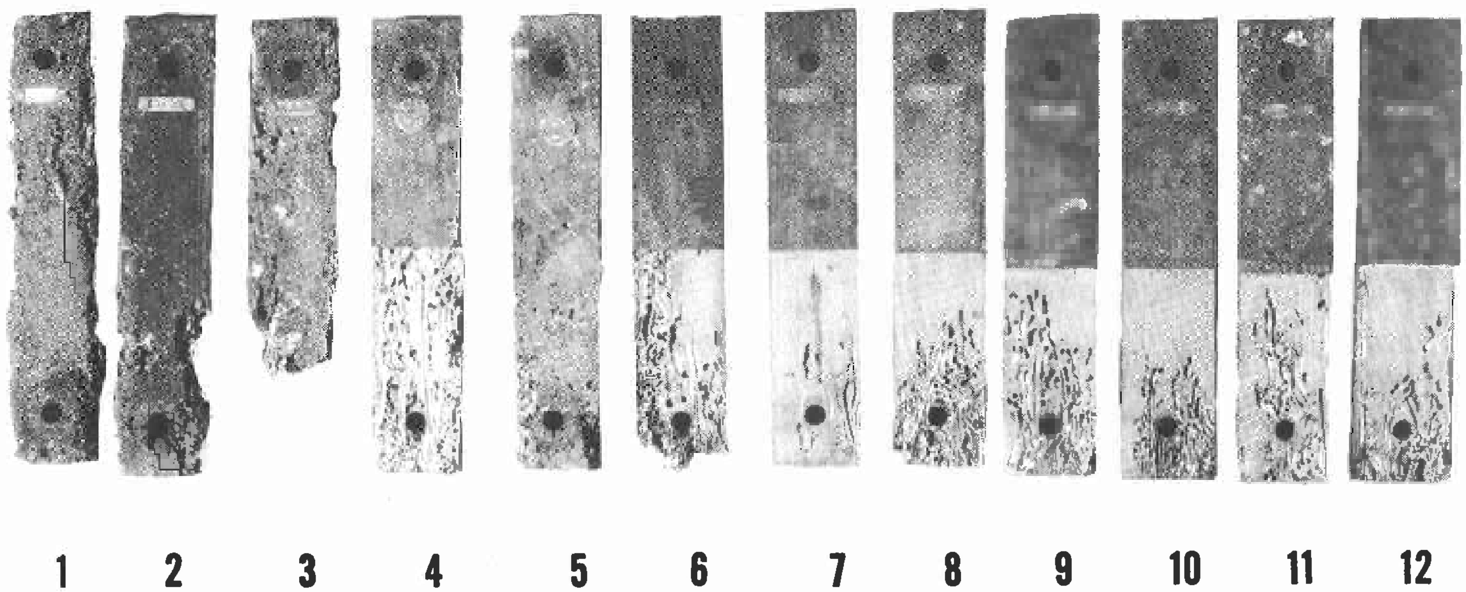

Figure 5.--Specimens treated with copper naphthenate in test at Pensacola, Fla., February 1942 to November 1943. Treatments of individual specimens are given in table 13.

