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ABSTRACT

Evaluation of previously established field trials of internal remedial treatments continues to verify the excellent long-term protection afforded by these treatments. Field trials with gell encapsulated methylisothiocyanate (MITC) demonstrate that gelatin does not interfere with chemical release, nor is addition of supplemental moisture required for release.

Field trials have been established to evaluate several new formulations including Basamid plus copper, boron/fluoride rods, and boron rods. Field trials of gelled and pelletized metham sodium indicate that both formulations are moving well through Douglas-fir poles one year after treatment. Evaluations of a copper naphthenate/boron paste for internal treatment indicate that the formulation has moved a short distance from the point of application 3 years after treatment.

Boron rod field trials were not fully sampled for residual chemical level this past year; however, evaluation of cores removed from fused borate rod trials in New York indicate that some additional boron diffusion has occurred. Examination of treatment holes suggests that considerable amounts of the boron remain in rod form 2 years after application.

In laboratory studies, we have evaluated the use of metham sodium/basamid mixtures and have found that these formulations provide enhanced MITC production over longer periods than either of the components alone. Both formulations were solid, creating the potential for development of safer formulations which provide a rapid release with long term protection. Field trials of these systems will be established in the coming months.

Studies also continue with Basamid in an effort to enhance decomposition of this compound. Studies have shown that moisture addition has the most significant effect on decomposition followed by the presence of copper and increasing pH. Further studies on decomposition products are planned to better understand the activity of this molecule.

Examination of Douglas-fir timbers treated with metham sodium indicate that MITC levels are similar to those found in poles at similar times after treatment. The presence increased surface area on timbers apparently did not adversely affect diffusion or chemical loss.

Evaluation of the fungitoxicity of mixtures of MITC and carbon disulfide is underway in an effort better understand the activity of metham sodium. This compound decomposes to produce a wide array of volatile compounds with varying degrees of toxicity to fungi. Preliminary trials have shown the relatively low toxicity associated with carbon disulfide, a major decomposition product, particularly under acidic conditions. Trials with mixtures will begin shortly.

Efforts to develop a three dimensional model of MITC movement are continuing. The model has been evaluated on data collected from small blocks and efforts are underway to verify these results. In

addition, full pole grids have been prepared to evaluate the effects of treatment hole geometry and orientation on fumigant movement.

Studies to identify alternative treatments for protecting western redcedar sapwood from decay are continuing. A variety chemicals have been shown to be effective 5 years after treatment; however, longer term trials of other formulations suggests that performance declines rapidly at longer time points. Field trials of remedial treatments for field drilled bolt holes continue to demonstrate the performance of diffusible boron and fluoride for preventing fungal attack. These trials will be evaluated again in the coming year.

Inspection of the above ground region of Douglas-fir poles in the Pacific Northwest have shown that many poles are colonized by decay fungi far above the groundline. Fungal incidence was greatest in poles near the coast, but decay fungi were also isolated from poles in drier climates. Sampling of additional poles is planned to provide a more detailed analysis of the risk of above ground decay in this region.

Efforts are also continuing to evaluate the performance of through-bored Douglas-fir poles to provide better data on the degree of preservative penetration required in the through-bored zone to achieve optimum performance. These trials have shown that most poles are well treated, but no decay has been detected in the through bored zone of poles with as little as 60 % of the through-bored zone treated. Efforts are also underway to evaluate penetration and retention of preservative in poles with various through-boring patterns.

Studies to identify optimum conditions for sterilization of air-seasoned Douglas-fir poles are continuing. These trials have evaluated pentachlorophenol in oil treatments. The results illustrate the value of long treatment cycles which incorporate Boulton-seasoning. The data from these trials will be used to construct heating curves for this treatment.

Trials of groundline preservative systems on Douglas-fir pole stubs continue to show that more recently developed formulations continue to move through the wood at rates which are similar to those found with older pentachlorophenol based systems. Trials in California on pine, Douglas-fir and western redcedar have provided similar results. Tests are now underway to establish thresholds for mixtures of groundline preservative formulations.

Copper naphthenate treated wood continues to perform well in both field and fungal cellar trials. Unweathered western redcedar stakes have tended to perform better than stakes which were weathered prior to treatment. These differences may reflect an increased permeability which enhances leaching.

ACKNOWLEDGEMENTS

The cooperative depends heavily upon the assistance of others in utilities, wood treatment facilities and allied disciplines to complete the outlined tasks. These contributions are essential for the success of the program and we gratefully acknowledge the numerous groups which have assisted us in the past year. We look forward to continued collaboration to enhance the performance of wood in utility systems.

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Electrical Utilities

- *Bonneville Power Administration
- *Central Lincoln P.U.D.
- *Empire State Electric Energy Research Corporation
- New York State Electric and Gas Corporation
- *Pacific Gas and Electric
- * Pacific Power Corporation
- * Puget Power
- Portland General Electric Company

*Western Wood Preservers Institute

- J. H. Baxter & Company
- Koppers Company, Inc.
- McFarland-Cascade Company
- Niedermeyer-Martin Company
- Taylor Lumber and Treating Company

*CSI, Inc.

*ISK Biotech

*OSMOSE Wood Preserving Inc.

*U.S.D.A. Forest Service, Forest Products Laboratory

*United Agricultural Products

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*Asterisk denotes funding. All supplied poles, hardware, or other assistance.

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OBJECTIVE I

DEVELOP SAFE ENVIRONMENTALLY ACCEPTABLE CHEMICALS FOR CONTROLLING INTERNAL DECAY OF WOOD POLES

While many utilities have incorporated either through-boring, kerfing, or radial drilling into their specifications to improve treatment in the groundline zone, millions of poles which have not received these pretreatment steps remain in service. As these poles season in service, untreated wood may be exposed in checks permitting the entry of fungi or insects and leading the development of internal decay. The development of effective remedial treatments for controlling internal decay was an important step in improving the performance of wood poles and these chemicals, including metham sodium (sodium n-methyldithiocarbamate) and chloropicrin (trichloronitromethane) are widely used by electric utilities, ports, and highway departments to arrest internal decay and extend wood service life.

While these treatments have been highly effective, the chemicals employed have some properties which users find objectionable. Chloropicrin is highly volatile and is a strong lacrymator. As a result, this chemical must be used while wearing a respirator and is generally only applied to poles not near inhabited structures. Metham sodium, while less difficult to handle, is caustic and will cause skin burns. This chemical is also extremely toxic to fish and should not be applied to wood over water or to wood in standing water.

The limitations presented with the existing fumigants have encouraged the development of safer, more controllable remedial treatments and this effort encompasses Objective I.

Table I-1. Characteristics of fumigants currently registered by the Environmental Protection Agency for application to wood.

Trade Name(s)	Active Ingredient	Concentration (%)	Toxicity (LD_{50})	Source
Timber Fume (Chloropicrin)	Trichloronitromethane "	96%	205 mg/kg	Osmose Wood Preserving Inc. Great Lakes Chemical Co.
Wood Fume	Sodium n-methyldithio-carbamate	32.1	1700-1800 mg/kg	Osmose Wood Preserving Inc.
Chap Fume	"			Chapman Chemicals Inc.
Vorlex	20% methylisothiocyanate 80% chlorinated C_3 hydrocarbons	99%	538 mg/kg	NorAm Chemical Co.
MITC-FUME	methylisothiocyanate	96%	305 mg/kg	Osmose Wood Preserving Inc.

A. EVALUATE PREVIOUSLY ESTABLISHED TESTS OF VOLATILE REMEDIAL INTERNAL TREATMENTS

Over the course of the initial fumigant project with the Electric Power Research Institute and the subsequent Cooperative Pole Research Program, we have established a number of field evaluations (Table I-2). These trials provide valuable data on field performance under actual exposure conditions. Such trials are evaluated annually until the desired information is obtained. For example, the original fumigant treatment trial was established in 1969 and was sampled for 20 years to determine when retreatment was required. The poles in this test were then retreated and the effectiveness of the retreatment was assessed for an additional 3 years. Once it was determined that retreatment was as effective as the initial treatment, the trial was discontinued.

1. Douglas-fir poles treated in 1977 with allyl alcohol, methyl-isothiocyanate or Vorlex: Douglas-fir poles located in the Willamette Valley in Western Oregon were sampled to determine the incidence of internal decay fungi. In 1977, poles containing uniform levels of infestation were then treated with 1 liter of allyl alcohol, 20 % methylisothiocyanate (MITC) in diesel oil, 100 % MITC, or Vorlex (20 % MITC in chlorinated C_3 hydrocarbons) applied to steeply sloping holes drilled at three equidistant sites around the pole near the groundline. The holes were then plugged and the chemicals presumably diffused upward and downward from the points of application. Each treatment was replicated on 9 poles, and an additional 9 poles were left untreated to serve as controls.

Table I-2. Active field trials evaluating the performance of selected remedial treatments.

Test Site	Chemicals Evaluated	Date Installed
Santiam-Toledo (BPA)	NaMDC, Chloropicrin, Vorlex®	1969
McGloughlin-Bethell (PGE) I	MITC	1977
Peavy Arboretum	field drilled bolt hole treatments	1981
Peavy Arboretum	cedar pole sprays	1981
Dorena Tap (BPA)	encapsulated Chloropicrin	1982
Hamburg Line (NYSEG)	encapsulated MITC	1982
McGloughlin-Bethell (PGE) II	encapsulated MITC	1983
Alderwood Tap (BPA)	encapsulated MITC	1987
Peavy Arboretum	encapsulated MITC (MITC-fume)	1987
Peavy Arboretum	Basamid	1988
Peavy Arboretum	copper naphthenate/boron	1989
Peavy Arboretum	Impel Rods	1989
Hilo, Hawaii (CSI)	Impel Rods	1990
Central Lincoln (CLPUD)	Encapsulated MITC	1990
Peavy Arboretum	Gelled NaMDC	1992
Owego, (NYSEG)	Impel Rods	1991
Peavy Arboretum	Preschem Rods	1993
Pacific Power	Basamid	1993

Chemical efficacy was assessed annually by removing 2 sets of increment cores from 3 equidistant sites around the poles 0, 1.2, 1.8 and 2.4 m above the groundline. The treated zone was removed from each core and discarded. The remainder of each core in the first set was placed into a plastic drinking straw which was labeled with the pole number and sample location, then stapled shut. The cores were returned to the laboratory where they were placed on the surface of 1.5 % malt extract agar in plastic petri dishes. Any fungi growing from the cores were examined for characteristics typical of basidiomycetes, a group of fungi containing many important wood decayers. Cores were examined for a minimum of 30 days.

The second set of cores were used to assess residual fumigant content of the wood using a closed tube bioassay. The outer and inner 25 mm segments of each core were individually placed into test tubes containing actively growing cultures of a test fungus, Postia placenta, on malt extract agar. The tubes were then sealed and incubated in an inverted position for 7 to 14 days so that the

Table I-3. Effectiveness of fumigants in Douglas-fir poles treated in 1977 as measured by culturing increment cores removed from the treated poles for the presence of decay fungi.[1]

		Number of poles containing decay fungi			
		Allyl		Methylisothiocyanate	
Year	Untreated	Alcohol/Vapam	Vorlex	20%[2]	100%
1977	9	9	7	9	8
1978	9	9	3	6	2
1979	9	9	4	4	0
1980	9	9	3	3	0
1981	5^{5}	6^{6}	0^{4}	1^{5}	0^{5}
1982	5	6	0	1	1
1983	5	6	0	3	2
1984	5	5	2	4	2
1985	4	5	1	2	1
1986	4	5	2	2	1
1987	3	3	2	1	2
1988	3	1	0	2	1
1989	[3]	[3]	1	2	0
1990	-	-	1	1	0
1991	-	-	2	3	1
1992	-	-	-	0	0

[1] Poles were treated with fumigants in 1977, and annually thereafter three cores were removed at five heights from the groundline and cultured for fungi. Superscripts denote poles remaining in test since 1981. Others were inadvertently treated with Vapam by a commercial applicator.

[2] Diluted in diesel oil.

[3] These poles were remedially treated with Vapam and were excluded from further testing.

Table I-4. Residual fumigant vapors in Douglas-fir poles 13 years after fumigant treatment as measured using a closed-tube bioassay.[1]

Meters above ground	Segment location from surface (cm)	Growth of the assay fungus (as % of control)											
		Vorlex				Methylisothiocyanate[2] 20%				MITC 100%			
		1989	1990	1991	1992	1989	1990	1991	1992	1989	1990	1991	1992
2.4	0-2.5	81	96	89	-	70	93	59	45	-	76	44	37
	12.5-15	65	93	63	-	76	100	42	72	65	100	70	92
1.8	0-2.5	49	90	57	-	100	87	54	54	57	83	93	44
	12.5-15	62	100	42	-	89	93	65	89	59	100	54	89
1.2	0-2.5	32	67	71	-	86	96	75	63	29	72	81	78
	12.5-15	92	99	62	-	98	90	42	65	62	100	38	74
0	0-2.5	54	96	65	-	81	72	57	55	27	79	69	22
	12.5-15	68	79	46	-	57	93	53	61	73	100	64	44
Control[3]	(no wood)	37	29	23	28	mm^2							

[1] For the closed-tube bioassay, a core was removed at each height from four to six poles. A 2.5-cm-long core segment was sealed in a test tube below an agar slant inoculated with Postia placenta. Suppressed growth of P. placenta compared to growth of the fungus where no wood was present (control) indicates the presence of fungitoxic vapors. Lower percentages indicate increased inhibition.

[2] In diesel oil.

[3] Average growth in 7-10 tubes.

wood was at the bottom and the fungus containing agar was at the top of the tube. Any fumigant in the wood can volatilize upward into the fungal colony where it should inhibit hyphal growth. Radial growth of the fungal colony is measured at the beginning and end of the test in the presence or absence of the fumigant treated wood. The closed tube bioassay is especially sensitive to low levels of fumigant and has been extensively employed in our field trials.

None of the cores removed from poles treated with 20 or 100 % MITC contained viable decay fungi at any of the locations sampled indicating that the chemical continues to protect the wood against fungal reinvasion (Table I-3). These results differ slightly from those found the previous year, where fungi were found in at least one pole in each MITC treatment (Figure I-1). The relatively low levels of fungi in poles 10 years after treatment are consistent with previous trials of Vorlex in Douglas-fir poles in the original BPA line. While these fungi are present, no decreases in residual shell thickness have been noted, suggesting that these fungi are not causing significant wood damage. The incidence of such fungi might be expected to vary with sampling since removing a sample with an inactive colony would have a lower probability of being detected each year from more active and therefore, more widespread infestations.

Closed tube bioassays of cores removed from the poles indicate that the wood has little residual fungitoxicity (Table I-4). Interestingly, the degree of inhibition was higher in the outer zones of the cores; however, this may reflect some contamination of core segments with chemical from the preservative treated zone rather than residual fumigant. The low levels of inhibition in the inner zones are consistent with previous results from this trial and indicate that retreatment of these poles will be necessary. The commercial applicator apparently sensed this need and treated all poles in the test. As a result, this trial has been discontinued.

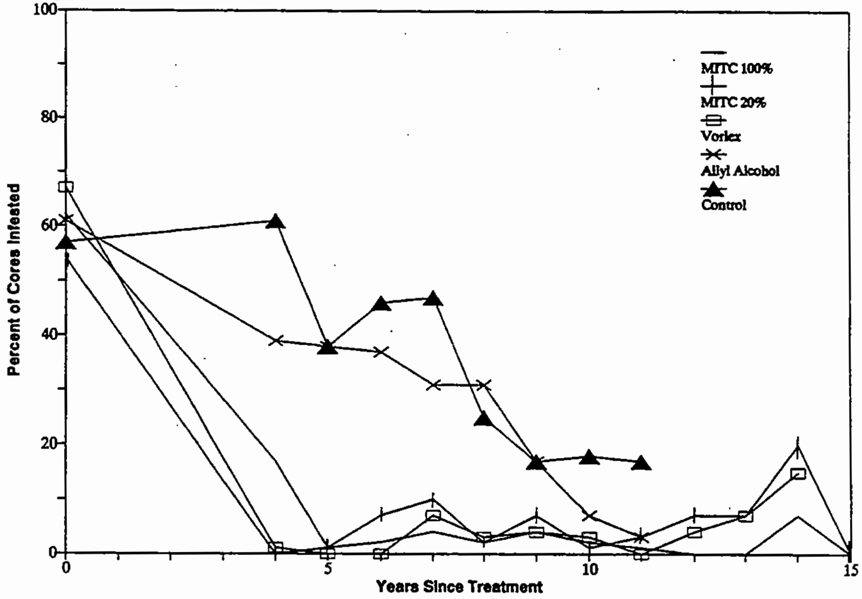

Figure I-1. Percent of cores removed from various sites on Douglas-fir transmission poles treated with Vorlex, 20 % MITC in diesel oil, 100 % MITC, or left untreated which contain basidiomycetes.

2. New York field test of encapsulated fumigants: The field test evaluating the efficacy of gelatin encapsulated MITC and Vorlex in CCA treated Douglas-fir poles ten years after application was reported on in last year's Annual Report (pages 3-5). These poles were not resampled this past year and will be resampled in 1994.

3. Effect of moisture addition on MITC release from gelatin capsules in Douglas-fir poles: The results obtained with gelatin encapsulated MITC in CCA treated Douglas-fir poles suggested that MITC release required 3 to 4 years for completion. In 1985, a field trial was initiated to determine if adding water to treatment holes at the time of application of gelatin capsules could speed chemical release and improve treatment efficacy.

Sixteen Douglas-fir poles were selected from a larger sample of poles based upon the presence of active internal decay. The poles were located in farmland between Salem and Gresham, Oregon, an area which receives most rainfall during the cooler winter months. Many of the poles contained active fungal infestations above the groundline in locations where moisture contents might be expected to vary seasonally.

A series of steep angled 1.8 cm diameter holes were drilled beginning at groundline and spiraling upward at 0.9 m and around the pole at 120 degree intervals. Each pole received 528 ml of gelatin encapsulated MITC equally distributed among the treatment holes. Holes in five poles received no water at the time of application, while five poles each received 40 or 80 ml of water per treatment hole.

The treatment holes were then plugged with tight fitting dowels to retard fumigant loss. Drill shavings were collected from each treatment hole and cultured on malt extract agar to provide a measure of the degree of fungal infestation at the time of treatment.

Fumigant efficacy was assessed annually by removing increment cores from 3 locations around the pole circumference at 0, 0.9, 1.8, 2.7, 3.6, 4.5, and 5.4 m above the groundline. The outer and inner 25 mm long segments of each core were used to detect the presence of residual MITC using the closed tube bioassay. The remainder of each core was cultured on malt extract agar for the presence of decay fungi.

This past year, the majority of the poles in the test were inadvertantly treated by a commercial inspector after our annual inspection. As a result, this test will be discontinued.

Culturing indicated that no viable decay fungi were present in any cores removed from the poles (Table I-5) (Figure I-2). Last year, only one core contained a decay fungus. As in previous years, there is no apparent difference in incidence of fungi between the three moisture regimes.

Closed tube bioassays indicate that residual fumigant vapors are present in all treatments at all heights sampled 9 years after treatment (Table I-6). Zones of inhibition appeared to be lowest near the groundline, suggesting that most of the chemical had diffused upward and out of the pole. The remainder of the samples indicate that the poles continue to exhibit evidence of residual fungitoxic vapors, particularly in the dry treatment.

Table I-5 Frequency of decay fungi isolated from Douglas-fir poles treated with gelatin-encapsulated methylisothiocyanate (MITC).

Sampling Date	Meters above Groundline	Cores with decay fungi (%)[1]		
		Dry	Moist	Wet
Sept. 1983	0	80	60	50
	0.9	100	100	83
	1.8	80	100	83
	2.8	60	67	67
	3.7	20	80	33
	4.6	20	40	17
Sept. 1984	0	60	0	20
	0.9	40	20	20
	1.8	0	20	0
	2.8	20	20	0
	3.7	40	20	40
	4.6	60	0	0
	5.5	20	20	40
Sept. 1985	0	0	0	0
	0.9	0	0	0
	1.8	0	0	0
	2.8	0	0	0
	3.7	0	0	0
	4.6	20	0	0
	5.5	0	0	0
Sept. 1986	0	-	-	-
	0.9	40	0	0
	1.8	0	40	60
	2.8	20	0	20
	3.7	40	0	20
	4.6	20	0	0
	5.5	40	0	0
Sept. 1987	0	0	0	0
	0.9	0	0	0
	1.8	0	0	0
	2.8	0	0	0
	3.7	0	0	0
	4.6	0	0	0
	5.5	0	0	10
Sept. 1988	0	0	0	0
	0.9	0	0	10
	1.8	0	0	0
	2.8	0	0	0
	3.7	0	0	0
	4.6	0	0	0
	5.5	10	0	0
Sept. 1989	0	0		
	0.9	0	0	0
	1.8	10	0	0
	2.8	0	0	0
	3.7	0	0	0
	4.6	0	0	10
	5.5	0	10	0
Sept. 1990	0	0	0	0
	0.9	0	0	0
	1.8	0	0	0
	2.8	0	0	0
	3.7	0	0	0
	4.6	0	0	0
	5.5	0	0	0
Sept. 1991	0	0	0	0
	0.9	0	0	20 (1 core)
	1.8	0	0	0
	2.8	0	0	0
	3.7	0	0	0
	4.6	0	0	0
	5.5	0	0	0
Sept. 1992	0	0	0	0
	0.9	0	0	0
	1.8	0	0	0
	2.7	0	0	0
	3.7	0	0	0
	4.6	0	0	0
	5.5	0	0	0

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[1] The initial fungal estimates were based on culturing of shavings collected during treatment hole drilling. Subsequent data has been based on culturing increment cores removed from sites opposite from the treatment holes. Either 0 ml (dry), 40 ml (moist), or 70 ml (wet) of water was added to each treatment hole to aid in fumigant release from the gelatin.

Table I-6. Fungal inhibition of increment cores removed Douglas-fir poles treated with 588 ml of MITC and varying degrees of water as shown by a closed-tube bioassay using Postia placenta as the test fungus.

Meters Above Groundline	Core Segment[b] (cm)	Avg Growth of Test Fungus (as % of control)[a]					
		DRY		MOIST		WET	
0	0 to 2.5	1991	1992	1991	1992	1991	1992
	10 to 12.5	20	46	53	4	69	0
		45	100	45	16	42	79
0.9	0 to 2.5						
	10 to 12.5	0	32	67	38	49	75
		66	100	32	86	15	93
1.8	0 to 2.5						
	10 to 12.5	54	0	57	52	49	0
		19	0	30	33	12	71
2.8	0 to 2.5						
	10 to 12.5	0	0	50	0	33	0
		5	46	15	52	24	11
3.7	0 to 2.5						
	10 to 12.5	0	0	42	42	26	0
		0	0	4	52	0	0
4.6	0 to 2.5						
	10 to 12.5	24	0	49	4	20	0
		0	29	12	29	0	68

Control tubes (no wood): Avg. = 26 mm (1988)/24 mm (1991)/28 mm (1992)

[a] The closed-tube bioassay used a 2.5 cm wood segment removed from the pole. These segments are placed in agar tubes preinoculated with an assay fungus, Postia placenta. Fumigant effectiveness is then evaluated as the ability of a wood sample to inhibit radial growth of the fungus and cores with low numbers have higher fumigant levels.

[b] Increment cores were divided into three segments: 0-2.5 cm, 2.5-12.5, and 12.5-1.5 cm. The middle segment was used for culturing, and the outer (0-2.5 cm) and inner (12.5-15 cm) segments were used for closed-tube assays.

[c] Control tubes showed poor growth in 1987, ranging from only 5 mm to 20 mm after 7 day's growth.

As in previous years, closed tube bioassays continue to demonstrate the presence of residual MITC in all of the treatment sites. Interestingly, the largest inhibition of growth of the test fungus was noted with the dry treatment. The bioassay is not directly quantifiable, but higher degrees of inhibition generally translate to higher chemical levels in the wood. The presence of higher levels of MITC in the poles which did not initially receive water may represent a benefit of slower release of MITC from the gelatin capsule. Slower release might permit a more uniform diffusion into the wood, while the presence of drier wood around the treatment hole might result in increased sorption of MITC from the capsule. Previous reports have shown that dry wood sorbs substantially higher quantities of MITC than comparable wet wood and that this sorbed chemical provides a reservoir for subsequent diffusion as the wood becomes wet. At present, the closed tube bioassays appear to reflect these effects, although the differences between the three treatment remain small and all treatments remain effective.

The results of the final inspection indicate that all three fumigant treatments continue to protect the wood. Initially, the wet and moist treatments provided slightly better fungal control than the dry treatment;

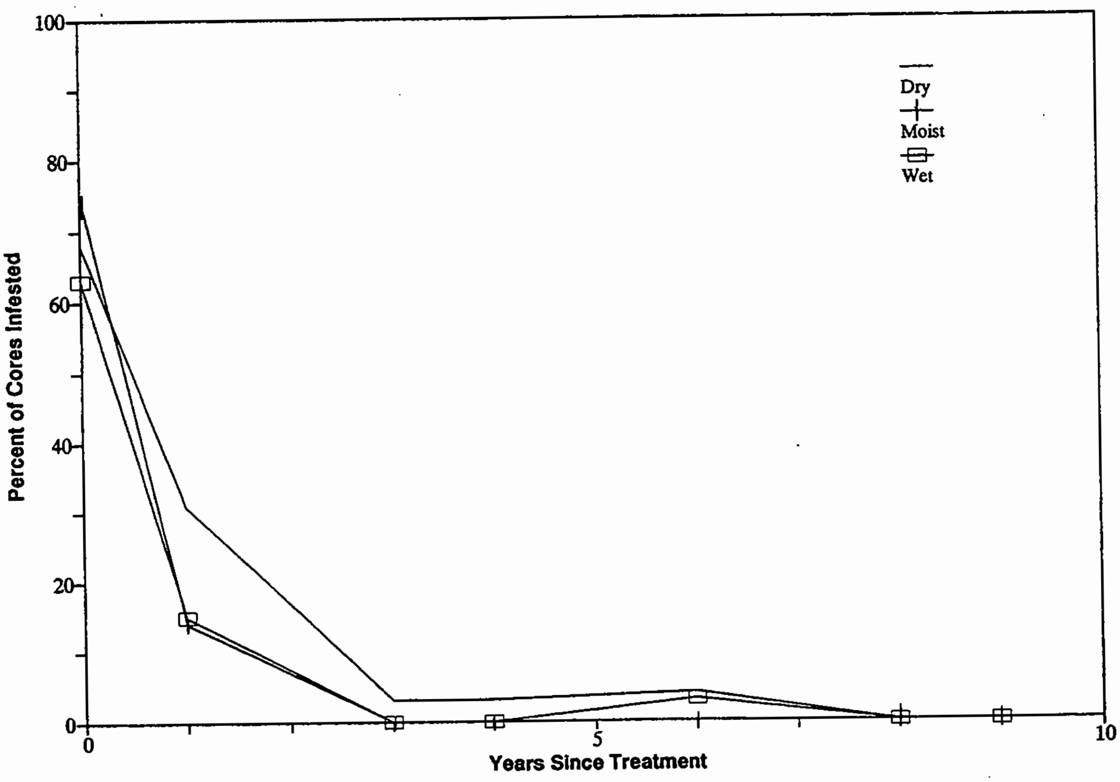


Figure I-2. Incidence of decay fungi in Douglas-fir poles nine years after treatment with gelatin encapsulated MITC and three levels of moisture.

however, this difference gradually disappeared and there is presently little difference between the three moisture regimes. Levels of fungal infestation remain uniformly low in all three treatments and at all positions above the groundline. These results closely follow those obtained with non-encapsulated MITC in the same line as well as those found with gelatin encapsulated MITC inthe New York study. These results indicate that addition of water at the time of treatment can produce slight improvements in the rate of fungal control, but these effects are only temporary. Where fungal attack was threatening the safety of a pole, such an increase in chemical release may be justified; however, this effect would be of minimal benefit in most situations where this chemical might be used.

4. <u>Treatment of through bored Douglas-fir poles with gelatin encapsulated MITC or chloropicrin</u>: A series of Douglas-fir poles were treated with gelatin encapsulated MITC or chloropicrin in 1982. These poles are inaccesible for a large part of the year and were not sampled last year as planned. The poles will be sampled in the coming weeks to assess chemical movement for each formulation.

5. <u>Above ground treatment with gelatin encapsulated or pelletized MITC</u>: Douglas-fir poles treated near the underbuilt

distribution portion of the pole were treated with either pelletized or gelatin encapsulated MITC in 1987. These poles were not sampled last year. Plans are underway to sample these poles in November of this year to provide 7 year data on performance of these systems above the ground.

6. Effectiveness of glass encapsulated MITC in Douglas-fir and southern pine poles: Douglas-fir and southern pine poles treated with MITC-Fume were evaluated using closed tube bioassays, GC analysis of chemical extracts this past year, and culturing of increment cores 1,2, and 3 years after treatment. No cores were examined in 1992, but the poles were inspected in 1993 to provide a five year assessment. At present, the results indicate that all dosages of MITC-Fume are outperforming the 500 ml metham sodium control treatment, although chemical levels in most treatments declined between the second and third year of the test. The results of the five year sampling will be reported in the next annual report.

