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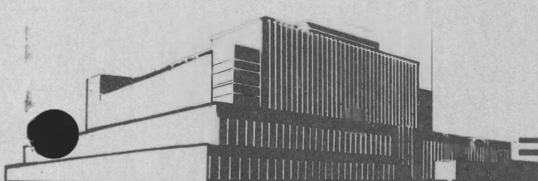

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UNITED STATES DEPARTMENT OF AGRICULTURE
FOREST SERVICE
In Cooperation with the University of Wisconsin

STUDY OF GROUNDLINE TREATMENTS APPLIED TO FIVE POLE SPECIES[1]

By

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Summary

Field tests were made on pressure-treated pole stubs of five important pole species at three locations, under different climatic conditions, to determine the distribution of preservative after application of seven supplementary groundline treatments. Maximum concentrations of the groundline preservatives, pentachlorophenol and sodium fluoride, were found within 1 year after application under dry site conditions, and within 3 months under somewhat wetter conditions.

Two years after groundline treatments by surface applications, the preservatives, pentachlorophenol and/or sodium fluoride, were confined mostly to the outer 1/2-inch zone of the pole. The concentration of sodium fluoride in the outer zone was usually less than that required to inhibit the growth of decay fungi, while that of pentachlorophenol was greater than that necessary for decay control. In the injection application used, the concentration of sodium fluoride was generally greater in the third zone than in the outer and second zones but the quantity was usually less than that required to control the growth of decay fungi.

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[1]The work reported herein was conducted by the U.S. Forest Products Laboratory in cooperation with the Rural Electrification Administration who proposed the study and contributed to its cost.

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

Introduction

Before World War II, groundline treatments were used almost exclusively on untreated poles of decay-resistant species such as cedar and chestnut. Since then, rising costs of labor and poles, and some unsatisfactory service with poles treated during the post-war period, have created an interest in such applications for treated poles. As a result of this interest, several new formulations have been developed for groundline application, and have been accompanied by numerous claims from their promoters. The Rural Electrification Administration and other pole users felt a need, therefore, to check on these claims, and to have tests to show the value and limitations of the various types of groundline treatments.

The purpose of this study was to determine the distribution of the more important preservatives, namely pentachlorophenol and sodium fluoride, in three zones, the outer 1/2 inch, the second 1/2 inch, and the second inch of the pole, after a reasonable time to permit the preservatives to move into the wood. Since moisture and climatic conditions were considered to have some influence on preservative distribution, tests were installed under three different climatic conditions, with the species in use in those areas. The seven groundline applications used in the study were those most commonly available at the time and typical of those currently in use.

Test Material

A total of 315 machine-peeled pole stubs, 5 to 7 inches in top diameter and 6 feet long, of Pacific Coast Douglas-fir, western larch, lodgepole pine, southern yellow pine, and western redcedar were used in the study.

The moisture content of the stubs, when received, was determined with a resistance-type electrical moisture meter with the electrodes driven to a depth of the sapwood prior to initial treatment. Average moisture meter readings for the lodgepole pine pole stubs was about 14 percent. Test stubs of the other species contained moisture in excess of fiber saturation, and were kiln dried before treatment to approximately 20 percent for the Douglas-fir, western larch, and western redcedar, and to 20 to 35 percent for the southern yellow pine.

To compare the effect of incised and unincised surfaces on preservative distribution, a band extending 1 foot above and 2 feet below the groundline was incised around one-half the circumference of the western redcedar stubs. A single, standard Greenlee incising tooth welded to a steel shaft was used to make the incisions approximately 3/4 inch deep. They were spaced on 2-inch centers longitudinally in rows, with the rows 3/4 inch apart. Each longitudinal row of incisions was offset 1/4 inch from the adjacent rows.

Initial Treatment of Pole Stubs

Suitably treated poles in service were not available for the study; therefore, to simulate such poles, freshly pressure-treated pole stubs with retentions as low as possible were used in order to avoid a heavy barrier of oil that might influence distribution of the groundline preservatives. In this connection, it was later found in the case of southern pine that the distribution of the groundline preservatives in these freshly treated pole stubs did not differ appreciably from that noted in stubs from creosoted poles that had been in service approximately 20 years before the groundline treatments were applied. These treatments were made at the Laboratory during the period from January to April 1957. The western redcedar stubs were treated by the Lowry process and the Rueping empty-cell process was used in treating the Douglas-fir, western larch, lodgepole pine, and southern yellow pine pole stubs.

Coal-tar creosote was used in the initial pressure treatment of the stubs with one exception, since that preservative would not interfere with later analyses for pentachlorophenol and sodium fluoride from the groundline treatments. One set of the lodgepole pine stubs to be treated with a paste of high sodium fluoride concentration was initially pressure treated, however, with a pentachlorophenol solution. The coal-tar creosote was from Laboratory stock purchased under Federal Specification TT-W-556, and complying also with American Wood-Preservers' Association Standard P1-54. The pentacholorphenol solution contained 5.10 percent of pentachlorophenol by weight, in a petroleum oil conforming generally to Standard P9-52 of the American Wood-Preservers' Association and consisting of 53.3 percent aromatic petroleum oil and 46.7 percent No. 2 fuel oil.

Preservative retentions were determined for individual stubs on the basis of total volume and difference in weight before and after treatment. Average retentions are shown in table 1.

The treated stubs were shipped to their respective test stations during the week of April 8, 1957.

Groundline Treatments

The following groundline applications, five proprietary and two nonproprietary, were used in this study:

(1) Creosote-penta-fluoride paste, which was reported to contain coal-tar creosote, 15 percent; pentachlorophenol, 10 percent; sodium fluoride, 10 percent; and penetrating oil, jelling agents, and fillers, 65 percent (by weight).

(2) Injection treatment, which was reported to contain sodium fluoride, 47 percent; dinitrophenol, 23 percent; arsenious anhydride, 23 percent; and binding substances, 7 percent (by weight). It was applied as a suspension composed of 60 percent dry chemicals and 40 percent water.

(3) Fluoride-coal-tar paste, which was reported to contain sodium fluoride, 46.3 percent; dinitrophenol, 3.4 percent; potassium bichromate, 2.0 percent; coal tar fortified with 2.5 percent of pentachlorophenol, 33.9 percent; and asbestos, solvent, and gel, 14.4 percent (by weight).

(4) Penta grease, which was reported to contain 10 percent technical pentachlorophenol (by weight).

(5) Penta gel, an oil-water emulsion, which was reported to contain 87 percent aromatic petroleum oil containing 10 percent pentachlorophenol and 13 percent emulsifiers or dispersing agents and water (by weight).

(6) Pentachlorophenol solution and sodium fluoride. The pentachlorophenol solution was a product that was sold to meet the Bell Telephone System requirement for "B" Wood Preservative AT7104 and was reported to contain 5.0 percent of pentachlorophenol (by weight) in a petroleum oil conforming to AWPA Standard P9. Technical grade sodium fluoride was used in conjunction with the pentachlorophenol solution.

(7) Pentachlorophenol solution. Same product as used in item (6) above.

Test Stations and Installation

Three stations, Madison, Wis., Fort Collins, Colo., and the Harrison Experimental Forest, Saucier, Miss., were used to test the groundline treatments. The stations provided variation in climate, particularly rainfall, which could influence the diffusion of sodium fluoride, as well as the movement of pentachlorophenol and its oil carrier in the wood. Annual rainfall at the Madison, Fort Collins, and Mississippi stations averages about 31, 14, and 60 inches, respectively.

The Madison, Wis., site was at the Forest Products Laboratory Valley View test station located 8 miles west of the city. It is well drained in a rolling, glaciated region with a loam soil. A composite soil sample taken to a depth of 20 inches at the start of the groundline applications in July 1957 showed a moisture content of about 20 percent.

The Fort Collins station was made available through the cooperation of the Colorado State University and the Rocky Mountain Forest and Range Experiment Station. It is located on a prairie site about a mile west of Fort Collins at the base of the Horsetooth Mountains and approximately 150 feet southeast of a small lake. The soil is a clay loam. A composite soil sample taken to a depth of 20 inches during August 1957 showed a moisture content of about 18 percent.

The soil type in the general area of the installation on the Harrison Experimental Forest is a Norfolk fine sandy loam. Composite soil samples, taken to a depth of 20 inches September 12 during comparatively dry weather and on September 24, 1957, after a tropical storm and subsequent heavy rains, showed 11 and 36 percent moisture content, respectively.

The pressure-treated pole stubs were spread out and exposed to the weather for 3 weeks at the test sites before setting during May 1957. They were randomly set in the plots to a depth of approximately 3 feet, with 5-foot spacing between and within the rows.

The groundline treatments were applied after the stubs had been in the ground from 3 to 4 months to permit the moisture in the wood to approach equilibrium with that in the soil. Prior to application, the soil was excavated to a depth of about 20 inches around each stub, and the exposed surface was cleaned with a wire brush.

Application of the Groundline Treatments

Five replicate stubs of each species were treated with each groundline preservative formulation. The proprietary groundline treatments were applied in accordance with instructions from the suppliers and recommendations of their representatives who were present when the treatments were made at Madison, Wis., during late July and early August 1957. Application of the pentachlorophenol solution plus sodium fluoride dust and the pentachlorophenol solution alone was made according to instructions contained in REA Bulletin 161-4, dated July 1957, and under the supervision of a representative of the Rural Electrification Administration. Applications were made by Laboratory personnel at Fort Collins during the period August 26 through 29, 1957, and on the Harrison Experimental Forest during the period September 11 through 25, 1957.