Z M 51549 F

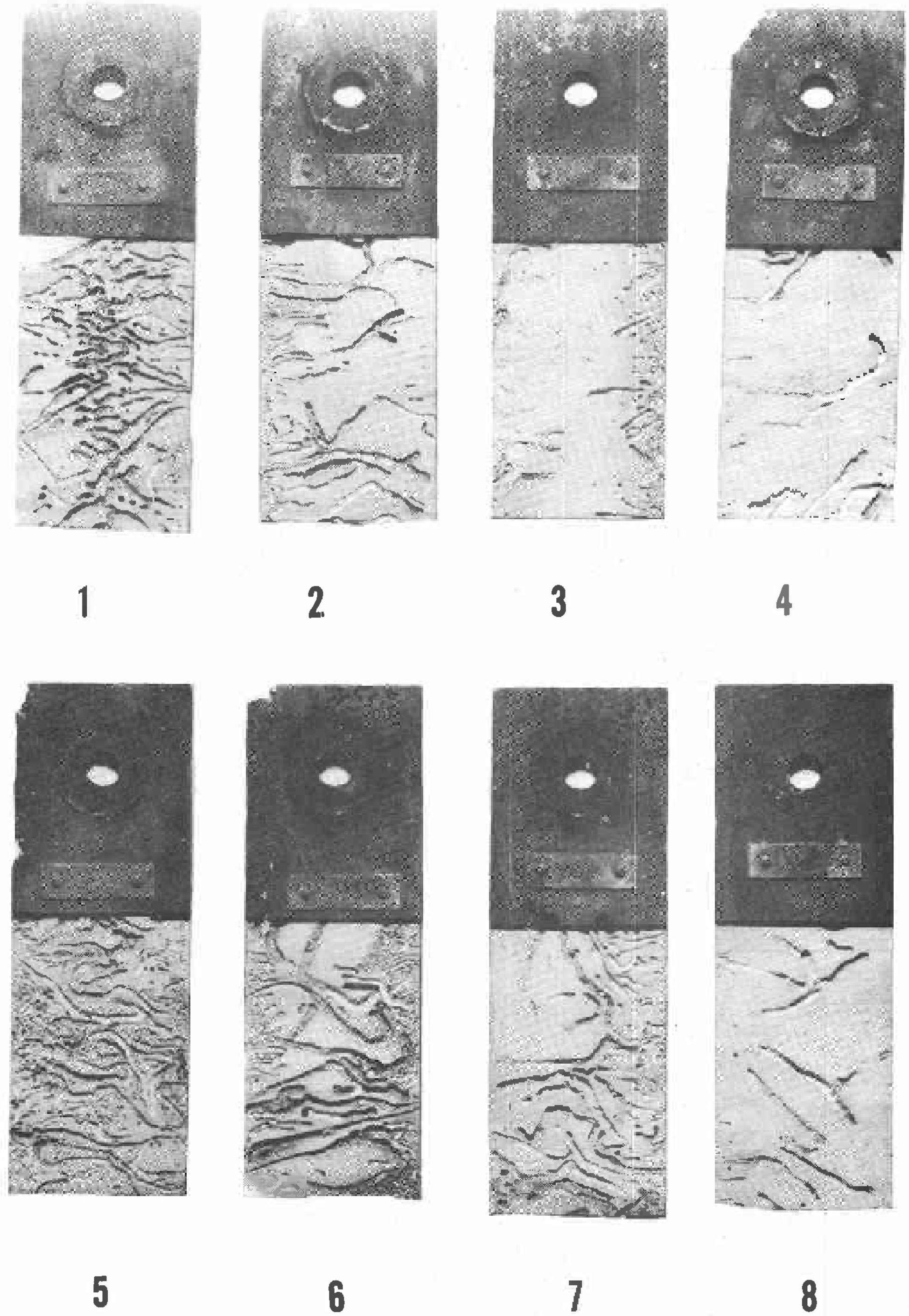

Figure 6.--Yellow-poplar plywood specimens in test 1 year, showing borer attack after removal of a section of face to expose wood. Individual specimens are described in table 17.

Z M 51588 F

SUBJECT LISTS OF PUBLICATIONS ISSUED BY THE

FOREST PRODUCTS LABORATORY

The following are obtainable free on request from the Director, Forest Products Laboratory, Madison 5, Wisconsin:

- List of publications on Box and Crate Construction and Packaging Data
- List of publications on Chemistry of Wood and Derived Products
- List of publications on Fungus Defects in Forest Products and Decay in Trees
- List of publications on Glue, Glued Products, and Veneer
- List of publications on Growth, Structure, and Identification of Wood
- List of publications on Mechanical Properties and Structural Uses of Wood and Wood Products
- Partial list of publications for Architects, Builders, Engineers, and Retail Lumbermen
- List of publications on Fire Protection
- List of publications on Logging, Milling, and Utilization of Timber Products
- List of publications on Pulp and Paper
- List of publications on Seasoning of Wood
- List of publications on Structural Sandwich, Plastic Laminates, and Wood-Base Aircraft Components
- List of publications on Wood Finishing
- List of publications on Wood Preservation
- Partial list of publications for Furniture Manufacturers, Woodworkers and Teachers of Woodshop Practice

Note: Since Forest Products Laboratory publications are so varied in subject no single list is issued. Instead a list is made up for each Laboratory division. Twice a year, December 31 and June 30, a list is made up showing new reports for the previous six months. This is the only item sent regularly to the Laboratory's mailing list. Anyone who has asked for and received the proper subject lists and who has had his name placed on the mailing list can keep up to date on Forest Products Laboratory publications. Each subject list carries descriptions of all other subject lists.