B. EVALUATE PREVIOUSLY ESTABLISHED TRIALS OF NON-VOLATILE REMEDIAL INTERNAL TREATMENTS

While we have concentrated heavily on the identification of more effective wood fumigants, we have also examined several non-volatile diffusible fungicides including boron and fluoride based systems. Both boron and fluoride have significant advantages in terms of safety and ease of application, but there is relatively little data on the diffusion of these compounds in western wood species.

1. Ability of fused borate rods to diffuse through Douglas-fir heartwood: Douglas-fir poles sections were treated with 2 % chromated copper arsenate by dipping, then stored under cover for 24 hours to permit fixation to occur. A 1.9 cm diameter hole was drilled through the pole 40 cm from the top and a single galvanized bolt was inserted into the hole. A second 20 cm long hole was drilled 15 cm above the bolt and 40 or 80 g of fused boron rod (1 or 2 rods) was added. The holes were plugged with tight fitting dowels and the poles were exposed out of ground contact at Corvallis, OR or Hilo, Hawaii. Poles were sampled one year after treatment by removing increment cores from sites above and below the treatment hole. The results indicated that very little boron had diffused into the wood over the first year of the test at either exposure site. Discussions suggested that the boron may have diffused completely out of the poles after the first year; however, this past year, we examined the original treatment holes at the Corvallis test site. Generally, boron rod could be detected within 3 to 5 cm of the top of the treatment hole. These results suggest that the wood moisture contents over exposure period were inadequate for diffusion. However, moisture measurements near the rod sites ranged from 18 to 65%. The inability of the boron to diffuse through the wood from the initial treatment hole when exposed out of ground contact raises some concern about the efficacy of these systems for arresting and preventng decay above ground.

2. Performance of fused borate rods in groundline treatments of Douglas-fir poles in Owego, New York: As a part of the evaluations of fused boron rods as internal decay treatments, a second field trial of these materials was established at a site near Owego, NY. Douglas-fir poles were presampled by removing increment cores from sites near the groundline. These cores

were cultured for the presence of decay fungi and the poles were segregated into 4 treatment groups of 6 poles each. Poles received 3 (120 g) or 6 (240 g) fused borate rods and either 0 or 150 ml of water at the time of treatment. The poles were sampled 16 months after treatment by removing increment cores from 3 sites around each pole 0, 0.3, and 0.9 m above the groundline. Analysis of these cores for the presence of boron indicated that little boron movement have occurred over the test period ('92 Annual Report, pages 25-27). This past winter, additional cores were removed by NYSE&G personnel. Cores were moved from selected poles at sites located 150 mm above and 75 or 225 mm below the location of the rod application site. Cores were initially sprayed with the salicylic acid/curcumin indicator specific for boron. Cores were ground and extracted in hot water, then analyzed for boron using the Azomethine H method.

Positive reactions for boron were noted in cores removed from 75 or 225 mm below the treatment zone, while cores removed from 15 cm above this zone contained no evidence of boron. The results of the interim analysis indicated that boron was present at slightly higher levels than were noted in the 16 month sample. Boron levels were extremely low (<0.01 % boric acid equivalent (BAE)) 150 mm above the treatment site in two poles, indicating that little upward diffusion had occurred. Boron levels were considerably higher 75 mm below the treatment site in the groundline zone ranging from 0.59 to 0.68 % BAE. Boron levels 225 mm below the groundline were only 0.05 % BAE. The results suggest that some boron is diffusing away from the original treatment site; however, the levels remain extremely low away from a narrow zone around the hole. As a result, relatively little of the original boron dosage is available to arrest and prevent fungal attack, even in the wetter groundline zone. These results suggest that extreme caution should be employed when using boron as a the sole internal groundline protection agent with Douglas-fir poles.

These poles are currently being resampled to determine if additional boron diffusion has occurred.

C. EVALUATE PROMISING NEW REMEDIAL TREATMENTS UNDER LABORATORY CONDITIONS

As a part of the remedial treatment development process, we are continually screening new fumigants using our small scale block test. These trials provide a simple basis for assessing the effectiveness of a new system without the expense of performing extensive field trials. The small block test has been used to evaluate over 100 test formulations for this purpose.

1. <u>Performance of solid metham sodium/Basamid mixtures for controlling wood decay fungi</u>: Both Basamid and solid metham sodium have provided excellent protection in previous laboratory trials but each has characteristics which limit its usefulness. Solid metham sodium release MITC more slowly than the liquid formulation of this chemical, but this formulation may still prove to have a release rate which is more rapid than other fumigants. Conversely, Basamid decomposes too slowly to provide the rapid fungal control required in wood with active infestations. This past year, we evaluated the use of combinations of pelletized

metham sodium and Basamid to enhance fungal control while providing longer term protection against fungal invasion.

Douglas-fir heartwood blocks (25 by 25 by 100 mm long) were pressure-soaked with water, then steamed for 30 minutes at 100 C. After cooling, the blocks were taped on the transverse faces and dipped in molten paraffin. The tape was removed and a 25 mm square of agar cut from an actively growing culture of Antrodia carbonica was placed on the transverse surface of the block. The agar squares were in turn covered with 25 by 25 by 12.5 mm long Douglas-fir blocks and the entire assembly was held together using a rubberband. The blocks were placed on plastic rods over water in a plastic chamber where they were incubated for 6 weeks at room temperature. Holes (12.5 mm in diameter by 20 mm long) were drilled at the center of the radial or tangential face of the blocks and measured amounts of pelletized 40 % metham sodium or Basamid were added to the holes. Blocks received 300 mg of chemical and the ratios of chemical were varied from 0:10, 1:9, 2:8, 3:7, 4:6, and 10:0 of metham sodium to Basamid. The treatment holes were then plugged with a tight fitting rubber septum and incubated at room temperature in an apparatus which permitted air to flow over the blocks to prevent buildup of fungitoxic vapors in the chamber.

After 1, 4, or 8 weeks, three blocks were removed from each treatment group for analysis. The outer blocks were removed and a series of three 5 mm thick sections were cut from each end of the block. The first was discarded, while the remaining two were cut into 16 equal sized sections. The inner 4 sections of the first wafer were placed on the surface of malt extract agar plates and observed for evidence of growth of the test fungus. Fungal survival was used as a measure of chemical efficacy. The inner 4 squares from the innermost wafer were placed into 5 ml of ethyl acetate and extracted for 48 hours at room temperature. The resulting extracts were analyzed for residual MITC by gas chromatography as previous described. The results provided an approximate measure of the levels of chemical required to eliminate decay fungi established in the wood after selected exposure periods as well as the typical residual chemical levels found in the material at those same time points.

Fungal survival varied widely over the treatments; however, much of this variation reflected contamination of the blocks with inhibitory Trichoderma spp. due to the use of blocks which had been exposed to decay fungi for too long before testing. As a result, the fungal survival results are of only minimal value and will not be discussed further.

Chemical assays proved more useful in this trial. As expected, basamid alone was associated with the lowest residual MITC levels while the metham sodium alone treatment was associated with the highest levels of this chemical after 1 week (Table I-7). MITC levels in metham sodium treated blocks were over 10 fold higher after 1 week than those found in Basamid treated materials. MITC levels increased steadily with increasing levels of metham sodium, although the linear relationship between increasing metham sodium level and higher residual MITC did not hold above the 40:60 ratio of metham sodium: Basamid level. These results suggest that decomposition of metham sodium at higher dosages may be limited by some external factors.

Table I-7. Residual MITC levels in Douglas-fir blocks 1,4, or 8 weeks after treatment with mixtures of pelletized metham sodium and Basamid.

Chemical Treatment/Block		MITC content (ug/g wood)[a]		
Basamid (mg)	Metham sodium (mg)	1 week	4 weeks	8 weeks
300	-	21.75 (6.49)	27.84 (19.38)	339.95 (83.26)
-	300	340.49(125.66)	21.83 (29.70)	36.27 (30.97)
270	30	88.05 (16.97)	103.48 (72.15)	250.99(209.05)
240	60	123.79 (29.74)	103.91 (43.17)	84.94 (25.12)
210	90	263.54 (94.80)	206.81 (70.44)	300.97(251.74)
180	120	282.97 (55.06)	298.17 (123.46)	183.00(114.71)

[a] Values represent averages of 8 replicates/time point. Values in parentheses represent one standard deviation.

MITC levels declined sharply over the exposure period in treatments receiving metham sodium alone, reflecting a rapid decomposition followed by slow evolution from the wood. These results were similar to those noted in earlier trials. MITC levels in Basamid treated blocks increased slightly over the exposure period, reflecting the slow but steady decomposition of this chemical in wood. Chemical levels in blocks receiving combinations of the two chemicals followed a different trend. These treatments experienced little or no loss of chemical over the first four weeks of exposure suggesting that the combination systems were producing a steady decomposition to MITC. The more stable MITC levels in the blocks over the treatment period was particularly interesting since combination treatments of two solid chemicals may provide a far safer approach to remedial internal treatment. Further trials of these mixtures are planned.

D. EVALUATE PROMISING NEW REMEDIAL TREATMENTS IN FIELD TRIALS

While laboratory trials are useful for identifying potential remedial treatments, field performance provides the ultimate measure of activity. The Cooperative has generally attempted to move potential new treatments to field trials as rapidly as possible, given the constraints of developing useful laboratory data on dosage and treatment parameters.

1. <u>Preliminary field trials using the solid fumigant Basamid amended with selected additives</u>: Basamid is a solid, crystalline compound (3,5-dimethyl-tetrahydro-1,3,5,2H-thiadiazine-2-thione) which has been used for soil treatments. This compound decomposes to produce a number of fungicides, including methylisothiocyanate, carbon disulfide, and methylamine. In previous studies, Basamid has provided some remedial protection against fungal attack, but the decomposition rate of this compound is too slow for it to be effective against actively growing infestations in a time period that would prevent signficant wood damage.

Basamid decomposition, however, can be enhanced by a number of factors, including pH and the presence of metals. The potential for employing additives to alter Basamid breakdown to MITC was evaluated on 80 untreated, air-seasoned Douglas-fir pole stubs (200 to 250 mm in diameter by 1.6 m long). Three holes (22 mm in diameter by 30.5 mm long) were drilled at a 60 degree angle 700, 800, and 900 mm from the base of each stub. Holes were rotated 120 degrees around the circumference from the preceeding hole. Each hole received 50 g of Basamid alone or amended with 1 % copper sulfate, 10 % glucose, 10 % ammonium lignin sulfonate, or 5 % sodium octaborate. Other poles received Basamid with 50 ml of ethanol, acetone, methanol, or water. All powdered additives were tested with or without 5 % powdered pH 12 buffer. The pole stubs were capped with roofing felt to limit top wetting and were placed above ground on a test fence at the Peavy Aboretum test site. Each treatment was replicated on five stubs. Control poles with no treatment or treated with 150 ml of metham sodium per hole were also installed.

The pole stubs were sampled 6, 12, 24, and 36 months after treatment by removing increment cores (5 mm diameter to the pith) from 3 equidistant sites around the stub 150 mm above or below the treatment zone. Additional cores were removed from sites 450 mm above or below the treatment holes 12, 24, or 36 months after treatment. The inner and outer halves of each core were placed into 5 ml of ethyl acetate and extracted for a minimum of 48 hours at room temperature. The extracts were then analyzed by gas chromatography using a Varian 3700 Gas Chromatograph equipped with a flame photometric detector and filters specific for sulfur compounds. MITC content was used as the measure of Basamid decomposition efficiency. GC conditions were as follows: injector temp. 150 C, column temp. 100 C, detector temp. 240 C, carrier flow rate: 30 ml/min nitrogen, and a glass column (2 mm inner diameter x 2 m long) packed with 10 % Carbowax 20M on 80/100 Supelcoport.

In previous reports, we have noted the effects of both copper compounds and pH 12 buffer on enhancing MITC levels. This past year, MITC levels in all treatments generally rose, possibly as a result of the very wet weather which was experienced in the past year (Table I-8). The test site had experienced several years of below average rainfall which might have sharply reduced the moisture available for decomposition.

As in previous years, the levels of MITC were highest in the Basamid plus copper sulfate and pH 12 buffer treatment, followed by the same treatment without buffer. Interestingly, both Basamid plus boron with pH 12 buffer or glucose without buffer were associated with residual MITC levels which were similar to those found with copper sulfate. MITC levels were slightly lower in the Basamid plus glucose and pH 12 buffer treatment, indicating that the increased pH slowed Basamid decomposition in the presence of sugar. In previous years, these treatments were associated with lower MITC levels, suggesting that the increased moisture levels present over the past year may improve the performance of some additives. These effects are under further study in laboratory trials.

The results indicate that copper sulfate alone or in combination with a high pH buffer continues to provide the best improvement in residual protection afforded by Basamid treatment.

Table I-8. Mean values for MITC distribution in Douglas-fir pole sections (n - 15 core segments) 1 to 3 years after internal treatment with metham sodium or Basamid amended with selected additives.

Treatment	pH 12[b]	Time since treatment (mo)	µg MITC/g wood (ovendry)[a]								
			Distance Above treatment zone				Distance Below treatment zone				All Measurements (n - 120)
			45 cm		15 cm		15 cm		45 cm		
			Outer	Inner	Outer	Inner	Outer	Inner	Outer	Inner	
Metham sodium	-	6	--	--	113.3	195.6	173.4	104.2	--	--	147
	-	12	9.6	79.1	29.9	80.4	19.8	54.5	12.2	34.5	40
	-	24	8.4	15.7	5.0	21.3	5.3	14.3	2.3	5.0	10
	-	36	1.7	3.7	5.3	10.6	4.3	3.5	2.5	3.1	4
Basamid alone	-	6	--	--	9.5	16.6	12.9	19.9	--	--	14
	-	12	5.2	13.7	9.7	10.8	5.9	26.5	1.1	5.6	10
	-	24	2.6	3.7	4.1	8.1	6.1	7.7	3.8	3.1	5
	-	36	11.6	14.8	6.0	20.0	15.3	60.7	9.7	12.4	18
	+	6	--	--	9.3	14.6	16.4	100.5	--	--	44
	+	12	0.0	5.7	0.2	13.5	11.0	44.8	0.1	10.8	11
	+	24	0.0	0.6	0.0	7.2	3.6	32.5	1.7	8.3	7
	+	36	3.1	5.8	10.9	21.9	24.9	49.0	9.3	16.6	18
Basamid plus copper sulfate	-	6	--	--	15.9	45.9	10.2	39.1	--	--	27
	-	12	20.8	17.8	11.2	45.7	13.5	48.6	0.0	3.9	20
	-	24	5.9	9.1	10.3	47.1	11.7	66.7	0.4	6.8	20
	-	36	3.4	12.7	34.1	104.9	43.1	95.2	14.5	5.4	39
	+	6	--	--	55.3	58.1	90.5	95.4	--	--	75
	+	12	8.2	76.3	22.0	120.8	21.4	203.1	6.7	64.3	65
	+	24	49.2	47.6	69.9	63.9	99.7	96.5	95.8	124.5	81
	+	36	50.1	48.5	60.7	59.4	72.1	69.6	79.9	78.9	65
Basamid plus glucose	-	6	--	--	7.6	13.2	1.3	20.5	--	--	11
	-	12	0.5	0.2	1.7	17.1	4.8	32.8	2.6	3.7	8
	-	24	0.0	0.0	2.7	13.8	7.8	30.9	0.0	3.5	7
	-	36	2.2	7.8	33.2	62.1	35.2	112.4	16.0	30.0	8
	+	6	--	--	16.6	37.1	17.6	62.8	--	--	33
	+	12	1.8	20.0	6.8	76.9	81.7	14.2	33.1	21.6	32
	+	24	0.6	1.9	9.0	33.5	21.2	54.5	2.3	5.0	16
	+	36	1.2	3.9	9.3	29.4	48.7	91.8	9.0	23.9	27
Basamid plus lignin	-	6	--	--	0.2	5.5	1.3	23.2	--	--	8
	-	12	1.4	2.8	2.9	24.9	4.8	93.1	2.1	14.0	18
	-	24	1.5	2.5	4.0	17.8	15.5	52.1	3.1	18.7	14
	-	36	2.3	6.6	8.7	20.8	16.0	33.0	3.7	5.8	12
	+	6	--	--	3.3	27.0	4.2	41.3	--	--	19
	+	12	3.2	17.4	7.0	63.6	16.1	79.6	5.5	3.0	24
	+	24	0.0	1.6	1.2	26.4	7.7	50.7	0.0	9.8	12
	+	36	2.1	1.6	19.3	13.5	35.3	28.9	3.1	9.2	14
Basamid plus boron	-	6	--	--	9.5	17.9	18.9	33.1	--	--	20
	-	12	0.4	11.3	6.6	30.8	15.0	49.6	0.1	5.2	15
	-	24	0.6	1.6	4.5	12.7	5.8	25.5	1.2	2.9	7
	-	36	0.3	0.3	7.6	17.9	21.6	27.1	2.6	2.6	10
	+	6	--	--	7.0	11.6	8.0	30.4	--	--	14
	+	12	0.0	11.8	7.7	24.2	17.2	33.5	1.0	5.6	13
	+	24	0.2	1.1	3.5	13.0	9.2	29.3	2.0	5.8	8
	+	36	29.2	54.5	8.8	17.7	66.5	33.8	11.3	49.1	34
Basamid plus ethanol	-	6	--	--	3.0	6.0	0.1	12.0	--	--	5
	-	12	0.0	2.1	0.4	15.3	0.2	7.3	0.0	0.0	3
	-	24	0.0	0.5	1.8	4.7	1.8	6.3	0.4	0.2	2
	-	36	0.1	0.8	1.0	8.4	3.0	12.5	0.7	1.4	4
Basamid plus methanol	-	6	--	--	2.8	7.2	0.8	16.0	--	--	8
	-	12	0.0	0.1	0.0	3.7	0.2	9.5	0.3	0.6	2
	-	24	0.0	0.5	0.8	3.3	2.6	8.6	0.0	0.1	2
	-	36	0.2	0.9	9.6	11.6	19.0	28.7	7.2	5.0	10
Basamid plus acetone	-	6	--	--	1.2	4.4	1.0	8.2	--	--	4
	-	12	4.3	18.3	9.3	17.0	15.2	26.1	15.6	12.9	15
	-	24	0.0	0.0	2.8	8.3	7.2	16.0	0.9	1.3	5
	-	36	2.0	4.2	9.3	27.3	14.0	38.2	7.0	15.3	14
Basamid plus water	-	6	--	--	1.0	3.0	1.6	14.8	--	--	5
	-	12	0.0	1.2	0.0	2.3	0.4	8.3	0.0	0.0	2
	-	24	0.3	2.0	1.5	7.3	5.1	22.1	2.6	7.7	6
	-	36	0.0	0.2	1.6	6.0	9.6	79.8	6.2	5.5	14

[a] -- indicates no core was taken

[b] Plus symbol indicates the addition of powdered pH 12 buffer (5% by weight) to Basamid.

Residual chemical levels in all but the Basamid plus ethanol treatment exceed those found with a comparable 450 ml metham sodium treatment and suggest that Basamid levels would be adequate for longterm protection against renewed fungal attack.

Additional field trials applying Basamid in-service utility poles are also underway to confirm these results.

2. Evaluate the efficacy of Basamid in Douglas-fir utility poles: The excellent results developed in small pole stubs have encouraged a field trial on Douglas-fir distribution poles in a Pacific Power line located near Corvallis, Oregon.

Thirty recently installed Douglas-fir distribution poles were selected for study because they lacked large decay pockets which might interfere with analysis of fumigant movement. A series of three steeply angled 17 mm diameter by 300 mm long holes were drilled at equidistant points around the pole beginning at groundline and moving upward 150 mm. The poles were treated with 200 or 400 g of Basamid equally distributed among the treatment holes. Basamid was used directly as received from the manufacturer or was amended with 1% copper sulfate. An additional set of poles was treated with 500 ml of metham sodium to serve as a comparative control. All treatment holes were plugged with tight-fitting dowels to retard fumigant loss. Each treatment was replicated on 10 poles.

The poles will be sampled 1,2, 3, and 5 years after treatment by removing increment cores from equidistant locations around the poles 150, 450, and 900 mm above the highest treatment site. The outer preservative treated zone will be discarded then the cores will be divided into inner an outer zones and each will be extracted and analyzed for residual MITC as described in an earlier section. The results should provide a comparison between the two Basamid treatments and metham sodium, the fumigant most commonly used for remedial treatment of wood poles.

3. Evaluate the efficacy of a fluoride/boron based internal remedial treatment: Last year, we reported on the development of a new combination fluoride/boron rod (24.3 % sodium fluoride and 58.2 % disodium octaborate tetrahydrate) developed in Australia for internal decay control in Eucalyptus poles. Rods were obtained from the Australian supplier (Preschem Pty Ltd., Cheltenham, Victoria).

Douglas-fir poles (250 to 300 mm in diameter by 2.4 m long) were treated with pentachlorophenol in P9 Type A oil. The poles were set to a depth of 0.6 m at the Peavy Arboretum test site. Sets of five poles each were drilled using the following patterns:

-3 holes beginning at groundline and spiraling upward at 120 degree intervals and 0.3 m height increments

-3 holes beginning at groundline and spiraling upward at 90 degree intervals and 0.3 m height increments

-6 holes beginning at groundline and spiraling upward at 120 degree intervals and 0.15 m height increments

-6 holes beginning at groundline and spiraling upward at 90 degree intervals and 0.15 m height increments.

Each hole received a single 23 gram rod and was plugged with a tight fitting wood dowel to limit chemical loss through the treatment hole. The poles were set this past June and will be sampled for chemical movement in 1 year. Three increment cores will be removed from equidistant points around the poles 150 mm above and below the treatment zone. Each sample will be divided into 3 equal segments and segments from the same pole treatment group will be combined prior to grinding and analyzed for fluoride using AWPA Standard A5 and for boron using the Azomethine H method. The sampling distances from the treatment zone will be increased with time as the rod components diffuse through the wood.

4. Evaluation of a gelled metham sodium formulation in Douglas-fir pole sections: Metham sodium is the fumigant most commonly used for remedial internal treatments of wood poles, but this chemical is caustic and workers often complain of burns from spills during application. We have been evaluating a 40 % gelled and 25% pelletized metham sodium formulations (ICI Chemical Co.) in the laboratory. The former formulation is provided in either caulking tubes or in gallon cans. Laboratory trials suggest that the gelled formulation provides fungal control at lower dosages than comparable liquid metham sodium, possibly because the gell retains moisture for a longer period after application. The presence of some water appears necessary for significant metham sodium decomposition.

The successful performance of this formulation under laboratory conditions encouraged the development of a field trial. Fifty ACZA treated Douglas-fir pole sections (250 to 300 mm in diameter by 3.6 m long) were set to a depth of 0.6 m at the Peavy Arboretum test site. Three steeply angled 19 mm diameter by 225 mm long holes were drilled in the pole beginning 0.9 m above the base and extending around the pole at 120 degree intervals and upwards at 150 mm increments. The poles were treated with 100, 200, 300, or 500 g of 40 % gelled metham sodium. Additional poles were treated with 100, 200, or 300 g of a 25 % pelletized metham sodium. Additional poles were treated 6 months later with 750 g per pole of 40 % gelled metham sodium. The holes were plugged with tight fitting wood dowels to retard fumigant loss. Each treatment was replicated on 5 poles and an additional set of 5 poles received 500 ml of liquid metham sodium.

The pole sections were sampled 6 and 12 months after treatment by removing increment cores from 3 equidistant sites around each pole 0.3, 0.9, and 1.5 m above the highest treatment hole. The inner and outer 25 mm of each core section inside the treatment zone were individually extracted in 5 ml of ethyl acetate prior to gas chromatographic analysis for residual MITC as described previously in this section. The remainder of each increment core was evaluated for residual fumigant levels using a closed tube bioassay with Postia placenta as the test fungus.

The chemical assays indicate that MITC was present 0.3 m above the initial treatment site in all of the gelled metham sodium treatments 6 months after application (Table I-9). MITC was detected sporadically 0.9 m above the treatment site in the gell treated poles, and was only detected in the outer zone of the 500 g treatment 1.5 m above the treatment zone. Pelletized metham sodium was also detected 0.3 m above the treatment zone with all three dosages tested, and was detected 1.5 m above the treatment site in the inner zone. MITC levels between the two metham sodium formulations were similar for the 100 and 300 g dosages, but differed markedly in the 200 g treatment. These differences may reflect differences in wood characteristics between the various poles in the test rather than ability of each chemical to diffuse. The results at 6 months must also be viewed with caution since relatively minor differences in application or wood condition can have substantial effects on subsequent diffusion. These effects are illustrated by the high standard deviations in chemical levels. These differences often decrease with time.

Chemical levels 12 months after treatment appeared to be slightly lower than those noted in the 6 month sample except in the 500 g treatment. Once again, some MITC was detected 1.5 m above the treatment zone, but the levels remained relatively low.

Closed tube bioassays suggest that some fungitoxic products were present in many positions of the poles 6 months after treatment (Table I-10). Degrees of inhibition were highest in the 300 g gelled treatment and the 200 g pelletized treatment. Degrees of inhibition of the remaining treatments, however, did not differ markedly from these levels. Closed tube bioassays of cores removed 12 months after treatment indicate that fumigant has become well distributed through the pole sections. Degrees of growth in comparison with the untreated controls ranged from 10 to 23 %, suggesting that volatile fungitoxic products have moved throughout the sampling zone. The closed tube bioassay has been found to be at least as sensitive to residual MITC as gas chromatographic analysis, making it perplexing that the GC and closed tube bioassays differ. It may be possible that other volatile decomposition products may enhance the effects of MITC. This possibility is under study and will be addressed in a later section of this report.

The results after 1 year indicate that gelled and pelletized metham sodium are both moving well through Douglas-fir heartwood. Both formulations reduce the risk of spilling during application and diminish the risk of worker exposure without adversely affecting efficacy. These trials will continue to be sampled 2, 3, and 5 years after application to ensure that the systems perform comparably to existing treatments.

5. Evaluation of a copper napthenate/boron paste for internal treatment of Douglas-fir posts: A copper naphthenate/boron paste previous employed for groundline treatment of poles has recently been registered for internal remedial treatment. In an effort to evaluate this material we established two sets of test material.

Twenty five pentachlorophenol treated Douglas-fir pole stubs (25-30 cm in diameter by 2.0 m long) were set to a depth of 0.6 m at the Peavy Arboretum test site. The poles were treated by drilling three 21 mm diameter holes at a 45 degree angle to depths of 100 or 175 mm beginning at the groundline and moving upward 15 cm and around the pole 120 degrees. Ten poles each received 150 or 300 g of a paste containing 18.16 % amine based copper naphthenate and 40 % sodium tetraborate decahydrate applied using a grease gun.

Table I-9. Residual MITC levels in Douglas-fir poles for 6 or 12 months after treatment with gelled or pelletized metham sodium.

			MITC level (ug/g oven-dry wood) at selected sampling heights[a]					
			0.3 m		0.9 m		1.5 m	
Chemical	Dosage (g)	Sampling zone	6 mos.	12 mos.	6 mos.	12 mos.	6 mos.	12 mos.
40% Gelled Metham sodium		(mm)						
	100	0-25	1(3)	1(2)	1(2)	0(0)	0(0)	0(0)
		50-75	6(11)	3(6)	4(10)	3(6)	0(0)	0(0)
	200	0-25	1(4)	0(0)	1(3)	0(0)	0(0)	0(0)
		50-75	3(8)	3(5)	0(0)	2(2)	0(0)	0(0)
	300	0-25	4(6)	5(9)	0(0)	0(0)	0(0)	0(0)
		50-75	17(30)	11(14)	0(0)	1(3)	0(0)	0(0)
	500	0-25	9(14)	18(19)	3(5)	0(0)	2(5)	0(0)
		50-75	12(5)	16(16)	2(4)	0(0)	0(0)	0(0)
	750	0-25	9(12)	-	0(0)	-	1(1)	-
		50-75	6(12)	-	4(8)	-	1(2)	-
25% Pelletized Metham sodium	100	0-25	7(11)	5(8)	0(0)	1(0)	0(0)	0(0)
		50-75	4(5)	4(5)	0(0)	0(0)	0(0)	0(0)
	200	0-25	20(21)	5(9)	3(6)	1(2)	0(0)	0(0)
		50-75	19(20)	14(19)	2(4)	1(2)	0(0)	0(0)
	300	0-25	0(0)	6(13)	0(0)	1(1)	0(0)	1(1)
		50-75	22(34)	13(15)	3(5)	0(0)	5(10)	0(0)

[a] Values represent means of 15 replicates. Values in parentheses represent one standard deviation.

Table I-10. Degree of inhibition of *Postia placenta* in a closed tube bioassay of wood samples removed from selected heights of Douglas-fir poles 6 or 12 months after treatment with gelled or pelletized metham sodium.