The creosote-penta-fluoride paste was applied approximately 1/4 inch thick with a scoop to a zone extending from 6 inches above to 18 inches below the groundline of the stubs (fig. 1). Following application, a duplex laminated bandage, consisting of sheets of polyethylene and kraft paper, was wrapped (plastic face toward stub) around the stub covering the treated zone. The bandage was secured to the stub with staples.

The suspension in the injection treatment, composed of 60 percent dry chemicals and 40 percent water (by weight), was prepared as needed and was injected into the wood with a specially designed tool (fig. 2). Five 2-inch-deep injections were spaced 4 inches apart in vertical rows extending from 5 inches above to 15 inches below the groundline of the stubs. The rows were spaced 2 inches apart and the injections staggered so that the corresponded in alternate rows. A bandage was not applied over the treated zone.

A layer of fluoride-coal-tar paste, approximately 1/16 to 1/8 inch, was applied with a window brush to a zone extending from 6 inches above to 18 inches below the groundline of the stubs (fig. 3). The wet surface of the stubs at the time of the application of the paste at the Harrison Experimental Forest made it difficult to obtain applications as heavy as those for the other two installations (see table 1). Immediately following application of the fluoride-coal-tar paste, a duplex polyethylene-kraft paper bandage was wrapped and stapled, polyethylene face toward the stub, around the treated zone covering all but the top 3 inches of the application.

A layer of penta grease, 1/4 inch thick, was applied with a trowel to the plastic face of a duplex polyethylene-kraft paper bandage. The bandage was then wrapped around the stub, preservative toward the stub, and held in place by staples (fig. 4). At the recommendation of the promoter, a 24-inch-wide bandage was used on the Harrison Experimental Forest, and the zone covered extended from 6 inches above to 18 inches below the groundline of the stubs. At Fort Collins and Madison, an 18-inch-wide bandage was used, and the zone covered extended from 6 inches above to 12 inches below the groundline of the stubs.

A layer of penta gel about 1/2 inch thick was applied with a scoop directly to the stubs to a zone extending from 4 inches above to 14 inches below the groundline (fig. 5). A bandage was not used. In backfilling, the soil was placed carefully against the side of the excavation to avoid disturbing the band of preservative. It was necessary to backfill immediately after application before slippage of the preservative down the stubs, particularly on those having an accumulation of exuded creosote on the surface.

In the treatment with 5 percent pentachlorophenol solution plus sodium fluoride, 1 pound of sodium fluoride was first dusted uniformly onto the surface of the stubs from about 3 inches above to 18 inches below the groundline (fig. 6). To obtain good adherence of the sodium fluoride to the dry pole surfaces, it was necessary at Madison and Fort Collins to coat the stub surfaces with about a pint of the pentachlorophenol solution, which was used in addition to the gallon as part of the regular application. Such a coating was not necessary at the Harrison Experimental Forest. Following application of the sodium fluoride, the excavation was about two-thirds filled with soil and a V-shaped trench was made around the stub to the depth of the original excavation.

Three-fourths gallon of the pentachlorophenol solution was then applied to the stub with a sprinkling can that had a fantail, slit-type spout. The solution was applied slowly as the sprinkling can was rotated around the stubs, with the spout held against the stub about 15 inches above the groundline. At least two complete revolutions were made during application, thus assuring complete coverage of the surface. After the pentachlorophenol solution was absorbed by the soil, the backfill was completed and a second V-trench about 5 inches deep was made around the stub. One-fourth gallon of the pentachlorophenol solution was applied (fig. 7) as before. The trench was then filled and the soil banked against the stub to complete the treatment.

The procedure described above also was used when applying the pentachlorophenol solution without sodium fluoride.

Weights of materials applied were obtained for individual stubs, and the average weights are shown in table 1.

Sampling of the Stub Material

The quantity and distribution of the principal components of the preservatives, pentachlorophenol or sodium fluoride, were determined in three zones, namely the outer half inch, the second half inch, and the second inch zones of the stubs at the groundline zone. This was done approximately 3 months and 1 year after application of the groundline treatments by taking a composite sample of borings from the five replicate pole stubs for each treatment and species, at 3 inches below the groundline of each stub. The sampling 2 years after the applications was made from cross-section disks cut from individual stubs at approximately 3 inches below the groundline. In the case of the western redcedar stubs, borings and disk sections were taken for analysis from both the incised and unincised areas.

Where possible, borings for the 1-year sampling were taken 180° around the stub from those taken for the 3-month sampling. Boring sections for the three zones were cut and composite samples assembled in the field immediately after extraction, in order to avoid the spread of preservative from one zone to another, particularly with preservative oils. Before cutting the boring into zone samples, a very thin section was sliced with a razor blade from the outside end to remove the unabsorbed preservative on the stub surface. The composite samples of the boring sections from the replicate sets of five stubs of similar species and treatment were wrapped in aluminum foil and placed in screw-top bottles. Borer holes were plugged with creosoted doweling as soon as the cores were extracted.

Two years after application of the groundline treatments, the stubs were pulled at the three test stations and 6-inch-long sections were cut from each stub between the groundline and 6 inches below the groundline. These were identified and returned to the Laboratory for further sectioning and analysis. Here again, a thin outside layer was first removed from the 6-inch-long sections to eliminate unabsorbed surplus preservative and a 1-inch-thick disk was sawn from the center of the section. These disks, from approximately 3 inches below the groundline, were then cut into zone samples. As each of the three zone samples was cut, the wood sections were taken from the saw, identified, and wrapped in aluminum foil. Later the sections were ground in a Wiley mill and analyzed for fluoride or pentachlorophenol.

To compare the results of chemical analyses from borings and disk sections of the same pole stubs 2 years after the application of the groundline treatments at Madison, Wis., five borings, which were equally spaced around the circumference of each of the five southern yellow pine stubs treated with the fluoride-coal-tar paste and those treated with the penta grease, were taken from 3 inches below the groundline. These borings were zoned as previously described, and composite samples were made of the sections for each of the three zones by individual stubs.

Chemical Analyses of the Pole Stub Samples

Composite samples of boring sections taken from the five replicate stubs after 3 months and 1 year, and the boring and disk samples from each test stub obtained 2 years after the application of the groundline treatments, were analyzed to show the quantity of arsenic trioxide, pentachlorophenol, or sodium fluoride. Chemical analyses were made in accordance with American Wood-Preservers' Association Standards A2-59 (method 2 for arsenic and method 8 for fluoride) and A5-58 (method 5 for pentachlorophenol).

The boring samples from the stubs treated with creosote-penta-fluoride paste, pentachlorophenol solution, penta grease, and penta gel were analyzed for pentachlorophenol, and those from the stubs were treated with fluoride-coal-tar paste, pentachlorphenol plus sodium fluoride, and, by injection, were analyzed for sodium fluoride. In addition, the boring and disk samples from the stubs taken 2 years after the groundline applications with creosote-penta-fluoride paste were analyzed for sodium fluoride, those that were treated by injection for arsenic trioxide, and those that were treated with fluoride-coal-tar paste and pentachlorophenol plus sodium fluoride were analyzed for pentachlorophenol.

Results of the Analyses

The results of chemical analyses made on borings and disks from the southern yellow pine stubs 2 years after treatment with the paste of high sodium fluoride (46.3 percent) content and the grease of high pentachlorophenol (10 percent) content in the Madison, Wis., test plot are compared in table 2. These data show that results for the boring samples were consistently higher than for the disk samples, an indication that a sample of five 0.20-inch-diameter borer sections may be too small for an accurate determination by the procedures used. More emphasis should therefore be given to the results of chemical analyses of the larger disk samples from individual pole stubs made 2 years after application, than on the two earlier samplings of the smaller composite boring sections from five replicate pole stubs.

The somewhat higher retentions noted in southern pine due to the fact that the 2-inch total thickness of the three zones sampled for chemical analysis was entirely of sapwood while that for the other species included less easily penetrated heartwood. The quantity of preservative applied and its concentration are other factors that could account for some of the differences that were noted.

Results from the samples of borings after 3 months and 1 year and disk samples after 2 years, as shown in table 3, indicate that concentrations of pentachlorophenol and sodium fluoride in the wood approached the maximum during the first 3-month period at Madison, Wis., and Saucier, Miss., and during the first year at Fort Collins, Colo. The concentration of the two chemicals, however, decreased progressively from the surface, resulting in a steep gradient with as much as 90 percent or more of the chemical deposited in the outer 1/2 inch of wood. The concentration gradient for pentachlorophenol did not change appreciably, while that for sodium fluoride became less steep during the 2 years of the study.

In the injection treatment, the concentration of sodium fluoride generally was greater in the third zone than in the outer and second zones. This would be expected since the injection needle penetrates 2 inches into the wood and the largest amount of solution is understood to be ejected from the needle just as retraction starts. In this third zone, after 2 years the quantity of sodium fluoride present was generally below the threshold in Wisconsin and Mississippi, and at or near the threshold at Fort Collins.

Where the fluoride-coal-tar paste was used on the same pole species at the three test sites, concentrations of sodium fluoride were highest at the wet Mississippi site, somewhat lower at the site of intermediate rainfall in Wisconsin, and lowest at the dry Colorado site. Pentachlorophenol concentrations were somewhat less subject to site and moisture variations.

Preservative thresholds, or the quantity of preservative necessary to inhibit growth of selected decay fungi in laboratory tests on wood, can be used to indicate the protection furnished by the amount of preservative found to be present by chemical analysis. Such threshold quantities usually have been determined for single preservative chemicals rather than for mixtures, but it does not necessarily follow that these same quantities are needed when other preservative chemicals also are present.

On the basis of soil-block tests, the threshold for pentachlorophenol against decay fungi is usually between 0.10 and 0.20 pound per cubic foot,[3] while that for sodium fluoride is between 0.15 and 0.25 pound per cubic foot.[4] Threshold values from soil-block tests have not been determined for arsenic trioxide alone or for combinations of this and other chemicals determined through chemical analyses.

