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Durability of Preservative-Treated Wood Utility Poles in Guam

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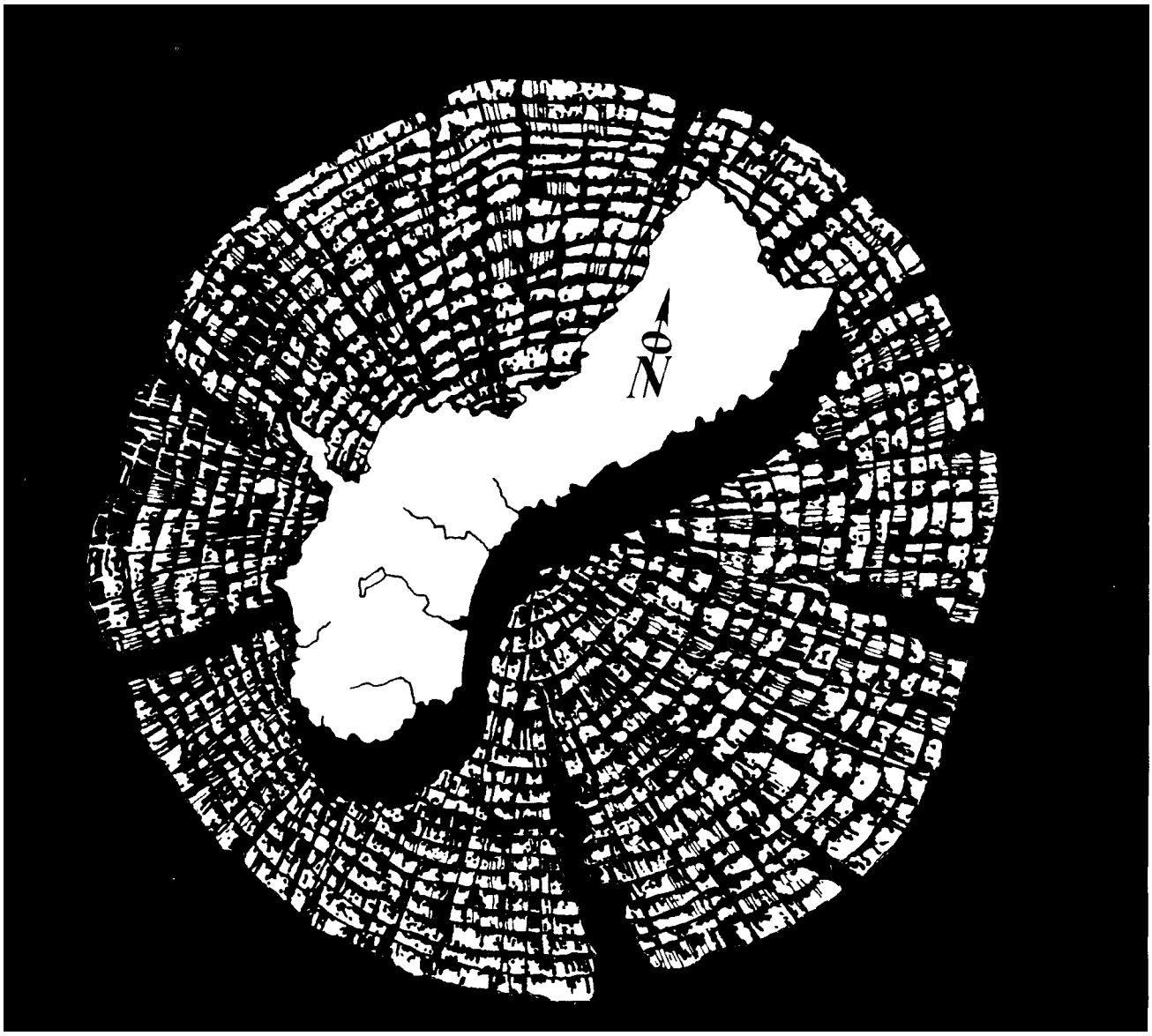

Abstract

Pressure-treated wood utility poles in Guam were inspected to evaluate efficiency of preservative standards. Formosan termites (*Coptotermes formosanus* Shiraki) can destroy the untreated heartwood of Douglas-fir poles treated with creosote, pentachlorophenol, and chromated copper arsenate (CCA). Where Formosan termites are a hazard, a supplemental soil treatment for termite control should be used around Douglas-fir poles pressure treated with creosote or pentachlorophenol. Where Formosan termites are a serious hazard, the utilization of CCA-treated Douglas-fir utility poles should be questioned. Pressure treatments with ammoniacal copper arsenate (ACA) seem to be effective in protecting heartwood of treated Douglas-fir poles from attack by Formosan termites, but additional documentation is needed to determine the full potential of that treatment. Early attack by soft-rot fungi and by termites were detected on some pentachlorophenol-treated southern pine poles in Guam.

Keywords: Poles, creosote, pentachlorophenol, CCA, ACA, preservative, termites, Formosan termites.

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This publication reports research involving pesticides. It does not contain recommendations for their use, nor does it imply that the uses discussed here have been registered. All uses of pesticides must be registered by appropriate State and/or Federal agencies before they can be recommended.

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Durability of Preservative-Treated Wood Utility Poles in Guam

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Introduction

Installation of properly treated utility poles will result in lower replacement costs and lower maintenance costs. For these reasons, it is wise to periodically evaluate the durability of poles already in the field and use this information to assess the adequacy of wood preservative standards for different uses and environments. In this paper we report our observations and evaluations of preservative-treated utility poles in Guam. Their durability is particularly interesting because of severe Formosan termite (*Coptotermes formosanus* Shiraki) activity there and because most of the poles purchased for use on Guam after the War of the Pacific were in compliance with Federal specifications (U.S. Federal Supply Service) for treated wood products. (They were procured through U.S. Navy supply channels.) The majority of wood poles on Guam are Douglas-fir (*Pseudotsuga menziesii* (Mirb.) Franco). Preservative penetration requirements reflect a relatively thin band of sapwood (American Wood-Preservers' Association (AWPA) 1983, Lassen and Okkonen 1969). The heartwood has been described as moderately durable (U.S. Department of Agriculture (USDA) 1974) or nondurable (Graham and Helsing 1979).

Causes of Deterioration

According to Graham (1973), large Douglas-fir poles normally are dried to meet treating requirements and not to moisture contents that they will attain in service. The heartwood moisture content of about 30 to 40 percent frequently remains unchanged until the treated pole is installed. In service, the interior of the pole at and above the groundline drops below the fiber saturation point, and seasoning checks may extend into the pole beyond the shell of treated wood. Fungi, termites, and carpenter ants enter the poles through the exposed untreated wood and may cause extensive internal deterioration within 10 years after installation. One might expect that this would be a problem of special consequence in tropical regions where termite activity is intense. The Formosan termite, for example, will readily feed upon Douglas-fir heartwood (Mannesmann 1973).

