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(1961 Progress Report)

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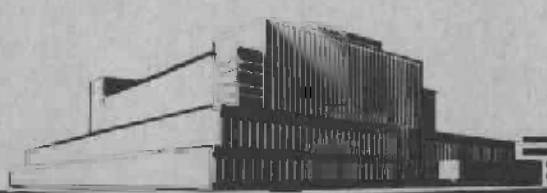

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UNITED STATES DEPARTMENT OF AGRICULTURE
FOREST SERVICE
In Cooperation with the University of Wisconsin

COMPARISON OF WOOD PRESERVATIVES IN MISSISSIPPI POST STUDY

(1961 Progress Report)

by

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Summary

Experimental untreated southern yellow pine posts installed from 1936 to 1938 at the Harrison Experimental Forest, Saucier, Miss., had an average life of 3.3 years. Untreated longleaf pine posts installed in 1949 had an average life of 2.3 years, while those treated with a No. 2 fuel oil and with Wyoming residual petroleum oil have an estimated average life of 5 and 8 years, respectively. Of southern yellow pine posts installed from 1936 to 1941, those treated with borax-boric acid have all failed with an average life of 10.6 years and those treated at the groundline and top with Osmoplastic have all failed after an average life of 11.2 years. Posts treated with the following preservatives and installed from 1936 to 1941 have had failures totaling 10 percent or less of the number installed and should last 38 years or longer on an average: Pentachlorophenol, 3 percent and 4.8 percent in crankcase oil[2]; copper sulfate and sodium arsenate applied by double diffusion; and zinc meta arsenite. Posts in test in 1936 to 1941 treated with other preservatives have an estimated average life of 8 to 37 years.

Introduction

During late 1936 and early 1937, the U. S. Forest Products Laboratory, in cooperation with the Southern Forest Experiment Station and the then existing Bureau of Entomology

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

[2] Crankcase oils may contain chlorinated naphthalenes, which are reported to be a contributing cause of "X-disease" (hyperkeratosis) in cattle. These oils are therefore not recommended for preservative treatment of wood with which cattle may come in contact.

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and Plant Quarantine, started a service test at the Harrison Experimental Forest, Saucier, Miss., on posts treated with 24 wood preservatives. A report by Wirka[3] contained a description of the preservatives and treatments used in the original installation of posts in a line approximately 8 miles long. This report also described the installation and presented the results of the test after 3 years of service. Additional posts were added to this line during the years 1938 and 1941. A report by Blew[4] in 1947 described these additions and presented the condition of all posts in the 8-mile line after approximately 5-1/2 to 10 years of service. During April and May 1949 the study was expanded to include posts treated with 44 preservatives and untreated controls that were installed in a plot on the Harrison Experimental Forest. Various commercial companies cooperated in this work by furnishing the preservatives and by contributing to the cost of making the treatments and of installing test posts. Annual progress reports[5] issued since 1950 describe the condition of the posts in the two installations.

This progress report deals with the condition of the posts at the time of the December 1960 inspection, or after 20 to 24 years of service in the line, and after 11-1/2 years in the plot installation. The report also briefly describes the materials and treatments used and the procedure followed in inspecting the posts.

Posts

All of the posts used in this study were of round southern yellow pine that consisted mostly of sapwood. Those treated in 1941 with Osmoplastic and by double diffusion were cut and treated while green on the Harrison Experimental Forest. All other posts were cut at McNeill, Miss., and were shipped to the Forest Products Laboratory for treatment. The posts to be treated with Osmosar were freshly cut and shipped green; the others were peeled, sprayed with stain-control chemical, and air-dried before shipment. The posts installed in the line from 1936 to 1941 were 7 feet in length and from 2-1/2 to 7 inches in top diameter. Those installed in the plot during 1949 were of longleaf pine 6 feet in length and from 2.8 to 5.3 inches in top diameter. These posts were peeled, dipped in a stain-control chemical, and shipped to the Laboratory for air or kiln drying. Many of them required repeeling, before treatment, to remove inner bark. The different diameter sizes were distributed as uniformly as practicable to each of the treatments used in the study.

Preservatives and Treatment

Tables 1 and 2 show the preservatives used. Table 1 includes 26 preservatives or treatments and also untreated control posts set in the line from 1936 to 1941.

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[3] Wirka, R. M. Comparison of Preservatives in Mississippi Fence-Post Study. Proceedings of the American Wood-Preservers' Association, 1941, pp. 365-379.

[4] Blew, J. O. Comparison of Preservatives in Mississippi Fence-Post Study After 10 Years of Service. Proceedings of the American Wood-Preservers' Association, 1947, pp. 26-41.

[5] Blew, J. O., and Kulp, John W. Comparison of Wood Preservatives in Mississippi Post Study (1960 Progress Report). Forest Products Laboratory Report No. 1757, January 1960.

Forty-four preservatives or treatments and untreated control posts are included in table 2 for the posts set in the plot during 1949.

In the line installation were included four nonpressure treatments: Steeping with mercuric chloride; full-length Osmose treatment of green posts with Osmosar; treatment at the groundline and at the immediate tops of the posts with Osmoplastic; and full-length double-diffusion treatment of green posts with copper sulfate and sodium arsenate. The remaining treatments in the line installation and all treatments in the plot installation were by pressure impregnation. In the pressure treatments, the oils were applied by the Rueping empty-cell process, and the waterborne preservatives were applied by the full-cell process.