Threshold quantities of pentachlorophenol generally were found after 2 years in the outer zone of the stubs of all species in the three areas treated with the three materials of 8.7 to 10 percent pentachlorophenol content, and also in lodgepole pine treated with 5 percent pentachlorophenol solution. Threshold quantities of pentachlorophenol also were noted after 2 years in the outer zone of the lodgepole pine stubs at Madison, Wis., and the southern yellow pine stubs which were treated with 5 percent pentachlorophenol solution plus sodium fluoride (table 3 and figs. 8, 10, and 12) at Fort Collins, Colo. Below threshold values of pentachlorophenol occurred in the second half inch and in the second inch, except in the case of southern pine stubs treated with penta grease which approached threshold quantities in the second half inch zone at the three test sites.

Threshold quantities of sodium fluoride in the outer zone were noted (table 3 and figs. 9, 11, and 12) 2 years after application of the fluoride-coal-tar paste only in the western larch, lodgepole pine, and southern yellow pine at Madison, Wis., the incised western redcedar (initially treated with creosote)

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[3] Duncan, C. G. Studies of the Methodology of Soil-Block Testing. U.S. Forest Prod. Lab. Rpt. No. 2114, 126 pp. June 1958.

[4] Baechler, R. H., and Roth, H. G. Laboratory Leaching and Decay Tests on Pine and Oak Blocks Treated with Several Preservative Salts. Proc. Amer. Wood-Preservers' Assoc. 52, pp. 24-34. 1956.

and lodgepole pine (initially treated with pentachlorophenol) at Fort Collins, Colo., and Douglas-fir and southern yellow pine which were the only species included at Saucier, Miss. Below threshold quantities of sodium fluoride were found in the second half inch and the second inch zones, except with the southern yellow pine stubs at Saucier, Miss., where threshold values were approached in the second half inch.

The data in table 3 and figures 8, 9, 10, and 11 indicate that incising did not influence significantly the distribution of pentachlorophenol and sodium fluoride in western redcedar.

Conclusions

(1) With surface applications of preservatives to the groundline area of pressure-treated poles of the species studied, the preservatives, pentachlorophenol and sodium fluoride, migrated into the wood so that maximum retentions were approached in the groundline zone within 3 months after application at the two wetter sites and within 1 year at the driest site.

(2) Distribution of the preservatives in the wood was not uniform, and retentions necessary to inhibit decay fungi were limited to the outer 1/2 inch, except with the thick-sapwood southern pine where inhibiting retentions were approached in the second half inch.

(3) Retentions of pentachlorophenol in the outer 1/2 inch after 2 years generally were above threshold values at the three test areas. Retentions of sodium fluoride in the outer 1/2 inch, after 2 years, however, generally were either borderline or below threshold values, particularly under the dry conditions in Colorado. This and the significantly higher leaching resistance of pentachlorophenol would indicate this preservative to be better suited, and possibly to furnish longer protection under various climatic conditions than sodium fluoride.

(4) Paste formulations containing 8.7 percent and 10 percent pentachlorophenol provide higher preservative retentions and, therefore, should provide longer protection than the pouring of a 5 percent solution on the pole surface.

(5) The injection treatment used with preservatives suspended in water generally furnished threshold retentions only in the second-inch zone of the pole stubs in the dry Colorado area. This application would appear, therefore, to have questionable value for the protection of the outer zone which largely contributes to the support of the pole.

(6) Incising in western redcedar poles, as used in this study, appeared to have no significant influence on the distribution of the sodium fluoride and pentachlorophenol applied in the groundline treatments.

(7) The results of this study indicate that selected surface applications of preservatives could be beneficial when applied to standing treated poles where shallow surface decay and other evidences of inadequate preservative protection are noted at the groundline zone.

Table 1.--Average quantity of preservative applied to pole stubs in initial and groundline treatments

Species	Diameter at ground-line	Sapwood depth	Retention of creosote in initial treatment	Amount applied in groundline treatment: Amount	Amount applied in groundline treatment: Standard deviation	Diameter at ground-line	Sapwood depth	Retention of creosote in initial treatment	Amount applied in groundline treatment: Amount	Amount applied in groundline treatment: Standard deviation	Diameter at ground-line	Sapwood depth	Retention of creosote in initial treatment	Amount applied in groundline treatment: Amount	Amount applied in groundline treatment: Standard deviation
	In.	In.	Lb. per cu. ft.	Lb.	Lb.	In.	In.	Lb. per cu. ft.	Lb.	Lb.	In.	In.	Lb. per cu. ft.	Lb.	Lb.
MADISON, WIS., TEST PLOT															
	Injection[1]					Fluoride-coal-tar paste					Penta grease				
Douglas-fir	6.2	0.6	6.2	0.96	0.135	6.0	0.8	7.0	2.10	0.548	6.7	0.5	6.1	4.20	0.758
Western larch	6.9	.7	5.3	1.02	.130	6.8	.8	5.0	2.10	.224	7.1	.8	5.1	4.70	1.151
Lodgepole pine	7.2	.7	3.2	1.00	.108	6.9	.7	3.3	1.90	.224	6.9	.9	3.7	3.80	.671
Southern yellow pine	6.5	2.4	6.5	.83	.232	7.0	2.8	7.2	1.90	.418	6.7	2.8	7.2	3.70	.570
Western redcedar	6.7	.6	12.3	1.08	.039	6.2	.6	10.8	2.00	.500	6.0	.6	14.5	3.80	.274
	Creosote-penta-fluoride paste					Fluoride-coal-tar paste[2]					Pentachlorophenol Solution				
Lodgepole pine	6.8	1.2	4.7	6.90	1.673	6.8	.6	2.9	1.50	.000	6.8	.6	3.4	(3)	....
	Penta gel					Pentachlorophenol Solution Plus Sodium Fluoride									
Douglas-fir	6.2	.6	6.5	5.30	.908	6.2	.7	6.3	(4)	....					
Western larch	6.7	.7	6.0	5.80	1.643	6.9	.8	6.4	(4)	....					
Lodgepole pine	6.5	.6	3.6	6.00	1.581	6.7	.9	3.7	(4)	....					
Southern yellow pine	6.6	2.6	6.8	6.60	2.845	6.4	2.7	7.0	(4)	....					
Western redcedar	5.8	.5	11.9	5.60	.652	6.4	.5	11.6	(4)	....					
FORT COLLINS, COLO., TEST PLOT															
	Injection[1]					Fluoride-coal-tar paste					Penta grease				
Douglas-fir	6.9	.6	5.9	.75	.250	6.2	.7	6.6	1.75	.354	6.5	.6	6.0	3.85	.379
Western larch	6.4	.7	5.3	.80	.112	6.8	.8	6.2	1.95	.647	6.9	.8	5.6	4.15	.548
Lodgepole pine	6.8	.7	4.0	.80	.112	7.2	.8	3.8	1.90	.224	6.5	.9	4.1	4.30	.570
Southern yellow pine	6.6	2.7	7.0	.70	.209	7.0	2.8	7.2	1.85	.285	6.9	2.9	7.4	4.35	.418
Western redcedar	7.6	.6	10.7	.95	.209	6.1	.5	10.7	1.95	.371	6.7	.6	10.5	4.10	.335
	Pentachlorophenol Solution					Fluoride-coal-tar paste[2]									
Lodgepole pine	6.8	1.0	3.9	(3)	....	6.8	.7	3.6	2.20	.274					
	Penta gel					Pentachlorophenol Solution Plus Sodium Fluoride									
Douglas-fir	6.3	.6	6.3	5.50	1.287	6.8	.6	5.9	(4)	....					
Western larch	6.6	.7	6.0	6.35	1.683	6.5	.7	5.9	(4)	....					
Lodgepole pine	7.2	.6	3.3	6.60	1.443	6.6	.7	3.4	(4)	....					
Southern yellow pine	6.6	2.8	7.1	5.55	1.110	6.6	2.7	6.6	(4)	....					
Western redcedar	6.6	.5	11.1	5.80	2.225	6.7	.5	14.2	(4)	....					
SAUCIER, MISS., TEST PLOT															
	Injection[1]					Fluoride-coal-tar paste					Penta grease				
Douglas-fir	7.0	.7	5.0	.80	.112	7.1	.5	5.1	1.00	.000	....	....	....	....	....
Southern yellow pine	6.8	2.7	7.1	.80	.112	6.9	2.9	7.3	1.10	.285	6.5	2.8	7.4	4.60	.576
	Penta gel					Pentachlorophenol Solution Plus Sodium Fluoride									
Douglas-fir	....	....	....	....	....	7.0	.6	5.0	(5)	....					
Southern yellow pine	6.3	2.6	7.3	5.30	.647	6.7	2.9	6.9	(5)	....					

[1] Suspension containing 40 percent water (by weight).

[2] Initial treatment was with 5.10 percent pentachlorophenol in a petroleum solvent.

[3] 1 gallon of 5 percent pentachlorophenol solution applied to each stub.

[4] 1 pound of sodium fluoride and 1 gallon of 5 percent pentachlorophenol solution were applied to each stub. An additional pint of the pentachlorophenol solution was used to coat the surface of the stub to obtain good adherence of the sodium fluoride.

[5] 1 pound of sodium fluoride and 1 gallon of 5 percent pentachlorophenol solution were applied to each stub.