Past Research

Two previous studies described conditions in large-diameter Douglas-fir poles. Graham et al. (1976) surveyed 479 Douglas-fir poles that were pressure treated with pentachlorophenol in heavy oil and were in service for 6 to 18 years in western Oregon. They found internal decay in 46 percent of the 60- to 80-foot-long poles.

Zabel et al. (1980) detected decay in 190 of 952 (approximately 20 pct) treated Douglas-fir poles installed for up to 10 years in the northeastern United States. Seventy-two percent (73/102) of chromated copper arsenate- (CCA) treated poles examined had decay. Fifteen percent (1061689) of poles pressure treated with pentachlorophenol in oil had decay.

The question often arises whether small-diameter Douglas-fir poles might perform better than large-diameter poles. Assumably, small-diameter poles would be less likely to develop deep seasoning checks which penetrate the peripheral zone of treated wood.

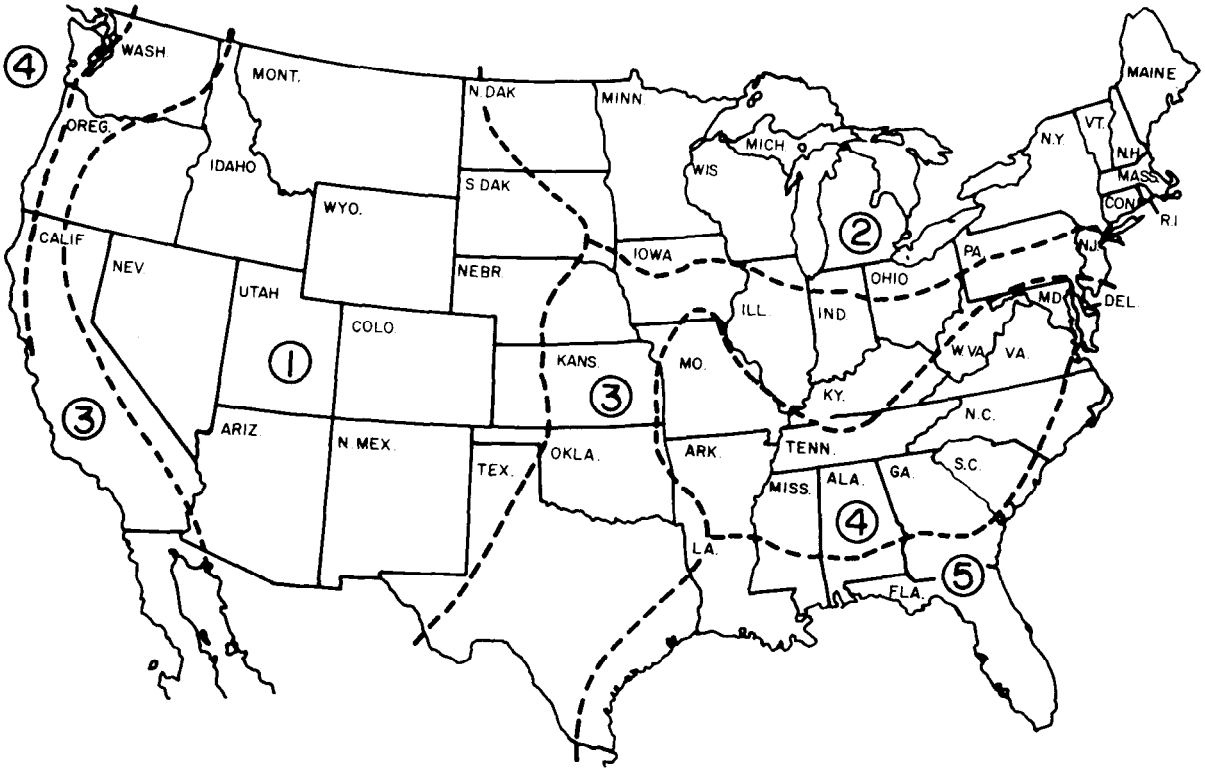

Figure 1.—Decay severity zones for wood utility poles as defined by the USDA Rural Electrification Association. Decay is least severe in zone 1, most severe in zone 5. (ML84 5657)

Most of the available information about performance of small-diameter Douglas-fir poles comes from experiments and field experience in temperate climates. Approximately 25 to 30 million poles are installed in rural electric systems that participate with the USDA Rural Electrification Administration (REA 1973) in periodic studies of pole performance. These studies reveal that within the contiguous United States 78 percent of all poles replaced by REA cooperatives were replaced because of decay, followed by woodpeckers (7.2 pct) and lightning (4.6 pct). For purposes of estimating decay hazards to poles, the REA divided the contiguous 48 states into 5 "decay" zones (fig. 1) which broadly group poles with like experiences. Zone 1 has the lowest hazard: Zone 5, the highest.

Within the REA system, creosoted Douglas-fir has been primarily used in less severe decay zones. The record for creosoted Douglas-fir poles in Zone 2 has been very good (REA 1973). Records of pole inspections by the Osmose Company during 1974 and 1975 also indicate good performance of Douglas-fir distribution poles in zones of low to medium decay hazard (table 1).

Pole-diameter, treated Douglas-fir posts (approximately 20 ft long, 7 to 9 in. in diameter) were exposed by the Bell System in a field plot near Orange Park, FL. That site had an annual rainfall of 54 inches and a sandy organic soil—Lakeland Sand (Ochrymowych and McOrmond 1978). Termite species native to Florida were present. After 21 years of exposure, posts treated to 0.5 pound per cubic foot (lb/ft^3) of ammoniacal copper arsenate (ACA) had excellent performance. Only one of 21 ACA-treated Douglas-fir posts had slight surface decay.

Forty-five Douglas-fir posts, treated with pentachlorophenol/liquified petroleum gas-isopropyl ether cosolvent, were exposed for 14 years at Orange Park. After 14 years, slight surface deterioration caused by either decay or termite attack was present on all posts. Nine percent of the posts showed moderate attack.

Table 1.—Condition of Douglas-fir distribution poles examined during 1974 and 1975 in low to medium decay-hazard zones of contiguous United States[1]

Region of observation	Preservative[2]	Number of poles in sample	Poles rejected		Poles with decay but not rejected	
			Number	Percent	Number	percent
California to Maine	C	2,787	112	4.0	276	11.9
California to New York	P	7,334	269	3.7	290	3.9

[1]Data provided by Mr. Robert E. Birtz Vice President, Utilities Division, Osmose, Buffalo, NY. Letter of May 18, 1984. Data is this report were randomly selected from actual pole inspection and treating program records.

[2]C = creosote; P = pentachlorophenol in oil.

A report on durability of telephone poles on the island of Hawaii (Boone 1965) is one of the few reports available on performance of U.S.-produced wood poles that are installed in the Tropics. Boone concluded from his examinations of utility company records that, after 20 years in line, 84 percent of the pressure-treated Douglas-fir poles were still serviceable, and 74 percent of the pressure-treated southern pine poles were serviceable in urban areas. He did not determine whether termites or wood decay were present in the serviceable poles. Treated poles were presumed to have been pressure treated with creosote to a retention of 8 lb/ft^3. Higher rainfall affected untreated species more than it did treated species. Neither rainfall nor differences in elevation appeared to have had any effect on the durability of treated poles.