		Fungal growth as % of control at selected sampling heights[a]					
		0.3 m		0.9 m		1.5 m	
Chemical	Dosage	6 mos.	12 mos.	6 mos.	12 mos.	6 mos.	12 mos.
40% Gelled Metham sodium	100	48(46)	18(13)	62(46)	20(13)	58(48)	21(14)
	200	46(39)	15(11)	60(44)	14(11)	41(41)	12(13)
	300	17(24)	16(15)	39(38)	17(16)	27(34)	13(14)
	500	30(29)	15(13)	58(42)	23(12)	36(43)	21(12)
	750	37(12)	-	29(11)	-	27(11)	-
25% Pelletized Metham sodium	100	29(37)	10(12)	44(42)	23(13)	20(39)	10(13)
	200	17(32)	12(12)	37(41)	22(8)	33(47)	15(9)
	300	50(45)	15(12)	81(44)	20(10)	37(52)	16(13)

[a] Values represent means of 15 replicates while those in parentheses represent one standard deviation.

The holes were plugged with tight-fitting wood dowels to retard chemical loss. In addition, smaller posts were remedially treated with smaller amounts of paste applied through a hole drilled near the center of the posts. These posts were exposed out of ground contact at the Peavy Arboretum test site to assess the effectiveness of this system in above ground applications.

The pole stubs were sampled 3 years after chemical application by removing increment cores from three equidistant locations around the pole at sites 77 mm below the groundline and 75, 150, and 224 mm above the groundline. The cores were divided in half and the wood was ground to pass a 20 mesh screen. Copper content was determined using an Asoma 8620 x-ray fluorescence analyzer run in the CCA mode. The wood was then extracted in hot water and analyzed for boron using the Azomethine H method.

The wood samples had a background level of boron ranging from 0.52 to 0.61 % boric acid equivalent. Boron levels increased with increasing dosage at a rate similar to the relative increase in dosage. Samples treated with 150 g of the preservative paste contained boron 75 and 150 mm above the groundline, while those treated with 300 g of paste also contained boron 224 mm above the groundline (Table I-11). These results suggest that the boron was capable of some movement upward from the point of application, although the distances were far lower than those which would be found with conventional fumigants. Boron was also present below the groundline, but the levels were generally lower. Boron is susceptible to leaching in ground contact and the results in this test illustrate that effect. As expected, boron levels tended to be highest in the inner core zone, relfecting both the tendency of boron near the surface to leach from the wood and the downward sloping application holes which would direct the chemical towards the center of the pole.

As expected, copper levels tended to be far lower than boron levels at a given location, reflecting both the lower levels of copper in the formulation and the diminished ability of this component to migrate through the wood. Copper levels tended to increase with increasing dosage and were higher in the inner assay zone. Levels were generally highest within 150 mm of the groundline, relfecting the higher moisture levels in this zone. Copper levels were generally low 224 mm above the groundline as well as 75 mm below the groundline. The former effect may reflect the lower moisture levels further above the groundline. While winter moisture levels can rise to the point where free water is present in the wood, the test site has experienced below average rainfall for 2 of the last 3 years. Lower moisture levels might translate to diminished copper movement. Lower copper levels below the groundline probably reflect leaching loss. The test site tends to become extremely wet during the cooler winter months, creating ideal conditions for chemical loss

It is difficult to assess the effectiveness of the combination internal treatment. While both chemicals are diffusing for short distances from the point of application, the levels of each component are below the threshold required for protecting wood against wood decay fungi. However, these levels in combination may be adequate for preventing growth by spores and hyphal fragments which may invade the

Table I-11. Residual chemical levels in Douglas-fir pole sections 3 years after internal treatment with a copper naphthenate/boron paste.

		Residual Chemical Level [b]	
Dosage (g)	Assay location[a]	Boron (%BAE)	Copper naphthenate (kg/m^3 as Cu)
0	all outer zones	0.061(0.046)	0.003(0.006)
	all inner zones	0.059(0.033)	0.008(0.018)
	total	0.060(0.040)	0.005(0.014)
150	all outer zones	0.098(0.170)	0.048(0.201)
	all inner zones	0.535(0.690)	0.263(0.424)
	total	0.317(0.548)	0.156(0.349)
300	all outer zones	0.134(0.298)	0.032(0.088)
	all inner zones	1.060(1.453)	0.505(0.751)
	total	0.597(1.147)	0.268(0.584)
0	-75 mm	0.069(0.047)	0.012(0.018)
	+75 mm	0.052(0.030)	0
150	-75 mm	0.125(0.030)	0.044(0.009)
	0	0.484(0.761)	0.207(0.443)
	75 mm	0.434(0.548)	0.259(0.440)
	150 mm	0.496(0.648)	0.255(0.391)
	224 mm	0.044(0.058)	0.013(0.040)
300	-75 mm	0.100(0.089)	0.017(0.025)
	0	1.020(1.517)	0.510(0.751)
	75 mm	1.151(1.552)	0.540(0.825)
	150 mm	0.605(0.928)	0.248(0.453)
	224 mm	0.102(0.132)	0.026(0.044)

[a] Inner and outer zones represent halves of each core, while total represents the average of both zones. Other sample values represent distances above or below the groundline.

[b] Values represent means of samples from 5 poles/treatment, while values in parentheses represent one standard deviation.

interior to the pole. Nevertheless, these systems have a disadvantage in their limited ability to diffuse for substantial distances. As a result, such systems would probably only be feasible where severe environmental concerns limited the use of more effective remedial treatments.

These pole sections will be assessed for chemical movement after an additional 2 years of exposure to determine if chemical levels remain stable over that time period.

6. Evaluation of metham sodium for remedial treatment of large Douglas-fir timbers: In 1990, a Douglas-fir highway

bridge located north of Salem, Oregon was treated with metham sodium. At the time, there was little data on the effectiveness of this chemical in large timbers. Sawn wood should have higher levels of exposed trachieds which might provide avenues for increased fumigant loss. As a result, fumigant performance might be expected to be reduced in these materials.

Metham sodium was applied through 19 mm diameter holes drilled at 1.2 m intervals along the timbers. One year after treatment, increment cores were removed from sites near the top and bottom edge 0.6 m from each treatment hole on 7 stringers. The outer, treated shell was discarded and the remaining untreated zone was divided in half and each section was placed in ethyl acetate. The cores were extracted for 48 hours prior to GC analysis of the extracts.

MITC levels nearly doubled between 1 and 2 years after treatment, although there were some decreases in levels in some positions (Table I-12). Fumigant levels appeared to increase consistently across the timbers. For example, average MITC levels in the top and bottom of the timbers were 40.8 and 44.8 ug/oven dry gram of wood, respectively, one year after treatment and 86.5 and 71.6 ug/OD g after 2 years. Similarly, average fumigant level differed little in the inner and outer assay zones, increasing from 43.4 and 42.3 ug/OD g after one year to 83.9 and 77.8 ug/OD g of wood, respectively after the second year. The lack of an apparent gradient from inside to the surface of the treated zone differed from that found in poles, perhaps reflecting the treatment pattern along the upper surface of the stringer and smaller dimension of these materials. These results indicate that MITC is becoming well distributed in the timbers. Although the levels of MITC found one year after treatment were lower than those noted in Douglas-fir poles, the levels two years after treatment are consistent with those found in round stock. These results suggest that metham sodium is performing in timbers in a manner similar to that found with poles; however, these timbers will be sampled for an additional year to confirm these trends.

E. EVALUATE BASIC PROPERTIES OF REMEDIAL INTERNAL TREATMENTS

While the successful development of effective remedial treatments remains the primary focus under this Objective, it has become increasingly clear that there are substantial gaps in the data available on movement and chemical properties of many commercially important remedial treatments. These data gaps make it difficult to accurately assess the relative merits of various formulations and may also become important when questions are raised concerning the fate of these products in the environment. As a result, we have endeavored to develop more basic information on fumigants currently in use as well as those in the developmental process.

1. Effect of wood and selected additives on Basamid decomposition: Previous laboratory and field tests have indicated that certain additives greatly affect the decomposition rate of Basamid in Douglas-fir heartwood. Temperature and moisture content of the wood are also key factors affecting these rates. However, it is unknown if these additives act alone or if wood or wood components play any role in catalysis.

Table I-12. Residual MITC content in Douglas-fir bridge stringers one or two years after metham sodium treatment as determined by gas chromatographic analysis of ethyl acetate extracts of wood samples.

Structure #	Stringer Position	ug MITC/OD g wood			
		Inner		Outer	
		1 year	2 years	1 year	2 years
5	Top	4.3	52.3	0.00	27.6
	Bottom	59.7	34.7	24.5	112.4
10	Top	40.2	136.1	53.2	60.3
	Bottom	75.8	114.9	39.9	59.4
15	Top	27.3	66.1	37.4	59.5
	Bottom	16.0	99.7	24.3	112.9
20	Top	26.2	115.5	65.4	130.6
	Bottom	82.7	42.6	23.2	19.9
25	Top	26.5	80.2	13.1	44.4
	Bottom	33.4	83.3	65.5	95.4
30	Top	73.2	126.8	100.3	98.5
	Bottom	83.6	40.8	75.8	63.7
35	Top	44.1	74.1	60.6	120.8
	Bottom	14.0	75.1	9.2	42.4
40	Top	-	50.1	-	140.4
	Bottom	-	92.1	-	56.7

The following tests were designed to determine the effect of wood and promising additives on the rate of Basamid decomposition and the efficiency of MITC production over other decomposition products including primary amines and carbon disulfide.

Forty ml glass vials equipped with Teflon-lined silicone septa as used in previous laboratory experiments were employed in these tests. Each vial received 100 mg Basamid either alone or amended with 50 mg Douglas-fir heartwood sawdust at 9% MC (ground to pass a 20-mesh screen), 5 mg pH 12 buffer powder, 2 drops pH 12 buffer solution, 2 drops pH 12 NaOH in water, 2.5 mg copper sulfate, or 2 drops 1N acetic acid. Each dry additive was tested alone or in tandem with 2 drops of water to determine if the additive required moisture to be effective. The vials were stored at room temperature (20-24°C) for the duration of the experiment.

Two headgas samples were removed from each vial through the septum with a gastight syringe. Each sample was injected into one of two Varian Model 3700 gas chromatographs operating at the following conditions: (1) amine analysis -- injector temperature 200°C, oven temperature 75°C, flame ionization detector temperature 240°C, 6 feet long by 2 mm inner diameter glass column packed with 4% Carbowax 20M on 0.8% KOH 60/80 Carbopack B, nitrogen carrier flow rate 30 cc/minute, or (2) sulfur analysis -- injector temperature 150°C, oven temperature 100°C, flame photometric detector temperature 240°C, 1.8m by 2 mm inner diameter glass column packed with 10% Carbowax 20M on 80/100 Supelcoport, nitrogen carrier flow rate 30 cc/minute. Standard amine solutions were made using distilled water as the solvent and MITC and carbon disulfide solutions were made in ethyl acetate. Concentrations of all detected compounds were determined by comparison with appropriate standards.

Unamended Basamid produced no detectable decomposition products throughout the test period (Table I-13) indicating the chemical was very stable when kept dry at room temperature.

Table I-13. MITC and CS_2 concentrations over a 48 hour period in headgas of vials containing 100 mg Basamid amended with selected additives.

	MITC Concentration			CS_2 Concentration		
	ng/ml air					
Additive	4 Hrs	24 Hrs	48 Hrs	4 Hrs	24 Hrs	48 Hrs
None	0	0	0	0	0	0
Water	0	410	236	0	T	0
Wood	0	0	0	0	0	0
Wood plus water	79	324	292	63	345	523
pH 12 powder	5	6	0	0	0	0
pH 12 powder plus water	108	421	334	2	14	0
pH 12 solution (from powder)	64	340	242	2	5	4
pH 12 solution (NaOH)	324	546	299	3	1	0
Copper sulfate	539	306	108	0	0	0
Copper sulfate plus water	2895	705	270	323	1091	850
Acetic acid	223	193	90	288	537	373

Wood at 9% MC also had no effect on decomposition. However, adding water had a substantial effect on MITC production in both instances. MITC production in the wood plus water treatment did not increase substantially in comparison with Basamid receiving only water, indicating that wood was not a major catalyst in Basamid decomposition to MITC. However, carbon disulfide levels in the wood with water treatment increased dramatically over those receiving water only. It should be noted that this analytical method resulted in two overlapping sulfur peaks, one being carbon disulfide (retention time approximately 0.41 minutes) and the other being unidentified (retention time approximately 0.36 minutes). The unidentified peak, believed to be either carbonyl sulfide or hydrogen sulfide, often overshadowed carbon disulfide, preventing integration of the carbon disulfide peak. Further experiments are needed to fully separate, identify, and quantify the more volatile sulfur-containing compounds.

The effect of pH on MITC production was evident, but moisture appeared to be necessary for this enhancement. Liquid NaOH was more effective than the powdered buffer solution indicating the phosphate compounds in the powder may have reduced its effect as a catalyst. Acetic acid also increased MITC production, but to a lesser degree than the higher pH treatments. Acetic acid, however, had an enhancing effect on carbon disulfide production, similar to the wood with water treatment. This was not surprising since Douglas-fir heartwood has a low pH similar to acetic acid; however, the obviously different decomposition pathways at lower versus higher pH's are poorly understood.

Copper sulfate clearly affected decomposition to a greater extent than any other additive tested, regardless of the presence of water. This result was not unexpected as previous experiments have yielded similar results. It was interesting to note that no added moisture was necessary for this phenomenon; however, the addition of water greatly enhanced the effect. Moisture also greatly increased carbon disulfide production in this treatment. Chromatograms indicated that water shifted the production of early-eluting sulfur compounds exclusively to carbon sulfide while an unidentified sulfur compound was noted in the absence of water.

Interestingly, neither mono- nor di-methylamine were detected in these experiments. This was perhaps the most baffling result of these tests, especially in those treatments which produced high levels of carbon disulfide. When carbon disulfide is removed from the Basamid molecule, presumably as sulfur from position 1 and carbon from the #2 position along with its double-bonded sulfur, the only remaining atoms are carbon, nitrogen, and hydrogen. It would seem very likely that at least some amine component would be produced in detectable quantities from this residue. Since this was not the case, further tests are needed to determine the fate of nitrogen-containing residues in Basamid treated wood.

2. Fungitoxicity of mixtures of MITC and carbon disulfide: Metham sodium has been used for nearly 25 years to arrest and prevent internal decay of Douglas-fir poles and remains the chemical most commonly used for this purpose. Despite this wide usage, there is relatively little data on the activity of this chemical in wood. In previous reports, we have described the decomposition products produced from metham sodium in wood, have examined the effects of wood species and temperature on decomposition, and have explored the role of potential additives in metham sodium decomposition. These studies have shown that metham sodium decomposes to produce MITC inefficiently in wood and produces

large amounts of other volatile compounds in the process. The toxicity of these compounds and their possible interaction with MITC in protecting the wood are poorly understood. The potential for interactions between metham sodium decomposition products encouraged the following study.

Douglas-fir heartwood and ponderosa pine sapwood wafers (3 by 10 by 10 mm) were sterilized and placed in sealable plastic bags containing a small air-permeable patch. Water was added to raise the bag moisture content to approximately 250 to 300 percent then the bags were loosely closed and autoclaved for 20 minutes at 121 C. After cooling, the bags were inoculated with 100 ml of a 1.5 % malt extract solution which had been inoculated with the test fungus 7 to 14 days earlier. The fungi tested were Irpex lacteus, Trametes versicolor, Gloeophyllum trabeum, Gloeophyllum saepiarium, Antrodia carbonica, Postia placenta, and Hormoconis resinae. The fungal mycelium in the malt extract was briefly macerated in a blender to fragment the mycelium. The bags were resealed and incubated until the fungi had thoroughly colonized the wood (usually 4 to 6 weeks). These blocks were used in all fumigant exposure tests.

The fungitoxicity of metham sodium decomposition products was assessed by placing fungal colonized blocks of a given species into 40 ml glass jars with teflon lined lids. Holes drilled in the lids were connected to a mixing vessel from which the fumigant was delivered and to an exit line from the system. A series of manifolds were constructed so that a stable amount of carbon disulfide, methylisothiocyanate, or both of these gases could be metered through the jars (Figure I-3). At present, carbon disulfide has been evaluated at 0.5, 3 to 4, and 8 to 9 parts per thousand (ppt). Additional trials of MITC are underway. Three blocks per fungus per wood species were then removed from the jars each day over a 10 day period. The blocks were aerated for several hours, then evaluated for fungal survival.

Aerated blocks were macerated using a Kleco 4100 Pulverizer (Kleco Kenetic Manufacturing Co., Visalia, CA). Briefly, the blocks were placed in stainless steel vessels along with 5 ml of sterile distilled water. A steel ball with a diameter slightly smaller than that of the vessel was added and the vessel was closed. The vessel was agitated rapidly for 5 seconds, resulting in complete maceration of the wood. The steel ball was lifted out with a magnetic bar and water was added to the top (30 ml total). One and one half ml of the resulting suspension was added to each of three bottles containing 10 ml of molten agar (45 C), and these mixtures were poured into a plastic petri dish. The dishes were incubated at room temperature and any colonies were counted. The average number of colony forming units (CFU's) served as a measure of the effect of various gas mixtures on fungal survival.

As expected, the number of CFU's varied between the fungal species, reflecting both the sensitivity of each species to the isolation procedures as well as the presence or absence of sporulation structures such as conidia or chlamydospores in the wood (Table I-15). In addition to the variations between species, CFU's in some non-fumigant exposed control blocks tended to decline slightly over the 10 day test period.

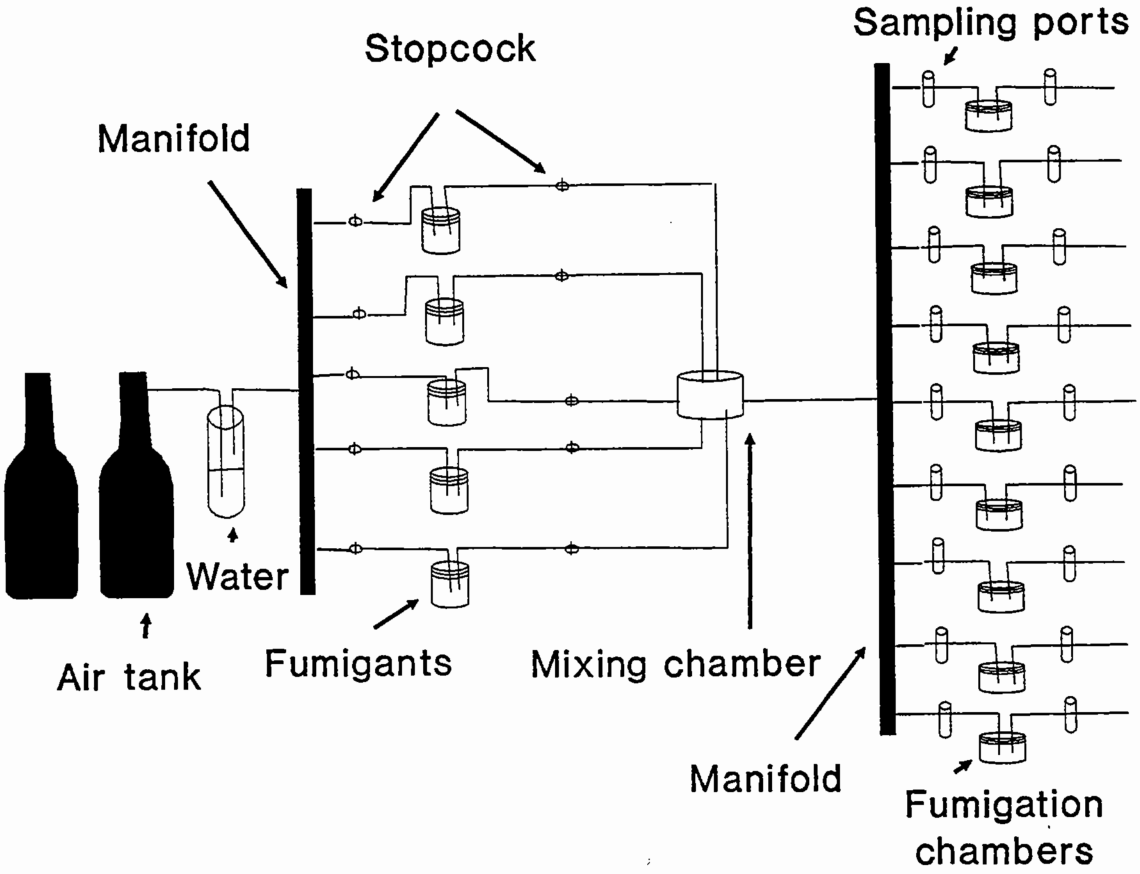


Figure I-3. Apparatus employed to evaluate the fungitoxicity of carbon disulfide and methylisothiocyanate.

Although efforts were made to humidify the atmosphere which passed over the blocks, CFU declines may reflect loss of viability due to drying during the exposure period. Despite these declines, CFU differences between control and chemically exposed samples were generally of a magnitude that permitted comparisons between the treatments.

Low levels of carbon disulfide (0.5 ppt) had only minimal effects on fungal survival for all of the species tested and appeared to stimulate growth in some treatments (Figure I-4). Increasing carbon disulfide levels to 3 to 4 ppt produced declined in colony forming units for virtually all of the fungi tested, but this level was only toxic for I. lacteus on ponderosa pine. Several other fungi experienced declines in CFU's which exceeded the controls, but none succumbed to the low level of fumigant.

Exposure to 8 to 9 ppt of carbon disulfide resulted in decreases in the CFU's for all of the fungi tested; however, several fungi survived a 10 day exposure to this level of chemical. Very low levels of survival were noted with P. placenta on both pine or Douglas-fir, A. carbonica on pine, T. versicolor on pine or Douglas-fir, G. trabeum on pine or Douglas-fir, and G. saepiarium on Douglas-fir, suggesting that the chemical might eventually be completely effective against these species upon longer exposures. Several fungi including A. carbonica on Douglas-fir, H. resinae on Douglas-fir or ponderosa pine, and G. saepiarium on ponderosa pine were relatiavely unaffected by exposure to this level of carbon disulfide. Antrodia carbonica is an important colonizer of Douglas-fir heartwood and the survival of this species in the presence of carbon disulfide would be a major drawback if this fumigant were the only decomposition product of metham sodium. Similarly, G. saepiarum is an important colonizer of pine, although studies at the SUNY College of Environmental Science and Forestry suggest that this species is not an important colonizer of preservative treated southern pine. The survival of H. resinae at the highest carbon disulfide level is not suprising in light of the well known tolerance of this species when exposed to a variety of biocides. This fungus has been implicated in the detoxification of creosote in utility poles, but its possible effects on residual fumigant in wood are unclear.

The results illustrate that exposure of wood colonized by various decay and non-decay fungi to low levels of carbon disulfide reduces the incidence of CFU's in the wood but does not completely eliminate these species. Metham sodium is a relatively short lived treatment whose limited residual time in the wood may permit survival of fungal propagules. If decomposition conditions shift heavily towards production of carbon disulfide, these fungi may later be able to germinate once conditions are again suitable.

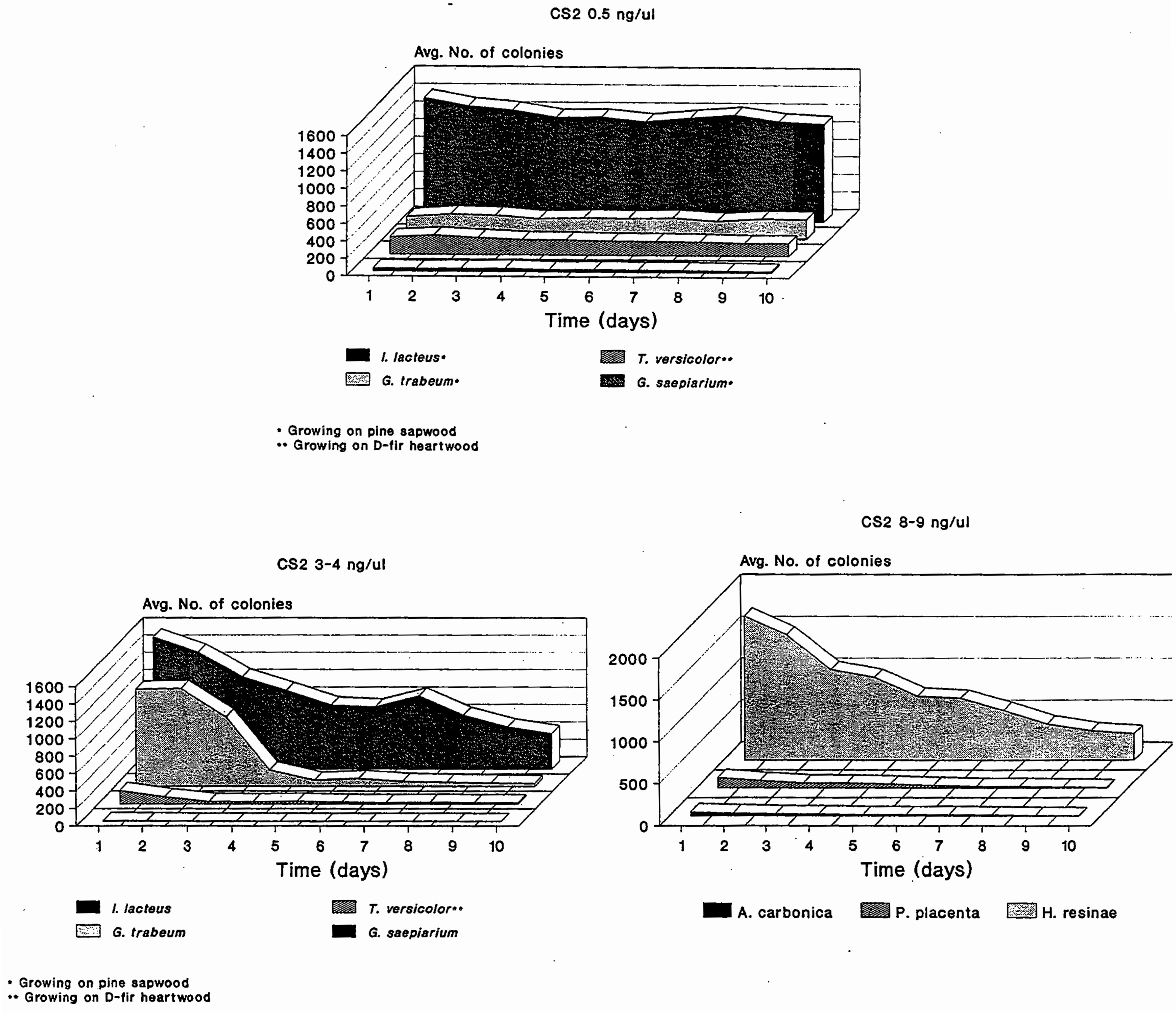
Further tests are now under way to determine the effects of MITC alone and sub-lethal mixtures of carbon disulfide and MITC on fungal survival.