Table 2.--Comparison of the results of analyses made on borings and disks from southern yellow pine pole stubs in the Madison, Wis., test plot treated with high pentachlorophenol or sodium fluoride content treatments[1]

Post No.	Pentachlorophenol						Sodium fluoride					
	Outer 1/2 inch		Second 1/2 inch		Next inch		Outer 1/2 inch		Second 1/2 inch		Next inch	
	Borings	Disks	Borings	Disks	Borings	Disks	Borings	Disks	Borings	Disks	Borings	Disks
	Lb. per cu. ft.	Lb. per cu. ft.	Lb. per cu. ft.	Lb. per cu. ft.	Lb. per cu. ft.	Lb. per cu. ft.	Lb. per cu. ft.	Lb. per cu. ft.	Lb. per cu. ft.	Lb. per cu. ft.	Lb. per cu. ft.	Lb. per cu. ft.
FLUORIDE-COAL-TAR PASTE CONTAINING 46.3 PERCENT SODIUM FLUORIDE AND 0.85 PERCENT PENTACHLOROPHENOL												
1-1	0.079	0.034	0.078	0.019	0.035	0.011	0.383	0.160	0.157	0.076	0.059	0.038
1-3	.092	.034	.067	.011	.064	.011	.650	.236	.143	.099	.052	.042
1-12	.070	.019	.054	.004	.017	.004	.312	.148	.108	.065	.052	.027
1-14	.109	.027	.034	.004	.018	.011	.364	.270	.165	.110	.065	.057
1-21	.077	.023	.041	.011	.032	.008	.372	.243	.200	.114	.082	.053
Average	.085	.027	.055	.010	.033	.009	.416	.211	.155	.093	.062	.043
PENTA GREASE CONTAINING 10 PERCENT PENTACHLOROPHENOL												
1-9	.517	.484	.164	.129	.019	.030						
1-13	.356	.256	.082	.034	.030	.010						
1-16	.630	.521	.173	.116	.027	.010						
1-19	.467	.382	.184	.127	.018	.022						
1-24	.646	.458	.154	.076	.022	.019						
Average	.523	.420	.151	.096	.023	.018						

[1]Assumed weight of 38 pounds used to convert percent to pounds per cubic foot.

Report No. 2227

Table 3.--Summary of analyses on borings taken 3 months and 1 year and on disks taken 2 years after application of groundline treatments to pole stubs

Treatment[1]	Wood species	Pentachlorophenol									Sodium fluoride									Arsenic trioxide		
		Outer 1/2 inch			Second 1/2 inch			Next inch			Outer 1/2 inch			Second 1/2 inch			Next inch			Outer 1/2 inch	Second 1/2 inch	Next inch
		3 months	1 year	2 years	3 months	1 year	2 years	3 months	1 year	2 years	3 months	1 year	2 years	3 months	1 year	2 years	3 months	1 year	2 years	2 years	2 years	2 years
		Lb. per cu. ft.	Lb. per cu. ft.	Lb. per cu. ft.	Lb. per cu. ft.	Lb. per cu. ft.	Lb. per cu. ft.	Lb. per cu. ft.	Lb. per cu. ft.	Lb. per cu. ft.	Lb. per cu. ft.	Lb. per cu. ft.	Lb. per cu. ft.	Lb. per cu. ft.	Lb. per cu. ft.	Lb. per cu. ft.	Lb. per cu. ft.	Lb. per cu. ft.	Lb. per cu. ft.	Lb. per cu. ft.	Lb. per cu. ft.	Lb. per cu. ft.
MADISON, WIS., TEST PLOT																						
Creosote-penta-fluoride paste	Lodgepole pine	1.16	0.82	0.62	0.09	0.10	0.06	0.03	0.02	0.02			0.11			0.06			0.02			
Injection	Douglas-fir										0.21	0.14	.07	0.43	0.17	.06	1.09	0.46	.10	0.02	0.03	0.09
	Western larch										.16	.09	.10	.15	.10	.10	.27	.18	.12	.02	.05	.08
	Lodgepole pine										.10	.10	.08	.06	.09	.08	.02	.14	.11	.01	.02	.04
	Southern yellow pine										.07	.13	.09	.05	.10	.07	.06	.18	.11	.02	.02	.04
	Western redcedar (not incised)										.10	.04	.06	.10	.08	.07	.18	.26	.11	.01	.03	.07
	Western redcedar (incised)										.12	.06	.05	.18	.06	.07	.46	.16	.10	.01	.02	.05
Fluoride-coal-tar paste	Douglas-fir			.02			.01			T[2]	2.57	.33	.12	.62	.05	.04	.02	.03	.02			
	Western larch			.02			.01			.01	2.72	.26	.17	.05	.11	.05	.03	.05	.03			
	Lodgepole pine			.02			T			T	6.40	1.02	.17	.13	.10	.08	.03	.04	.04			
	Southern yellow pine			.03			.01			.01	1.69	.41	.21	.07	.09	.09	.04	.04	.04			
	Western redcedar (not incised)			.02			T			.01	2.35	.43	.10	.04	.18	.04	.02	.01	.03			
	Western redcedar (incised)			.02			.01			T	1.45	.41	.11	.11	.13	.05	.07	.05	.04			
	Lodgepole pine[3]										2.61	1.21	.21	.11	.16	.11	.03	.04	.07			
Pentachlorophenol solution	Lodgepole pine	.28	.17	.11	.05	.01	.01	.02	.01	T												
Pentachlorophenol solution plus sodium fluoride	Douglas-fir			.05			T			T	(4)	.02	.02	.01	.02	.02	.01	.02	.01			
	Western larch			.04			.01			T	.03	.03	.01	.04	.03	T	.02	.02	T			
	Lodgepole pine			.11			.01			T	.03	.03	.02	.02	.01	.01	.01	.02	.01			
	Southern yellow pine			.08			.01			T	.05	.04	.01	.04	.03	T	.02	.02	T			
	Western redcedar (not incised)			.06			T			T	.02	.02	.01	.02	.02	T	.02	.02	T			
	Western redcedar (incised)			.06			.01			T	.05	.01	.01	.02	.01	T	.01	.01	T			
Penta grease	Douglas-fir	.69	.24	.24	.08	.03	.01	.04	.02	T												
	Western larch	.58	.37	.27	.08	.02	.01	.03	.05	.01												
	Lodgepole pine	.69	.49	.39	.07	.02	.02	.04	.01	.01												
	Southern yellow pine	.60	.48	.42	.16	.11	.10	.05	.02	.02												
	Western redcedar (not incised)	.45	.27	.25	.20	.06	.01	.03	.02	.01												
	Western redcedar (incised)	.48	.26	.25	.16	.08	.01	.06	.04	T												
Penta gel	Douglas-fir	.33	.20	.19	.04	.04	.01	.01	.01	.01												
	Western larch	.27	.25	.21	.06	.03	.02	.02	.01	.01												
	Lodgepole pine	.49	.40	.34	.04	.02	.02	.01	.01	T												
	Southern yellow pine	.46	.54	.44	.05	.10	.08	.02	.02	.01												
	Western redcedar (not incised)	.46	.34	.32	.03	.02	.01	.02	.01	.01												
	Western redcedar (incised)	.34	.21	.28	.11	.06	.01	.03	.03	T												

Table 3.--Summary of analyses on borings taken 3 months and 1 year and on disks taken 2 years after application of groundline treatments to pole stubs--Continued