This Study

Guam is the largest and southernmost island of the Mariana Islands. It lies about 13.5° N, 145° E, with the Philippine Sea on the west and the Pacific Ocean to the east. The climate of Guam is almost uniformly warm and humid. The mean annual temperature is 78.7 °F; the mean annual precipitation (rainfall) is 102.1 inches. The dry season extends from January through April. The rainy season lasts from mid-July to mid-November. About 15 percent of the annual rainfall occurs during the dry season and 55 percent during the rainy season. Typhoons move directly across Guam at a frequency of about 1 every 8 years (National Oceanic and Atmospheric Administration 1982).

Soils in Guam vary considerably. In northern Guam, soils are generally neutral to slightly alkaline and have a coraline parent material. Most southern soils are typically acidic, being derived from volcanic materials.[1]

Until 1978, soil treatments with termiticides were used around new and old poles to control attack by subterranean termites. Unfortunately, no records were kept on year or location of those treatments. Consequently, poles set before 1978 and still sound cannot be accepted as evidence for intrinsic durability because of the possibility that soil treatments could have been used around those poles. No other records on individual pole histories were available for any utility lines, with the exception of one with which Mr. Lauret has personal experience. In that line, located on U.S. Navy property, 2 percent chlordane was applied around poles as they were installed in 1969.[2] A segment of that line was examined in this study (table 8). For all other lines and poles discussed in this report, data for poles installed after 1977 reflect performance without benefit of soil treatments to control subterranean termites.

[1]Joan Jordon, Soil Conservation Service, U.S. Department of Agriculture, University of Guam Station, Mangilao, Guam 96913. Personal communication dated 2/17/84.

[2]About 3 to 4 gal of 2 pct chlordane were sprayed into the cavity around the pole at the time of backfilling when the poles were set. Later this process was changed to rodding the material down alongside the pole after it was set. This permitted better coordination of the different crews that were needed to set poles and treat soil. The U.S. Environmental Protection Agency currently would require a special use permit for application of 2 pct chlordane around poles as described here.

Methods

Poles on Guam were inspected in March 1984. Personnel from the U.S. Navy Public Works Center and from Guam Power Authority identified lines with different histories and participated in the field inspections. In addition, Dr. Robert Bielarski, U.S. Naval Facilities Engineering Command, Alexandria, VA, joined in the inspection of several line segments.

Our experimental approach was to document current conditions in individual line segments or in groups of poles of like species, size class, preservative treatment, or history. Where possible, attempts were made to examine consecutive poles in a line (tables 1-8). Such runs always began at an intersection, road, or some other distinctive geographical benchmark to avoid personal bias in selecting line segments. A number of creosote-treated Douglas-fir poles that were already removed from lines because of termite attack were also examined individually to determine depths of preservative penetration. Because most poles on Guam are in size Classes 1 through 3[3], poles of smaller size classes (table 9) were examined wherever they were located. A few additional poles were examined individually as we were enroute to points of interest.

All poles that we inspected were visually inspected for evidence of termite attack above ground and were sounded with a hammer. In more detailed inspections given to some poles, increment cores were extracted from the base of poles about 6 inches above the groundline. Depths of preservative penetration were measured directly on the cores using chrome Azurol for CCA and ACA and Penta-Check for pentachlorophenol (AWPA, Standard M2). Thickness of solid wood was determined from increment cores and with a shell thickness indicator. Some cores subsequently were chemically analyzed for the amount of preservative present within the appropriate assay zone (AWPA 1983). Cores from some of the older, creosote-treated poles without a legible brand were also checked for chlorine content to determine if they might have been treated with a creosote-pentachlorophenol mixture. The species of some poles could not be identified in the field, so species identification was made in the laboratory on the basis of anatomical characteristics of the increment cores. Species identification, based on wood anatomy, grouped the southern yellow pines, lodgepole, and ponderosa pines in one category: “yellow pines.”

Some poles were also inspected below grade. Soil was removed from the base of the pole to a depth of 6 inches, and the exterior of the poles was examined for evidence of decay and termite attack.

[3]Class sizes of poles are described in REA Bulletin 44-2:345-1, Spec. No. DT-SC (Electric) PE-9 (Telecommunications), Jan. 1982, USDA, Washington, DC.

Six lines of poles were examined:

A. A maintained line in a residential area, west central Guam. This line was presumably installed in the 1950's (tables 2 and 3).

B. Abandoned and replacement poles in a line located near an abandoned housing area along the northwestern side of Guam. This line was originally installed in 1959. Replacement poles were set in 1977 (tables 4 and 5).

C. An old line of Douglas-fir poles. The installation date of this line is unknown, but Guam Power Authority personnel regard these poles as examples of their oldest poles in service (table 6).

D. A line of poles in a rural area at the north end of Guam. This location never was urbanized. Installation date of line is unknown (table 7).

E. A line of poles which received soil treatments with termiticides as poles were being set in the ground in 1969 (table 8). Mr. Lauret personally observed the pesticide application around poles in the line segment included in this study.

F. A line of southern pine poles that were installed after 1979 in a residential area in central Guam (table 9).

Table 2.—Condition of 31 consecutive Class 1 through 3 Douglas-fir poles in a line through residential area in west central Guam (Line A)[1]

Preservative[2]	Poles attacked by termites	Poles not attacked by termites	Brand dates that were observed on poles[3]
	----------Number----------		
C	2	15	1957, 1957, 1959, 1970
P	1	2	1969
ACA	0	3	
CCA	3	5	1972, 1979, 1972, 1970, 1976

[1]Poles were 35 to 45 ft long. Occasional poles of non-United States species were skipped. The proportion of original/replacement poles was not determined.

[2]ACA = ammoniacal copper arsenate; C = creosote; CCA = chromated copper arsenate; P = pentachlorophenol in oil.

[3]Dates were legible on only 10 poles.

Table 3.—Condition of 10 Class 1 through 3 Douglas-fir poles in a line through residential area In west central Guam (Line A)[1]

Circumference	Brand date[2]	Preservative Type[3]	Preservative Penetration	Retention by assay[4]	Termite attack[5]	Pole solid/hollow[6]	Depth of sound wood
In.	*Yr*		*In.*	*Lb/ft*^{3}			*In.*
42		ACA	1.4			S	>5.0
53		C	1.9 2.8 1.4	10.5 (3)	–	S	>5.0
48	1957	C	1.5	3.6 (2)	+	H	1.5
40	1972	CCA	.8 .6 .8	.6 (3)	+	~	.5-.8
37		C	1.2 2.0 1.2 1.3	8.5 (4)	–	S	>4.0
46		CCA	1.0	.3 (1)	+		
41	1962	P	1.7 1.8 1.7	.8 (3)	–	S	>4.0
43	1967	P	1.9 2.6 2.2	.4 (3)	+	H	1.9-2.6
47	1972	CCA	.8 .8 1.0 1.0	.1 (2) .6 (2)	+	H	1.9->4.0
52		C	2.0 2.0 2.1 2.1 2.0	12.0 (5)	+	H	2.0-2.1

[1]These poles were specifically selected for detailed observation after the condition of the whole line (table 1) had been determined. Poles were 35 to 45 ft in length.