Minimum, maximum, and average preservative retentions are shown in tables 1 and 2. Borings taken from posts following each pressure treatment showed, for the most part, either complete or nearly complete penetration of the sapwood. Exceptions were noted, however, in the posts pressure-treated for the 1936 installation with coal tar, with 10 percent of coal-tar creosote and 90 percent of used crankcase oil, with lignite coal-tar creosote, with water-gas tar, and with No-D-K (hardwood-tar creosote). In these treatments, a high percentage of the posts bored showed penetrations of less than 60 percent of the sapwood depth. Borings taken from the posts treated by steeping in mercuric chloride all showed poor penetration of the preservative. Penetration measurements were not made on the posts treated with Osmosar, those treated by double diffusion, or those treated with Osmoplastic.

Installation of Posts

The posts, at the start of the test, were set from late 1936 until February 1937 in a line approximately 8 miles long on the Harrison Experimental Forest, Saucier, Miss. The posts were grouped into 100 units, each of which included 1 post of the different treatments selected at random, and, for the most part, 1 untreated control post. It was possible to install only 65 untreated posts at the same time the treated posts were installed, and the remaining 33 were set during November and December 1938. The position of the treated posts and of the untreated control post within each unit was also randomized. During 1941, two additional treatments were added to this line, with 1 post from each treatment being installed in each of the 100 units. The line installation was originally designed so that about 70 percent of the posts of each treatment were set on the drier, well-drained sites of the area (pine hills or dry hardwood sites), 20 percent in moist soil (pitcher-plant areas or any area with fluctuating water table), and 10 percent in swamp or standing water.[6] A careful check during several post inspections, which included both extremes of dry and wet weather, indicated that the segregation according to dry, damp, and wet sites varied slightly with the different treatments but was generally about 65 percent, 18 percent, and 17 percent, respectively.

In the line, 100 posts were originally installed for each preservative or treatment. The number of test posts has since been reduced for some treatments by fire loss and pilferage, or by other removals not occasioned by decay or termite attack.

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[6] Throughout the report these sites will be referred to as "dry," "damp," and "wet," although these terms are relative and apply only to the Mississippi test area.

The posts in the more recent installation on the Harrison Experimental Forest were set in a comparatively dry site during April and early May, 1949 (fig. 1). Twenty-five posts were installed for each treatment, along with 25 untreated control posts. These posts were installed in a plot by the randomized block method, by which the plot was divided into 25 blocks, each containing 1 post from each treatment and 1 untreated control post, selected at random. The posts were set 3 feet apart in rows, and the rows were 3 feet apart in the blocks.

The soil in the general area of Saucier, Miss., is reported to be a Norfolk fine sandy loam with a pH of 5.0 to 5.5. In the plot with the posts installed during 1949 the soil pH is 4.98 to 5.04.

Results to Date

During the December 1960 inspection, as in the previous inspections, each post was given a moderate push by the inspector, under the force of which it could usually be expected to break off if decay or termite attack had progressed to a critical point. If it broke off, the cause of the failure was determined.

Conditions of Posts Installed from 1936 to 1941

The conditions of the posts installed from 1936 to 1941 are shown in table 1 and are discussed, according to preservatives and treatments used, in the following paragraphs.

Untreated control posts. --The 65 untreated control posts set from late 1936 to February 1937 had an average life of 3.1 years, and the 33 installed during November and December 1938 had an average life of 3.7 years. The average life of all untreated posts in the line was 3.3 years. The untreated posts installed in well-drained, comparatively dry soil had an average life of 2.6 years and failed mostly because of decay and termite attack. Those installed in moist soil and in swamps or standing water had an average life of 4 and 4.8 years, respectively, and failed mostly because of decay. Some of the posts set in water remained serviceable for more than 5 years and failed mainly because of top decay. The untreated posts were removed as follows:

Years after installation	1	2	3	4	5	6
Number (cumulative) removed	3	33	60	79	93	98

Acid copper chromate (Celcure). --Acid copper chromate is prepared from copper sulfate and sodium dichromate in an acid solution. Approximately 22 percent of the posts treated with this preservative have been removed, mostly because of decay. The estimated average life of the 88 test posts is 32 years. The 19 posts removed had an average retention of 0.90 pound per cubic foot; the average retention for the posts installed was 0.92 pound per cubic foot. Twenty-eight percent, 7 percent, and 12 percent of the posts set respectively in dry, damp, and wet sites, have been removed. Removals to date are as follows:

Years after installation	1	3	4	5	9	12	16	19	20	21	22	24
Number (cumulative) removed	1	2	3	5	6	7	9	10	12	15	17	19

Beta-naphthol, 5 percent in organic solvents. --Ninety-seven percent of the posts treated with beta-naphthol solution have been removed. The estimated average life of the posts is 14 years on the basis of the time when 60 percent were removed. The average retention of preservative solution for the posts removed was 6.2 pounds per cubic foot, the same as that for the 100 posts originally installed. Removals have been due principally to combined decay and termite attack. One hundred percent of the posts installed in dry and damp sites, and 83 percent of those installed in wet sites have been removed. Removals to date are as follows:

Years after installation	4	5	6	7	8	9	10	11	12	13
Number (cumulative) removed	3	6	16	22	27	34	39	42	51	55