Treatment[1]	Wood species	Pentachlorophenol									Sodium fluoride									Arsenic trioxide		
		Outer 1/2 inch			Second 1/2 inch			Next inch			Outer 1/2 inch			Second 1/2 inch			Next inch			Outer 1/2 inch	Second 1/2 inch	Next inch
		3 months	1 year	2 years	3 months	1 year	2 years	3 months	1 year	2 years	3 months	1 year	2 years	3 months	1 year	2 years	3 months	1 year	2 years	2 years	2 years	2 years
		Lb. per cu. ft.	Lb. per cu. ft.	Lb. per cu. ft.	Lb. per cu. ft.	Lb. per cu. ft.	Lb. per cu. ft.	Lb. per cu. ft.	Lb. per cu. ft.	Lb. per cu. ft.	Lb. per cu. ft.	Lb. per cu. ft.	Lb. per cu. ft.	Lb. per cu. ft.	Lb. per cu. ft.	Lb. per cu. ft.	Lb. per cu. ft.	Lb. per cu. ft.	Lb. per cu. ft.	Lb. per cu. ft.	Lb. per cu. ft.	Lb. per cu. ft.
FORT COLLINS, COLO., TEST PLOT																						
Injection	Douglas-fir	...	...	...	...	...	...	...	...	...	0.06	0.08	0.10	0.03	0.07	0.14	0.08	0.23	0.20	0.03	0.05	0.09
	Western larch	...	...	...	...	...	...	...	...	...	.12	.10	.14	.18	.13	.14	.31	.49	.27	.04	.07	.13
	Lodgepole pine	...	...	...	...	...	...	...	...	...	.04	.10	.10	.03	.23	.09	.02	.43	.14	.02	.03	.06
	Southern yellow pine	...	...	...	...	...	...	...	...	...	.20	.08	.10	.35	.05	.11	.44	.10	.15	.03	.03	.05
	Western redcedar (not incised)	...	...	...	...	...	...	...	...	...	.06	.07	.08	.07	.14	.07	.44	.19	.11	.02	.03	.06
	Western redcedar (incised)	...	...	...	...	...	...	...	...	...	.14	.04	.06	.34	.05	.07	.07	.23	.13	.02	.03	.07
Fluoride-coal-tar paste	Douglas-fir	...	...	0.02	...	...	T	...	...	T	1.03	1.20	.07	.04	.01	.03	.03	.02	.03	...	...	...
	Western larch	...	...	.02	...	...	T	...	...	0.00	.23	.78	.10	.05	.01	.02	.03	.01	.01	...	...	...
	Lodgepole pine	...	...	.02	...	...	0.01	...	...	T	.82	1.19	.07	.05	.07	.03	.03	.01	.01	...	...	...
	Southern yellow pine	...	...	.02	...	...	.01	...	...	T	.67	.32	.08	.11	.02	.03	.08	.01	.02	...	...	...
	Western redcedar (not incised)	...	...	.02	...	...	T	...	...	T	.53	.23	.09	.05	.02	.03	.04	.01	.03	...	...	...
	Western redcedar (incised)	...	...	.03	...	...	.01	...	...	.00	.20	.74	.18	.04	.03	.03	.02	.02	.02	...	...	...
	Lodgepole pine[3]	...	...	...	...	...	...	...	...	...	.74	.68	.15	.03	.06	.08	.03	.01	.04	...	...	...
Pentachlorophenol solution	Lodgepole pine	0.10	0.01	.16	0.05	0.01	.01	0.01	0.00	T	...	...	...	...	...	...	...	...	...	...	...	...
Pentachlorophenol solution plus sodium fluoride	Douglas-fir	...	...	.03	...	...	T	...	...	.00	.02	.03	.02	.02	.02	.02	.01	.01	.01	...	...	...
	Western larch	...	...	.07	...	...	.01	...	...	T	.06	.04	.03	.03	.02	.01	.01	.02	.01	...	...	...
	Lodgepole pine	...	...	.07	...	...	T	...	...	.00	.04	.03	.03	.03	.02	.01	.01	.01	.01	...	...	...
	Southern yellow pine	...	...	.10	...	...	.02	...	...	T	.08	.03	.02	.04	.02	.02	.03	.02	.01	...	...	...
	Western redcedar (not incised)	...	...	.07	...	...	T	...	...	T	.02	.05	.01	.02	.02	.01	.02	.01	.01	...	...	...
	Western redcedar (incised)	...	...	.08	...	...	.01	...	...	T	.10	.05	.03	.03	.01	.01	.01	.01	.01	...	...	...
Penta grease	Douglas-fir	.39	.22	.19	.05	.01	.02	.03	.01	.01	...	...	...	...	...	...	...	...	...	...	...	...
	Western larch	.38	.49	.35	.04	.01	.02	.02	.01	.01	...	...	...	...	...	...	...	...	...	...	...	...
	Lodgepole pine	.38	.49	.43	.09	.07	.06	.02	.01	.01	...	...	...	...	...	...	...	...	...	...	...	...
	Southern yellow pine	.40	.71	.45	.11	.12	.12	.03	.02	.02	...	...	...	...	...	...	...	...	...	...	...	...
	Western redcedar (not incised)	.46	1.02	.38	.04	.09	.01	.02	.01	T	...	...	...	...	...	...	...	...	...	...	...	...
	Western redcedar (incised)	.48	.96	.35	.05	.05	.01	.02	.01	T	...	...	...	...	...	...	...	...	...	...	...	...
Penta gel	Douglas-fir	.16	.26	.24	.01	.01	.01	.02	.00	T	...	...	...	...	...	...	...	...	...	...	...	...
	Western larch	.14	.29	.31	.03	.02	.02	.02	.01	.01	...	...	...	...	...	...	...	...	...	...	...	...
	Lodgepole pine	.44	.49	.41	.06	.09	.03	.01	.01	T	...	...	...	...	...	...	...	...	...	...	...	...
	Southern yellow pine	.22	.46	.36	.04	.05	.04	.01	.01	.01	...	...	...	...	...	...	...	...	...	...	...	...
	Western redcedar (not incised)	.16	.55	.36	.02	.01	.01	.02	.00	T	...	...	...	...	...	...	...	...	...	...	...	...
	Western redcedar (incised)	.20	.98	.36	.06	.09	.02	.01	.01	T	...	...	...	...	...	...	...	...	...	...	...	...

Table 3.--Summary of analyses on borings taken 3 months and 1 year and on disks taken 2 years after application of groundline treatments to pole stubs--Continued

Treatment[1]	Wood species	Pentachlorophenol									Sodium fluoride									Arsenic trioxide		
		Outer 1/2 inch			Second 1/2 inch			Next inch			Outer 1/2 inch			Second 1/2 inch			Next inch			Outer 1/2 inch	Second 1/2 inch	Next inch
		3 months	1 year	2 years	3 months	1 year	2 years	3 months	1 year	2 years	3 months	1 year	2 years	3 months	1 year	2 years	3 months	1 year	2 years	2 years	2 years	2 years
		Lb. per cu. ft.	Lb. per cu. ft.	Lb. per cu. ft.	Lb. per cu. ft.	Lb. per cu. ft.	Lb. per cu. ft.	Lb. per cu. ft.	Lb. per cu. ft.	Lb. per cu. ft.	Lb. per cu. ft.	Lb. per cu. ft.	Lb. per cu. ft.	Lb. per cu. ft.	Lb. per cu. ft.	Lb. per cu. ft.	Lb. per cu. ft.	Lb. per cu. ft.	Lb. per cu. ft.	Lb. per cu. ft.	Lb. per cu. ft.	Lb. per cu. ft.
SAUCIER, MISS., TEST PLOT																						
Injection	Douglas-fir										.09	.38	.07	.19	.09	.06	.35	.14	.09	.01	.02	.05
	Southern yellow pine										.21	.09	.09	.13	.14	.06	.20	.28	.09	.01	.01	.02
Fluoride-coal-tar paste	Douglas-fir			.02			.01			.01	2.84	.85	.18	.05	.05	.08	.02	.01	.04			
	Southern yellow pine			.03			.01			.01	2.22	.38	.35	.03	.11	.16	.02	.04	.11			
Pentachlorophenol solution plus sodium fluoride	Douglas-fir			.04			.02			.01	.06	.04	.02	.03	.02	.01	.02	.01	.01			
	Southern yellow pine			.06			.02			.01	.03	.06	.04	.03	.02	.02	.02	.01	.02			
Penta grease	do	.73	.73	.78	.17	.15	.24	.09	.02	.05												
Penta gel	do	.36	.41	.41	.05	.05	.05	.02	.01	.02												

[1]Refers to groundline treatment of pressure-creosoted stubs except where otherwise noted.

[2]T signifies trace.

[3]Original treatment was with 5.10 percent pentachlorophenol solution.

[4]Sample lost.

Note: Assumed weights used to convert percent to pounds per cubic foot: Douglas-fir, 30 pounds; western larch, 36 pounds; lodgepole pine, 29 pounds; southern yellow pine, 38 pounds; and western redcedar, 23 pounds.

(Sheet 3 of 3)

Figure 1. --Applying creosote-penta-fluoride paste to stub with a scoop.

ZM 113 773

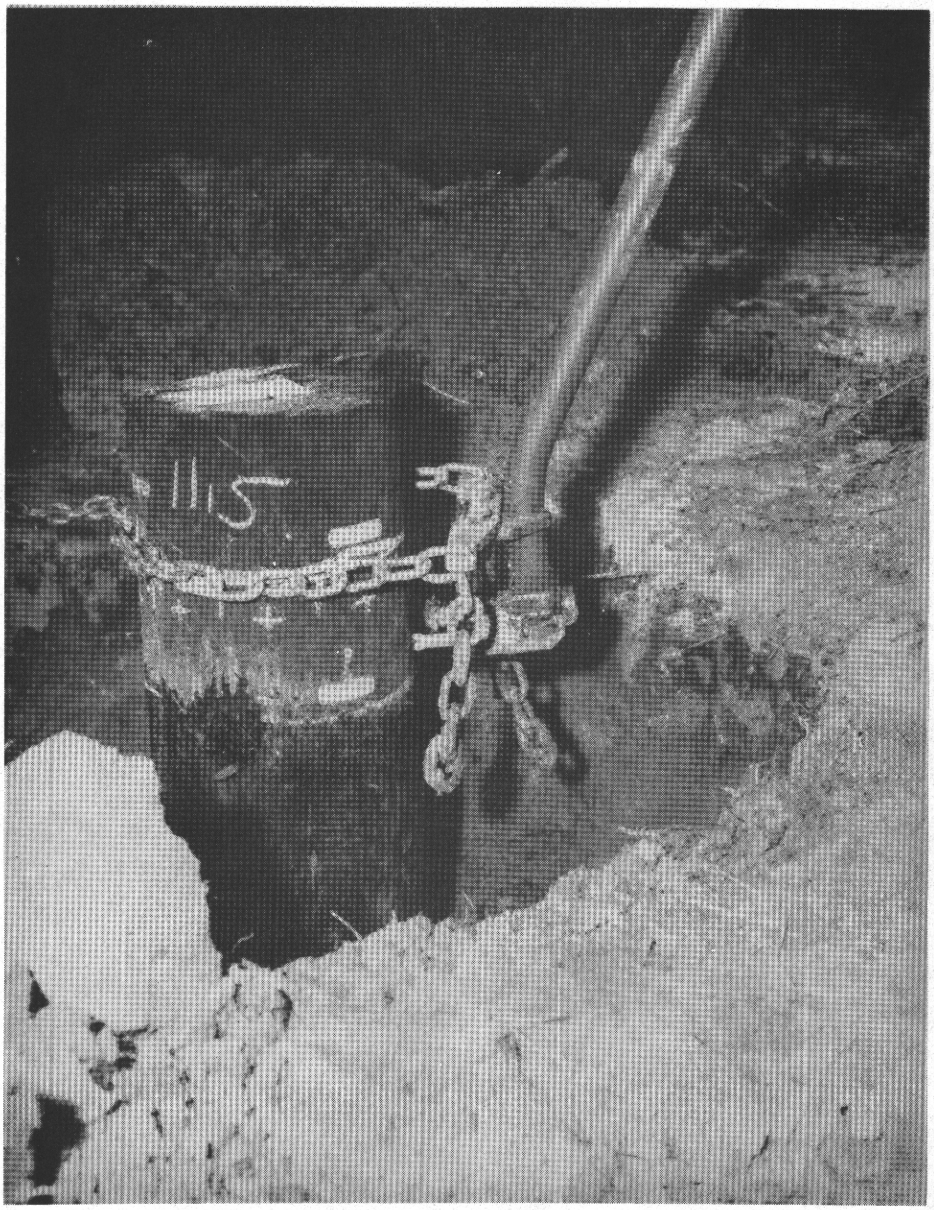


Figure 2. --Tool used for injection treatment is positioned on pole stub. Injection needle about to be plunged into the wood.