[2]Only dates that were legible are listed. Omissions indicate either that brand (or tag) was not seen or that the date was illegible.

[3]ACA = ammoniacal copper arsenate; C = creosote; CCA = chromated copper arsenate; P = pentachlorophenol in oil.

[4]The number of increment cores in the composite sample that was analyzed is shown in parentheses. Assay zone = 0.25 to 1.0 in. from surface.

[5]+ = visual evidence of termite attacks; – = no termite attack observed.

[6]S = solid; H = hollow: ~ = termite attack present, but pole not hollow yet.

Table 4.—Condition of six consecutive Class 1 and 2 creosote-treated, Douglas-fir poles that were set out in 1959 and abandoned in 1977 (Line B)[1]

Pole number[2]	Circum-ference	Depth of Preservative penetration	Depth of Sound wood	Termite attack[3]	Pole solid/hollow[4]
	In.	*In.*			
GPA 6	42	1.8	1.8	+	H
GPA 7	43	1.6	1.6	+	H
GPA 9	37	1.2	1.2	+	H
GPA 12				+	H
GPA 13	42			+	H
GPA 16	39	1.5	>5.0	–	S

[1]These poles are still standing, but they are not being used. They were replaced in 1977 by poles shown in table 5. Poles were 30 to 45 ft long. Omissions in table occur where no measurements were taken.

[2]Number refers to entry in field record book, not to utility number for pole.

[3]+ = visual evidence of termite attacks; – = no termite attack observed.

[4]S = solid; H = hollow.

Table 5.—Condition of 5 consecutive, pentachlorophenol-treated, Douglas-fir poles set in 1977 as replacements for poles shown in table 4 (Line B)[1]

Pole number[2]	Size class[3]	Depth of Preservative penetration	Depth of Sound wood	Preservative retention[4]	Termite attack[5]
		In.		*Lb/ft³*	
GPA 8	2	1.9	>4.5	1.1	–
		2.9	>4.5		
GPA 10	1	1.8	>5.0	0.7	
		2.2	>5.0		
GPA 11	2	2.1	>5.0	0.6	–
		2.2	>5.0		
GPA 14	2	2.5	>5.0	1.2	–
		3.2	>5.0		
GPA 15	2	2.7	>5.0	1.3	–

[1]These poles replaced the 1959 poles described in table 4. These poles were often set close to an old pole that was attacked by termites. Poles were not inspected below ground.

[2]Number refers to entry in field record book, not to utility number for pole.

[3]Poles were 45 ft long.

[4]Retentions reported are average of two increment cores taken 90° apart, 6 in. above groundline. Assay zone = 0.25 to 1.0 in. from surface. Assays were performed by the lime ignition method.

[5]+ = visual evidence of termite attacks; – = no termite attack observed.

Table 6.—Condition of 11 consecutive 45- to 55-foot, Douglas-fir poles in a line that was identified by Guam Power Authority personnel as one of the oldest on the island (Line C)

Pole number[1]	Brand date[2]	Circum-ference	Preservative[3]	Depth of penetration	Depth of Sound wood	Termite attack[4]	Pole solid/hollow[5]
	Yr	*In.*		*In.*			
GPA 17		47	C	1.8	1.8	+	H
GPA 18	1962	47	C	1.9	1.9	+	H
GPA 19		48	C	1.8	1.8	+	H
GPA 20	1967	48	C	1.1	>4.2	–	S
GPA 21	1962	43	C	1.2	1.5	+	H
GPA 22		46	C	1.8	>4.0	+	S
GPA 23		50	C	1.6	1.6	+	H
GPA 24		47	C	1.2	1.4	+	H
GPA 25	1972	43	ACA	.9	>4.0	–	S
GPA 26	1957	48	C	1.5	>4.0	–	S
GPA 27	1957	48	C	1.2	1.2	+	H

[1]Number refers to field record book, not to utility line number.

[2]No entries were made where information could not be read on the brand.

[3]ACA = ammoniacal copper arsenate; C = creosote.

[4]+ = visual evidence of termite attacks; – = no termite attack observed.

[5]S = solid; H = hollow.

Table 7.—Condition of 11 consecutive, 30- to 45-foot, Douglas-fir poles in a rural line at the northern end of Guam (Line D)[1]

Pole number[2]	Brand date[3]	Circum-ference	Preservative		Retention		Termite attack[5]	Pole solid/ hollow[6]
			Type	Pene-tration	On brand	By assay[4]		
	Yr	*In.*		*In.*				
1	1972	48	CCA	1.7		0.7	–	S
2	1971	46	CCA	1.1		.4	+	H
3	1966		C		8		–	S
4		44	ACA	1.2		.6	–	S
5			CCA	2.2		.5	+	H
6	1965	41	C	1.9		5.7	+	H
7		51	P	1.7		.7	–	S
8	1965	40	C	1.6		13.0	–	S
9		37	C	4.2	8	10.7	–	S
10		41	P	1.4		0.2	–	S
11		([7])	C	3.0		5.0	–	S
12		43	C				–	S

[1]This area was never urbanized. Omissions in table occur where no measurements were taken.

[2]Numbers refer to poles examined, not the utility line number.

[3]0nly information that was legible on the brand is entered. Where information couldn't be found or read on brand, no entry is made.

[4]Assay results are reported for a single core only. No assay was made on poles 3 and 12. Assays for pentachlorophenol were by the lime ignition method.

[5]+ = visual evidence of termite attacks; – = no termite attack observed

[6]S = solid; H = hollow.

[7]The eleventh pole in this series is not a Class 1 Douglas-fir pole. It was identified from wood anatomy as being "yellow pine."

Table 8.—Condition of 10 consecutive poles that received soil treatments with 2 percent chlordane for termite control as poles were being set in line in 1969 (Line E)[1]

Pole number[2]	Brand date	Circum-ference	Wood species and preservative[3]	Length	Depth of preservative	Preservative retention by assay[4]	Termite attack[5]	Pole solid/ hollow[6]
	Yr	*In.*		*Ft*	*In.*	*Lb/ft³*		
14	1960	38	DF-C	40	1.5 1.6	3.6	–	S
15	1971	48	DF-P	55	2.5 2.4	.3	–	S
16	1965	43	WL-P	40	.8 1.0	.5	–	S
17	([7])	38	DF-C	([7])	1.6 2.4	6.1	–	S
18	1965	42	WL-P	40	1.2 1.3	1.1	–	S
19	1962	40	DF-C	40	.6 .5	1.8	–	S
20	1961	38	DF-C	45	1.6 1.8	2.9	–	S
21	1969	46	DF-P	60	2.0 1.6	.1	–	S
22	1962	37	DF-C	40	1.0 1.6	9.1	–	S
23	1961	41	DF-C	([7])	2.1 2.3	6.3	–	S

[1]Coauthor Mr. Lauret observed the soil treatment of poles in this line segment which is located along the edge of a wooded area. All poles were sound at this inspection.