Years	14	15	16	17	18	19	20	21	22	24
Number	65	71	79	83	87	89	91	92	94	95

Borax-boric acid. --All posts treated with borax-boric acid have been removed after 20 years, and the average life of the 97 test posts is 10.6 years. Forty-six percent of the posts failed because of combined decay and termite attack, 36 percent because of termite attack, and 18 percent were removed because of decay alone. The 63 posts installed in dry areas had an average life of 9.8 years, while 17 posts in damp areas and 17 in wet areas had average lives of 11.0 years and 13.2 years, respectively. Removals by years are as follows:

Years after installation	5	6	7	8	9	10	11	12	13	14
Number (cumulative) removed	4	6	19	32	45	49	63	71	75	81

Years	15	16	17	18	19	20
Number	87	90	91	93	94	97

Chromated zinc chloride. --Chromated zinc chloride contains not less than 77.5 percent of zinc chloride and 17.5 percent of sodium dichromate. Fifty-two percent of the posts treated with this preservative have been removed because of decay or combined decay and termite attack. The estimated average life of the posts in test is 25 years. The average retention of preservative in the posts removed was 0.84 pound per cubic foot, or slightly less than that for the installation. Seventy-five percent of the posts installed in damp sites have been removed and 47 percent have been removed from both the dry and wet sites. Removals to date are as follows:

Years after installation	4	5	6	7	9	10	11	12	14	16
Number (cumulative) removed	1	3	6	10	13	14	15	18	21	25

Years	17	18	19	20	21	22	23	24
Number	30	32	35	37	39	43	44	49

Coal tar. --Thirty-five percent of the posts treated with coal tar have been removed because of decay or combined decay and termite attack. The estimated average life of the posts is 28 years. The average retention of coal tar in the 33 posts removed was 5.9 pounds per cubic foot, as compared with an average of 6.5 pounds for the posts installed. Of posts installed in the dry, damp, and wet areas, 44 percent, 20 percent, and 12 percent, respectively, have been removed. Removals to date are as follows:

Years after installation	5	7	9	11	13	14	15	16	17	19
Number (cumulative) removed	1	2	3	4	5	6	7	9	12	14

Years	20	21	22	23	24
Number	16	19	28	30	33

Coal-tar creosote. --The coal-tar creosote used was of American Wood-Preservers' Association Standard 4 e-grade. Seventeen posts treated with this preservative have failed mostly because of decay. These posts had an average preservative retention of 5.4 pounds per cubic foot, compared with an average of 6 pounds for the installation. The estimated average life of the posts is 33 years. Five posts were removed from damp sites, one from a wet site, and 11 from dry sites. Removals to date are as follows:

Years after installation	13	15	17	18	19	20	21	22	23	24
Number (cumulative) removed	1	2	3	4	5	7	10	13	15	17

Coal-tar creosote 50 percent and used crankcase oil 50 percent. --Ten posts treated with an average of 4.2 pounds per cubic foot of a 50-50 solution of creosote and crankcase oil failed because of decay. On the basis of 11 percent of the posts having failed, the average life of the 93 posts in test is 37 years. Nine posts were removed from dry areas and one from a wet site. Removals to date are as follows:

Years after installation	12	17	19	20	24
Number (cumulative) removed	1	5	6	7	10

Coal-tar creosote 10 percent and used crankcase oil 90 percent. --Eighty percent of the posts treated with a solution of 10 percent creosote and 90 percent crankcase oil have failed, principally because of decay. Sixty percent of the posts failed in 11 years, the estimated average life. The 79 posts removed had an average solution retention of 5.8 pounds per cubic foot, as compared with an average of 7.1 pounds for the original installation. Of all posts installed in dry, damp, and wet sites, 85 percent, 82 percent, and 59 percent respectively, have failed. Failures to date are as follows:

Years after installation	1	2	3	4	5	6	9	11	12	13
Number (cumulative) removed	13	31	37	48	50	55	57	61	63	64

Years	14	15	16	17	18	21	22	24
Number	66	67	70	72	73	74	78	79

Crankcase oil. --Of the posts treated with automobile crankcase drainings, 93 percent have been removed, mostly because of decay. The estimated average life is 8 years since 60 percent failed at that time. The average retention of oil in the removed posts was similar to that for the installation. All of the posts set in dry areas, 75 percent of those set in damp areas, and 81 percent of those set in wet sites have been removed. Failures to date are as follows:

Years after installation	1	2	3	4	5	6	7	8	9	10
Number (cumulative) removed	7	31	42	45	52	54	58	60	64	65

Years	11	12	13	14	16	17	18	20	21	22	23	24
Number	68	73	75	77	80	82	84	86	87	88	89	90

Fluor chrome arsenate phenol (Tanalith). --Fluor chrome arsenate phenol contains sodium chromate, sodium arsenate, sodium fluoride, and dinitrophenol. Forty-six percent of the posts treated with this preservative have been removed, mostly because of decay or combined decay and termite attack. The estimated average life of the 96 posts in test is 26 years. The 44 posts removed had an average preservative retention

of 0.34 pound per cubic foot or approximately the same as the average for the installation. Forty-four percent, 59 percent, and 40 percent of the posts set on dry, damp, and wet sites, respectively, have been removed. Removals to date are as follows:

Years after installation	7	8	9	12	14	15	16	17	18	20	21	22	23
Number (cumulative) removed	2	3	4	6	10	13	19	21	29	32	34	42	44