ZM 113 772

Figure 3.--Fluoride-coal tar paste being applied to a stub with a window brush.

ZM 115 965

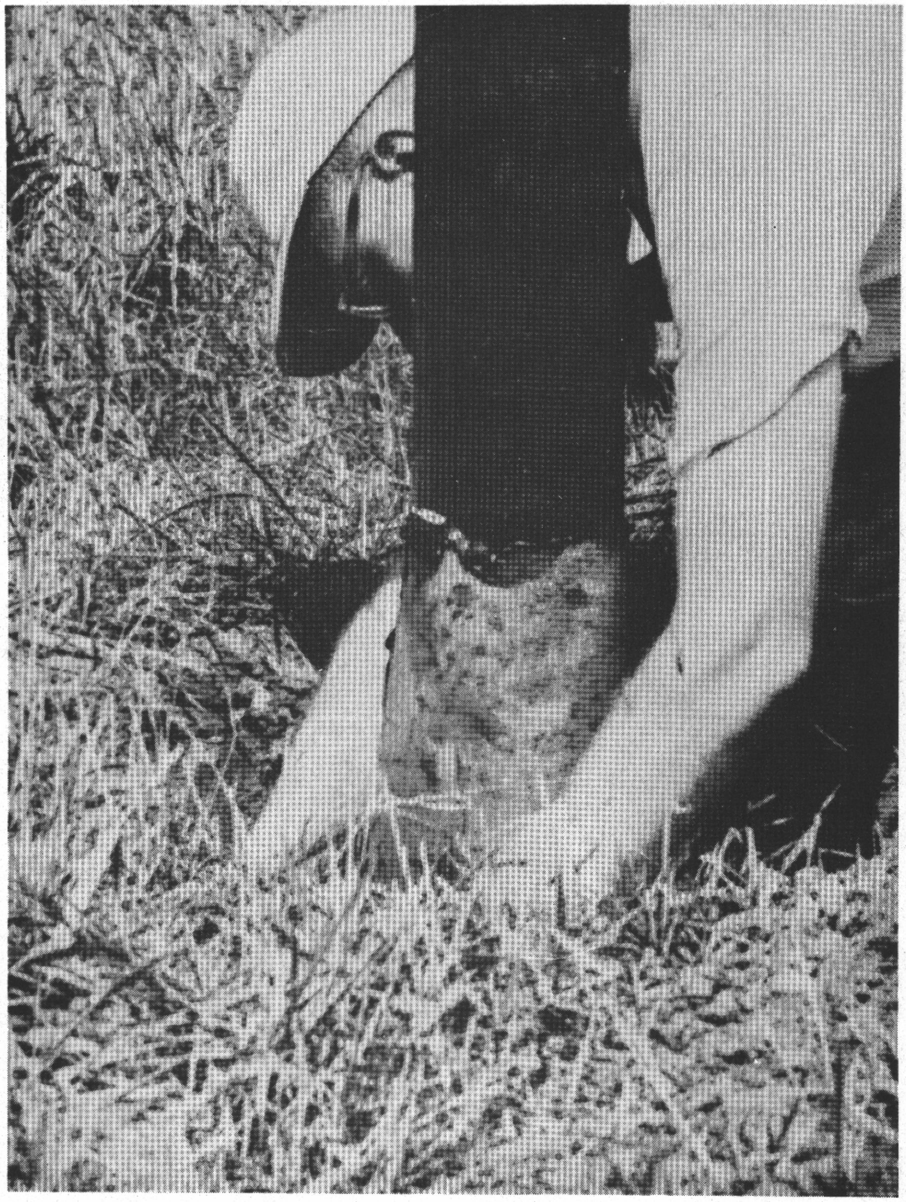


Figure 4.--Wrapping bandage coated with penta grease around pole.

ZM 115 966

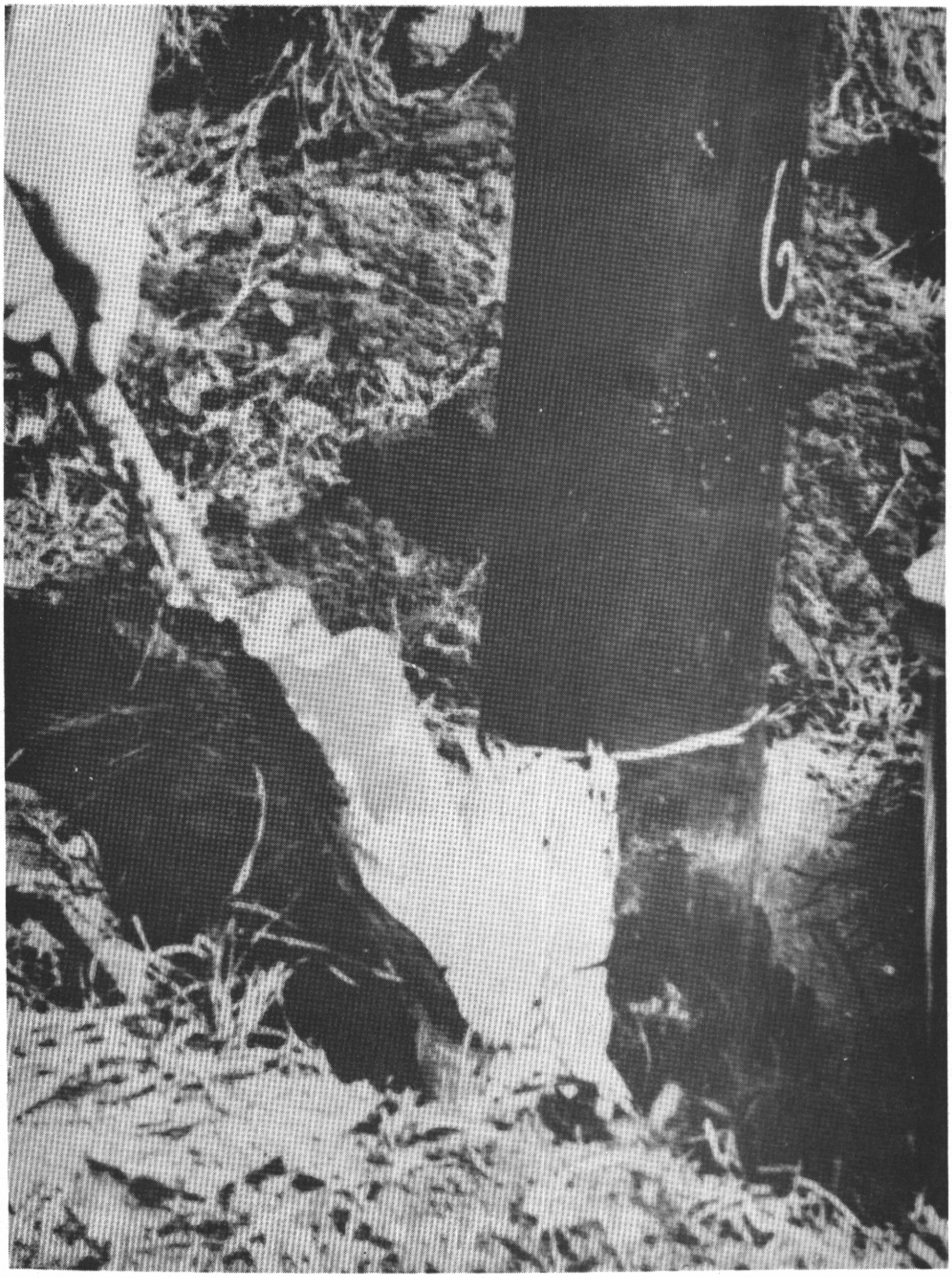


Figure 5. --Scooping penta gel onto a stub.

ZM 115 964

Figure 6.--Sodium fluoride powder applied to groundline area of stub.

ZM 118 004

Figure 7. --Final application of pentachlorophenol solution.