[2]Pole numbers refer to numbers in field record book, not to utility pole number. Pole No. 15 is presumed to be a replacement pole.

[3]DF = Douglas-fir; WL = western larch; C = creosote; P = pentachlorophenol in oil.

[4]Assay of two cores taken 90° apart, 6 in. above grade. Assay zones were 0.25 to 1.0 in. from surface for DF; 0.1 to 0.6 in. from surface for WL.

[5]+ = visual evidence of termite attacks; – = no termite attack observed.

[6]S = solid; H = hollow.

[7]Omissions occur where information could not be read on brand.

Table 9.—Condition of 10 consecutive, pentachlorophenol-treated, 40-foot southern pine poles in a line through a residential area in central Guam (Line F)[1]

Pole number[2]	Brand date	Circum-ference	Preservative retention[3]	Exterior of pole 0 to 6 inches below grade	
				Termite attack[4,5]	wood soft or firm[6]
	Yr	*In.*	*Lb/ft*^{3}		
24	1979	47	[7]0.46	+	S
25	1979	42	[7].54	–	S
26	1979	43	[7].49	–	S
27	1979	41	[7].43	–	F
28	1979	42	[7].41	–	S
29	1979	44	.39	–	S
30	1979	42	.56	–	S
31	1979	43	.66	–	S
32	1979	44	7.20	+	S
33	1979	44	.41	Grazing, but no active infestation	S

[1] Information on pole species, height, and preservative treatment recorded from brand.

[2]Numbers refer to entries in field record book, not to utility number of poles in line.

[3]Increment cores, taken from poles in the field, were analyzed by the lime ignition method. Preservative penetration appeared to meet or exceed requirements of Federal Specification TT-W-571, but this was difficult to verify in the field with indicator solutions.

[4]Formosan termites (*Coptotermes formosanus* (Shiraki)).

[5]+ = visual evidence of termite attack; – = no termite attack observed.

[6]Softened wood (either due to decay or soft rot) usually occurred from 2 to 6 in. below grade, but in pole No. 24 it extended to several inches above ground. Radial depth of softened wood was from 1/8 to 1/4 in. S = soft; F = firm.

[7]Average of independent analysis on each of two cores (three cores for pole No. 24). Values reported for poles 21, 29, 30, 31, and 33 are for individual cores. Assay zone is 0.5 to 2.0 in. from surface.

The majority of poles installed more than 12 years ago were pressure treated with creosote. Poles treated with pentachlorophenol were used to a lesser extent. More recently, poles treated with the waterborne preservatives ACA or CCA have also been used. No estimate was made of the relative proportions of each type of preservative that exists within the total population of poles.

Formosan termites have destroyed the central core of heartwood in many of the preservative-treated Douglas-fir utility poles present in lines on Guam (tables 3,4,6,7,10,11). This occurs in poles of small diameter (table 10) as well as in larger poles (tables 3,4,6,7,11). Nevertheless, some poles survive (tables 4,6), even in old lines with severe termite attack. We estimated that up to 20 percent of creosote-treated Douglas-fir poles in old lines are not attacked by termites.

Soil Treatments

Ninety percent of the Douglas-fir and western larch poles that received a soil treatment with 2 percent chlordane as the poles were set in line were sound after approximately 14 years in service, even though some of the residual preservative retentions appear rather low (table 8).

Creosote

Douglas-fir utility poles that are pressure treated with creosote, and which do not receive a supplemental soil treatment, are susceptible to attack by Formosan termites. Termites can destroy the internal, untreated heartwood throughout the length of the pole (figs. 2a,2b), but do not attack the peripheral ring of creosote-penetrated wood. Creosote in the peripheral ring of wood, which is penetrated during pressure treatment, adequately protects that wood from attack by decay fungi, termites, and other insects. Analytical results for creosote and pentachlorophenol content that are derived from a small number of cores/pole are not exact. Still, values for composites of three or more cores from the same pole indicate a substantial loading of creosote. A seven-core composite showed 9.1 lb/ft^3 in the assay zone of another Douglas-fir pole that was attacked by termites (fig. 3). All poles are presumed to be treated with creosote and not with creo-penta mixtures. We saw no brand indications for creo-penta mixtures, and we did not detect any high chlorine contents in our chemical analyses.

Table 10.—Condition of small, creosote-treated, Douglas-fir poles observed at different locations on Guam

Pole number[1]	Brand date[2]	Circum-ference	Class[2]	Length[2]	Depth of Preservative penetration	Depth of Sound wood	Termite attack[3]	Pole solid/ hollow[4]
	Yr	*In.*		*Ft*	*In.*	*In.*		
GPA 3		34			1.5	1.5	+	H
GPA 4		35		40	1.6	>4.0	–	S
GPA 5		31			1.5	1.5	+	H
GPA 41		34	5	45	1.8	>4.5	–	S
GPA 44	1966	31	5		1.4	>4.5	+	S
GPA 45		30	5		1.5	>4.5	–	S
GPA 46	1964	29	4	30	.9	.9	+	H
GPA 47	1965	28		30	1.9	>4.2	–	S
GPA 48	1953	29	5	25	1.9	>4.5	–	S
GPA 49	1965	33	4	35	1.5	>4.5	–	S

[1]Poles 3, 4, and 5 were in an abandoned housing area. They probably were installed in the mid-1950's. Pole 41 was in a rural area. Poles 44 to 49 were in a city. All pole numbers refer to entries in record book: they are not actual utility numbers.

[2]0nly information that was legible on brand or tag is entered.

[3]+ = visual evidence of termite attack; – = no termite attack observed.

[4]S = solid; H = hollow.

Table 11 .—Condition of Douglas-fir poles on Guam examined individually or in small groups

Pole number[1]	Brand date	Circum-ference	Preser-vative	Depth of Preservative penetration	Depth of Sound wood	Termite attack[2]	Pole solid/ hollow[3]
		In.		---------- *In.*	----------		
GPA 28	1968	39	C	0.8-1.5	1.0-2.0	+	H
GPA 29	1968	40	C	.8-1.5	.8-1.5	+	H
GPA 30	1968	42	C	a. 1.8	1.8	+	H
				b. 1.8	1.9		
				c. 1.4	1.6		
				d. 1.8	2.0		
				e. 1.5	1.6		
GPA 31		33	P	2.0	>5.0	–	S
GPA 32	1968		C	1.4	>5.0	–	S
GPA 33	1962	37	P	1.5-2.1	>5.0	–	S
GPA 34	1958	41	C			–	S
GPA 35	1974	49	CCA	1.1	>5.0	+	S
GPA 36	1976	48	ACA	0.9	>5.0	–	S
GPA 37	1972	55	ACA	2.1	>5.0	–	S
GPA 38	1972	49	ACA	1.6	>5.0	–	S
GPA 39		47	ACA			–	S
GPA 40	1972	48	ACA			–	S

[1]Pole numbers refer to numbers in record book, not to utility number of poles in line. Poles of unique interest: GPA 28, 29, and 30 are three Douglas-fir poles that were creosote-treated in 1968, set in service for at least 10 years in Guam, and removed from service in March 1984 because of attack from Formosan termites.