Lignite coal-tar creosote. --Forty-three percent of the posts treated with lignite coal-tar creosote have failed, principally because of decay or combined decay and termite attack. The estimated average life of the 97 posts in test is 27 years. The average retention of preservative for the 42 posts removed was 3.0 pounds per cubic foot, or considerably less than that of 6.3 pounds for the posts installed. Forty-six percent of the posts installed in dry areas have been removed; 35 percent and 41 percent, respectively, have been removed from the damp and wet sites. Removals to date are as follows:

Years after installation	3	5	7	8	9	10	11	12	13	14
Number (cumulative) removed	1	2	3	7	8	10	11	14	18	20

Years	15	16	17	18	19	20	21	22	24
Number	23	26	28	30	32	36	38	40	42

Mercuric chloride. --Forty-eight percent of the posts treated by steeping in mercuric chloride have been removed, principally because of combined decay and termite attack. The estimated average life for the 99 posts installed is 26 years. The preservative retention of the 48 posts removed was 0.11 pound per cubic foot, or similar to the average retention for the installation. Fifty-two percent of the posts installed in dry sites have been removed; 41 percent and 39 percent respectively, have been removed from the damp and wet sites. Removals to date are as follows:

Years after installation	8	9	10	11	12	13	14	15	16	17	18
Number (cumulative) removed	1	4	6	9	13	14	18	20	25	28	30

Years	19	20	21	22	23	24
Number	31	36	38	42	45	48

No-D-K (hardwood-tar creosote). --Sixty-nine percent of the posts treated with No-D-K have been removed, mostly because of decay or combined decay and termite attack. The estimated average life of the 100 posts in test is 21 years. Eighty-six percent of the posts set in dry areas, 50 percent of those set in damp areas, and 26 percent of those set in wet areas have been removed. The average retention of preservative for the posts removed was 5.9 pounds per cubic foot, compared with 6.6 pounds for the installation. Removals to date are as follows:

Years after installation	2	3	4	5	6	7	8	9	10	11	12
Number (cumulative) removed	1	4	5	12	18	21	23	25	26	30	31

Years	13	14	15	16	17	18	19	20	21	22	23	24
Number	33	36	37	48	54	55	58	59	62	67	68	69

Osmosar. --The Osmosar preservative was reported to be a mixture of sodium fluoride, dinitrophenol, potassium dichromate, sodium arsenate, and gum arabic. Fifty-seven percent of the posts have been removed to date, mostly because of decay or combined

decay and termite attack. The estimated average life of the 95 test posts is 24 years. Fifty-eight percent of the posts set in dry sites, 63 percent of those set in damp sites, and 41 percent of those set in wet sites have been removed. Removals to date are as follows:

Years after installation	5	6	7	10	12	13	14	15	16	17
Number (cumulative) removed	1	2	4	5	6	8	13	16	25	27

Years	18	19	20	21	22	23	24
Number	33	35	40	44	49	50	54

P. D. A. (phenyldichlorarsine) 0. 84 percent (by weight) in gas oil. --Seventy-four percent of the posts treated with P. D. A. in gas oil have been removed, because of decay and termite attack. The estimated average life of the 94 posts in test is 21 years. The average retention of preservative solution in the 70 removed posts was 5. 7 pounds per cubic foot, or slightly less than the average retention for the installation. Of the posts installed in the dry, damp, and wet areas, 83 percent, 69 percent, and 50 percent respectively, have been removed. Removals to date are as follows:

Years after installation	5	6	7	8	9	10	11	12	13	14
Number (cumulative) removed	2	4	6	9	12	13	15	16	19	28

Years	15	16	17	18	19	20	21	22	24
Number	30	36	42	47	51	56	58	66	70

Pentachlorophenol, 4. 82 percent (by weight) in used crankcase oil. --One post treated with this preservative was removed from a dry area after 17 years of service because of decay. This post was treated with 4. 6 pounds of solution per cubic foot.

Pentachlorophenol, 3. 02 percent (by weight) in used crankcase oil. --Of the 86 posts treated with 3. 02 percent of pentachlorophenol in used crankcase oil, 4 have been removed from dry sites because of decay. The average retention of preservative in these 4 posts was 4. 0 pounds per cubic foot, which is lower than that of 6. 4 pounds for the posts installed. Removals to date are as follows:

Years after installation	8	13	19	24
Number (cumulative) removed	1	2	3	4

Sodium dichromate. --Eighty-two percent of the posts treated with sodium dichromate have been removed, for the most part because of termite attack or combined decay and termite attack. The average retention by the removed posts was 0. 89 pound per cubic foot, nearly the same as that for the installation. The estimated average life of the 97 test posts is 18 years. Eighty-three percent of the posts set on dry sites, 100 percent of those set on damp sites, and 67 percent of those set on wet sites have been removed. Removals to date are as follows:

Years after installation	5	7	8	9	10	11	12	13	14	15
Number (cumulative) removed	4	10	12	13	14	16	25	27	37	40

Years	16	17	18	19	20	21	22	24
Number	50	55	61	64	68	71	76	80

Sodium chromate. --Eighty-four percent of the posts treated with sodium chromate have been removed, principally because of termite attack or combined decay and termite attack. The estimated average life of the 88 posts in test is 16 years. For the 74 posts removed, the average retention of sodium chromate was 0.97 pound per cubic foot, or slightly greater than that of 0.93 pound for the installation. Ninety-one percent of the posts set in dry areas, 82 percent of those set in damp areas, and 65 percent of those set in wet areas have been removed. Removals to date are as follows:

Years after installation	4	5	6	7	8	9	10	11	12	13
Number (cumulative) removed	1	9	10	13	21	23	25	33	37	40

Year	14	15	16	18	19	20	21	22	24
Number	49	51	59	62	64	65	66	71	74

Tetrachlorophenol, 2.9 percent (by weight) in used crankcase oil. --Twenty percent of the posts treated with 2.9 percent of tetrachlorophenol in used crankcase oil have failed because of decay. The estimated average life of the 92 posts in test is 32 years. The 18 posts removed had an average solution retention of 5.7 pounds per cubic foot; that for the installation was 7.1 pounds. These removed posts constituted 28 percent of those installed in dry areas and 7 percent of those in damp sites. There have been no failures in the wet sites. Removals to date are as follows:

Years after installation	11	12	13	14	15	17	18	19	20	22	23
Number (cumulative) removed	1	2	3	4	5	6	9	10	12	17	18

Tetrachlorophenol, 4.83 percent (by weight) in used crankcase oil. --Fourteen percent of the posts treated with 4.83 percent of tetrachlorophenol in used crankcase oil have failed in dry sites due mostly to decay. The estimated average life of the 94 posts in test is 35 years. The posts removed had an average solution retention similar to that for the installation. Removals to date are as follows:

Years after installation	18	19	20	21	22	23	24
Number (cumulative) removed	2	3	4	6	8	10	13

Water-gas tar. --Approximately 11 percent of the posts treated with water-gas tar have failed because of decay and combined decay and termite attack. The average life of the 93 test posts is therefore estimated to be 37 years. One post failed in a damp site, one in a wet site, and 8 in dry sites. The average retention of preservative in the 10 posts was 4.0 pounds per cubic foot, compared with the average of 6.3 pounds per cubic foot for the installation. Removals to date are as follows:

Years after installation	14	16	19	20	21	22	23	24
Number (cumulative) removed	1	2	4	6	7	8	9	10

Zinc chloride. --Forty-seven percent of the posts treated with zinc chloride, with an average retention of 0.98 pound per cubic foot, have been removed because of decay or combined decay and termite attack. The estimated average life of the 96 posts in test is 26 years. Forty percent, 69 percent, and 53 percent, respectively, of the posts set in dry, damp, and wet areas have been removed. Removals to date are as follows:

Years after installation	5	8	13	14	16	17	18	19	20	21	22	23	24
Number (cumulative) removed	1	2	3	9	15	18	23	25	32	34	38	39	45

Zinc meta arsenite. --Zinc meta arsenite is prepared from arsenious acid, zinc oxide, and acetic acid. Two posts treated with an average retention of 0.40 pound of this preservative per cubic foot were removed from dry sites. The first failed after 20 years and the second after 22 years service.

Copper sulfate and sodium arsenate applied by double diffusion. --Five posts treated with copper sulfate and sodium arsenate, applied by double diffusion have failed because of decay or combined decay and termite attack after nearly 20 years. Three were located in dry sites and one each in damp and wet sites. Removals to date have been as follows:

Years after installation	12	16	18	20
Number (cumulative) removed	1	2	4	5

Osmoplastic (groundline treatment). --The Osmoplastic used was reported to contain sodium fluoride, dinitrophenol, potassium dichromate, refined coal tar, and coal-tar creosote. All of the posts treated with this preservative at the groundline zone (a 15-inch band extending 3 inches above and 12 inches below the groundline) and at the immediate tops have been removed after nearly 20 years of service. The average life is 11.2 years. Fifty-five percent of the posts failed because of combined decay and termite attack, 32 percent because of decay, and 13 percent because of termite attack. The average life of 63 posts located in dry sites is 10.0 years, of 18 posts in damp areas is 10.1 years, and of 18 posts in wet areas is 12.6 years. Removals by years were as follows:

Years after installation	3	5	6	7	8	9	10	11	12	13	14	15	16	18	20
Number (cumulative) removed	1	3	6	13	19	23	39	54	68	74	82	85	94	95	99

Condition of Posts Installed in 1949

General information on the composition of the preservatives used in the pressure treatment of the posts installed in 1949 is given in table 2. That table also shows the condition of the test posts at the December 1960 inspection.

All of the untreated control posts failed after approximately 3-1/2 years of service. Their average life was 2.3 years. Failures were mostly because of combined decay and termite attack. Removals were as follows:

Years after installation	1-1/2	2-1/2	3-1/2
Number (cumulative) removed	13	20	25

Fifty-two treated posts failed because of decay and combined decay and termite attack after approximately 11-1/2 years of service. The number (cumulative) removed by year and preservative is given in table 3. The estimated average life for posts treated with the No. 2 fuel oil is 5 years while that for the posts treated with Wyoming residual petroleum oil is 8 years.