ZM 118 003

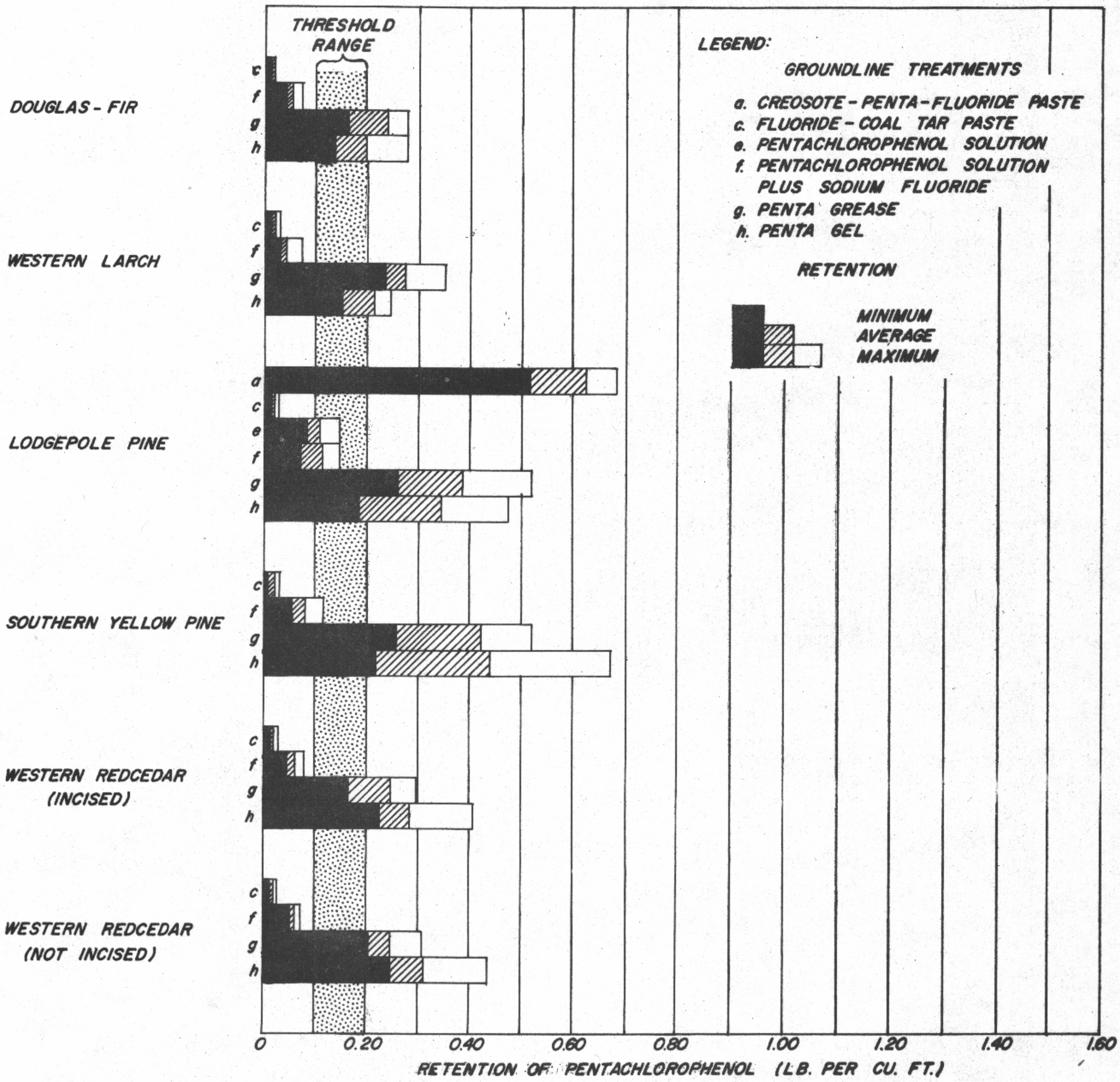


Figure 8. --Retention of pentachlorophenol in the outer 1/2 inch of pole stubs after 2 years at Madison, Wis.

Z M 119 927

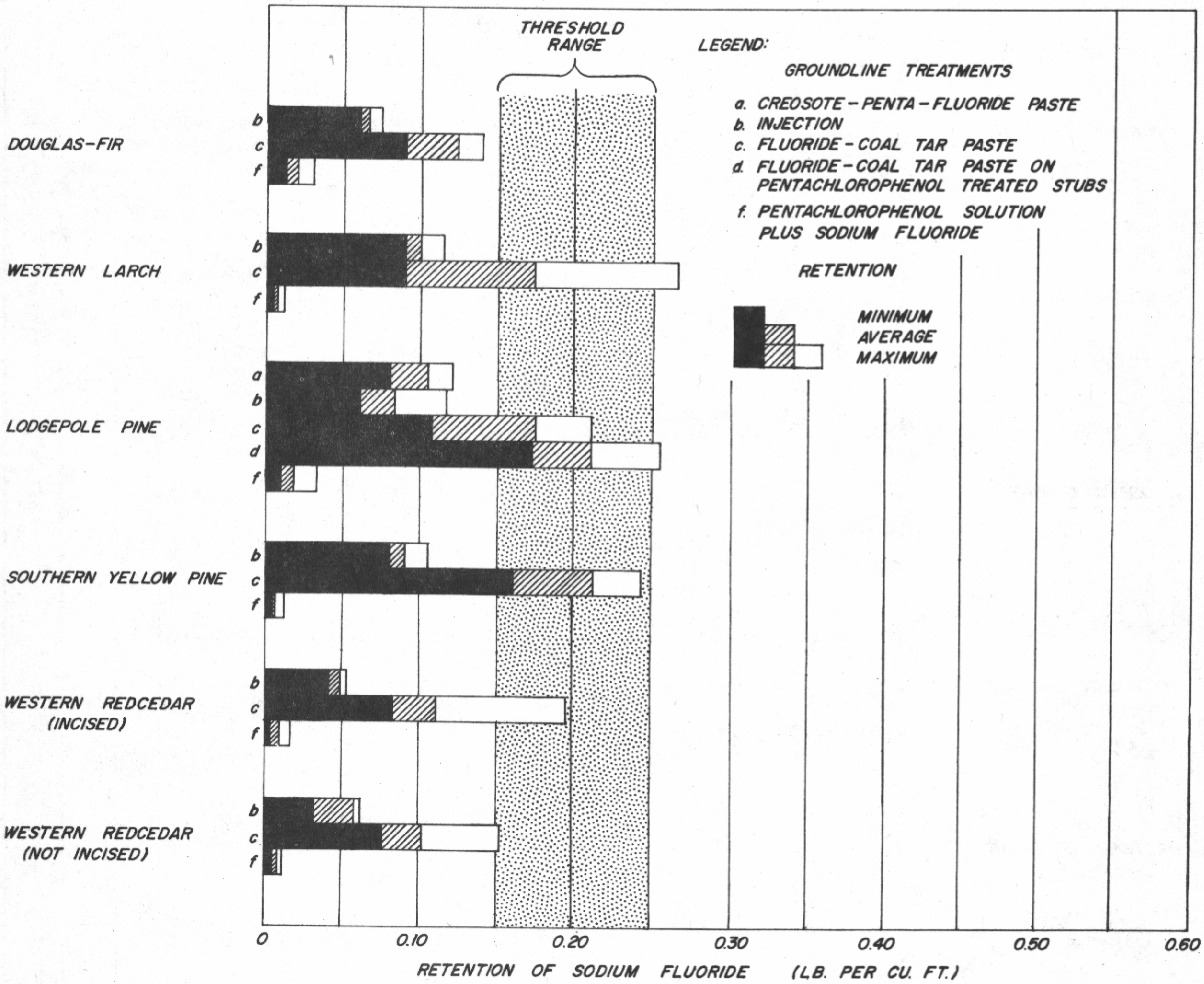


Figure 9. --Retention of sodium fluoride in the outer 1/2 inch of pole stubs after 2 years at Madison, Wis.

Z M 119 928

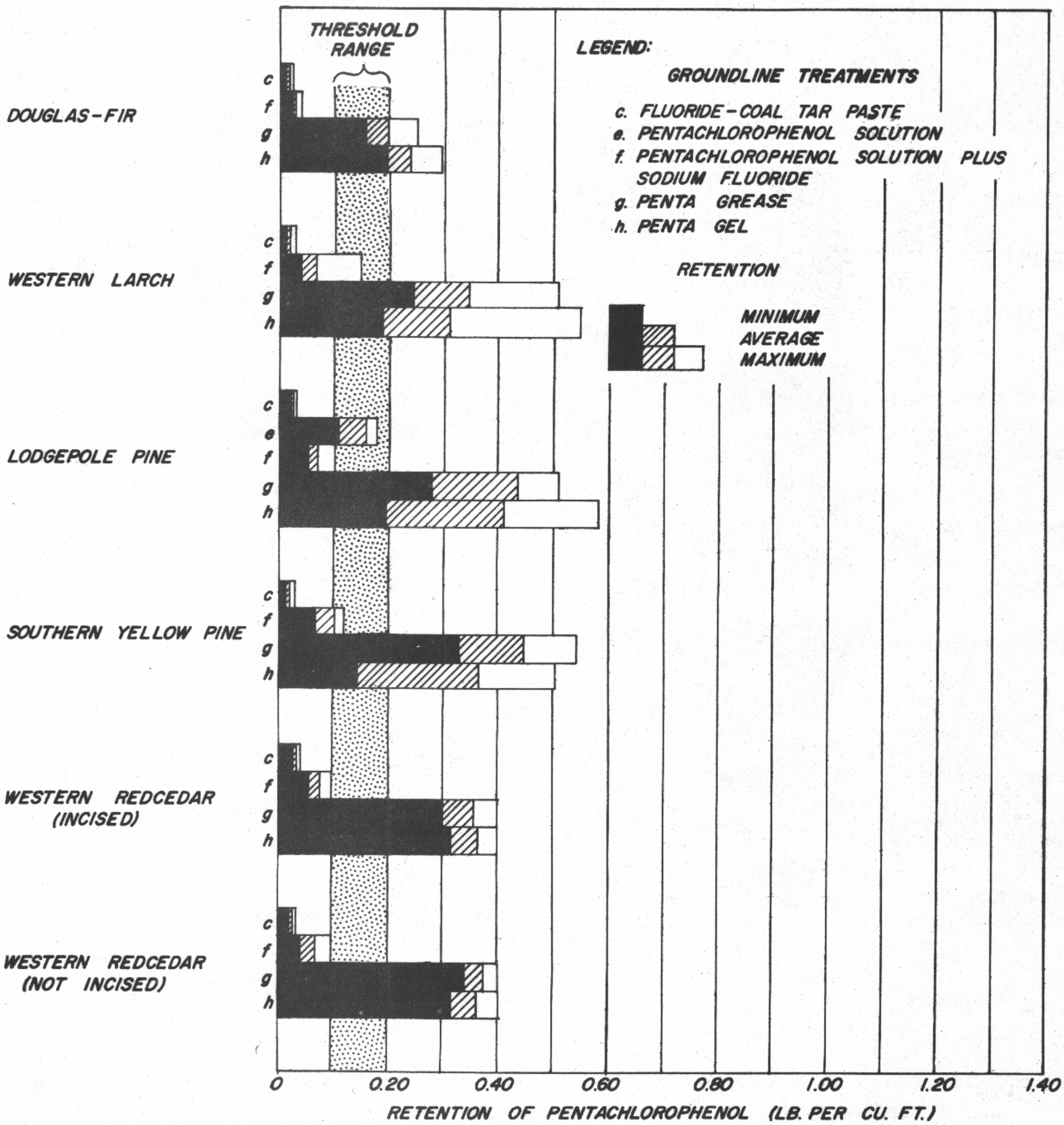


Figure 10. --Retention of pentachlorophenol in the outer 1/2 inch of pole stubs after 2 years at Fort Collins, Colo.