GPA 31 and 32 are two sound Douglas-fir poles that were located in vicinity of 28-30. Note that poles GPA 30 and 32 have equivalent preservative penetrations.

GPA 33–sound pole that was recently taken down.

GPA 34–sound pole in front of shopping center.

GPA 35–CCA pole along road at north end of island. We stopped for an inspection when we spotted pole.

GPA 36 through 40–five consecutive ACA-treated Douglas-fir poles on west side of island near north end. No increment cores were taken from GPA 39 and 40.

[2]+ = visual evidence of termite attack; – = no termite attack observed.

[3]S = solid: H = hollow.

The amount of solid wood remaining in termite-attacked, creosote-treated, Douglas-fir poles represented the depth of preservative penetration. The minimum depth of solid wood in all standing poles that were attacked by Formosan termites was always more than 1 inch. However, less than 1 inch of creosote penetration was observed in one sound pole that was protected from subterranean termite attack by a supplemental soil treatment applied at time of pole installation (table 8).

Some of the old, but sound, creosote-treated Douglas-fir poles had internal rings filled with preservative. Often, these rings were several inches from the peripheral band of treated wood (fig. 4). This pattern was not observed in all creosote-treated poles that were sound, but did occur with sufficient frequency to give an impression that deep penetration of creosote into checks, shakes, or other internal voids contributed to long-term durability of poles in line.

The old line (table 6) of creosote-treated Douglas-fir was comprised of mostly hollow poles. This line was heavily supported with guy wires, which probably contributed to the line's survival.

Pentachlorophenol in Petroleum Oil

Mixed results were observed on poles treated with pentachlorophenol in petroleum oil. Penta treatments on western pole species (tables 2,3,5,7,11) usually were extremely dark brown to almost black. These poles had been in line for 7 or more years. No decay was observed below grade on penta-treated western poles in lines A or E. Lines B and D were not examined below grade. With some of the penta-treated Douglas-fir poles, Formosan termites attack the heartwood in the same manner as they attack heartwood in creosote-treated poles.

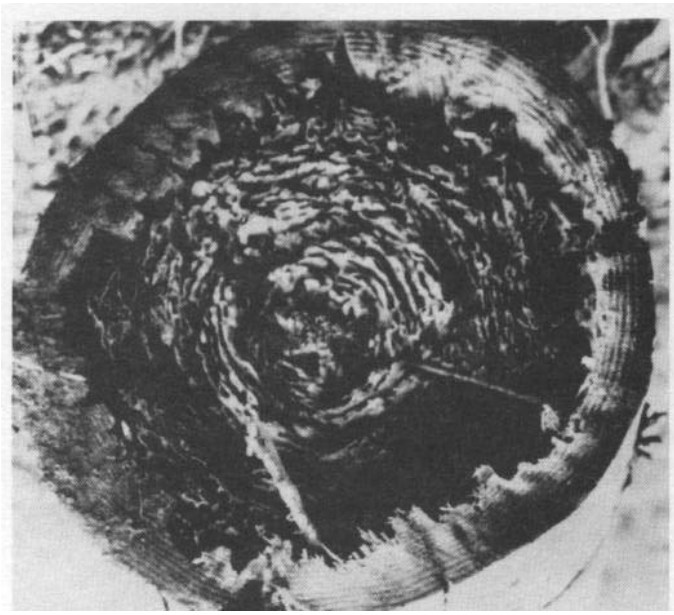

Figure 2a.—Cross section of creosote-treated Douglas-fir utility pole that was attacked by Formosan termites, C. formosanus. *The central core of heartwood was destroyed and has been replaced by termite-produced "carton." (M84 0175)*

Figure 3.—Replacement poles are *customarily installed next to the base of old, termite-infested poles. The creosote retention in the assay zone of the termite-attacked pole being removed was 9.1 lb/ft^3 This was determined from* a *composite of seven increment cores. (M84 0180)*

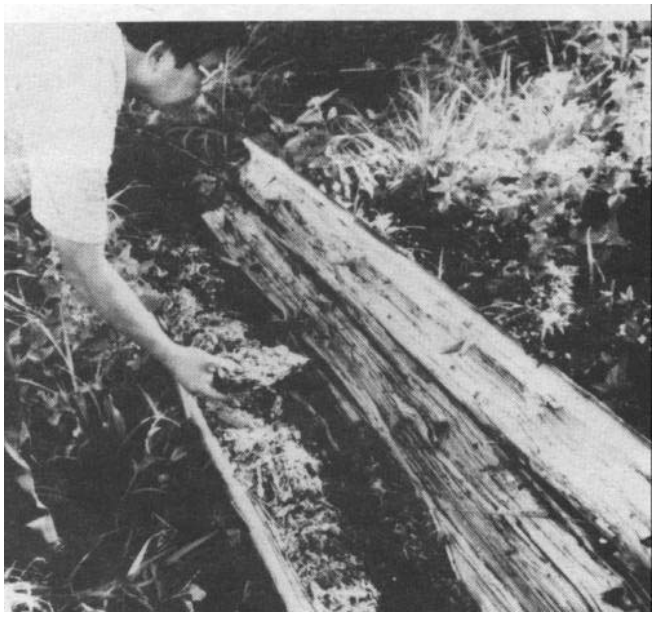

Figure 2b.—Section of creosote-treated Douglas-fir pole that has been attacked by Formosan termites. Termites destroyed the heartwood throughout the length of the pole. (M84 0178)

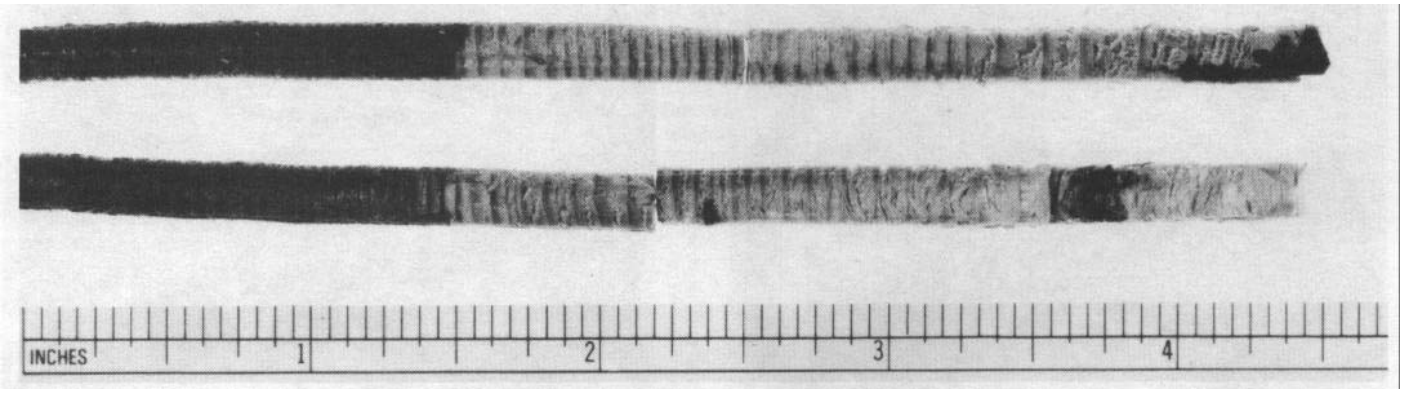

Figure 4.—Increment borings from sound, creosote-treated Douglas-fir poles. Isolated loadings of creosote deep within the pole are evident. This pattern was often seen in sound poles. (M84 0113)