No-D-K (hardwood-tar creosote), P. D. A. (phenyldichlorarsine), sodium dichromate, and sodium chromate. Posts given the following treatments are estimated to have an average life of 24 to 37 years: Posts pressure treated with acid copper chromate (Celcure), chromated zinc chloride, coal tar, coal-tar creosote, 50 percent of coal-tar creosote and 50 percent of used crankcase oil, fluor chrome arsenate phenol (Tanalith), lignite coal-tar creosote, tetrachlorophenol (approximately 3 percent and 5 percent) in used crankcase oil, water-gas tar, and zinc chloride; posts steeped in mercuric chloride; and posts treated full length with Osmosar. Posts pressure treated with pentachlorophenol (approximately 5 percent and 3 percent) in used crankcase oil, and zinc meta arsenite, and those treated by the double-diffusion process with copper sulfate and sodium arsenate should last longer than 37 years on an average, but have not yet shown a sufficiently high percentage of removals to warrant an estimate on possible average life.

(3) The failures of untreated and treated posts to date, on the basis of posts installed under the three site conditions, have occurred earlier in the dry and damp areas than in the swamps.

(4) The posts installed during 1949, except for petroleum oil-treated controls, have not been in test long enough to indicate important differences in the preservatives. Posts treated with No. 2 fuel oil and those treated with the Wyoming residual oil are estimated to have an average life of 5 years and 8 years respectively since 60 percent failed in that time. One of the posts treated with chromated zinc arsenate (Boliden salts) failed after 6-1/2 years because of decay and 2 of the posts treated with copperized chromated zinc chloride failed within 5-1/2 years because of decay caused by a fungus, Poria ridiculosa, which is fairly tolerant to copper compounds. In the case of posts installed in 1936 and treated with acid copper chromate (Celcure), another copper compound, a small percentage of the posts failed during the first years of test, presumably from decay caused by the same or a similar fungus. Two posts treated with 50-50 lignite coal-tar creosote and Wyoming residual petroleum oil failed after 10-1/2 years, and 3 treated with different aromatic petroleums have failed during the same period. After 9-1/2 years of service, 1 post treated with chromated zinc chloride FR (fire retardant) failed because of decay while another post treated with coal-tar creosote (medium residue, low in fraction from 235° to 270° C., crystals removed) failed from combined termite attack and decay. One post treated with Termiteol (softwood-tar creosote) failed after 11-1/2 years of service.

Although some of the posts installed during 1936 and 1937 were pointed after treatment to facilitate driving in wet or damp sites (this practice should not be encouraged), few if any post failures can be charged to this factor alone. In most cases, the pointed part of the post was submerged in water or water-soaked soil so that decay and termite attack at the pointed section were not the controlling factors in its life. Furthermore, the posts were mostly of sapwood, which was generally well penetrated by the preservative, and cutting of such treated wood was less serious than it would be with poorly penetrated posts.

The results obtained in this particular test are not necessarily indicative of the performance that can be expected of the preservatives under other conditions of exposure. Furthermore, they should not be considered as indicating the service life to be expected from the preservatives applied to other species or applied by other methods. Waterborne preservatives usually perform better under conditions not favorable to leaching than when used for the treatment of wood installed in contact with the ground or water.

Some of the waterborne preservatives appear to be performing well in this test, but the fact that others are performing less satisfactorily does not indicate that they will not provide adequate protection when used under drier or more favorable circumstances. Adequate retentions and penetrations are necessary for a high degree of protection with any preservative, and it follows that high retentions and heavy concentrations of preservative usually perform better than low retentions and low concentrations. For the preservatives included in tables 1 and 2, Federal Specification TT- W-571 recommends the following minimum retentions for lumber and posts:

Preservative	Minimum retention (Pounds per cubic foot) Lumber and structural timber		
	In contact with the ground or fresh water	Not in contact with the ground or water	Posts
Coal-tar creosote	10.0	6.0	6.0
Creosote petroleum solution (50-50)	12.0	7.0	7.0
Pentachlorophenol, 5 percent in petroleum	10.0	6.0	6.0
Copper naphthenate, 0.75 percent copper equivalent in petroleum	10.0	6.0	6.0
Acid copper chromate (Celcure)	1.00*	.50	1.00
Ammoniacal copper arsenite (Chemonite)	.50*	.30	.50
Chromated zinc arsenate (Boliden salt A)	1.00*	.50	1.00
Chromated zinc chloride	1.00*	.75	1.00
Copperized chromated zinc chloride	1.00*	.75	1.00
Fluor chrome arsenate phenol (Tanalith and Osmosar)	.50*	.35	.50

*Occasional exposure to water or constant exposure to the ground in areas of moderate rainfall.

Table 1.--Condition of round southern yellow pine experimental fence posts on the Harrison Experimental Forest, Saucier, Miss., after about 20 to 24 years of service (treated posts were installed from late in 1936 to May 1941)