Z M 119 929

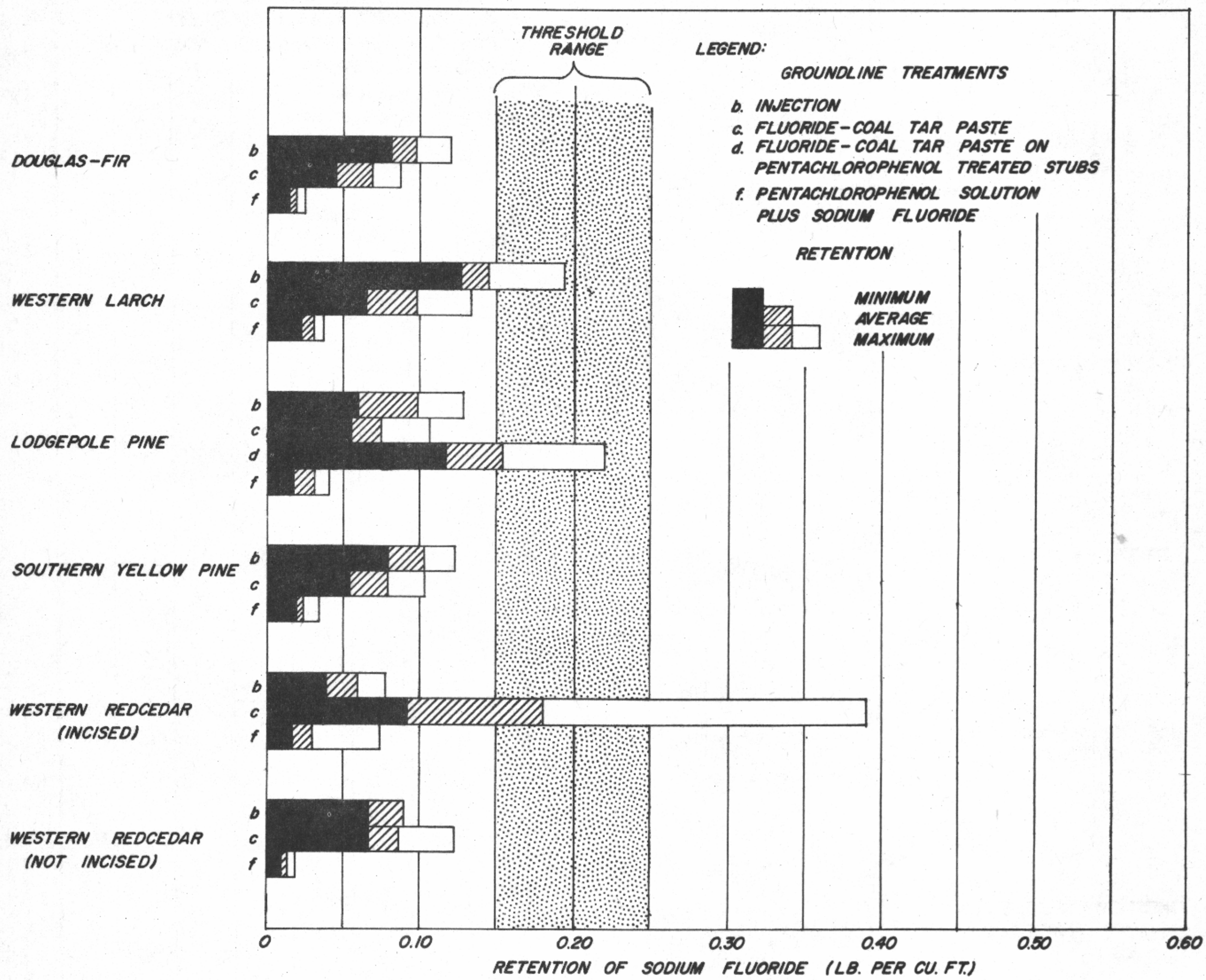
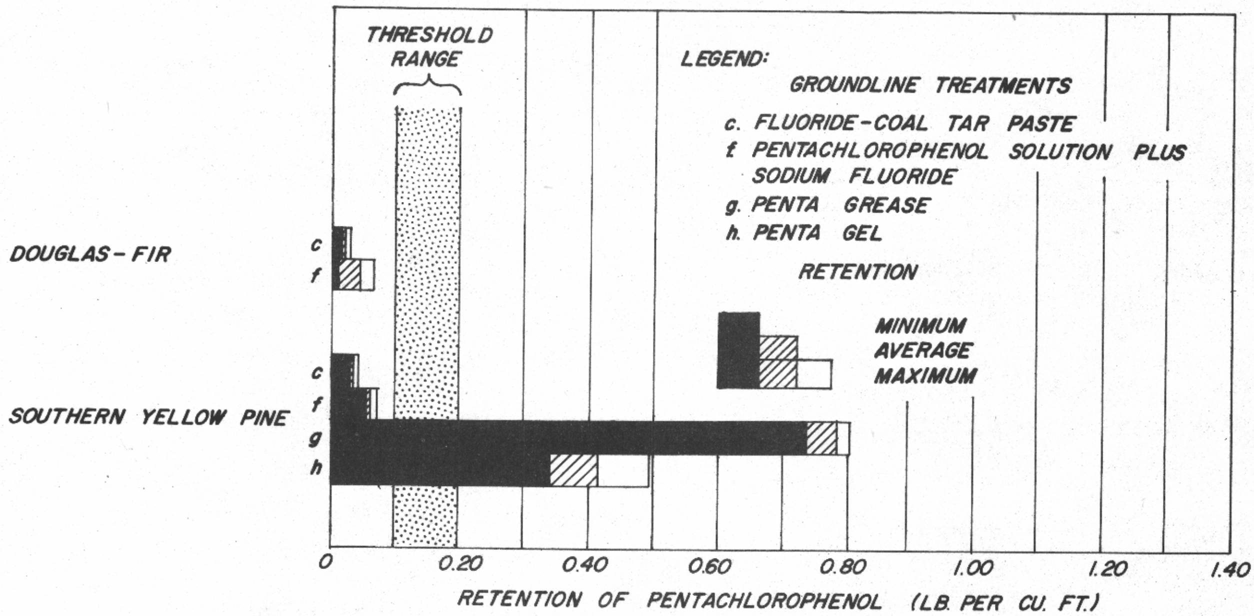


Figure 11.--Retention of sodium fluoride in the outer 1/2 inch of pole stubs after 2 years at Fort Collins, Colo.

Z M 119 930



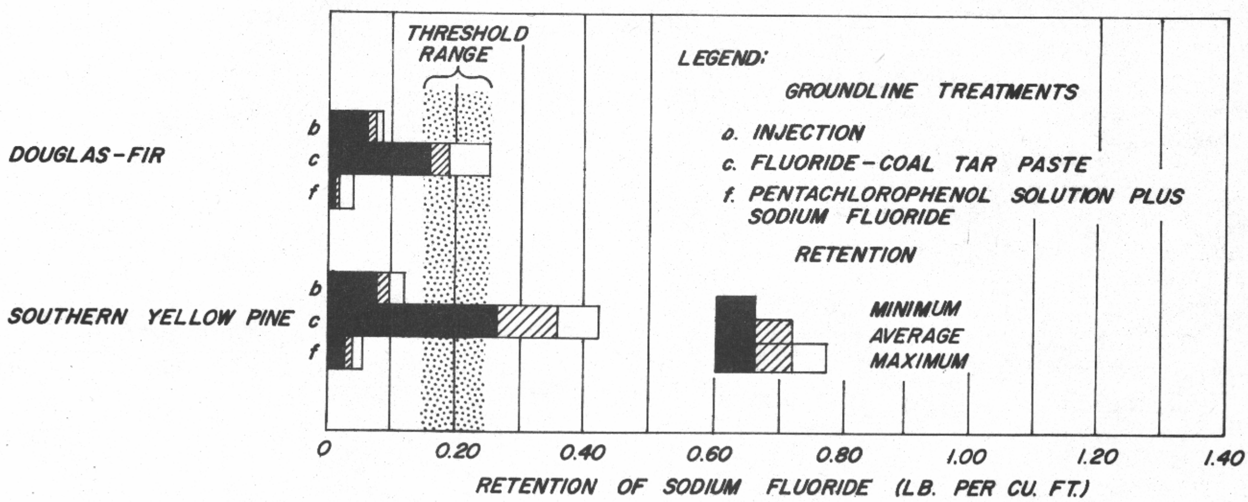


Figure 12.--Retention of pentachlorophenol and sodium fluoride in the outer 1/2 inch of pole stubs after 2 years at the Harrison Experimental Forest, Saucier, Miss.

Z M 119 931

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