3. Effect of decay voids on fumigant movement and effectiveness in Douglas-fir poles: Wood poles are often remedially treated despite the presence of large decay pockets. Many utilities have concerns about the effectiveness of such treatments given the fact that voids are often associated with

Table I-14. Effect of exposure to 0.5, 3-4, or 8-9 ng of carbon disulfide per ul of air on number of colony forming units per block of wood colonized by selected wood inhabiting fungi[a]

Time (days)	I. lacteus (Pine)		T. versicolor (pine)		G. trabeum (Douglas-fir)		G. saepiarium (Douglas-fir)		A. carbonica (pine)		A. carbonica (Douglas-fir)		P. placenta (pine)		P. placenta (Doug-fir)		H. resinae (pine)		H. resinae (Douglas-fir)	
	Control	Treatment	Control	Treatment	Control	Treatment	Control	Treatment	Control	Treatment	Control	Treatment	Control	Treatment	Control	Treatment	Control	Treatment	Control	Treatment
	(0.5 ng/ul)																			
1	28	51	39	90	200	188	855	1255	249	225	862	924	38	58	29	62	1695	2765	1469	2380
2	26	40	42	82	167	177	845	1252	265	234	841	907	33	57	29	77	1661	2547	2323	2334
3	30	31	44	81	187	174	883	1240	220	241	799	854	35	51	36	72	1581	2498	2417	2222
4	23	32	30	71	153	164	771	1323	274	312	779	783	44	57	25	63	1628	2412	2199	2283
5	21	30	26	71	153	164	776	1119	280	428	691	756	27	49	36	58	1560	2407	2053	2247
6	27	24	40	74	171	159	759	1153	301	561	567	744	27	46	31	52	1521	2214	1919	2349
7	18	20	21	78	165	145	770	958	408	562	666	660	27	41	42	46	1517	2273	1728	2366
8	21	20	33	74	151	143	698	995	428	456	692	683	31	37	38	46	1443	2184	1620	2033
9	17	20	38	68	138	138	707	937	498	462	571	648	25	34	30	43	1348	2181	1449	2071
10	19	18	27	74	135	143	682	938	538	502	554	584	21	33	30	42	1223	1959	1642	2086
	(3-4 ng/ul)																			
1	27	10	60	152	385	1121	1150	1524	158	160	1137	1046	44	85	31	73	1606	2043	2541	2178
2	13	7	25	91	342	1131	724	1349	147	148	1063	1068	47	136	31	89	1439	1917	2258	2111
3	31	2	49	28	267	800	942	1064	115	138	862	966	44	80	45	80	1817	1836	2391	2020
4	16	1	46	25	353	187	1377	906	205	133	862	832	79	71	42	52	1533	1567	2254	1834
5	11	0	28	30	232	71	1119	739	270	116	715	844	129	58	44	41	1542	1401	1848	1687
6	12	0	20	21	249	91	1000	716	343	98	603	772	205	34	50	46	1392	1201	1357	1503
7	16	0	31	17	264	58	784	845	506	87	632	649	343	23	55	39	1376	1041	1504	1323
8	10	0	24	19	264	50	921	624	507	80	651	531	394	17	53	30	1340	901	1436	1198
9	8	0	20	17	282	40	765	488	461	63	657	359	346	12	41	20	1159	804	1297	953
10	8	0	20	16	249	35	797	410	454	70	635	298	294	9	32	17	1196	792	1303	900
	(8-9 ng/ul)																			
1	40	19	1276	1602	33	74	165	149	100	150	1064	1298	27	99	19	78	2445	1720	2535	1878
2	18	11	1188	1168	42	71	141	107	129	190	899	1051	64	122	122	101	2029	1498	2221	1591
3	21	5	1055	893	45	57	108	83	109	142	762	662	71	108	108	109	1933	1082	2401	1368
4	14	3	1089	721	34	100	63	62	222	187	718	501	84	77	77	79	2421	988	2265	1140
5	14	0	659	280	27	45	55	67	287	191	619	510	134	56	56	72	1986	763	1811	990
6	14	0	608	144	17	57	47	43	421	105	662	422	254	40	40	50	2180	738	1361	779
7	20	0	337	17	41	38	39	24	569	48	575	406	298	24	24	37	1923	595	1440	755
8	16	0	305	13	25	19	45	21	545	14	569	270	276	10	10	23	1725	495	1378	674
	13	0	337	7	34	8	51	2	464	5	570	180	397	2	2	2	1643	350	1241	571
10	14	0	334	4	29	5	51	0	436	1	504	151	314	1	1	0	1678	326	1289	428

[a] Values for controls represent means of three colony counts per time point while those for CS_2 exposed samples represent nine replicates.



• Growing on pine sapwood
•• Growing on D-fir heartwood

• Growing on pine sapwood
•• Growing on D-fir heartwood

Figure I-4. Number of colony forming units in Douglas-fir heartwood or ponderosa pine sapwood blocks colonized by selected wood inhabiting fungi and exposed to three levels of carbon disulfide.

checks which open to the outside of the pole and can enhance chemical loss.

In 1987, we established a field trial to evaluate the effects of voids on fumigant movement. Twelve Douglas-fir pole sections were cut in half and a 50 mm diameter by 150 mm long void was drilled into the exposed surface of each half of the pole. An additional 12 poles were left without voids to serve as controls. The voids were filled with brown rotted wood and the pole sections were reassembled. The cut edges were sealed with epoxy to retard radial fumgiant loss and the poles were treated with 80 or 160 ml of chloropicrin or metham sodium applied to holes drilled above the void. Each treatment was applied to 3 poles which were exposed outdoors at the Forest Research Laboratory.

The metham sodium treated poles have been sampled annually by removing increment cores from 3 equidistant points around the pole at sites 0.3 and 0.9 m above and below the voids. The cores were extracted in ethyl acetate for metham sodium treated poles for 48 hours prior to GC analysis.

The results continue to show that the fumigants were capable of moving around the void at levels which would be sufficient to eliminate any decay fungi present (Table I-15). Chemical levels have generally declined to low levels in all treatments regardless of the presence of a void. These declines probably reflect the small size of the poles, coupled with the relatively low dosages of chemical applied. The results continue to indicate that the presence of small voids has little influence on overall fumigant effectiveness. The fumigant is apparently able to either diffuse around or across the void to protect wood on the opposite side. Larger voids than those studied would be of a greater concern owing to the lower amounts of wood around the void which would be available for the chemical to diffuse through.

4. <u>Development of a three-dimensional model for predicting movement of fumigant through Douglas-fir poles</u>: As we continue to producing data on the performance of fumigants in wood poles, it becomes increasingly clear that much of the treatment process has developed empirically, with little regard to the fundamental aspects of the fumigants or the wood. The continued development of data on fumigant movement and interactions provides a unique opportunity to assemble a predictive model of fumigant movement through wood poles. Over the past 5 years we have endeavored to produce a model which predicts MITC movement in wood poles. Initially, model development progressed using a program written in Fortran then moved to a Pascal based program. Both of these efforts were limited by the programs as well as the available computer memory. More recently, we have adapted finite element software available through ANSYS (version 5.0). Last year, we reported on initial efforts to model fumigant loss from MITC-Fume treated wood and on efforts to improve the model to permit predictions of larger wood samples.

Table I-15. Residual MITC at various sites above or below voids in Douglas-fir poles 3 to 6 years after treatment with selected dosages of metham sodium.

Metham Sodium Dosage (g)	Void[b] (+/-)	Height (m)	Average ug MITC/g oven dry wood[a]					
			Outer			Inner		
			3 yr	5 yr	6 yr	3 yr	5 yr	6 yr
80	+	-0.9	3.7	0.0	0.0	3.0	0.0	0.0
		-0.3	9.7	3.5	4.7	15.9	1.7	0.8
		+0.3	12.4	3.8	1.8	11.0	1.9	2.5
		+0.9	4.2	0.0	1.4	3.4	0.0	0.8
	-	-0.9	-	0.8	4.4	2.5	0.0	2.0
		-0.3	8.1	2.7	7.2	57.7	2.6	8.1
		+0.3	9.4	1.5	5.2	15.1	1.8	5.8
		+0.9	-	0.0	2.8	3.9	0.0	0.0
160	+	-0.9	4.2	0.0	3.7	10.5	0.0	4.0
		-0.3	13.1	1.2	10.1	32.4	0.0	7.1
		+0.3	8.9	5.1	4.4	20.0	5.9	4.4
		+0.9	-	1.5	1.2	5.3	2.9	1.4
	-	-0.9	2.1	0.0	11.0	4.5	1.2	6.1
		-0.3	15.4	6.1	11.2	30.3	13.1	8.2
		+0.3	20.4	9.2	10.9	28.1	6.7	6.3
		+0.9	3.4	0.0	4.9	3.9	0.0	5.1

[a] Values represent averages of 9 replicates (-) denotes missing data. Outer zone refers to the 0.25 mm section inside the treated shell while the inner zone represents the inner 25 mm of the core.

[b] Poles with (+) on without (-) voids below the treatment site.

The model has been constructed by using the finite element program ANSYS, version 5.0 which is capable of thermal analysis in 3-D solids. By substituting fumigant diffusion coefficients for thermal conductivity, fumigant concentration for temperature, or fumigant flow for heat flow, we can model fumigant movement and concentration in structures such as wood poles. The model shown in Figure I-5 represents a 30 cm by 3.6 m long pole with eight fumigant treatment holes spaced at 15 cm intervals from groundline. For any single run of the model there can be one to eight treatment holes, each up to 26 cm long. Treatment holes can be placed in various patterns around the pole. Models of poles having different diameters, lengths, additional treatment holes or different treatment hole spacings can be easily constructed. This will give us the ability to study the effect of different treatment hole patterns on fumigant distribution.

Additional tests are in progress to test the accuracy of the fumigant model. Solid MITC has been placed in wood blocks which are being monitored in a controlled environment. At selected time intervals, fumigant flow from block surfaces as well as fumigant concentration within the wood will be measured. These measurements will be compared with values computed by the finite element model of fumigant concentration and movement through a wood block.

These results from the full scale model will be used to evaluate the effects of treatment variables on fumigant performance as a means for enhancing the performance of these systems.

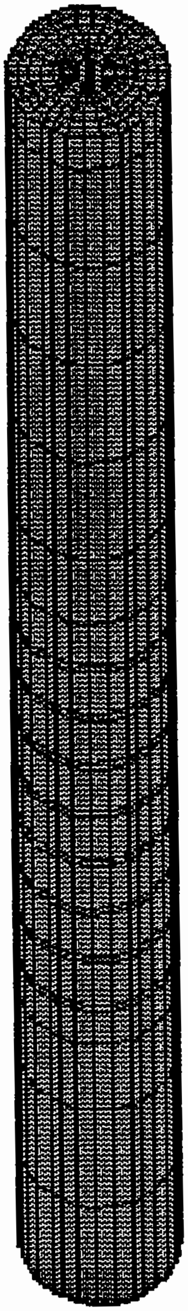


Figure I-5. Mesh used to model a 30 cm by 3.6 m long wood pole containing up to eight fumigant treatment holes placed at selected patterns around the pole at 15 cm intervals from groundline.

OBJECTIVE II

IDENTIFY ENVIRONMENTALLY ACCEPTABLE CHEMICALS FOR PROTECTING WESTERN REDCEDAR SAPWOOD AND FIELD DRILLED BOLT HOLES

A. ACCELERATED FIELD TRIALS OF POTENTIAL PENTACHLOROPHENOL REPLACEMENTS FOR PROTECTING WESTERN REDCEDAR SAPWOOD ON FULL SCALE POLES

Sapwood decay of western redcedar continues to be problem for utilities with large numbers of either butt treated or untreated poles with in their systems. Western redcedar heartwood is highly durable, but the sapwood has no durability. As the sapwood decays, the interface between the decayed sapwood and the durable heartwood separates. Lineman climbing these poles will tend to cut-out and slide down the pole, creating a serious risk of injury. For many years, sapwood decay was controlled by regular external application of 10 % pentachlorophenol in diesel oil. More recently, copper naphthenate has replaced penta for this purpose. While these treatments have performed extremely well, there is a continuing interest in the identification of less toxic chemicals for this purpose.

Over the years, the Cooperative have evaluated a variety of biocides for preventing surface decay of western redcedar poles using small scale laboratory tests. While these trials are useful, exposing these chemicals on western redcedar sapwood under field conditions is essential before extensive field use of any chemical is considered.

1. <u>Performance of supplemental external preservatives on western redcedar poles at Peavy Arboretum</u>: In 1981, 23 untreated western redcedar pole stubs (2.4 m long) were set at the Peavy Arboretum test site. Each pole was kerfed lengthwise at 3 equidistant points around the circumference. Two of the faces were each sprayed with 1.25 L of a test chemical, while the third face served as an untreated control (Table II-1). Each treatment was replicated on 6 faces. Treatments extended downward for 1.8 m from the top. Metal sheets were placed into the kerfs on either side of a face to minimize the risk of spray drifting onto adjacent faces. For the first 5 years, the poles were automatically sprinkled with water during the dry summer months to encourage leaching and stimulate decay development.

Chemical performance was assessed using soil block tests and <u>Aspergillus</u> <u>niger</u> bioassays. In the former instance, increment cores removed from the poles were placed onto potato dextrose agar seeded with spores of <u>A</u>. <u>niger</u>, a common mold which produces black spores and observed for the development of zones of inhibition (no fungal growth) or effect (no sporulation) typical of this fungus. The radii of these zones were measured and provided a measure of the residual chemical in the core. This test works best with chemicals which have some water solubility.

Wood plugs were also cut from the pole face and cut into 4 zones corresponding to 0 to 3 mm, 3 to 6 mm, 6 to 9 mm, and 9 to 12 mm from the surface. These wafers were then weighed and tested in a small scale soil block test using Postia placenta as the test fungus. In these trials, 60 ml glass bottles were filled with 25 ml of forest soil and enough water was added to raise the moisture content to 60 %. A small western hemlock feeder strip (0.5 by 1.9 by 1.9 cm) was placed on the soil and the bottles were capped prior to autoclaving for 45 minutes at 121 C. After cooling, the feeder strips were inoculated with the test fungus and then incubated until the fungus covered the wood strip. The test wafers were steamed for 20 minutes at 100 C, then placed on the feeder strip. The bottles were incubated for 12 weeks at 28 C, then blocks were removed, scraped clean of adhering mycelium, reconditioned and weighed to determine wood weight loss over the exposure period. Weight loss served as a measure of residual chemical protection.

After 11 years, only the penta and copper hydroxide treatments produced substantial zones of effect in the Aspergillus bioassay (Table II-2). The penta treatments have previously produced substantial zones of effect and the bioassay was developed using this preservative. The remaining treatments generally produced ZOE's of 0 to 2 mm near the surface, suggesting that little chemical was available to migrate from the wood. Examination of several additional treatments 9 years after application showed that 5 % copper naphthenate in water, FCAP, Arquad C-50 and ACA all produced measurable zones of effect near the wood surface. The presence of a ZOE with Arquad is perplexing since this quaternary ammonium compound has strong wood interactions which should sharply limit its mobility. These results suggest that some chemical remains in each of these treatments, while little or no zone of effect was noted with zinc naphthenate or oilborne copper naphthenate.

Evaluation of decay resistance of wafers cut from different depths in the test poles 11 years after chemical application indicated that most treatments had little residual protective effect. Weight losses in the controls approached 30 %, while those for copper 8 quinolinolate and IPBC exceeded that level. The CWP treatment was only tested using cores from one pole due to difficulties in obtaining sound samples from the remaining test poles in this group and will not be discussed further. Weight losses for the three penta formulations ranged from 19 to 25 %, suggesting that these treatments provided only slight protection 11 years after application. Western redcedar west of the Cascades is typically treated on a 10 to 15 year cycle. The poles in the current study were subjected to supplemental watering which should enhance the leaching rates typical in this region. As a result, the performance of penta in these poles is probably well within that expected under field conditions. Interestingly, ammonium bifluoride provided surface protection which exceeded all other treatments. ABF is a water soluble biocide which might be expected to leach rapidly from the wood; however, the decay tests suggest some residual ABF levels.

Examination of poles treated 8 years earlier indicated that most continued to provide some supplemental protection to the wood. ACA provided the best protection of the 6 treatments, limiting weight losses in the outer 3 mm to 2 %, while all of the remaining treatments limited weight losses to between 10 and 19 % in that same zone. Weight losses further into the poles varied widely suggesting the possibility that some heartwood was included in the core samples. The results, however, indicate that 2 % copper naphthenate, the treatment currently employed for spraying western redcedar, provides excellent protection against fungal attack. Similar levels of protection were noted with 5 % waterborne copper naphthenate, FCAP or Arquad C-50, while protection afforded by zinc naphthenatetreatment was slightly lower. Zinc is typically less active against decay fungi than copper and these results reflect that difference.

The results indicate that several of the treatments continue to protect western redcedar sapwood against fungal attack under field conditions.

B. EVALUATION OF POTENTIAL CHEMICALS FOR PROTECTING WESTERN REDCEDAR SAPWOOD USING FIELD TRIALS OF SMALL SCALE BLOCKS

While the field trials outlined under section A have proven useful, these trials have proven difficult to establish owing to a lack of fully weathered western redcedar heartwood which had not yet received a supplemental preservative treatment. In subsequent trials, it was decided to treat smaller scale blocks containing sapwood faces and expose them on a south facing fence. Several western redcedar pole sections were obtained and tested for the presence of pentachlorophenol which would indicate prior spray treatment. Those with evidence of prior penta treatment were rejected since this prior treatment would confound the results obtained with the supplemental chemicals.

The pole sections were cut into a series of 15 cm cubes containing one heartwood face. The radial and inner tangential face of each block were coated with epoxy resin to retard chemical treatment of these faces and the uncoated, sapwood face of each block was dipped for 30 seconds in one of 30 test solutions (Table II-3). An elastomeric paint was applied to the non-chemically treated faces 24 hours after treatment and blocks were allowed to air dry for 4 weeks prior to being placed on a southern facing fence at a 30 degree angle. The blocks were watered for a 3 hour period each day during the drier summer months to stimulate both leaching and microbial growth.

The blocks were evaluated after 2 and 5 years by removing a series of 5 mm diameter by 12 mm long increment cores and 9 mm diameter by 12 mm long plugs. The increment cores were divided into outer (0 to 6 mm) and inner (6 to 12 mm) segments which were evaluated using the Aspergillus bioassay. The plugs were cut into four 3 mm thick wafers and evaluated for decay resistance in a soil block test as described above.

Aspergillus ZOE's of cores removed from the blocks five years after treatment were generally low, suggesting that little mobile chemical remained in the wood (Table II-4). Substantial ZOE's were noted with Amical 48, isothiazolone, penta, and

TBTO. These products were all oilborne and apparently resisted the severe leaching conditions to which the wood was exposed.

Decay tests of plugs removed from the same blocks produced slightly different results. Penta provided the best protection to the outer 3 mm of the plugs 5 years after treatment. Copper-8-quinolinolate and Kathon 930 plus Arquad C-50 produced slightly lower levels of protection in the outer 3 mm; however, the former chemical also provided protection much deeper into the plug. Kathon 930 alone provided somewhat diminished protection near the surface, but protection similar to copper-8 deeper into the wood. Some levels of decay resistance near the surface were also noted with 4 % TCMTB and NW100WD. The remaining treatments provided little residual protection against fungal attack 5 years application. These results differ substantially from those found with plugs removed 2 years after chemical treatment. In that case, 15 chemicals provided reasonable protection to the outer 3 mm of the plug and 12 provided protection up to 6 mm from the surface. The exposure employed in this study entailed severe leaching which would sharply diminish the activity of most biocides. For example, 10 % penta in diesel oil performed far better in full scale tests after 11 years than it did in the smaller blocks after only 5 years. Furthermore, the protective effects extended further into the wood in the longer exposure period. These differences illustrate the differences in severity and suggest that those chemicals which provide even moderate improvements in decay resistance in the small block tests would perform well in the field.

These trials will continue to be monitored at the 7 year point to determine when retreatment of the most effective treatments is required.

C. EVALUATE TREATMENTS FOR PREVENTING DECAY IN FIELD DRILLED BOLT HOLES

The protection of field cuts made in Douglas-fir poles from decay poses a major challenge to utilities. While many utilities specify the such cuts be treated by squirting a 2 % copper naphthenate (as copper) solution into the hole, many lineman dislike the oily nature of this chemical and ignore this requirement. It is virtually impossible to verify that such treatments have been applied, yet, we know from limited field surveys that decayed associated with bolt holes can affect 10 % or more of poles in service. This decay permits increased movement around the connector, creating longterm maintenance problems and the potential for pole failure under high wind or ice loads. The problem may be most acute in the area where cable attachments are made since lineman performing these activities are not under direct control of the pole owner.

In 1981, a series of Douglas-fir poles were lightly treated with pentachlorophenol in P9 Type A oil, then a series of 8 holes, 2.5 cm in diameter were drilled into the poles beginning 60 cm above groundline and extending upward at 45 cm intervals to within 45 cm of the top. The holes were treated with 10 % pentachlorophenol in diesel oil (an accepted standard at the time of test establishment)(Penta), powdered ammonium bifluoride (ABF), powdered disodium octaborate tetrahydrate (Boron), or 40 % boron in ethyl glycol (Boracol). Each treatment was replicated on eight holes in each of 4 poles, while holes in an additional 8 poles were left untreated to serve as controls. An additional set of 4 poles received no chemical treatment, but chemically impregnated washers containing 37.1 % sodium fluoride, 12.5 % potassium dichromate, 8.5 % sodium pentachlorophenate, 1 % sodium tetrachlorophenate, and 11 % creosote were used to attach bolts to these holes. Metal gain plates were inserted in one half of the holes in each treatment, while plastic gain plates were used for the remainder.

Control poles were sampled annually for the first 5 years by removing increment cores from sites directly below each bolt hole gain plate on one side of the pole and from sites directly above the washer on the opposite side. Cores were cultured on malt extract agar for the presence of decay fungi as described previously.

Untreated controls contained little evidence of decay until 5 years, then levels of fungal colonization rose slightly and have remained stable since that time (Table II-5). None of the control poles have evidence of significant advanced decay near the bolts holes 11 years after treatment. All poles, including those receiving chemical treatments have been sampled as described for the control poles since the sixth year of the test.

In general, application of chemicals at the time of treatment was associated with lower levels of fungal colonization except with the chemically impregnated washers (Table III-5). In the latter instances, it is likely that the chemical was unable to migrate at significant levels into the bolt hole to protect the exposed wood. Diffusible treatments including ABF, boron and boracol all were associated with very low levels of fungal colonization. These chemicals have the ability to migrate for some distance into the wood. As a result, these chemicals may be better able to move along checks which open in the wood as the pole seasons in service, providing longer protective periods against fungal invasion. Interestingly, colonization levels near bolt holes receiving pentachlorophenol continue to be intermediate between those found with controls and the diffusible treatments. These results suggest that penta, while able to protect against most fungal attack on the bolt hole surface, cannot migrate further into the wood as checks develop in service. Copper naphthenate, the chemical currently employed for these treatments should perform in a manner similar to penta. As a result, diffusible treatments may be more useful for providing long term protection to field drilled bolt holes despite their reputation as temporary treatments under wetting conditions. The moisture contents present in poles near bolt holes may be low enough to limit extensive loss of chemical from the bolt hole region. Further tests of moisture regimes above the ground are planned.

Table II-1. Chemicals Evaluated in field tests at Peavy Arboretum for protection of western redcedar sapwood.

Abbrev.	Chemical	Solvent	Trade Name	Source	Concentration Used (%)
ABF	Ammonium bifluoride	Water	Ammonium bifluoride	VanWaters and Rogers	20.0
ACA	Ammoniacal copper arsenate	Water	Chemonite	J.H. Baxter & Co.	3.0
CWP	CuOH/Methanolamine/dimethyl dialkyl ammonium chloride	Water	CWP-44	Chapman Chemical Co.	10.0/20.0/40.0
Cunap	Copper naphthenate	Water	Cunapsol-S	Chapman Chemical Co.	2.0 (Cu)
IPBC	3-iodo-2-propynylbutyl carbamate	Water	Polyphase	Troy Chemical Co.	2.0
Penta 1	Pentachlorophenol	Oil	-	Vulcan Chemical Co.	10.0
Penta 2	Pentachlorophenol	Water			10.0
Penta 3	Ammoniacal Pentachlorophenol	Water	PAS	Reichhold Chemical Co.	2.5

Table II-2. Wood weight losses and <u>A</u>. <u>niger</u> zones of effect of samples at successive depths from the surface of plugs removed from western redcedar poles 11 years after application of selected biocides.

Chemical Treatment[a]	Solvent	<u>Aspergillus</u> ZOE (mm)[b]		Wood Weight Loss (%)[c]			
		0-6 mm	7-12 mm	0-3 mm	3-6 mm	6-9 mm	9-12 mm
Ammonium bifluoride (20%)	water	0(0)	1(1)	14.4(10.8)	20.3(10.6)	19.6(11.1)	22.8(12.1)
Copper 8 quinolinolite (0.12%)	oil	1(1)	1(1)	33.0(12.4)	25.7(17.6)	25.0(12.2)	15.7(9.7)
Copper 8 quinolinolite (0.9%)	water	2(2)	2(2)	35.5(21.5)	30.5(21.5)	-	-
3 iodo 2 propynyl butylcarbamate (2.0%)	water	0(0)	4(2)	34.0(-)	19.0(7.1)	45.0(3.0)	25.0(18.2)
Pentachlorophenol[1] (10%)	oil	7(3)	3(2)	22.0(15.7)	10.5(9.7)	5.1(4.1)	16.8(12.6)
Pentachlorophenol[2] (10%)	water	5(3)	2(3)	19.2(6.7)	19.8(11.3)	36.5(4.5)	13.6(13.1)
Pentachlorophenol[3] (2.5%)	water	1(2)	0(0)	25.0(14.4)	23.7(12.5)	26.8(13.0)	19.8(12.8)
CuOH/DDAC (10/5%)	water	7(3)	8(2)	4.0(-)	-	28.5(11.5)	14.0(3.0)
Copper naphthenate (5%)	water	8(2)	5(3)	10.0(2.0)	20.0(-)	13.0(-)	8.0(4.5)
Copper naphthenate (2%)	oil	0(0)	1(2)	11.4(13.9)	5.4(2.5)	11.2(11.9)	13.6(12.2)
Zinc naphthenate (2%)	water	1(1)	1(1)	19.0(13.3)	24.4(16.2)	8.5(8.0)	3.2(1.6)
FCAP (5%)	water	7(3)	7(3)	13.7(4.6)	9.5(0.5)	4.5(3.5)	-
Aquad C-50 (5%)	water	6(3)	4(2)	14.3(7.3)	11.8(10.8)	34.0(23.4)	22.0(14.2)
ACA (3%)	water	10(2)	7(4)	2.0(0.8)	12.0(15.6)	7.5(3.5)	-
Control	-	1(3)	2(3)	30.9(12.4)	32.3(13.6)	27.3(14.4)	26.9(14.8)

[a] Values in parentheses represent chemical concentrations tested as % active ingredient except for copper-8-quinolinolite, copper naphthenate and zinc naphthenate, where percent as metal is used.

[b] Values represent means of 18 samples/treatment, while values in parentheses represent on standard deviation.

[c] Values represent average of 12 samples/treatment, while values in parentheses represent one standard deviation.

Table II-3. Preservative formulations tested on western redcedar sapwood blocks.

Trade name[a]	Chemical name	Source	Solvent	Concentration tested (%ai.i)
Amical 48	Diiodomethyl p-tolyl sulfone	Akzo Chemie, N. Chicago, IL	0.5 oil and 0.5 acetone	1.0
Arquad C-50	Trimethyl cocammonium chloride	"	water	5.0
Busan 1009	Methylene bisthiocyanate and thiocyanomethyl thiobenzothiazole	Buckman Laboratories, Int., Memphis, TN	"	4.0
"	"	"	"	2.0
Busan 1009 and Busperse 47[b]	"	Buckman Laboratories (both)	"	4.0 (Busan) and 5.0 (Busperse)
"	"	"	"	2.0 (Busan) and 2.5 (Busperse)
Busan 1030	Thiocyanomethyl thiobenzothiazole	"	"	4.0
"	"	"	"	2.0
Busan 1030 and Busperse 47[b]	"	"	"	4.0 (Busan) and 5.0 (Busperse)
"	"	"	"	2.0 (Busan) and 2.5 (Busperse)
Cu-8	Copper-8-quinolinolate	Nuodex, Inc., Piscataway, NJ	"	0.3 (Cu)
Cunap	Copper naphthenate	Tenino Wood Preservatives, Seattle, WA	oil	2.0 (Cu)
CWP-44	Copper hydroxide/methanol amine/dimethyl dialkyl ammonium chloride	Chapman Chemical Co., Memphis, TN	water	10.0
Kathon 930	Dichloro-n-octyl-isothiazolone	Rohm and Hass, Inc., Spring House, PA	oil	1.0
Kathon 930 and Aquad C-50	"	Akzo Chemie and Troy Chemical Co., Rahway, NJ	"	0.5 (Kathon) and 3.0 (Arquad)
Kathon 930 and Busperse 47[b]	"	Akzo Chemie and Buckman Laboratories	water	1.0 (Kathon) and 5.0 (Busperse)
MGARD 550	Zinc naphthenate	Mooney Chemical Co., Cleveland OH	"	4.0
MGARD 553	"	"	"	4.0
"	"	"	"	2.0
NW 100 SS	Dodecyl dimethyl benzyl ammonium salt of naphthenic acid	Nuodex, Inc., Piscataway, NJ	oil	8.0
NW 100 WD	"	"	water	8.0
Penta	Pentachlorophenol	Chapman Chemical Co., Memphis, TN	oil	10.0
Pole Spray 675	Copper-8-quinolinolate	"	"	0.12 (Cu)
Polyphase	3-iodo-2 propynyl butyl-carbamate	Troy Chemical Co., Rahway, NJ	water	2.0
Polyphase and Arquad C-50	"	Troy Chemical Co. and Armak Co.	oil	1.0 (Polyphase) and 3.0 (Arquad)
Polyphase and Busperse 47[b]	"	Troy Chemical Co. and Buckman Laboratories	"	1.0 (Polyphase) and 5.0 (Busperse)
Rodewod SC-5033	1-{[2-(2,4-diichlorophenyl)-1,3-dioxolan-2yl]-methyl}-1H-1,2,4 triazole	Janssen Pharmaceutica, Beerse, Belgium	water	0.3
"	"	"	"	0.15
TBTO	Tributyltinoxide	M&T Chemical, Inc., Rahway, NJ	oil	5.0
Woodlife	3-iodo-2 propynl butyl-carbamate	DAP Inc., Dayton, OH	"	0.5

[a] All trade names are registered except Cu-8, CWP-44, Penta, Pole Spray 675, and TBTO.

[b] Chemical name unavailable from manufacturer.

Table II-4. Aspergillus bioassay zones of effect (ZOE) or wood weight losses in a soil block test of wood samples removed from remedially treated western redcedar blocks after 2 or 5 years of exposure on a test fence.