Preservative	Posts in test[1]	Form of preservative	Retention of preservative[2]				Method of treatment	Condition of posts, December 1960				Total removed	Average life[3]
			Minimum	Maximum	Average	Standard deviation		Serviceable	Removed because of				
									Decay	Decay, termites	Termites		
	No.		Lb. per cu. ft.	Lb. per cu. ft.	Lb. per cu. ft.	Lb. per cu. ft.		Percent	Percent	Percent	Percent	No.	Percent	Yr.
Posts set late in 1936 to February 1937														
Acid copper chromate (Calcure) (AWPA-P5)	88	Salt	.75	1.05	.92	.08	Pressure	78	18	4		19	22	32
Beta-naphthol, 5 percent (by weight) in oil mixture	98	Solution	3.90	10.00	6.20	1.30	do	3	19	59	19	95	97	14
Borax-boric acid (50-50 mixture)	97	Salt	.64	1.32	.92	.11	do	18	46	36		97	100	10.6
Chromated zinc chloride	95	do	.37	1.33	.87	.19	do	48	31	21		49	52	25
Coal tar	94	Oil	1.60	19.20	6.50	2.90	do	65	22	13		33	35	28
Coal-tar creosote, grade 1	94	do	1.90	8.60	6.00	1.50	do	82	16	2		17	18	33
Coal-tar creosote, 50 percent used crankcase oil, 50 percent (by volume)	93	Solution	1.60	14.80	5.40	2.20	do	89	11			10	11	37
Coal-tar creosote, 10 percent used crankcase oil, 90 percent (by volume)	99	do	.10	23.20	7.10	3.80	do	20	71	8	1	79	80	11
Crankcase oil (used)	97	Oil	2.50	16.80	7.60	2.90	do	7	89	4		90	93	8
Fluor chrome arsenate phenol (Tanalith) (AWPA-P5)	96	Salt	.20	.47	.35	.07	do	54	27	14	5	44	46	26
Lignite coal-tar creosote	97	Oil	1.10	11.60	6.30	3.20	do	57	19	21	3	42	43	27
Mercuric chloride	99	Salt	.05	.15	.09	.03	Steeping	52	11	25	12	48	48	26
No-D-K (hardwood-tar creosote)	100	Oil	1.30	13.60	6.60	3.50	Pressure	31	20	45	4	69	69	21
Osmosar	95	Salt			4 2.30		Osmose	43	23	26	8	54	57	24
P.D.A. (phenyldichlorarsine) 0.84 percent in gas oil (by weight)	94	Solution	4.10	11.00	5.90	.90	Pressure	26	18	43	13	70	74	21
Pentachlorophenol, 4.82 percent (by weight) in used crankcase oil	96	do	2.90	9.50	6.70	1.60	do	99	1			1	1	
Pentachlorophenol, 3.02 percent (by weight) in used crankcase oil	86	do	3.10	11.40	6.40	1.80	do	95	4			4	5	
Sodium dichromate	97	Salt	.59	1.14	.88	.11	do	18	7	35	40	80	82	18
Sodium chromate	88	do	.70	1.19	.93	.10	do	16	6	26	49	74	84	16
Tetrachlorophenol, 2.9 percent (by weight) in used crankcase oil	92	Solution	1.20	16.10	7.10	3.10	do	80	20			18	20	32
Tetrachlorophenol, 4.83 percent (by weight) in used crankcase oil	94	do	3.50	9.40	5.80	1.50	do	86	12	2		13	14	35
Water-gas tar	93	Oil	1.20	19.00	6.30	3.00	do	89	9	2		10	11	37
Zinc chloride	96	Salt	.67	1.11	.94	.10	do	53	25	21	1	45	47	26
Zinc meta arsenite	94	do	.25	.54	.42	.06	do	98	2			2	2	
Untreated posts (set Feb. 1937)	65						None		3	94	3	65	100	3.1
Posts set in 1938 and 1941														
Untreated posts (set Nov., Dec. 1938)	33						None		33	64	3	33	100	3.7
Copper sulfate and sodium arsenate (set May 1941)	98	Salt			(.35		Double	95	4	1		5	5	
					(.16		diffusion							
Osmoplastic ground-line treatment (set Feb. 1941)	99	Mixture			5 .34		(5)		32	55	13	99	100	11.2

[1] Installations included 100 posts for each treatment. This number has since been reduced in some cases by fire and pilferage.

[2] Based on the 100 posts treated in each group, unless otherwise indicated.

[3] Average life of all untreated posts is 3.3 years; average life is shown where all posts have been removed. Other values are estimates taken from a mortality curve or based on test time when 60 percent of posts have failed. Where percentage of posts removed is 10 percent or less, no estimate on average life is given.

[4] Average application.

[5] Average application per post to a 15-inch band (3 inches above and 12 inches below ground line) and to top surface of post.

Table 2.--Condition of round longleaf pine experimental posts on the Harrison Experimental Forest, Saucier, Miss., after about 11-1/2 years of service (all treatments by pressure impregnation. Posts were installed during April and May 1949.)