Nine of 10 penta-treated southern pine poles (line F, table 9) that were examined had external soft rot (fig. 5) below grade. Two of the ten poles were also being attacked by Formosan termites. In contrast to creosote-treated Douglas-fir poles, termite attack was on the exterior of the pentachlorophenol-treated southern pine poles (fig. 6). On southern pine poles, termite attack appeared to follow attack by soft-rot fungi. These poles were treated in 1977. Thus they are rather new poles. Chemical analyses indicate that the retention level of pentachlorophenol in those poles probably met standards (table 9).

Chromated Copper Arsenate

Twelve CCA-treated Douglas-fir poles were examined in utility lines. Six of these were attacked by Formosan termites (Tables 2,7,11). Channels that had been excavated by Formosan termites were observed in treated sapwood of Douglas-fir poles (fig. 7). In some CCA-treated Douglas-fir poles that had Formosan termites in the heartwood, the residual amount of sound wood at the perimeter of the pole was occasionally as little as 0.5 inch. Whether this reflected poor preservative penetration or destruction of treated wood by the colony of termites in the heartwood could not be determined.

Ammoniacal Copper Arsenate

Ten ACA-treated Douglas-fir poles were examined in line. None of these was attacked by Formosan termites (tables 2,6,7,11). Five of these ACA-treated poles (table 11) were part of a longer series of ACA poles on the northeast side of the island.

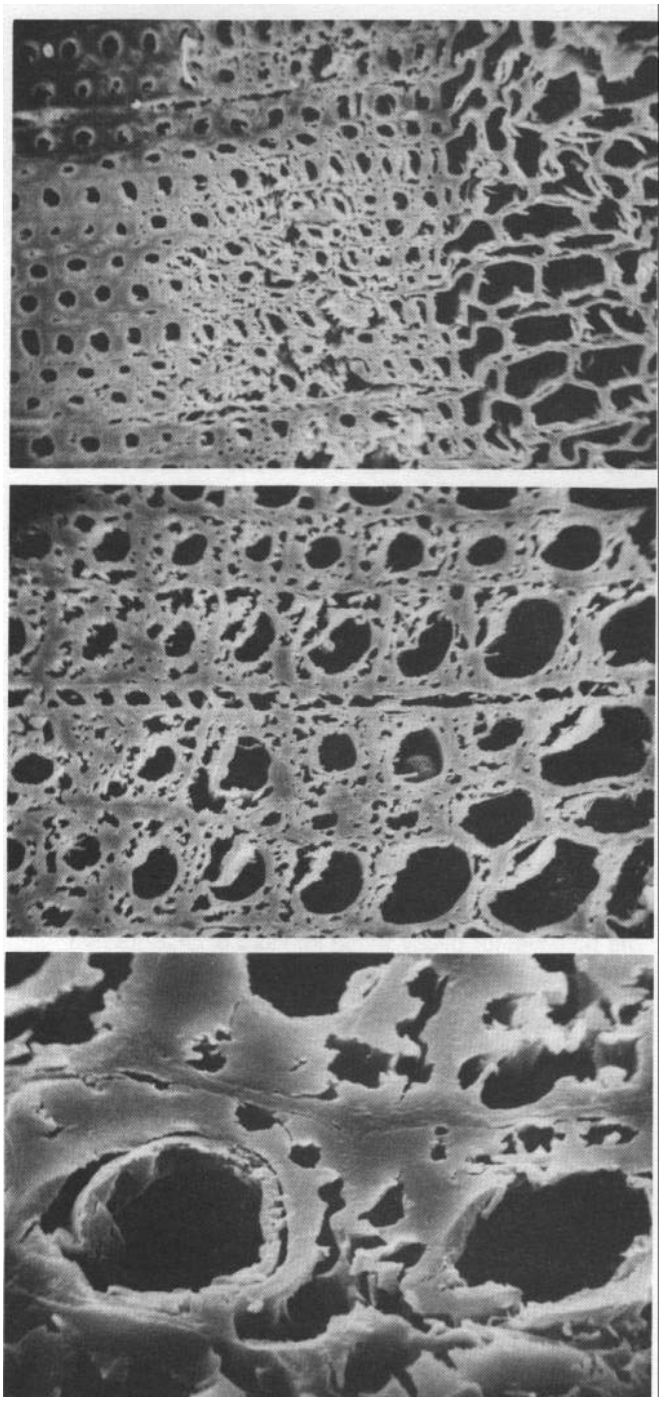

Figure 5.—Scanning electron micrographs of transverse sections of wood collected below grade from exterior of southern pine poles treated with pentachlorophenol in petroleum solvent. (A) Boundary between soft-rotted wood and unattacked wood within latewood of an annual ring, (B) Latewood showing uniformity of attack, where it occurs, and (C) Soft-rot cavities within S_2 layers of fiber cell walls. (M85 0107)

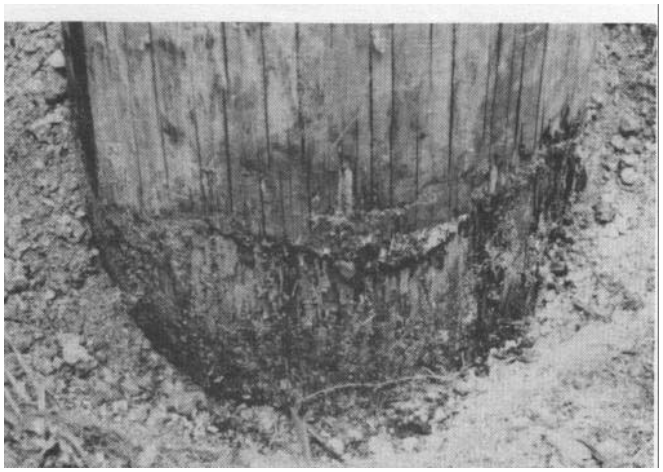

Figure 6.—Termite attack observed below grade on a pentachlorophenol-treated southern pine poles. (M84 0382)