Chemical	Concentration (%)	Solvent	Aspergillus ZOE (mm)		Wood Weight Loss (%)							
			5 years		5 years				2 years			
			outer (0-6mm)	inner (6-12mm)	0-3mm	3-6mm	6-9mm	9-12mm	0-3mm	3-6mm	6-9mm	9-12mm
Amical 48	1	oil	4.9	1.1	40	33	33	31	9	8	11	8
Arquad C-50	5	water	0	0	27	27	20	34	22	23	22	20
Busan 1009	2	water	0	0	43	37	24	13	33	30	32	35
	4	water	0.5	0	30	36	36	34	15	17	18	16
Busan 1009/Busperse 47	2.0/2.5	water	0	0	41	46	41	43	12	17	31	28
	4.0/5.0	water	0.4	0.6	29	38	35	31	8	17	27	26
Busan 1030	2.0	water	1.0	0.6	33	28	39	42	33	40	33	47
	4.0	water	0.8	1.6	24	40	40	35	16	21	31	26
Busan 1030/Busperse 47	2.0/2.5	water	0.4	0.3	34	47	36	31	16	27	40	35
	4.0/5.0	water	0.9	1.3	36	44	41	29	15	23	24	25
Cu-8	0.3(Cu)	water	0	0	16	17	19	18	31	27	45	36
Cunap	2.0(Cu)	oil	0	0	38	44	23	21	13	18	29	27
CWP	10.0	water	0	0	42	27	28	30	25	29	39	37
Kathon 930	1.0	oil	4.0	3.8	25	20	18	24	8	5	8	8
Kathon 930/Arquad C-50	0.5/3.0	oil	2.3	1.8	16	31	25	28	9	9	15	19
Kathan 930/Busperse 47	1.0/5.0	oil	5.0	2.1	31	25	34	43	11	8	9	9
MGARD 550	4.0	water	0	0	45	46	34	37	25	29	39	37
MGARD 553	2.0	water	0	0	46	46	38	38	33	34	25	34
	4.0	water	2.0	1.8	44	41	40	45	24	29	31	28
NW100 SS	8.0	oil	0	0	32	35	24	18	11	10	21	18
NW100 WD	8.0	water	0	0	27	23	27	35	27	36	42	42
Penta	10.0	oil	8.5	4.9	11	36	32	46	10	9	8	10
Pole Spray 675	0.12(Cu)	oil	0	0	31	27	36	50	20	17	34	34
Polyphase	2.0	water	0	0	45	47	36	32	26	30	35	23
Polyphase/Arquad C50	1.0/3.0	oil	0	0	42	44	32	34	34	29	29	31
Polyphase/Busperse 47	1.0/5.0	oil	0	0.8	43	40	33	36	37	35	37	32
Rodewood SC 5033	0.30	water	0	0	38	36	24	29	32	36	28	36
	0.15	water	0	0.3	38	41	25	29	33	35	37	47
TBTO	5.0	oil	11.6	7.8	40	44	16	21	7	7	9	8
Wood life	0.5	oil	1.1	0.6	45	41	41	47	28	27	30	31
Control	-	-	0	1.3	35	34	35	34				

Table II-5. Basidiomycetes and other fungi found in preservative-treated Douglas-fir poles 6 to 10 years after bolt holes were drilled and treated in the field, as shown by cultures from increment cores.

Field Treatment	Percentage of cores containing...											
	Basidiomycetes						Other Fungi					
	6 yr	7 yr	8 yr	9 yr	10 yr	11 yr	6 yr	7 yr	8 yr	9 yr	10 yr	11 yr
Ammonium bifluoride (n=32)	0	2	0	2	2	2	5	2	16	42	9	47
Boracol® 40 (n=32)	0	2	0	0	3	0	18	27	33	66	16	70
Patox® washer (n=32)	5	5	8	14	13	11	12	22	31	66	27	55
Pentachlorophenol (n=32)	2	2	8	5	6	5	25	17	25	51	25	80
Timbor® (n=32)	0	0	0	2	2	2	11	25	25	37	14	75
Control (n=64)	3	9	17	9	8	11	30	26	46	70	33	86

OBJECTIVE III

DETECT EARLY DECAY AND ESTIMATE RESIDUAL STRENGTH OF POLES IN SERVICE

While we have identified a variety of highly effective methods for protecting wood poles against fungal and insect attack, our ability to detect decay at the early or incipient stages of decay, lags far behind. A variety of studies have shown that some bending properties of wood can decrease as much as 60 % with as little as a 5 % loss in weight. At that point, the decayed wood would be indistinguishable from sound wood, yet its properties would be dramatically different. Thus, detecting decay at the earliest possible point has important implications on pole strength and, ultimately, service life. Furthermore, a number of trials suggest that decayed wood is less receptive to remedial treatment.

As a part of our efforts to detect incipient decay, we have evaluated a variety of laboratory and field decay detection devices including chemical indicators, the Pilodyn, and acoustic methods; however, each has had certain limitations. In addition, we have evaluated methods which might be used to limit the incidence of internal decay development such as kerfing or through-boring and have examined the incidence of decay above ground in Douglas-fir poles.

A. ESTIMATE THE INCIDENCE OF INTERNAL DECAY ABOVE THE GROUNDLINE IN DOUGLAS-FIR POLES EXPOSED UNDER VARYING ENVIRONMENTAL CONDITIONS

Utilities are increasingly incorporating through-boring or radial drilling into their specifications to reduce the development of internal decay at the groundline. As a result, the incidence of internal decay in this zone of the pole should gradually diminish in utility systems employing some type of groundline treatment specification. Over the years, decay has also been noted above the groundline, particularly west of the Cascade Mountains, where wet winters tend to increase wood moisture content above the ground. As utilities extend the service life of their poles using combinations of through boring and internal remedial treatment, what was once seen as a a minor incidence of internal decay may increase to levels of economic concern.

In an effort to evaluate the potential for above ground decay in Douglas-fir utility poles in the Pacific Northwest, the following survey was undertaken.

Douglas-fir poles in service for varying periods of time were sampled in zones corresponding to the Oregon coast, the Puget Sound area, the Willamette Valley, and Eastern Oregon/Washington. Poles were sampled by removing 2 increment cores 120 degrees apart from sites

1.5, 3.0 and 4.5 m above the groundline. The depth of preservative treatment and the presence of any visible decay on the core was recorded and the wood were cultured on malt extract agar for the presence of decay fungi. A total of 274 poles have been sampled in the Willamette Valley of Oregon, the Oregon Coast, and Eastern Oregon using these procedures. Additional poles are currently being sampled in the Puget Sound area.

In general, poles in lines located near the coast contained higher levels of fungal infestation (21.6 % colonized) compared to lines located in the Willamette Valley (15.4 % poles colonized) or Eastern Oregon (8 % of poles colonized) (Table III-1). Elevated infestation levels along the coast most probably reflects the increased incidence of wind driven rain in this region. Many utilities along the Oregon coast contend that above ground decay is the primary reason for early pole failure. The Willamette Valley also receives copious wind-driven rainfall during the winter months and this is apparently sufficient to increase the above ground moisture content to a level which supports fungal growth. The incidence of any above ground decay in Eastern Oregon is suprising since the line sampled lies in an area receiving less than 50 cm of rainfall per year. Decay in this region typically occurs 15 to 30 cm below the groundline where sub-soil moisture is adequate for fungal growth. Above this point, internal wood moisture contents should be too low to support active fungal attack. The poles sampled in this region were all at least 30 years old, making it extremely unlikely that these fungi had survived in the pole through the treatment process and then remained dormant as the pole remained in service. None of the poles in Eastern Oregon contained evidence of advanced decay above the gorundline, suggesting that fungal attack was extremely limited. Additional poles will be sampled in this region to confirm the colonization levels noted.

In addition to pole location, fungal infestation levels also varied with height above the groundline. As expected, fungal incidence in poles exposed in the Willamette Valley was highest 1.5 m above the groundline and lowest an additional 3 m above that site. The degree of infestation varied more widely with height along the coast, probably reflecting the influence of wind driven rain. The degree of fungal infestation at 4.5 m was similar to that found 1.5 m above the groundline at both Long Beach and Coos Bay, while it was highest at 4.5 m at Reedsport and Florence. Fungal infestation levels were lowest 4.5 m above the groundline in poles sampled near Tillamook, Oregon. Variation in the incidence of fungi among individual lines along the Oregon Coast may reflect distance inland from the coast, since the Coast Range Mountains rise sharply from the coastline and can block the levels of wind. Rainfall levels in the Coast Range, however, are often much higher than those found directly on the coast.

The effect of pole age on incidence of fungi above ground was unclear (Table III-2). Fungal infestation levels rose with increasing age between 0 and 30 years, then declined slightly. Previous evaluations of the incidence of internal decay in kerfed poles of varying ages showed that decay incidence rose markedly between 10 and 20 years after installation, then declined. This decline may reflect a tendency for inspections to detect and remove badly decayed poles, leaving a group of survivor poles which for some reason are less likely

Table III-1. Incidence of basidiomycetes at selected locations above the groundline in Douglas-fir poles located at selected Pacific Northwest Locations.

Location	Sample Size	% cores infested[a]			Poles Infested (%)
		1.5 m	3.0 m	4.5 m	
	Willamette Valley				
Corvallis, OR	49	7.1	1.0	2.0	16
Eugene, OR	29	3.4	8.6	1.7	14
Coast					
Tillamook, OR	49	9.2	7.1	3.1	16
Long Beach, WA	55	11.8	8.2	10.0	29
Coos Bay, OR	23	10.9	6.5	8.7	26
Reedsport, OR	11	0	0	4.5	9
Florence, OR	10	0	0	5.0	10
Eastern Oregon					
Redmond, OR	48	0	2.1	2.1	8

[a] Values based upon removal of 2 cores from each sampling site per pole.

Table III-2. Incidence of basidiomycetes at selected locations above the groundline of Douglas-fir poles in various age groups exposed throughout the Pacific Northwest

Pole Age (years)	Sample Size	% cores infested[a]			Poles Infested (%)
		1.5 m	3.0 m	4.5 m	
1-10	12	-	-	4.2	8
11-20	93	81	5.4	5.4	20
21-30	23	19.6	8.7	6.5	30
31-40	146	4.1	4.5	3.8	21

Table III-3. Degree of preservative penetration in increment cores removed from the through bored zone of Douglas-fir poles 13, 18, or 25 years after treatment.

					% of Cores in Each Visual Penetration Group			
Treatment	Year Treated	Years in Service	# of Poles	# of Cores	60-69%	70-89%	90-99%	100%
Creosote	1980	13	15	45	0	0	0	100
Penta	1968	25	51	102	0	2	1	97
	1975	18	25	50	6	6	4	84

to develop internal decay. In the current study, poles older than 30 years of age were not through-bored prior to installation and extensive efforts were made in the early 1970's to identify and remove decaying poles in this age group. It is likely that this process left behind better treated poles with smaller checks which did not tend to penetrate into the untreated heartwood. This process would produce a set of poles with a lower likelihood to develop internal decay. Utilities lengthening the service life of poles through regular remedial groundline treatments should consider the possibility for development of an above ground decay problem as poles in their system age. At present, only a limited number of chemicals would be available for internal remedial treatment above ground including MITC-Fume, boron rods, metham sodium, and CuRap 20. Field trials with boron rods andCuRap 20 as above ground internal decay treatments have shown that both move very slowly through the dry wood which characterizes the above ground pole zone. Metham sodium, while highly effective, can be spilled during application. MITC Fume, is also highly effective, but the cost of this chemical has limited application. It is apparent that further testing of safer, above ground treatments will be necessary as utilities continue to extend the useful life of their wood system.

The evaluation of fungal incidence above ground will be completed this summer and should provide useful guidance for utilities addressing pole performance and ultimate service life.

B. TREATMENT OF THROUGH-BORED DOUGLAS-FIR POLES: EFFECT OF TREATMENT SKIPS ON PERFORMANCE

Through-boring has been employed for improving the treatment of Douglas-fir poles for over 30 years, but many utilities have only recently begun to incorporate this practice into their specifications. As these specifications are developed, many users have questioned the requirement that preservative completely penetrate the through-bored zone. In an effort to examine this issue, preservative penetration in the through-bored zone was assessed in Douglas-fir poles treated over a number of years. Increment cores (17.5 cm long) were removed from three locations in the through bored zone of 91 poles. These cores were then split lengthwise and penetration of preservative was visually assessed. Poles had been treated with either pentachlorophenol in P-9 Type A oil or creosote. All of the poles were in the Bonneville Power Administration system and additional efforts are underway to collect cores from poles in the Portland General Electric system since these two utilities employ slightly different through-boring patterns.

Results in the BPA system indicate that 94.4 % of the cores examined were completely treated with preservative (Table III-3). Penetration varied slightly with pole age, although only 3 ages have been examined to date. For example, 84 % of cores from poles treated in 1975 were completely penetrated, while 97 and 100 % of cores from poles treated in 1968 and1980, respectively, were completely treated. Penetration never fell below 60 to69 % of the core surface and was worst with the poles treated in 1975. Examination of the cores also indicated no evidence of decay in any of the untreated zones.

While additional efforts are underway to collect cores from other through bored poles, the initial results suggest that most poles are well treated in the through bored zone. It is, of course, difficult to determine if the excellent treatment reflects good initial treatment or subsequent migration of preservative downward into untreated areas. Further trials are planned using freshly treated materials. The absence of detectable decay in the through-bored zone, does, however, reinforce the value of this pretreatment step for protecting wood against internal decay.

C. EVALUATION OF A DECAY DETECTING DRILL IN DOUGLAS-FIR AND WESTERN REDCEDAR POLES

As mentioned, detecting decay as early as possible has numerous advantages from both structural and remedial treatment points of view. As a part of our efforts to evaluate new wood pole inspection instruments as they become available, we recently examined a Decay Detecting Drill (Sibert Instruments DDD 200, Shannon Technology Corp, Phoenix, AZ). This device was developed in Northern Ireland for estimating density of standing trees. This device traces the drill path of a fine drill bit as it is inserted into the wood. Bands between lines can then be related to wood density which can in turn be related to presence of decay or weakened wood.

In our trials, 9 Douglas-fir and 9 western redcedar transmission poles were inspected by drilling three holes at equidistant points around the groundline using the Decay Detecting Drill (Table III-4). Above ground zones were also sampled on selected poles. The poles had been in service for 1 to 35 years and were treated with creosote or pentachlorophenol in P9 Type A oil. An increment core was then removed from the same location as the drill hole so that the drill hole was included in the increment core. The cores were examined for depth of preservative penetration, number of rings per cm in the inner and outer zones, and evidence of visible decay, then placed in plastic drinking straws for later culturing for the presence of basidiomycetes.

Since the poles were sampled during the wet season the wood was wetter and therefore less resistant to drill penetration. As a result, several sites which apppeared to be otherwise sound had increased rotational patterns which implied the presence of internal decay. Examination and culturing of cores confirmed that the wood was sound. While drill resistance should differ markedly between wet sound wood and dry decayed wood, differences in resistancce would also exist between wet and dry sound wood. These sifferences would necessitate some judgement on the part of the inspector.

As expected, the drill patterns varied between western redcedar and Douglas-fir, reflecting the lower density of the former species (Figure III-1). This device might need extensive calibration for use on softer woods where the differences between sound and decayed wood might be very slight in terms of resistance to a drill bit.

In general, the time required for drilling the test holes was short and the device was relatively non-destructive. The small holes, however, could become points of entry for decay fungi and would have to be either remedially treated or plugged with a treated dowel. In addition, it was sometimes difficult to distinguish between decay pockets and soft wood. For example, a decay pocket was detected near the groundline of pole #7/4A, a western redcedar pole, and the drill pattern appears to reflect this damage. Sampling in sound wood 1.2 m above the decay pocket, however, produced a drill pattern which differed little from that found near the void. The similarity of patterns would necessitate additional inspection of all holes, negating the value of the smaller inspection device. Alternatively, some adjustments in rate of drilling might improve the sensitivity of the drill on softer species.

While the Decay Detecting Drill was simple to use, its high cost and difficulty in separating sound soft wood from decaying wood would limit its usefulness for inspecting wood poles. This device might be more practical for inspecting the interior of buildings where reducing the damage from inspection holes might have an asthetic value. Furthermore, the need to remedially treat inspection holes inside a building would be sharply diminished. Attempts to employ the device for wood pole inspection would require the development of a more substantial data base to distinguish decay from other natural wood defects.

D. PRESERVATIVE PENETRATION AND RETENTION IN FULL LENGTH THROUGH BORED DOUGLAS-FIR POLE SECTIONS

Through-boring has sharply reduced the incidence of internal decay at groundline, but field inspections have noted an increasing incidence of decay above that zone. Above ground inspections for decay detection are expensive and time consuming.

A need for regular above ground inspection of wood poles would sharply alter the long term maintenance costs of wood poles and create a problem with identifying potential remedial treatments which could be applied in this zone. One potential approach to limiting this decay is to continue the through boring up the remainder of the pole. While this can have some impact on wood strength, complete treatment of the wood would ensure that decay could not further deteriorate the wood. Thus, a utility would trade a slight loss in initial bending strength for a more reliable service life.

This past year, a cooperative trial was initiated between Bonneville, Power Administration, Portland General Electric, Pacific Power and Light, Pacific Wood Treating, and OSU to evaluate the feasibility of full length through boring. Twenty-four pole sections were drilled to 4 patterns based upon the PGE or BPA through boring specifications (Figure III-2) and treated with pentachlorophenol in P9 Type A oil using a conventional treatment process. Twelve cores were removed from each pole section both parallel and perpendicular to the through bored holes. Preservative penetration was visually measured on each core, then the cores were divided into 2.5 cm long segments which were combined for analysis by x-ray fluorescence using an Asoma 8620 Analyzer. The analyses are still underway and the results will appear in the next annual report.

The pole sections were then cut into 0.75 m long sections which were split vertically to assess preservative distribution. The results of these trials should provide a basis for assessing the effects of through boring pattern on above ground treatment. Further trials willl then be undertaken to assess the effects of above ground through-boring on pole bending properties.

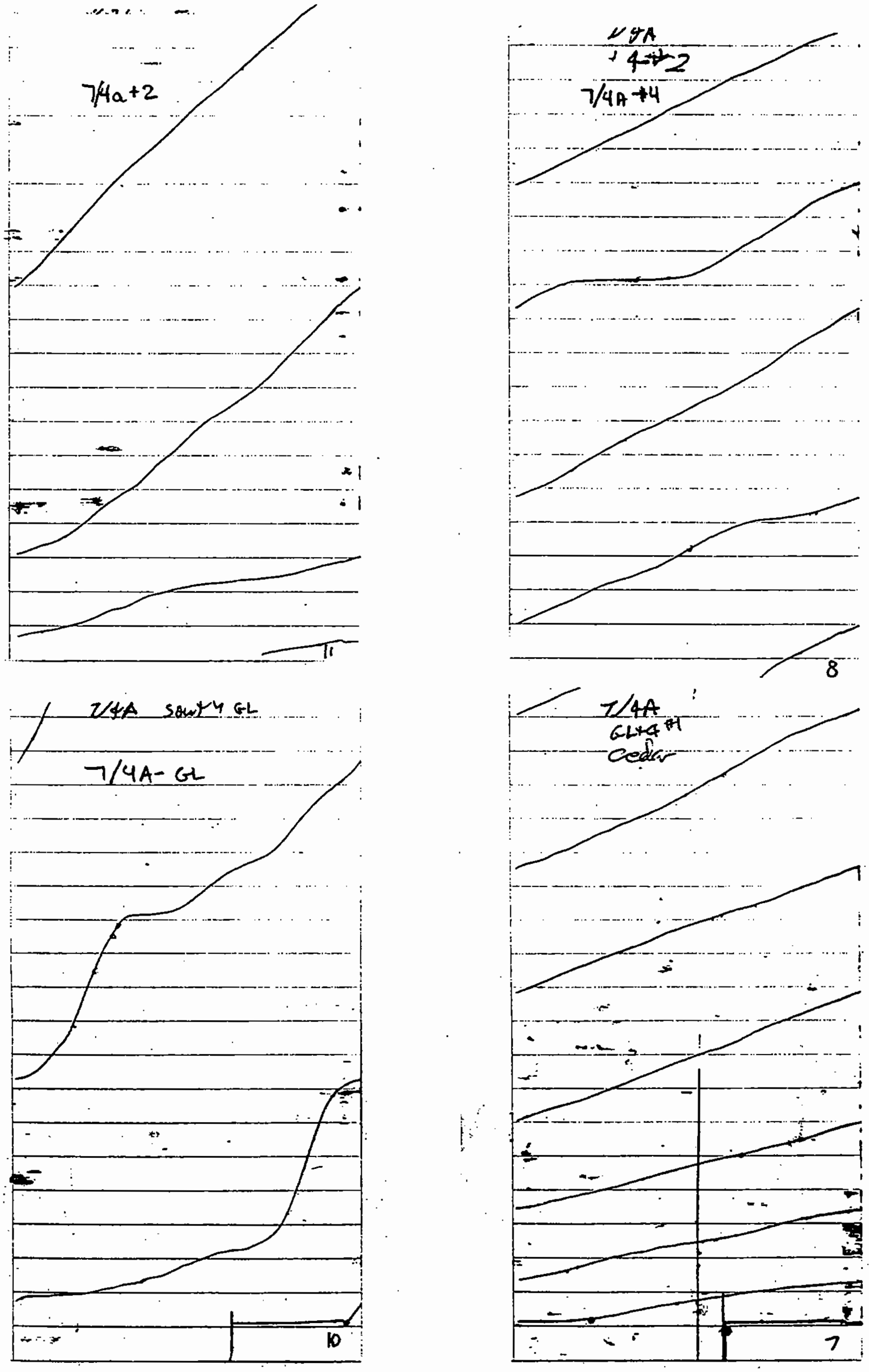
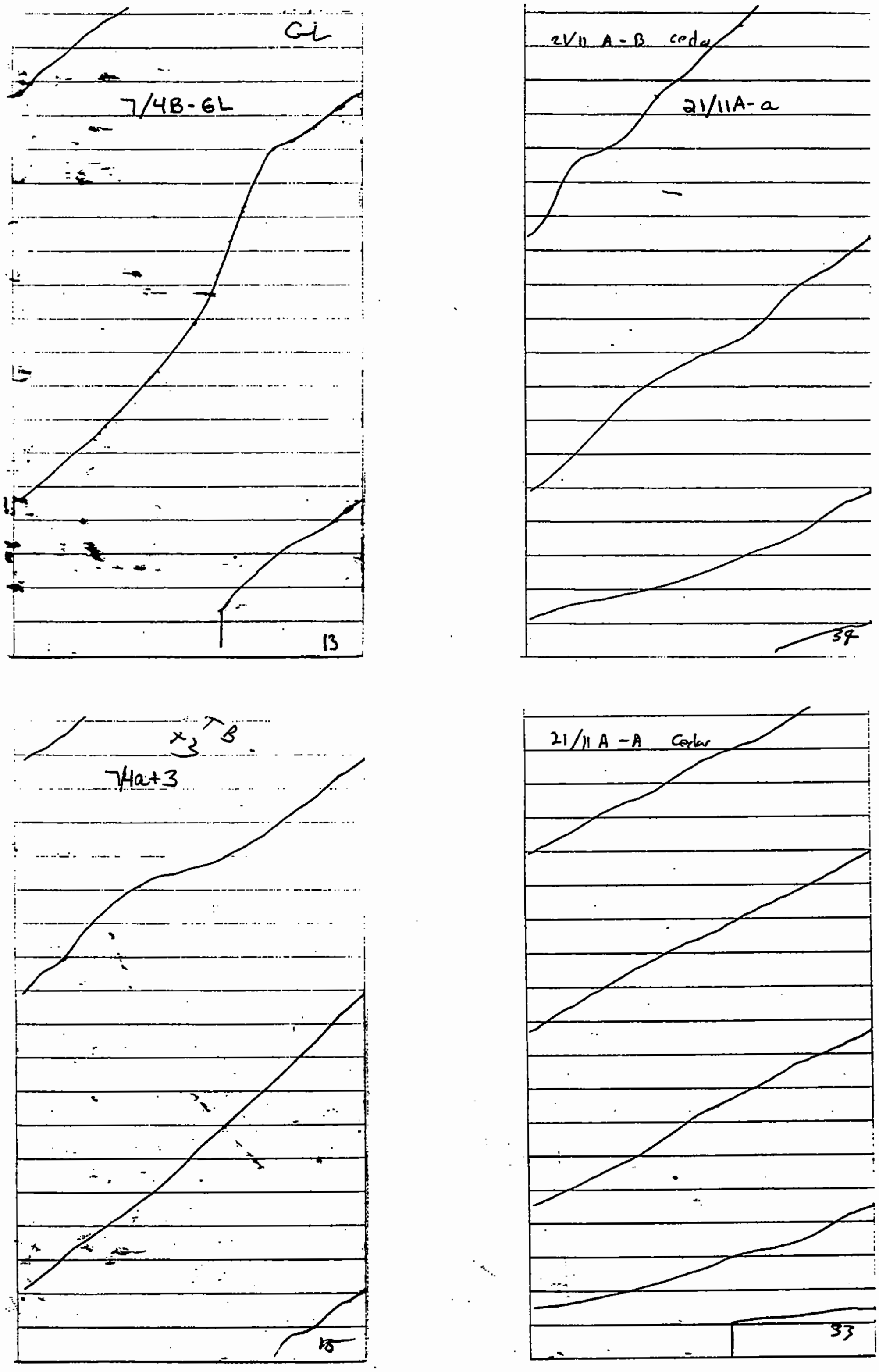


Figure III-1. Decay detecting drill patterns and presence of internal decay observed for Douglas-fir and western redcedar poles.