Preservative	Posts in test	Retention of preservative				Condition of posts, December 1960					Average life[1]
		Form of preservative	Minimum	Maximum	Average	Standard deviation	Service-ability	Removed because of--Decay	Removed because of--Decay, termites	Removed because of--Termites	Total removed	
	Number		Lb. per cu. ft.	Lb. per cu. ft.	Lb. per cu. ft.		Percent	Percent	Percent	Percent	Number	Percent	Yr.
Ammoniacal copper arsenite (Chemonite) (AWPA-P5)	25	Dry salt	0.30	0.39	0.34	0.029	100						
Boliden salt B ($ZnO + H_3AsO_4 + CrO_3$)	25	...do...	.43	.57	.50	.035	100						
Carbosota (coal-tar creosote)	25	Oil	5.2	6.9	6.0	.593	100						
Chromated zinc arsenate (Boliden salts) (AWPA-P5)	25	Dry salt	.65	.76	.70	.029	96	4			1	4	
Chromated zinc chloride, copperized ($ZnCl_2 + Na_2Cr_2O_7.2H_2O + CuCl_2.2H_2O$)	25	...do...	.89	1.06	.98	.055	92	8			2	8	
Chromated zinc chloride, FR ($ZnCl_2 + Na_2Cr_2O_7.2H_2O + H_3BO_3 + (NH_4)_2SO_4$)	25	...do...	2.71	3.59	3.25	.254	96	4			1	4	
Coal-tar creosote:													
Straight run, low residue	25	Oil	4.6	7.5	5.9	.903	100						
Straight run, medium residue	25	...do...	4.2	7.7	5.6	.899	100						
Straight run, high residue	25	...do...	4.9	7.5	6.0	.873	100						
Medium residue, low in tar acids	25	...do...	4.6	6.9	5.7	.638	100						
Medium residue, low in naphthalene	25	...do...	5.2	7.1	6.1	.519	100						
Medium residue, low in tar acids and naphthalene	25	...do...	4.8	7.6	6.0	.701	100						
Low residue, low in tar acids and naphthalene	25	...do...	5.3	6.9	6.0	.516	100						
High residue, low in tar acids and naphthalene	25	...do...	5.4	6.8	6.1	.399	100						
Medium residue, low in fraction from 235° to 270° C., crystals removed	25	...do...	5.1	7.0	6.1	.591	96	4			1	4	
High residue, crystals removed	25	...do...	5.1	6.8	6.0	.528	100						
Low temperature	25	...do...	5.5	6.9	6.3	.401	100						
English, vertical retort	25	...do...	5.0	6.9	6.3	.552	100						
English, coke oven	25	...do...	4.5	7.4	6.0	.715	100						
English, vertical retort 50% and coke oven 50% (by volume)	25	Solution	5.2	6.8	6.0	.489	100						
Medium residue [low in tar acids and naphthalene] with 2-1/2% pentachlorophenol (by weight)	25	...do...	5.1	6.9	6.0	.594	100						
Coal-tar creosote 70%, and coal-tar 30% (by volume)	25	...do...	5.2	6.9	6.1	.574	100						
Coal-tar creosote (medium residue, low in tar acids and naphthalene) 50%, and petroleum oil (No. 2 distillate) 50% (by volume)	25	...do...	5.2	6.8	5.9	.418	100						
Coal-tar creosote (medium residue, low in tar acids and naphthalene) 50%, and petroleum oil (Wyoming residual) 50% (by volume)	25	...do...	5.2	6.9	6.9	.497	100						
Coal-tar creosote (medium residue, low in tar acids and naphthalene) 50%, and petroleum oil (Wyoming residual) 50% (by volume); fortified with 2-1/2% pentachlorophenol (by weight of total solution)	25	...do...	5.3	6.7	6.0	.453	100						
Copper naphthenate, 0.5% copper-metal equivalent (by weight) in petroleum oil (No. 4 aromatic residual)	25	...do...	5.2	6.9	6.0	.540	100						
Gasco (oil-tar creosote)	25	...do...	5.1	6.8	5.9	.616	100						
Gasco (oil-tar creosote) with 2% pentachlorophenol (by weight)	25	...do...	5.3	6.8	5.8	.455	100						
Lignite coal-tar creosote	25	Oil	5.1	6.8	6.3	.518	100						
Lignite coal-tar creosote, 50% and coal-tar creosote (medium residue, low in tar acids and naphthalene), 50% (by volume)	25	Solution	5.6	6.9	6.3	.376	100						
Lignite coal-tar creosote, 50% and petroleum oil (Wyoming residual), 50% (by volume)	25	...do...	5.5	7.1	6.4	.440	92	8			2	8	
Pentachlorophenol:													
Five percent (by weight) in petroleum oil (No. 2 distillate)	25	...do...	5.1	7.0	6.3	.531	100						
Five percent (by weight) in petroleum oil (No. 4 aromatic residual)	25	...do...	5.3	7.0	5.9	.482	100						
Three percent (by weight) in petroleum oil (No. 4 aromatic residual)	25	...do...	5.3	6.9	6.0	.412	100						
Five percent (by weight) in petroleum oil (Wyoming residual)	25	...do...	4.5	7.4	6.0	.817	100						
Pentachlorophenol, 5% in petroleum oil (No. 4 aromatic residual), 50%; and copper naphthenate, 0.5% copper-metal equivalent, in petroleum oil (No. 4 aromatic residual), 50% (by volume)	25	...do...	5.4	7.0	6.2	.543	100						
Petroleum oil:													
Aromatic, high residue (S.W.)	25	Oil	5.1	6.7	6.1	.553	100						
Aromatic, low residue (S.W.)	25	...do...	5.1	6.9	6.1	.557	100						
Highly aromatic (S.O.)	25	...do...	5.1	6.9	6.0	.484	100						
Highly aromatic, high residue (S.O.)	25	...do...	5.1	6.9	6.1	.503	92	4	4		2	8	
No. 2 distillate (mid-United States)	25	...do...	5.0	7.2	5.9	.650	12	36	56		23	92	5
No. 4 aromatic residual (Calif.)	25	...do...	5.2	6.8	5.9	.448	96	4			1	4	
Wyoming residual	25	...do...	5.1	6.9	5.8	.691	28	56	16		18	72	8
Termitrol (softwood-tar creosote)	25	...do...	6.9	6.9	6.1	.505	100		4		1	4	
Untreated control posts	25							20	80		25	100	2.3

[1] Average life taken when 60 percent of posts have failed, except where all have been removed.

Figure 1. -- Test posts installed during 1949 in a plot at the Harrison Experimental Forest, Saucier, Miss.

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