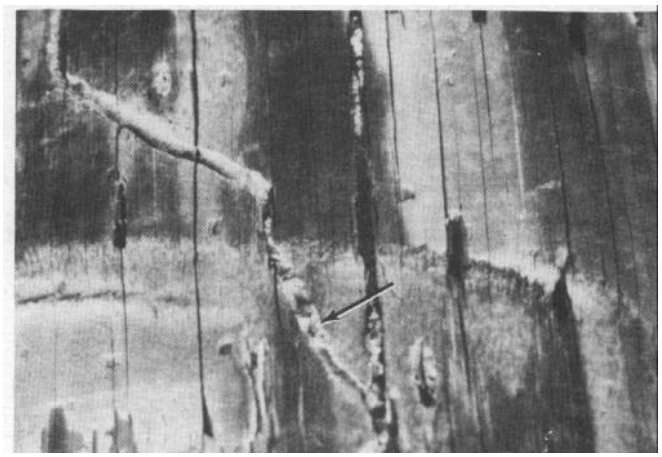

Figure 7.—Formosan termite channels (arrow) on exterior of CCA-treated sapwood of Douglas-fir poles. (M84 0176)

Discussion

About 20 percent of the poles, even in old lines, are not attacked by Formosan termites. Several factors could contribute to this; namely, repeated application of soil treatments around certain poles; extraordinarily deep penetration of preservative into internal voids within the poles as was noted with some creosote treatments (fig. 4); or feeding patterns of Formosan termites.

Dr. Minoru Tamashiro[4] believes that Formosan termites do not randomly search for food as is thought to be true for *Reticulitermes* spp. in the Southeastern United States. Instead, the Formosan termites have a more directed feeding pattern, which would explain why they might miss some items in a linear array (e.g., utility poles).

Replacement poles, however, are usually installed close to cutoff stubs of old termite-destroyed poles. Unless a soil treatment is used, an active termite colony in the old pole stubs probably would soon find the new pole. To maximize the life of replacement poles, the soil around the poles should be treated with an approved termiticide as the poles are set in line.

Creosote

We assume that the minimum depth of preservative penetration allowed in specifications (0.75 in.) was in effect when these poles were treated. The ring of sound wood in surviving, but termite-attacked, Douglas-fir poles consistently was more than 1 inch thick. Many of the termite-attacked Class 1 through 3 poles were supported in part by guys and adjacent poles in line. Even for poles with supplemental support, there seems justification in questioning whether a minimum of 3/4-inch penetration is adequate for creosote treatments of Class 1-3 poles.

Pentachlorophenol

Variations in the petroleum oils used with the different pentachlorophenol treatments may be one factor contributing to differences in performance of pentachlorophenol-treated poles (c.f. Baechler and Roth 1962, Duncan and Richards 1950, Gjovik and Gutzmer 1983 (table 17)).

Another factor to consider is the time between treatment and ultimate installation. Often, this is more than 1 year. That is not desirable for optimum performance of poles treated with oilborne preservatives, but long shipping and storage times are a reality for islands in the western Pacific.

[4]Dr. Minoru Tamashiro, Dep. of Entomology, Univ. of Hawaii, Honolulu, HI. Personal communication, March 1984. On file with Dr. DeGroot.

Chromated Copper Arsenate

With regards to termite attack of treated poles, a significant difference between CCA and creosote treatments is that creosote protects the peripheral zone of preservative-penetrated wood from attack by termites. CCA does not. Consequently, the zone of treated wood in CCA-treated poles cannot be regarded as a potential source of residual strength, once attack by Formosan termites begins.

We observed that creosote-treated sapwood of Douglas-fir poles was more resistant to attack by Formosan termites than that of the CCA-treated poles. We presume that this is because vapors of creosote treatments have some repellency effect, which the CCA treatment lacks. CCA is fixed within the treated sapwood, is odor-free, and leach resistant. As such, it has no repellency effect for termites, which can quickly pass through the shell of CCA-treated sapwood.

Utility personnel within the U.S. Navy Public Works Center have the impression that CCA-treated Douglas-fir poles on Guam are attacked more quickly than are poles treated with other preservatives. Would soil treatments with termiticides be as effective in protecting CCA-treated Douglas-fir as they are in protecting creosote- and pentachlorophenol-treated poles of that species? They probably would be; but in many residential settings, shrubbery or other materials contact aboveground portions of poles and provide a bridge over soil treatments. Where such bridges occurred, the lack of any repellency seemingly would allow ready colonization of the poles.

The potential for decay within interiors of CCA-treated Douglas-fir poles (Zabel, Lombard, and Kenderes 1980) would not be altered by soil treatments. That decay in CCA-treated Douglas-fir poles can be a serious problem in New York implies that potentials for wood decay should also be of concern in the Tropics. Therefore, we question whether current standards for CCA-treatment of Douglas-fir poles adequately address potentials for attack by both termites and decay fungi in the Tropics.

We make no extrapolation from observations of CCA-treated Douglas-fir poles to CCA-treated poles of other species. Whether Formosan termites will penetrate CCA-treated sapwood of thick sapwood species with a lesser volume of untreated heartwood as readily as they penetrate CCA-treated sapwood of Douglas-fir could not be determined in this inspection. We were unable to determine whether the termites went directly through the shell of treated wood from the outside of the pole or whether they only attacked the treated wood after a colony was well established within the pole.

Conclusions

Ammoniacal Copper Arsenate

ACA-treated poles are regarded by utility personnel in the U.S. Navy Public Works Center as being the most durable treated wood pole on Guam. Because of the lack of records on soil treatments around poles in line, we were unable to verify this impression. We observed an occasional ACA-treated pole, not in a utility line, that had termite attack. Nevertheless, we share the impression that ACA poles have relatively good durability where Formosan termites are present, but we cannot present a definitive argument to this point. Additional documentation is needed in areas where soil treatments were never used to better appreciate the durability of ACA-treated Douglas-fir poles.

Class 1 through 5 Douglas-fir utility poles that are pressure treated with creosote are susceptible to attack by Formosan termites. These termites can destroy the untreated heartwood on the inside of the pole but do not destroy the peripheral ring of treated wood. The level of creosote that was required by specifications for the assay zone provides adequate protection against termites and decay fungi for that peripheral ring that is penetrated by the preservative. Additional protection is needed for the interior heartwood.

Additional protection for creosote- and pentachlorophenol-treated Douglas-fir can be achieved by treating the ground around the pole with a termiticide when poles are set in line. Current specifications for pressure treatment of Douglas-fir poles with creosote and with pentachlorophenol, for use where Formosan or comparable species of termites are a hazard, should be supplemented with an additional requirement for soil treatment with an approved termiticide.

Current Federal specifications for treatment of Douglas-fir poles with CCA should be reviewed with regard to use in areas where Formosan termites are a serious hazard.

Additional documentation of the field performance of ACA-treated Douglas-fir poles is needed to determine whether this treatment more effectively protects the heartwood of Douglas-fir poles from attack by Formosan termites than do other preservatives.

Additional investigation is also needed to determine the cause of variation in durability of pentachlorophenol-treated poles. The early appearance of soft rot and termites in southern pine poles, seemingly with adequate retentions of pentachlorophenol, is of particular concern for poles exposed in environments such as that in Guam.

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