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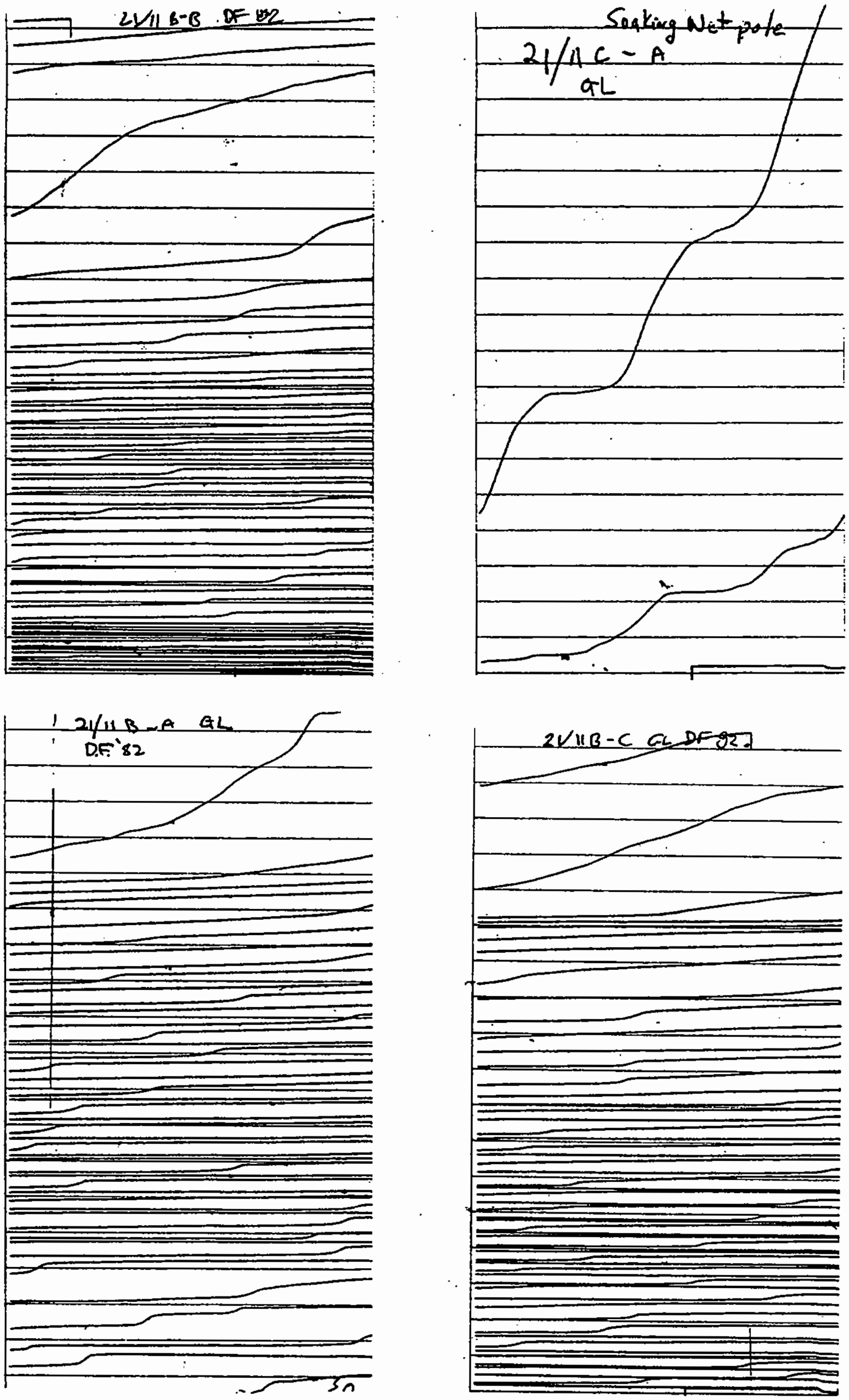

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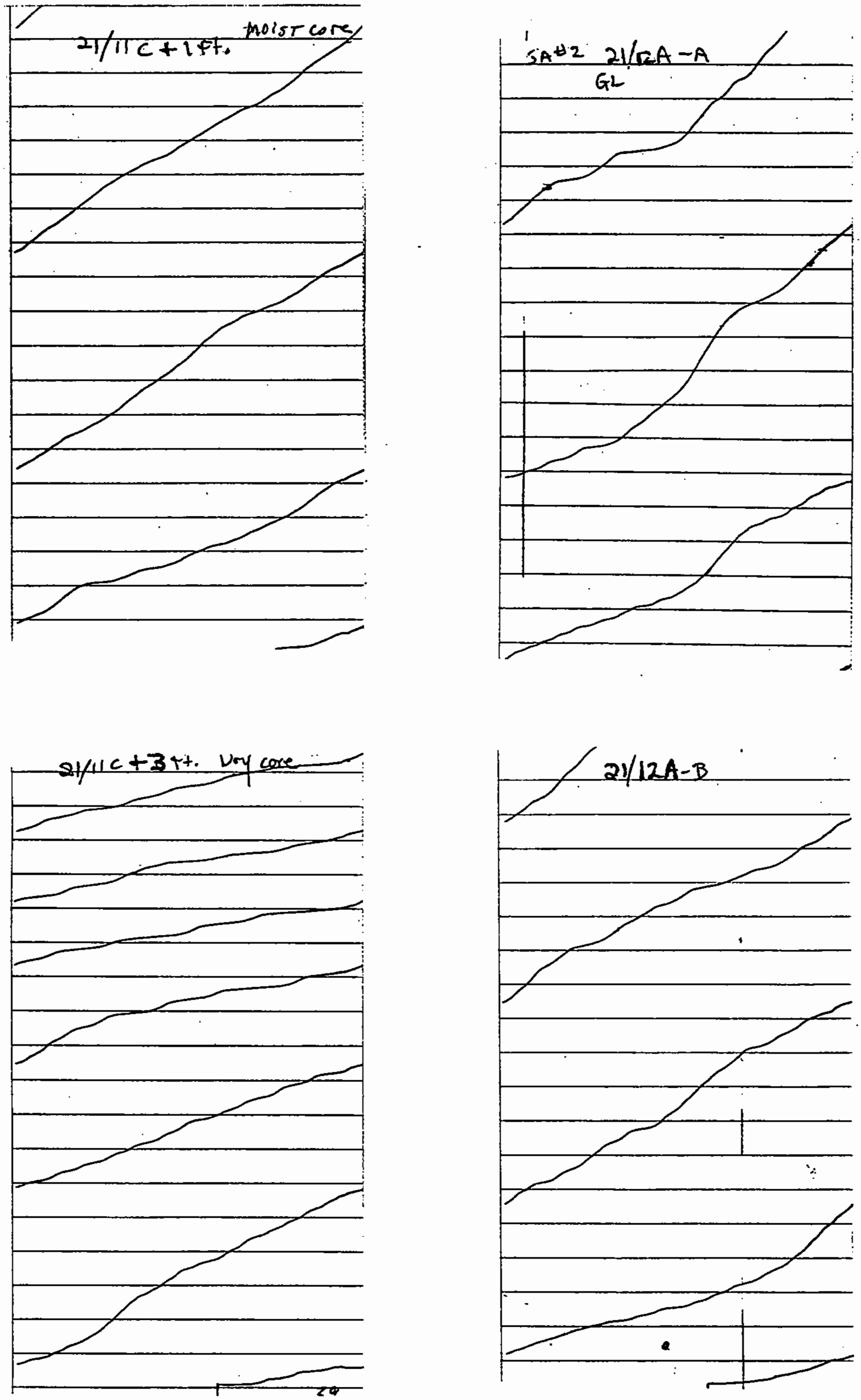

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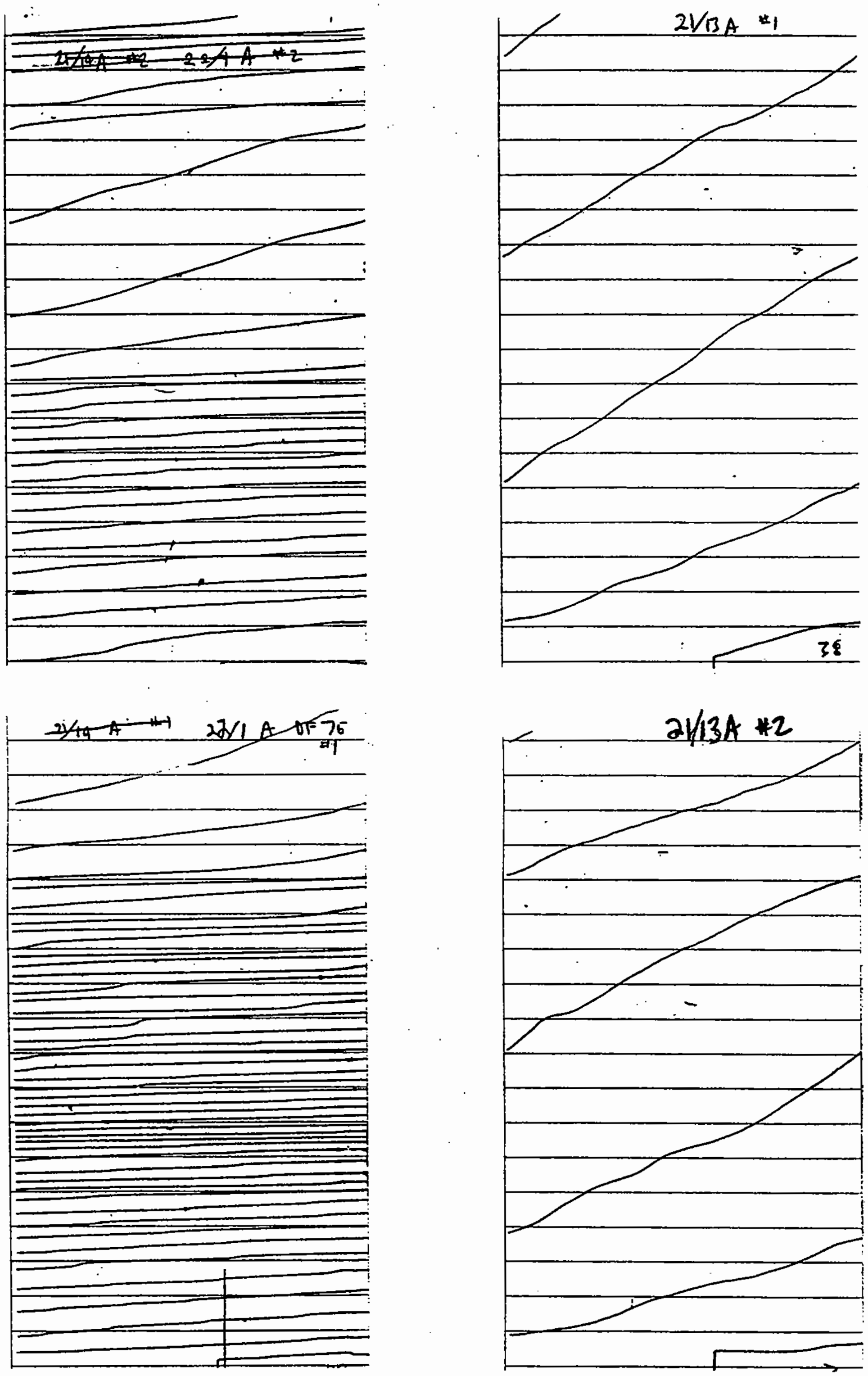

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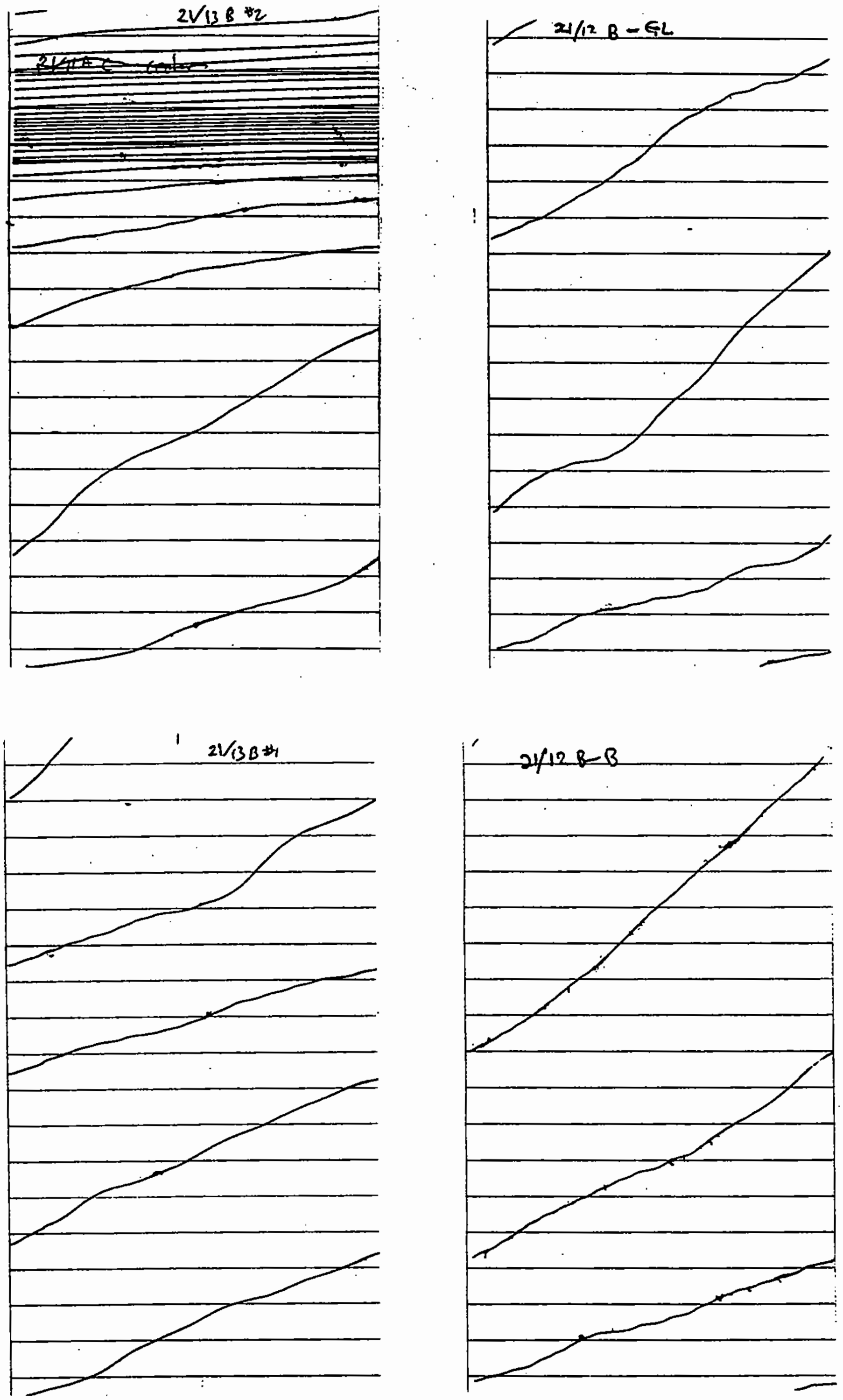

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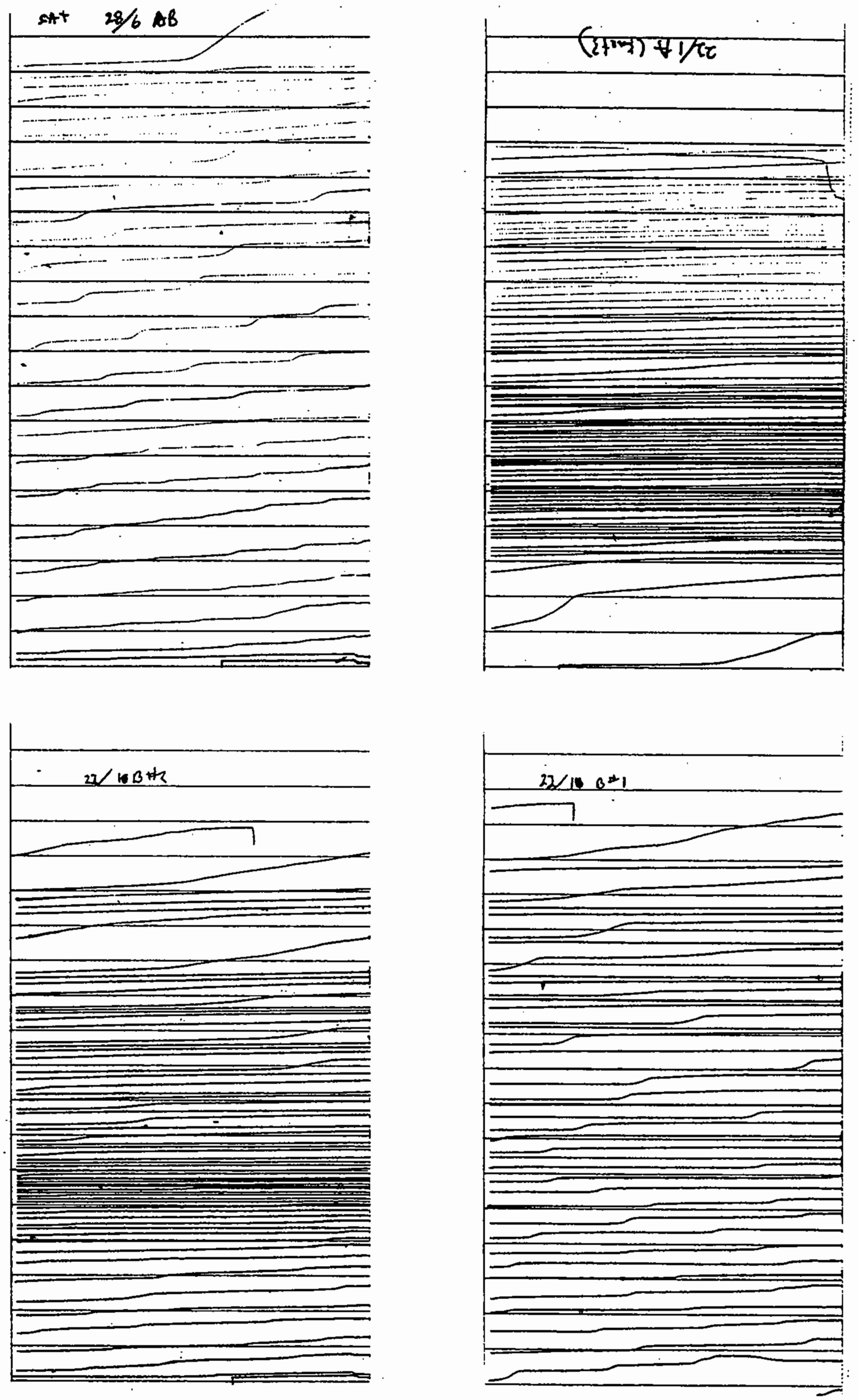

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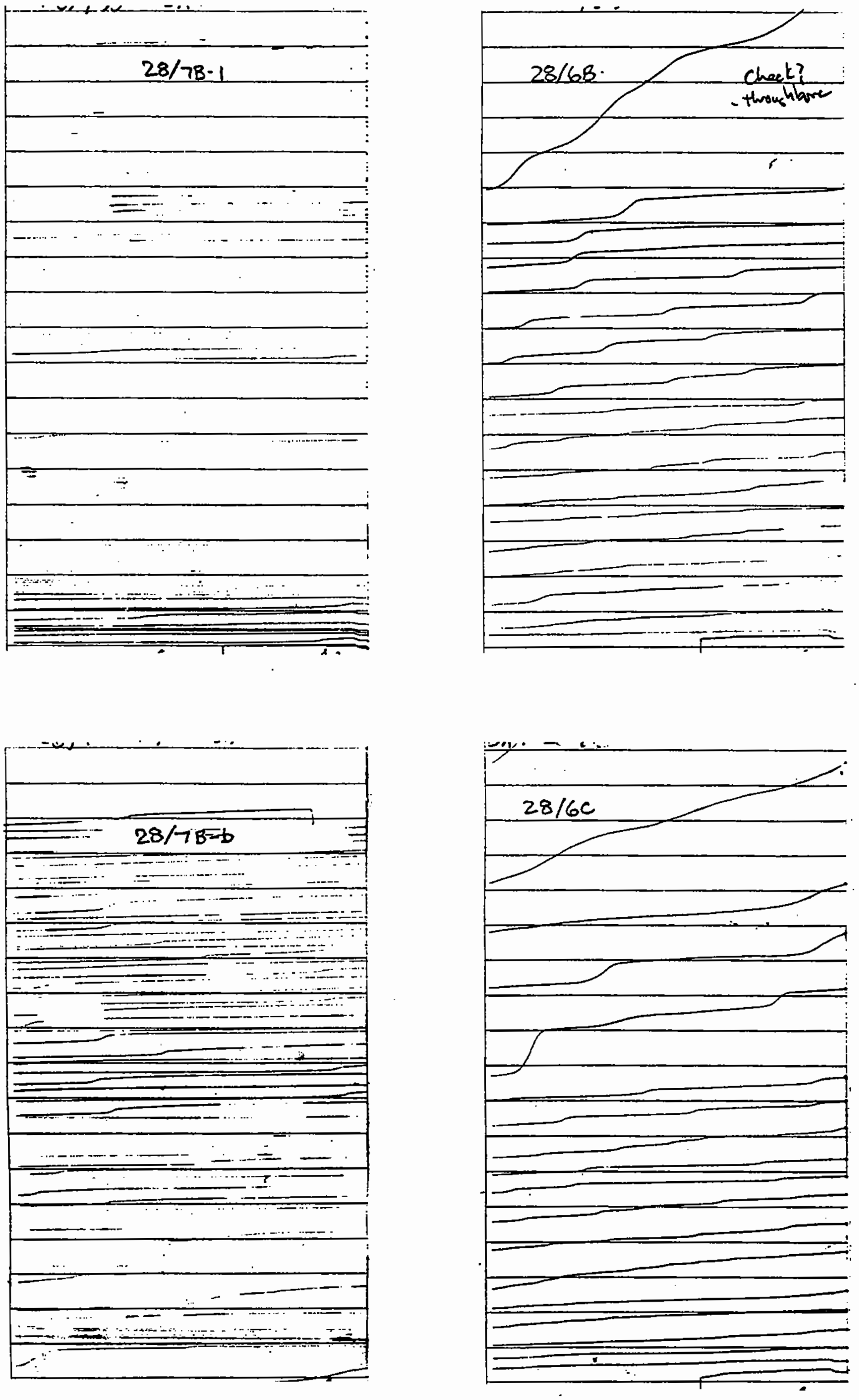

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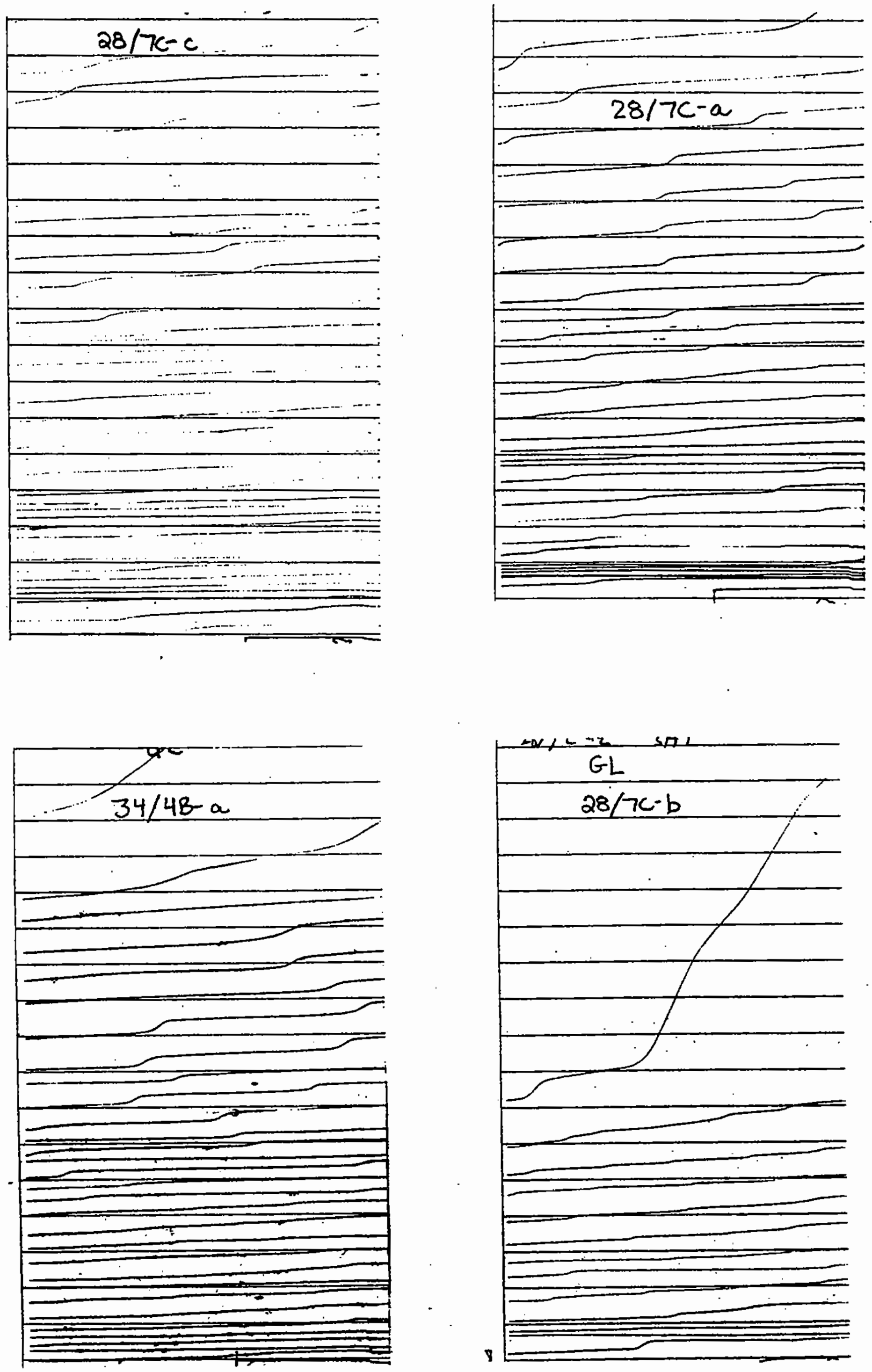

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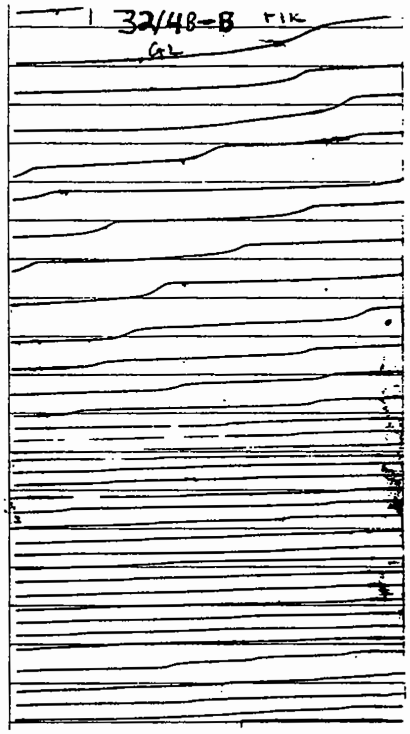


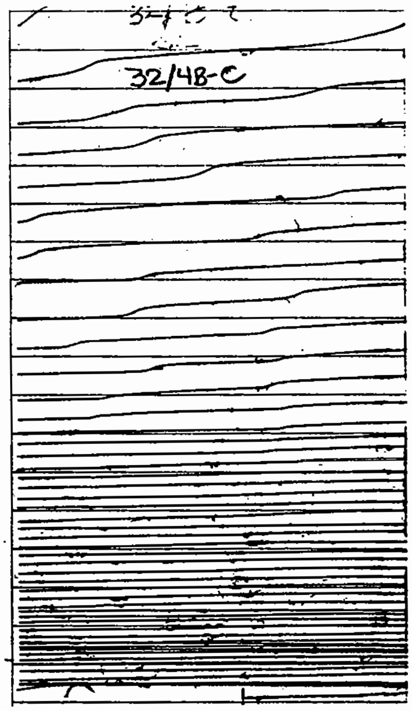


Figure 111-1 (continued)

Table III-4. Results of internal sampling of Douglas-fir and western redcedar poles using an increment borer.

Pole #	Wood Species	Treatment Zone (cm)	Residual Shell (cm)	Rings/cm		Presence of			Comments
				outer	inner	Decay fungus	Non-decay Fungus	Decay Pocket	
7/4 A +0.5	W. redcedar	2.0	15.0	20	-	-	-	+	
+2.0	W. redcedar	1.5	15.0	24	7	-	-	-	
+4.0	W. redcedar	1.0	15.0	21	-	-	-	-	
+4.0	W. redcedar	0.5	15.0	20	-	-	-	-	
7/4 B GL	W. redcedar	4.0	16.0	21	6	-	+	-	
+1	W. redcedar	1.5	16.0	21	6	-	-	-	
+3	W. redcedar	1.0	16.0	21	6	-	-	-	
21/11A- a	W. redcedar	1.0	15.0	6	4	-	-	-	
b	W. redcedar	0.5	13.5	6	4	-	-	-	
21/11B- a	Douglas-fir	13.0	13.0	2	2	NC	NC	-	
b	Douglas-fir	15.0	15.0	2	2	NC	NC	-	
21/11C 0.5	W. redcedar	2.0	17.0	3	3	-	+	+	Wet Pocket
1.5	W. redcedar	1.5	15.0	3	3	-	+	-	Wet Pocket
3.0	W. redcedar	0.5	17.0	3	3	-	+	-	Wet Pocket
21/12A- a	W. redcedar	1.0	15.0	6	2	-	+	-	
b	W. redcedar	2.0	13.0	7	2	-	+	-	
21/12B- a	W. redcedar	2.5	15.0	5	5	-	+	-	Wet Pocket
b	W. redcedar	1.0	14.0	5	5	-	+	-	Wet Pocket
21/12C- a	W. redcedar	1.5	13.5	7	2	-	+	-	Wet Pocket
b	W. redcedar	3.0	14.0	6	6	-	+	-	
21/13A- a	W. redcedar	1.5	13.0	8	8	-	-	-	
b	W. redcedar	1.0	16.0	6	6	-	+	-	
21/13B- a	W. redcedar	1.0	13.0	20	9	-	+	-	Wet Pocket
b	W. redcedar	0.5	17.0	21	10	-	-	-	Wet Pocket
22/1A - a	Douglas-fir	15.0	15.0	5	2	NC	NC	-	All Treated
b	Douglas-fir	15.0	15.0	5	2	NC	NC	-	All Treated
c	Douglas-fir	12.0	12.0	6	-	NC	NC	-	All Treated
22/1B - a	Douglas-fir	13.0	13.0	4	2	NC	NC	-	All Treated
b	Douglas-fir	14.0	14.0	4	12	NC	NC	-	
28/6B- a	Douglas-fir	16.0	16.0	5	2	NC	NC	-	
b	Douglas-fir	15.0	15.0	6	2	NC	NC	-	
28/6C- a	Douglas-fir	15.0	15.0	10	2	NC	NC	-	
b	Douglas-fir	14.0	14.0	8	4	NC	NC	-	
28/7B- a	Douglas-fir	8.0	16.0	3	3	-	-	-	
b	Douglas-fir	8.0	16.0	3	3	-	+	-	
28/7C- a	Douglas-fir	3.5	14.0	5	2	-	+	+	Wet Pocket
b	Douglas-fir	6.0	8.0	5	5	-	+	+	Carpenter ants
28/7C+ 2-	Douglas-fir	4.5	6.5	5	2	-	-	-	
32/4B- a	Douglas-fir	5.0	13.0	7	3	-	-	-	
b	Douglas-fir	8.0	14.0	6	2	-	-	-	
c	Douglas-fir	9.0	15.0	7	2	-	-	-	

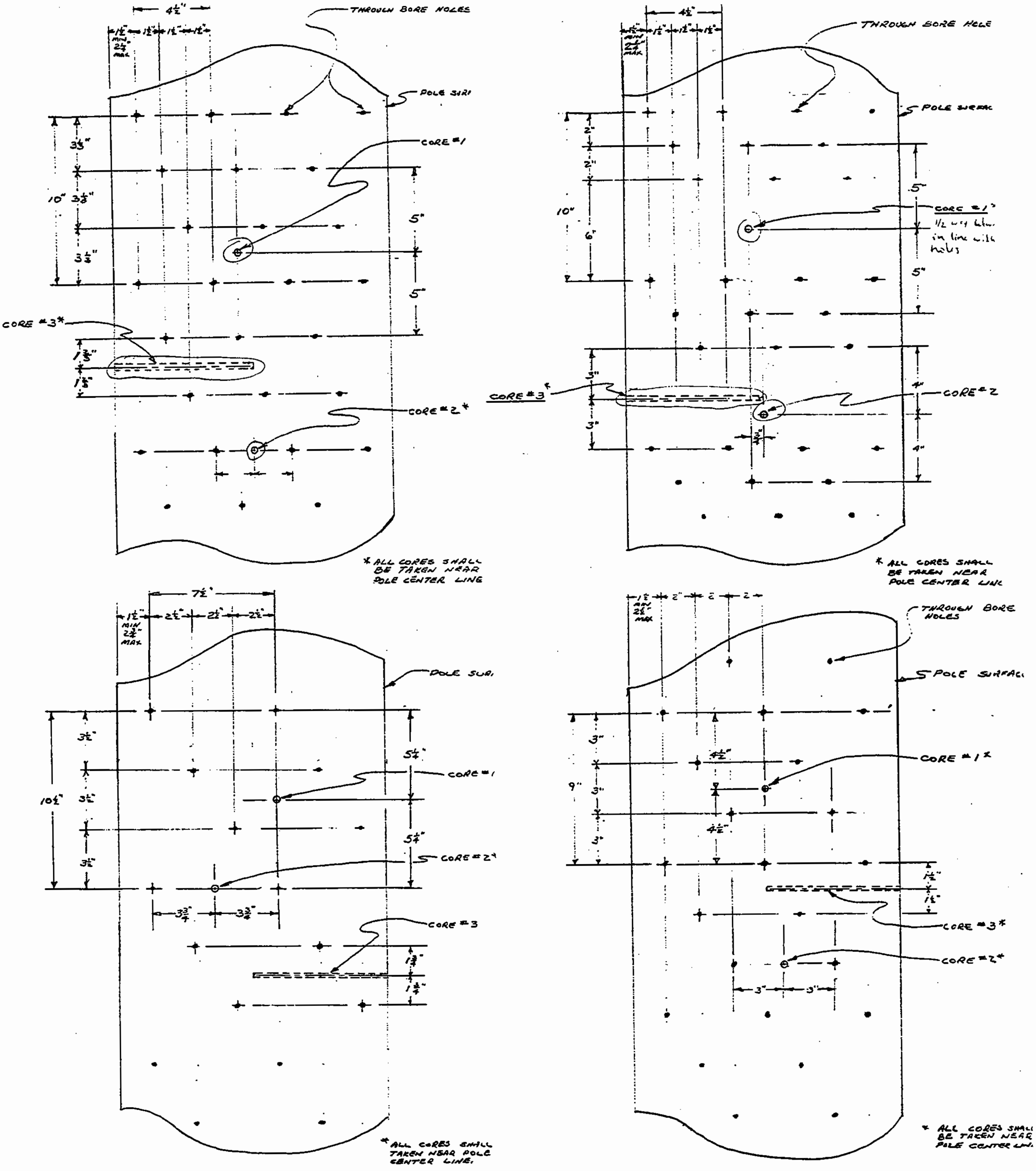


Figure III-2. Patterns employed for above ground through boring of Douglas-fir poles: a) PGE pattern, b) modified PGE pattern, c) BPA pattern, or d) modified BPA pattern.

OBJECTIVE IV
EVALUATE THE POTENTIAL FOR DECAY DEVELOPMENT DURING AIR-SEASONING AND IDENTIFY CONTROL STRATEGIES

Since 1981, the Cooperative has evaluated the fungi associated with air-seasoning Douglas-fir poles and explored methods for preventing or eliminating such colonization. The studies have shown that most air-seasoned poles are invaded by one or more decay fungi during the seasoning process, although the level of colonization varies widely between seasoning sites. The studies have also shown that colonization does not significantly impact wood strength unless the poles are seasoned for more than 2 years.

As a result of these studies, the research has shifted towards identifying methods for either preventing fungi from colonizing air-seasoning poles and ensuring that treatment processes are adequate for eliminating any fungi which do become established in the wood. As a part of this, we have identified fluoride or boron dip or spray treatments which can delay the entry of decay fungi into air-seasoning poles. In addition, we have explored the ability of the various treatment process to achieve sterilization of wood. These studies are on-going and will be described below.

A. IDENTIFY METHODS FOR PREVENTING COLONIZATION OR FOR ELIMINATING DECAY FUNGI FROM AIR-SEASONING DOUGLAS-FIR POLES

1. Internal temperature development in Douglas-fir poles during kiln drying: Green Douglas-fir pole section (30 to 35 cm in diameter by 2.4 m long) were obtained from McCormick and Baxter Creosoting Co. The poles were end-sealed with an elastomeric paint and six holes 0.95 cm in diameter were drilled perpendicular to the grain to depths of 7.5, 12.5, and 20.5 cm along the upper surface of each pole at least 60 cm from the ends. Copper constantin thermocouples were threaded through the center of a 2.5 cm dowel; then, the tip was inserted in a lengthwise notch along the side of a second dowel. This dowel was driven to the bottom of the hole. The holes were then filled with Dow Corning silicone rubber to within 3.75 cm of the surface; then, the first dowel was driven into the wood, and the remainder of the hole was filled with a two-part epoxy sealant and allowed to cure for a minimum of 24 hours. The poles were then included in a kiln charge of freshly peeled Douglas-fir poles and temperatures at the different depths were monitored and collected over the kiln cycle using a 21X microdata logger. The resulting files were then transferred to an IBM PC for further manipulation. A total of 12 logs in 6 kiln charges were evaluated in this manner. The kiln cycles varied in length from 120 to 200 hours and temperatures began at approximately 50 C and increased to 75 C over the cycle.

Sterilization is typically considered achieved when the wood has been heated to 67 C at the center for a minimum of 75 minutes. While these values were originally developed by M. Chidester in the 1930's using fungi common to southern pine, subsequent studies have shown that this value is also applicable to the fungi colonizing Douglas-fir.

The results indicate that poles dried using the kiln schedule outlined were over 60 C for 20 to 30 hours (Figure IV-1). Thus, these poles would require no further sterilization during preservative treatment, provided there was not an extended dealt between drying and treatment.

This past year, we attempted to use the data collected during the 6 kiln charges to develop heating curves for the poles. As this portion of the work was undertaken, it became apparent that we had failed to collected adequate moisture data over the course of the kiln cycle. Since heat transfer rates change with moisture level, the lack of this data severely diminished the value of the data.

To develop addition data, two freshly peeled pole sections (25 to 30 cm in diameter by 2.4 m long) were obtained from McFarland-Cascade and store under a sprinkler. Thermocouples were inserted to depths of 5, 10, and 12.5 cm in each pole as described above and the poles were placed inside an 8 foot steam fired kiln. The poles were dried using a schedules similar to that used for the 6 pole kiln charges. Moisture content of the pole sections over the kiln schedule was determined by removing increment cores. The core was divided into zones corresponding to 0 to 3.75, 3.75 to 6.25, 6.25 to 8.75, 8.75, to 11.25, and 11.25 to 12.50 cm from the surface. The second, fourth and fifth segments from each core were quickly weighed then oven dried at 104 C and reweighed to determine wood moisture content at each depth. Samples were removed after 0, 4, 8, 12, 24, 36, 48, 54, 60, 72, 78, 84, 96, 102, 108, and 120 hours of the kiln cycle.

The results (Figure IV-2) indicate that the pole sections were relatively dry prior to kiln drying, starting at an average moisture content of 32 % five cm into the pole. At the conclusion of the kiln cycle, moisture content at the same depth had declined to 24.6 %. As expected, moisture levels deeper in the wood were initially lower and declined at a slower rate than was found nearer the surface. Kiln drying, as with other pole seasoning practices, does not seek to season the pole to in-service moisture content. Schedules are primarily directed at lowering the moisture content in the outer 5 cm to approximately 20 to 25 % and to set any checks prior to treatment. Drying deeper into the pole, while beneficial, is generally not economical and can lead to other defects such as enlarged checks.

The data for internal temperature and moisture content is currently being analyzed to develop heat prediction curves for kiln drying Douglas-fir poles. this data will be reported in the next Annual Report.

2. <u>Internal temperature development during treatment of Douglas-fir pole sections with pentachlorophenol in P9 Type A oil</u>: Oilborne preservatives such as pentachlorophenol and copper naphthenate remain the primary systems used for treatment of Douglas-fir utility poles and many utilities continue to wonder whether

treatment schedules used for oilborne systems are adequate for sterilization. In previous trials at treating plant "A" we examined internal temperature development during two charges with pentachlorophenol using the procedures described in Section 1 of this objective. The results indicated that internal temperatures 15 cm from the surface were at or above the target temperature (67 C) for over 30 hours, a more than adequate period to eliminate any decay fungi which might have become established during the seasoning period (Figure IV-3). In an effort to further delineate the internal temperatures in Douglas-fir poles during treatment with oilborne preservatives, we examined an additional 5 charges at a different treating plant "B" again using pentachlorophenol in oil. Procedures were similar to those described above.

The results indicate internal temperature in pole sections were well above those required for sterilization for period well in excess of 20 hours. In addition, there was a considerable lag in heat loss following treatment. Previous laboratory trials have shown that long exposures to temperature slightly lower than the accepted lethal value are also adequate for sterilization.

The result so of these studies are also being evaluated to develop heat prediction curves for Douglas-fir poles during treatment using a Boulton seasoning cycle. Finally trials are planned at one treating plant which uses a far shorter treatment cycle to ascertain if poles treated using this cycle are sterilized during treatment.

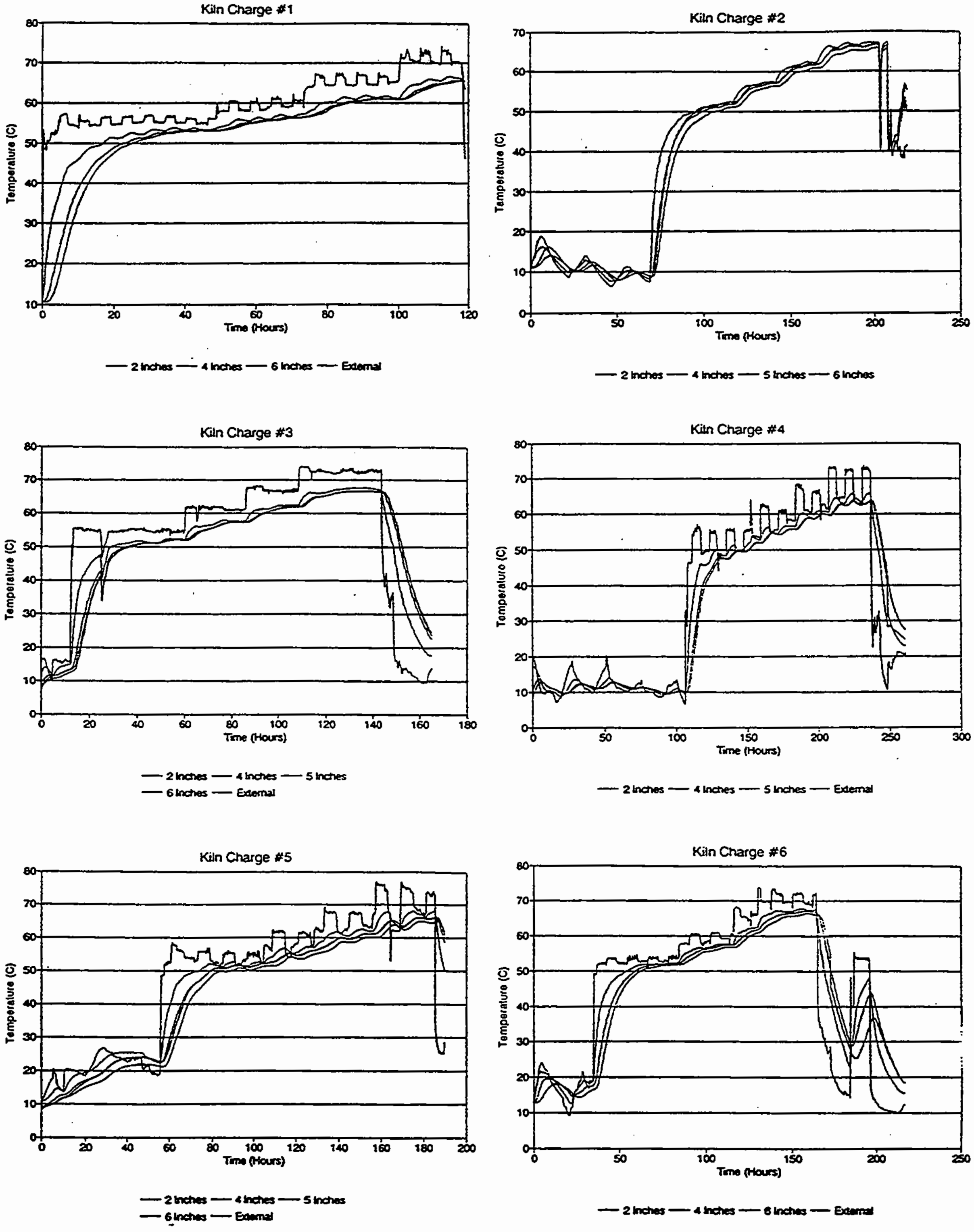


Figure IV-1. Internal temperature development during kiln-drying of Douglas-fir sections in 6 different kiln charges.

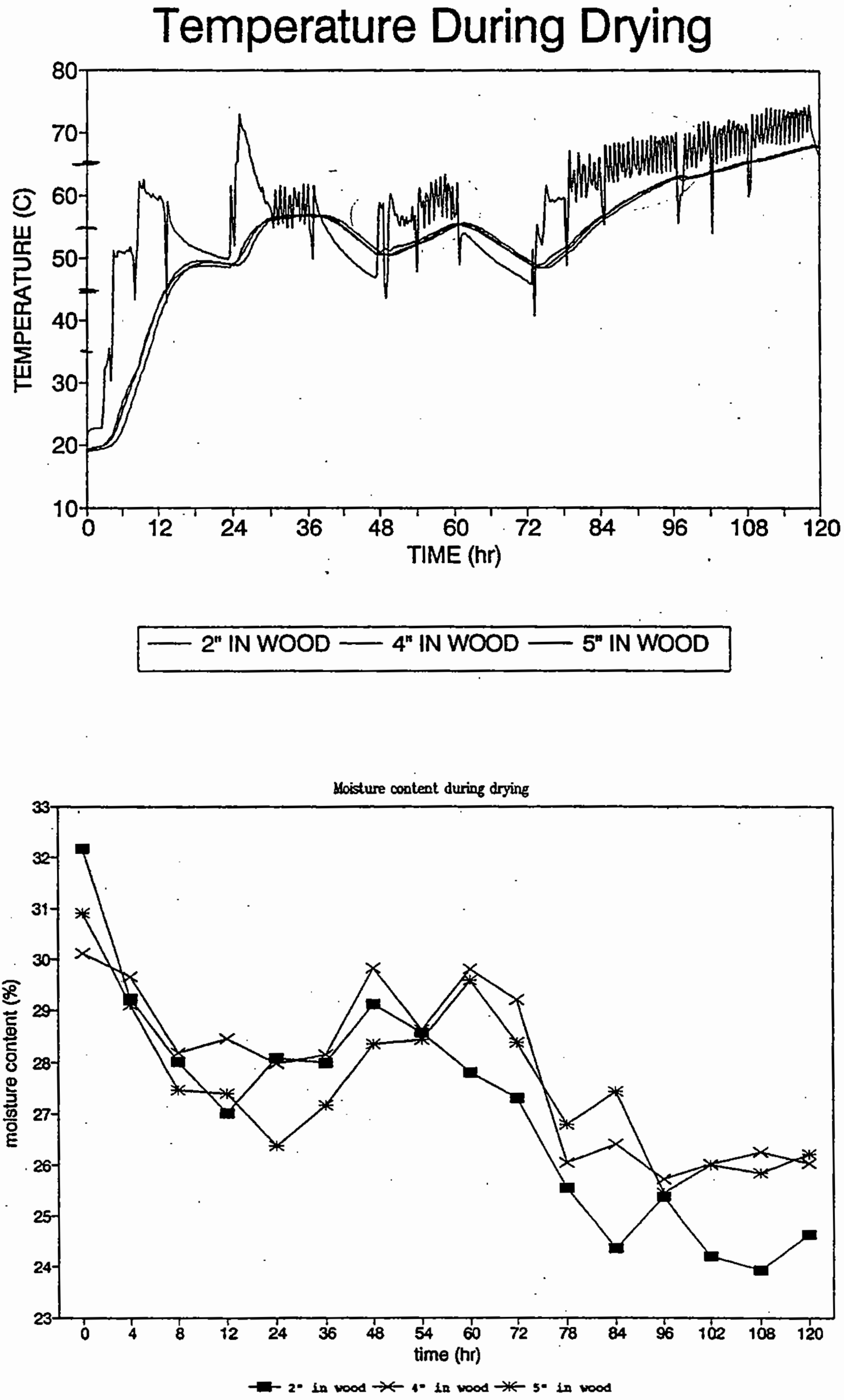


Figure IV-2. Internal temperature development and internal moisture content of Douglas-fir pole during kiln drying.

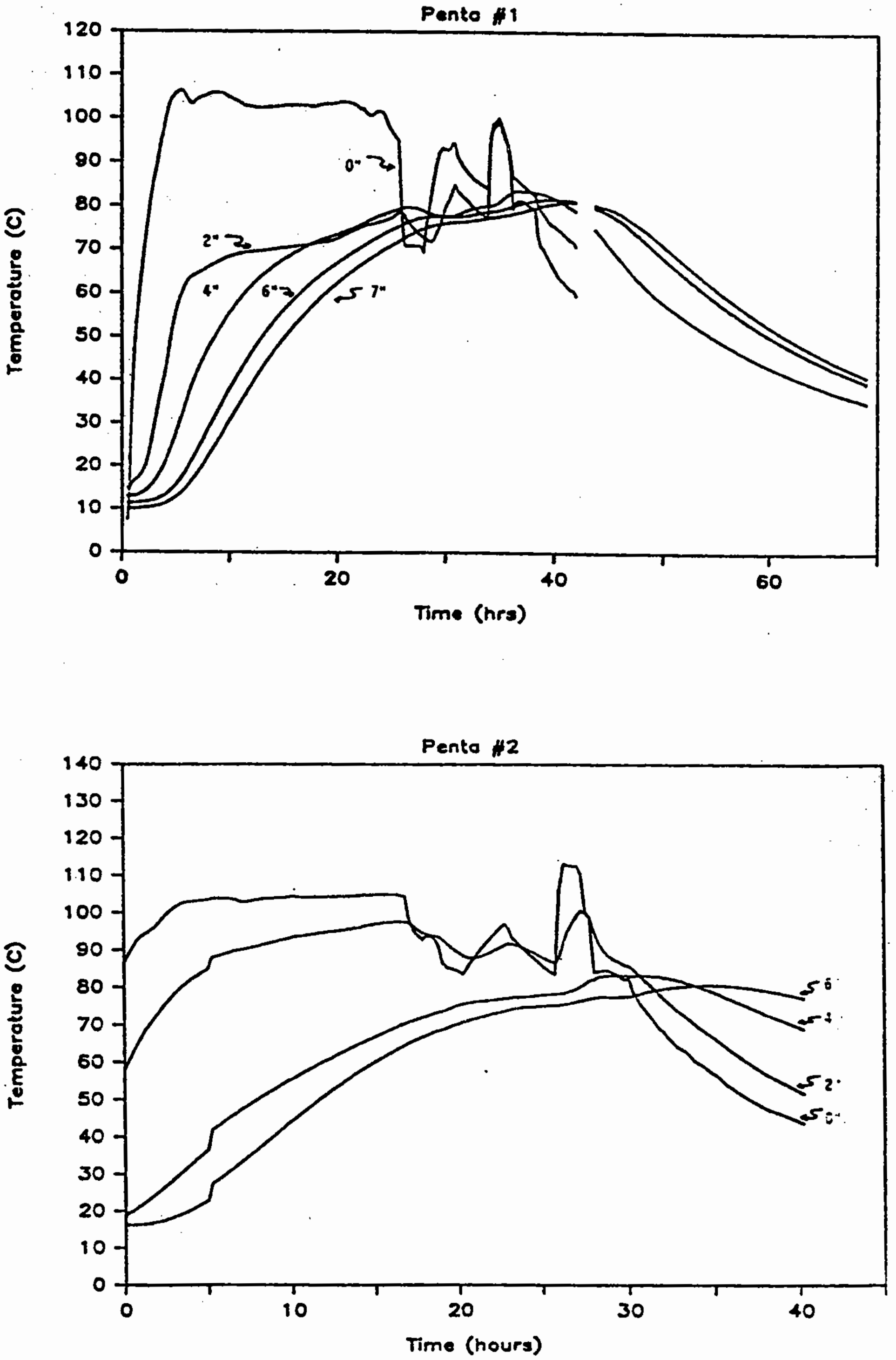
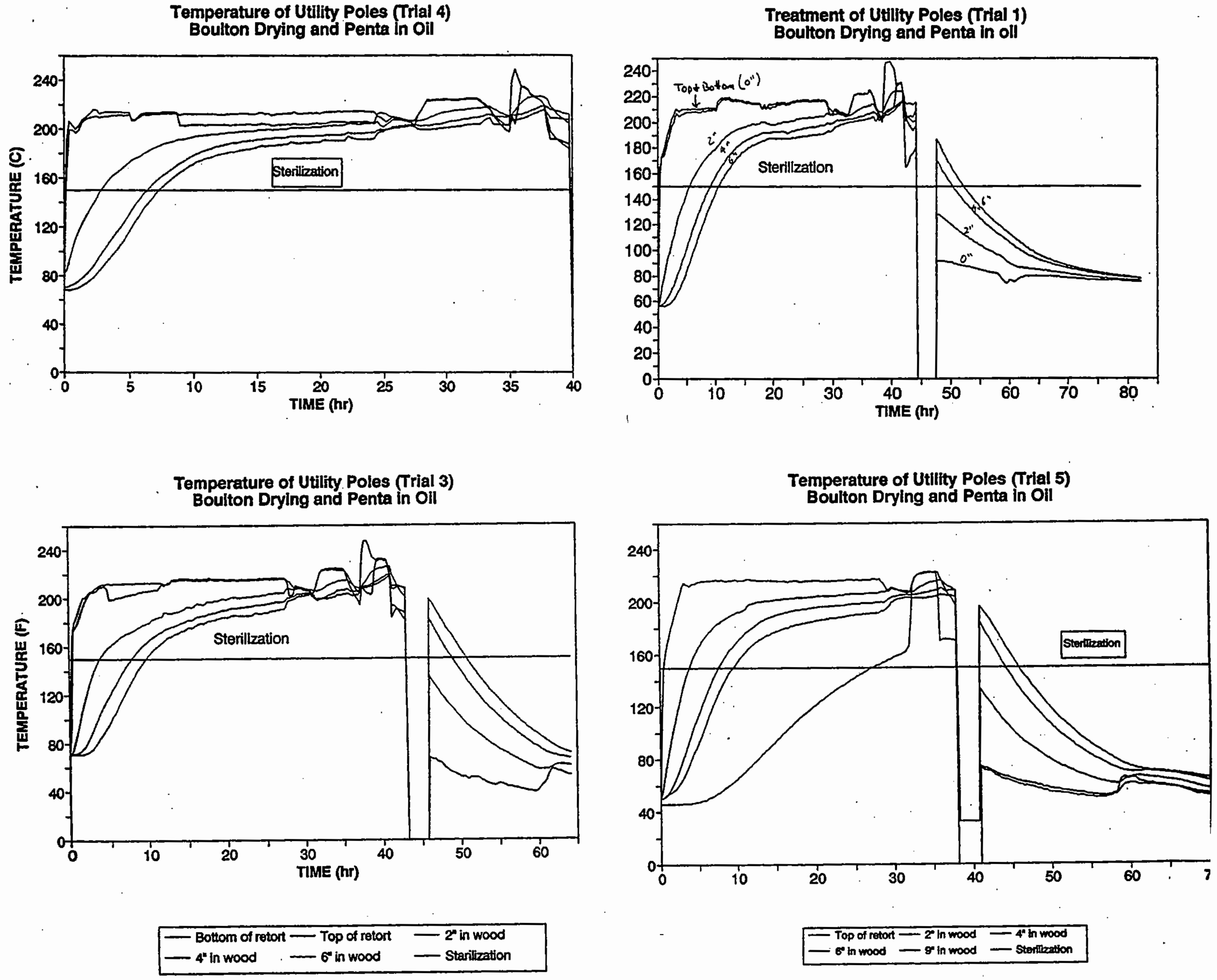


Figure IV-3. Internal temperature development in Douglas-fir poles at selected depths during 2 treatment charges with pentachlorophenol in P9 Type A oil at plant A.



Temperature of Utility Poles (Trial 4) Boulton Drying and Penta in Oil

Treatment of Utility Poles (Trial 1) Boulton Drying and Penta in oil

Temperature of Utility Poles (Trial 3) Boulton Drying and Penta in Oil

Temperature of Utility Poles (Trial 5) Boulton Drying and Penta in Oil

Figure IV-4. Internal temperature development in Douglas-fir poles at selected depths during 4 treatment charges with pentachlorophenol in P9 Type A oil at plant B.

OBJECTIVE V

EVALUATE THE EFFICACY OF GROUNDLINE PRESERVATIVE SYSTEMS FOR WESTERN WOOD SPECIES

Preservative treatment using pressure processes produces a well protected outer shell, however, this protection can gradually diminish as biocide migrates with time. Many utilities apply supplemental preservatives at regular intervals after installation to prevent the development of external decay. These systems generally have contained mixtures of oil and water soluble biocides including creosote and pentachlorophenol. Environmental restrictions have led to substitutions of a variety of chemicals, many of which have not been tested for their efficacy in groundline systems. This objective seeks to develop data on diffusion and efficacy of various commercial groundline preservative systems containing non-traditional biocides.

A. PERFORMANCE OF MODIFIED SYSTEMS ON DOUGLAS-FIR POLES IN CORVALLIS OREGON

Douglas-fir pole sections (25 to 30 cm in diameter by 1.8 m long) were seasoned for 6 months, then treated with one of the following formulations:

CUNAP WRAP (CSI inc.) containing 2.0 % copper naphthenate (as Cu) on an absorbant pad.

CuRAP 20 (ISK Biotech) a paste containing 18.16 % amine based copper naphthenate and 40 % sodium tetraborate decahydrate

COP-R-NAP (Osmose Wood Preserving Inc.) a paste containing 19.25 % copper naphthenate.

COP-R-PLASTIC (Osmose Wood Preserving Inc.) a paste containing 19.25 % copper naphthenate and 45 % sodium fluoride.

Pole Nu 15-15 (ISK Biotech) a grease containing 12.9 % pentachlorophenol 15 % creosote, and 1.5 % chlorinated phenols.

Pole Nu (ISK Biotech) a grease containing 10.2 % pentachlorophenol.

The latter two systems were included to provide comparisons between new formulations and those used previously for this purpose.

The pastes were applied according to manufacturer's directions. All but the self-contained CUNAP Wrap were covered with polyethylene wrap prior to being set in the ground to a depth of 45 cm at the Peavy Arboretum test site. The tops were then capped with roofing felt to retard decay above the groundline.

The Peavy test site receives an average of 105 cm of rainfall per year, with

81 % of the precipitation falling between October and March. Average monthly temperatures range from 3.9 to 11.7 C during that same period. Temperatures outside that period rarely exceed 30 C or fall below 0 C. The soil is an Olympic silty-clay and is slightly acidic (pH 5.4). During the winter months, the water table at the test site rises to within 15 cm of the soil surface. Over the course of the study, however, the site has experienced below average rainfalls.

Preservative performance has been assessed 18, 30, and 42 months after treatment by removing either increment cores or 1 cm diameter plugs from 3 equidistant sites around each pole section 15 cm below the groundline. Plugs were initially employed, however, it became difficult to obtain solid plugs as the poles became wetter and increment cores were substituted. The samples were cut into segments corresponding to 0 to 4, 4 to 10, 10 to 16, and 16 to 25 mm from the wood surface. Segments from the same zone for a given pole were combined and the wood was ground to pass a 20 mesh screen.

The wood was then analyzed for copper or pentachlorophenol using an Asoma 8620 X-ray fluorescence analyzer (XRF). Borate analysis was performed using the Azomethine H method as previously described ('92 Annual Report, page 73). Fluoride analyses were performed on a blind sample basis by R. Ziobro, (Osmose Wood Preserving Inc.) using AWPA Standard A2 Method 7.

The untreated control pole sections in the test exhibited evidence of surface decay 18 months after installation and their condition has continued to decline. These samples were too heavily decayed at 30 and 42 months to be sampled. As a result, samples were removed from above ground to provide controls for analysis. Externally treated posts appear sound after 42 months, although it is becoming difficult to obtain solid increment cores, suggesting the some surface decay is present.

Chemicals levels in posts treated with penta based systems continue to show a steady decline with time (Table V-1). Penta levels in posts treated with Pole Nu 15-15 have declined 50 percent in the outer 0 to 4 mm in the past 24 months while those in the Pole Nu treatment declined 56 % in the same time period. These levels are at or near the retentions considered to be the threshold for protection with pentachlorophenol; however, in conventional treatments, the external preservative paste would be acting as a supplemental treatment to enhance the protection of the initial wood treatment.

Copper levels in the remaining treatments varied more widely and appeared to increase in several instances. Copper levels in the inner two zones were generally low. Levels of copper in the outer zones of CUNAP Wrap declined between 18 and 30 months, then increased in the next 12 months in all 4 sampling zones. COP-R-NAP and Cu-RAP 20 also experienced increased copper levels in the outer assay zone between 30 and 42 months, while inner levels remained constant. Copper levels in COP-R-PLASTIC remained constant in the outer zone, but increased in the inner three zones. In all instances, the copper levels in the outer zone remain well above those required for protecting wood from fungal attack. While inner levels were generally below the threshold, these zones would not be expected to be exposed to a high decay hazard. The increased copper levels detected between 30 and 42 months may reflect a marked increased in precipitation in the months prior to sampling. After 4 years of below normal rainfall, the site received 2 months of near normal precipitation. Cu-RAP 20 contains a water-soluble amine based copper naphthenate, which may have benefitted from the increased rainfall. The nature of increased copper levels in the other two systems remains unclear.

Two of the systems evaluated in this study contained water-diffusible components. After a precipitous decline in chemical levels between 18 and 30 months, boron levels in Cu-Rap 20 declined only slightly after an additional 12 months. At present, boron levels appear to be uniform across the 4 sampling zones suggesting that the chemical has completely diffused into the wood. Boron levels are generally below the threshold for fungal growth; however, the presence of the amine based copper naphthenate would continue to provide protection to these poles. Fluoride levels declined approximately 40 % in the outer two zones between 30 and 42 months and two zones between 30 and 42 months and remained stable in the inner two zones. Fluoride levels remain far higher than boron levels in each assay zone.

The results indicate that, while penta levels have declined in the control systems, copper naphthenate levels appear to be stable in all four systems containing this biocide. Boron levels appear to have declined to a stable, low level. Fluoride levels continue to decline, but remain markedly higher than boron levels. Chemical levels in all treatments remain at or above the threshold for protection against fungal attack. These treatments will continue to be monitored on an annual basis to determine when retreatment might be advisable. This data, in combination with the threshold studies already underway, should provide a sound basis for determining retreatment cycles for external groundline preservatives.

B. PERFORMANCE OF MODIFIED EXTERNAL PRESERVATIVE SYSTEMS ON DOUGLAS-FIR, PONDEROSA PINE AND WESTERN REDCEDAR POLES IN MERCED, CA

While the field trials established at Corvallis have provided a measure of the ability of the various biocides to migrate into untreated wood, questions have arisen concerning the effects of an existing preservative treatment on the migration of these same chemicals. To answer these questions, a second field trail was established on active utility poles.

Douglas-fir, western redcedar and ponderosa pine poles in a Pacific Gas and Electric Co. line located near Merced, CA was sampled by removing increment cores from three sites around the groundline. These cores were ground to pass a 20 mesh screen prior to analysis for residual penta content by XRF and segregated into 3 groups of nine poles per wood species so that each group had an approximately similar distribution of preservative retentions.

The poles were then treated with CUNAP Wrap (CSI Inc.), CuRAP 20 (ISK Biotech) or Patox II (Osmose Wood Preserving, Inc.). The composition of the former two systems was described in Section A. Patox II contains 70.3 % sodium fluoride. Wraps were applied from a zone extending 8 cm above the ground to 45 cm below the groundline and soil was replaced around the poles.

The poles were sampled one and two years after treatment by removing increment cores from sites 15 cm below the groundline in one third of the poles in a given treatment group. These cores were divided into zones corresponding to 0-4, 4-10, 10-16, and 16-25 mm from the wood surface and zones from a given pole were combined prior to grinding to pass a 20 mesh screen. The wood was then analyzed for copper, boron or fluoride content as described in Section A.

As expected, copper levels were generally highest near the surface of the poles. This effect was most noticeable in poles treated with CuRAP 20, where copper levels were nearly 4 times higher than those found in the outer zone of poles treated with CUNAP Wrap (Figure V-1). Copper levels remained fairly similar over the 2 years of sampling, suggesting that either diffusion was still continuing from the wood surface inward or that the environment around the poles was not rapidly depleting copper. Copper levels in ponderosa pine and Douglas-fir poles treated with CuRAP 20 were similar. Copper levels in ponderosa pine poles treated with CUNAP Wrap were similar at all four assay zones, while levels followed a more typical gradient in Douglas-fir poles treated with this chemical. Western redcedar poles were not sampled this year due to difficulty in obtaining solid cores from these tests with the equipment used.

Boron levels in poles receiving CuRap 20 followed similar gradients inward from the surface (Figure V-2). Once again, boron levels in pine had shallower gradients than those from Douglas-fir poles. These differences most probably reflect the higher permeability of ponderosa pine. Boron levels continue to rise in both species, suggesting that inward diffusion of wrap components from the wood surface is continuing.

Unlike boron, which showed increased levels between 1 and 2 years, fluoride levels levels all declined slightly over the second year of exposure. These results differ from those previously noted with a fluoride containing system evaluated at the Corvallis site. The reasons for this difference are unclear, particularly given the high loading of sodium fluoride (73 %) on the system employed in California. Chemical levels in the poles, however, remain well above the previously reported threshold for this biocide.

These trials will be sampled in the coming year to confirm the results, then sampled again 5 years after installation. At present, the three systems appear to be moving well through the test species at levels which would be adequate for inhibiting fungal attack even in the absence of an existing preservative treatment.

Figure V-1. Copper retentions at selected depths in the below ground portion of Douglas-fir, ponderosa pine and western redcedar pole sections two years after treatment with CUNAP wrap or CuRap 20.

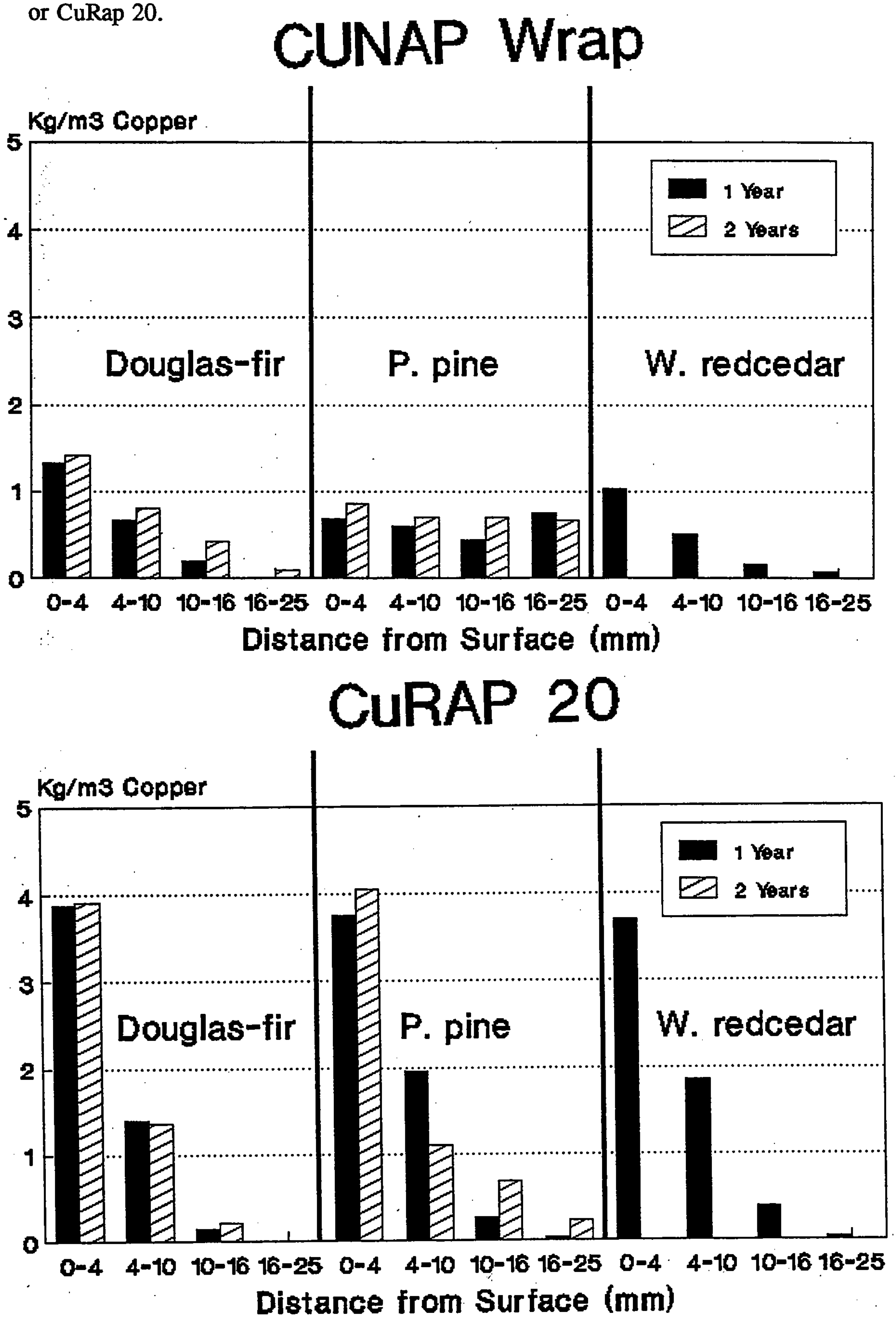
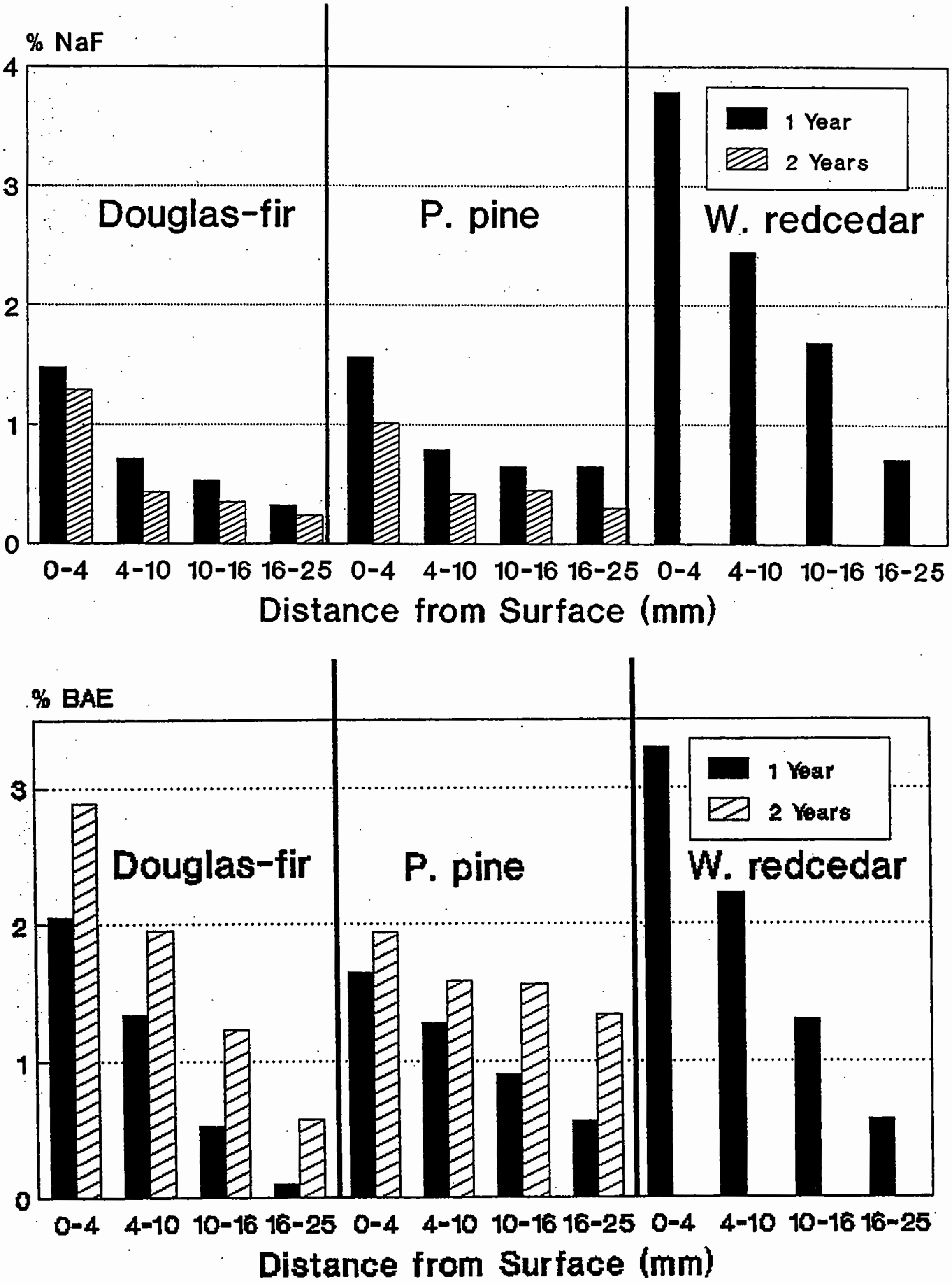


Figure V-2. Boron and fluoride levels present in the below ground zones of Douglas-fir, ponderosa pine or western redcedar poles one or two years after treatment with CuRap 20 or Patox II.



C. ESTABLISH THE THRESHOLD VALUES OF BIOCIDE MIXTURES EMPLOYED IN EXTERNAL PRESERVATIVE SYSTEMS

The data being developed on diffusion of various external groundline preservatives into Douglas-fir, ponderosa pine or western redcedar will provide comparative information on the relative rates of movement for new and existing systems; however, this data is difficult to apply with information on the levels of chemical required for wood protection. To develop the latter information, we established the following trial.

Small ponderosa pine sapwood cubes (1 cm^3) were oven-dried (54 C) and weighed. These blocks were then treated to selected retentions of amine based copper naphthenate, sodium tetraborate decahydrate, sodium fluoride, and two oil-based copper naphthenate formulations. The blocks were immersed in the respective treatment solutions and subjected to a 30 minute vacuum (26 inches Hg) followed by a 1 hour pressure period to ensure that the blocks were thoroughly impregnated with chemical. After treatment, the blocks were reweighed and the weight gain was used to calculate gross chemical absorption. In the case of oilborne copper naphthenate/sodium fluoride system, the waterborne system was first applied, then the blocks were oven-dried prior to copper naphthenate impregnation (Table V-2). Each chemical retention was evaluated on eight blocks.

The blocks were then evaluated for resistance to decay in a non-sterile soil burial test. Small 56 ml glass jars were half filled with non-sterile garden loam and a single block was placed on the surface. The block was then buried with additional soil and the soil was moistened. the jars were capped and incubated at 32 C for 4 months. At that time the blocks were removed, scrapped clean of adhering soil and oven-dried (54 C) prior to reweighing to determine wood weight loss. Weight losses in all of the blocks were generally less than 3 %, the level considered to be indicative of some soft rot attack. As a result, the blocks were returned to their original soil bottles and additional fresh garden compost was added to enhance the decay capacity of the soil. These chambers will be incubated for an additional 3 months to assess decay resistance.

The results should provide guidance concerning the efficacy of mixtures of biocides against soft rot fungi. As the chemical levels decline in the outer zone of the external groundline preservative treated poles, this information will be especially useful in determining when levels decline below a threshold for protection.

Table V-1. Chemical content at selected depths from the wood surface of Douglas-fir posts 18, 30, or 42 months after treatment with selected groundline bandage systems.

Chemical Treatment	Exposure Period (Mos)	Average Chemical Level															
		Copper				PENTA				Boron				Sodium Fluoride			
		0-4 mm	4-10 mm	10-16 mm	16-25 mm	0-4 mm	4-10 mm	10-16 mm	16-25 mm	0-4 mm	4-10 mm	10-16 mm	16-25 mm	0-4 mm	4-10 mm	10-16 mm	16-25 mm
		(kg/m³)				(Kg/m³)				(% BAE)				(% wt/wt)			
CUNAP	18	2.56	1.60	0.80	0.32	-	-	-	-	-	-	-	-	-	-	-	-
	30	1.60	1.28	0.64	0.16	-	-	-	-	-	-	-	-	-	-	-	-
	42	2.24	1.76	0.96	0.48												
Cop-R-Rap	18	2.72	0.64	0.32	0	-	-	-	-	-	-	-	-	-	-	-	-
	30	2.24	0.64	0.32	0	-	-	-	-	-	-	-	-	-	-	-	-
	42	2.40	0.64	0.32	0												
CuRAP 20	18	3.36	0.80	0.16	0	-	-	-	-	1.75	1.41	0.87	0.51	-	-	-	-
	30	2.40	0.48	0.16	0	-	-	-	-	0.27	0.27	0.28	0.23	-	-	-	-
	42	2.88	0.48	0.16	0					0.15	0.22	0.26	0.17				
COP-R-PLASTIC	18	3.84	1.12	0.48	0.16	-	-	-	-	-	-	-	-	2.38	1.21	0.55	0.35
	30	2.88	0.64	0.32	0.16	-	-	-	-	-	-	-	-	2.38	1.23	0.81	0.55
	42	2.88	0.96	0.48	0.32									1.32	0.71	0.57	0.52
Pol-Nu 15-15	18	-	-	-	-	3.36	1.44	0.48	0.16	-	-	-	-	-	-	-	-
	30	-	-	-	-	2.40	0.96	0.32	0.16	-	-	-	-	-	-	-	-
	42					1.60	0.96	0.32	0.16								
Pol-Nu	18	-	-	-	-	6.24	2.56	0.80	0.16	-	-	-	-	-	-	-	-
	30	-	-	-	-	4.32	1.76	0.64	0.16	-	-	-	-	-	-	-	-
	42					2.72	1.44	0.32	0.16								

[a] By distance (mm) from wood surface

Table V-2. Retentions of copper naphthenate, fluoride or boron in ponderosa pine sapwood blocks used to study thresholds of external preservative formulations.

Initial Chemical	Retention Kg/m^3	Retentions of co-biocide (Kg/m^3)
Amine Copper Napthenate	0.32	3.04, 6.24, 12.48, 24.96 (boric acid equivalent)
	0.64	3.04, 6.24, 12.48, 24.96 (boric acid equivalent)
	1.28	3.04, 6.24, 12.48, 24.96 (boric acid equivalent)
	2.40	3.04, 6.24, 12.48, 24.96 (boric acid equivalent)
	4.80	3.04, 6.24, 12.48, 24.96 (boric acid equivalent)
	15.20	3.04, 6.24, 12.48, 24.96 (boric acid equivalent)
Oil-based copper naphthenate	0.32	1.12, 2.24, 4.64, 9.12 (as fluoride)
	0.64	1.12, 2.24, 4.64, 9.12 (as fluoride)
	1.28	1.12, 2.24, 4.64, 9.12 (as fluoride)
	2.56	1.12, 2.24, 4.64, 9.12 (as fluoride)
	5.12	1.12, 2.24, 4.64, 9.12 (as fluoride)
	15.36	1.12, 2.24, 4.64, 9.12 (as fluoride)
Oil-based copper naphthenate	0.32	none
	0.64	none
	1.44	none
	2.88	none
	6.24	none
None	-	3.04, 6.24, 12.48, 24.96 (as boric acid equivalent)
	-	1.12, 2.24, 4.64, 9.12 (as fluoride)
	-	none

OBJECTIVE VI

PERFORMANCE OF COPPER NAPHTHENATE TREATED WESTERN WOOD SPECIES

Copper naphthenate is increasingly proposed as an alternative to conventional treatment of utility poles with pentachlorophenol or creosote. While this chemical has been widely tested on southern pine, there is relatively little data on the efficacy of this chemical on western wood species. In an effort to develop data on performance of this biocide, we have established a number of laboratory and field trials.

A. DECAY RESISTANCE OF COPPER NAPHTHENATE TREATED WESTERN REDCEDAR SAPWOOD IN A FUNGUS CELLAR EXPOSURE

Western redcedar is the preferred pole species for many utilities owing to its highly durable heartwood. Like all woods, however, the sapwood of western redcedar remains susceptible to decay and must be protected. For many years, utilities used either butt treated or untreated western redcedar, but these poles often experienced shell rot of the above ground portion of the wood. This decay made the poles unsafe to climb. Many utilities instituted spray programs using pentachloro-phenol and subsequently copper naphthenate in diesel oil at regular intervals to protect the sapwood. These programs enhanced performance to the point where poles remained sound even when removed from service as lines reached obsolescence. One utility, Bonneville Power Admini-stration, attempted to further extend the life of these poles by retreating the wood with copper naphthenate in heavy oil using conventional pressure treatment. In this process, the potential for attack of the wood by copper tolerant fungi was considered; however, there was little data on the potential for such attack in the Pacific Northwest.

To answer this question, western redcedar stakes (1.25 by 2.5 by 15 cm long) were cut from freshly sawn western redcedar sapwood as well as from the above ground portion of poles which had been exposed for approximately 15 years in service. The stakes were conditioned and treated with copper naphthenate diluted in diesel oil to produce retentions of 0.8, 1.6, 2.4, 3.2 and 4.0 kg/m^3 (as copper). Ten stakes of each wood type were treated to each target retention.

The stakes have been exposed at 28 C and 80 % relative humidity in a forest loam soil. The soil is regularly watered, but is allowed to cycle between wet and dry to stimulate the development of brown rot attack. The stakes were regularly assessed for degree of fungal attack on a treatment scale from 0 to 10 where 0 represents complete failure and 10 represents no evidence of attack.

After 40 months, all of the copper naphthenate treated stakes continue to perform well in the test, while untreated controls have failed completely and the condition of stakes treated with diesel oil continues to decline in weathered wood. As in previous inspections, there is a continuing difference in performance of stakes cut from freshly sawn material versus those cut from weather wood. While weathered stakes initially retained higher levels of copper naphthenate, the weathered wood tends to have higher permeability due prior fungal and bacterial attack on the pits as well as removal of some lignocellulosic polymers due to the effects of U.V. light. These changes may create the potential for increased preservative depletion, which in turn leads to earlier fungal attack.

The current standards of the American Wood Preserver's Association specify a copper napthenate retention of 0.12 pounds per cubic foot of wood (as Cu) for freshly treated wood. The fungus cellar trials indicate that wood treated to these levels is performing well regardless of whether the wood was previously leached prior to exposure. Non-weathered samples treated to one half of the specified level continue to perform well, while weathered samples treated to 67 percent of the recommended level have experienced some fungal attack. The differential performance in weathered materials may necessitate a closer examination of the groundline zone of retreated poles for evidence of decay. It must be noted, however, that most of the poles which are retreated in this fashion would normally have some residual preservative from the initial butt treatment which would combine to provide enhanced protection. In our trials we selected wood which had not previously received preservative treatment to minimize the potential for variation between samples.

The efficacy of copper naphthenate on these samples will continue to be monitored at regular intervals.

B. EVALUATION OF COPPER NAPHTHENATE TREATED DOUGLAS-FIR POLES IN CALIFORNIA AND OREGON

As copper naphthenate treated poles of western wood species are installed, we have begun to collect data on the rate of microbial colonization. These trials are in cooperation with OMG. Each pole has been sampled by removing duplicate increment cores from sites located at groundline and 1.65 m above the groundline. The cores are placed into plastic drinking straws for return to the laboratory where they are placed on the surface of malt extract agar in petri dishes and observed for evidence of fungal growth. The duplicate core from each site has been segmented into zones corresponding to 0-1.25, 1.25-2.50, 2.50-3.75, 3.75-5.00, 5.00-6.25, 6.25-7.50, and 7.50-10.00 cm for analysis of residual copper content by OMG personnel. The goal of this study is to develop chemicaldepletion data in concert with fungal colonization levels at various sites. At present, poles at sites in California and near Eugene, Oregon have been evaluated. Poles at the Eugene site were also sampled at one location 15 cm below the groundline. Poles from the California site contained no viable fungi 1 year after treatment. Culturing of cores from the poles exposed in Eugene also contained no viable decay fungi, and only a limited number of non-decayers. The Bonneville Power Administration specification requires long heating periods during treatment and the lack of viable fungi apparently reflects this requirement.

Table VI-1. Condition of western redcedar sapwood stakes treated to selected retentions with copper naphthenate in diesel oil and exposed in a soil bed for 6 to 40 months.

	Weathered Samples					New Samples				
Target Retention[1] (kg/m^3)	Actual Retention (Kg/m^3)	Average Decay Rating[2]				Actual Retention (Kg/m^3)	Average Decay Rating[2]			
		6 mos.	14 mos.	26 mos.	40 mos.		6 mos.	14 mos.	26 mos.	40 mos.
control	-	4.7	0.9	0.4	0.1	-	6.6	3.2	1.3	1.1
diesel	-	8.5	6.8	5.3	3.8	-	9.9	8.4	8.0	8.6
0.8	1.6	9.0	8.0	7.5	6.9	0.6	10.0	9.6	9.4	9.5
1.6	1.4	9.5	8.9	8.8	9.0	1.3	10.0	9.4	9.3	9.2
2.4	2.1	9.6	9.2	9.1	8.6	1.9	10.0	9.4	9.4	9.2
3.2	2.7	9.6	9.1	9.0	8.8	2.6	10.0	9.2	9.2	9.0
4.0	4.0	9.9	9.2	9.1	9.1	3.4	10.0	9.5	9.4	9.4

[1] Retentions measured as kg/m^3 (as copper).

[2] Values represent averages of 10 replicates per treatment, where 0 signifies completely destroyed and 10 signifies no fungal attack.

OBJECTIVE VI

PERFORMANCE OF COPPER NAPHTHENATE TREATED WESTERN WOOD SPECIES

Copper naphthenate is increasingly proposed as an alternative to conventional treatment of utility poles with pentachlorophenol or creosote. While this chemical has been widely tested on southern pine, there is relatively little data on the efficacy of this chemical on western wood species. In an effort to develop data on performance of this biocide, we have established a number of laboratory and field trials.

A. DECAY RESISTANCE OF COPPER NAPHTHENATE TREATED WESTERN REDCEDAR SAPWOOD IN A FUNGUS CELLAR EXPOSURE

Western redcedar is the preferred pole species for many utilities owing to its highly durable heartwood. Like all woods, however, the sapwood of western redcedar remains susceptible to decay and must be protected. For many years, utilities used either butt treated or untreated western redcedar, but these poles often experienced shell rot of the above ground portion of the wood. This decay made the poles unsafe to climb. Many utilities instituted spray programs using pentachloro-phenol and subsequently copper naphthenate in diesel oil at regular intervals to protect the sapwood. These programs enhanced performance to the point where poles remained sound even when removed from service as lines reached obsolescence. One utility, Bonneville Power Admini-stration, attempted to further extend the life of these poles by retreating the wood with copper naphthenate in heavy oil using conventional pressure treatment. In this process, the potential for attack of the wood by copper tolerant fungi was considered; however, there was little data on the potential for such attack in the Pacific Northwest.

To answer this question, western redcedar stakes (1.25 by 2.5 by 15 cm long) were cut from freshly sawn western redcedar sapwood as well as from the above ground portion of poles which had been exposed for approximately 15 years in service. The stakes were conditioned and treated with copper naphthenate diluted in diesel oil to produce retentions of 0.8, 1.6, 2.4, 3.2 and 4.0 kg/m^3 (as copper). Ten stakes of each wood type were treated to each target retention.

The stakes have been exposed at 28 C and 80 % relative humidity in a forest loam soil. The soil is regularly watered, but is allowed to cycle between wet and dry to stimulate the development of brown rot attack. The stakes were regularly assessed for degree of fungal attack on a treatment scale from 0 to 10 where 0 represents complete failure and 10 represents no evidence of attack.

After 40 months, all of the copper naphthenate treated stakes continue to perform well in the test, while untreated controls have failed completely and the condition of stakes treated with diesel oil continues to decline in weathered wood. As in previous inspections, there is a continuing difference in performance of stakes cut from freshly sawn material versus those cut from weather wood. While weathered stakes initially retained higher levels of copper naphthenate, the weathered wood tends to have higher permeability due prior fungal and bacterial attack on the pits as well as removal of some lignocellulosic polymers due to the effects of U.V. light. These changes may create the potential for increased preservative depletion, which in turn leads to earlier fungal attack.

The current standards of the American Wood Preserver's Association specify a copper napthenate retention of 0.12 pounds per cubic foot of wood (as Cu) for freshly treated wood. The fungus cellar trials indicate that wood treated to these levels is performing well regardless of whether the wood was previously leached prior to exposure. Non-weathered samples treated to one half of the specified level continue to perform well, while weathered samples treated to 67 percent of the recommended level have experienced some fungal attack. The differential performance in weathered materials may necessitate a closer examination of the groundline zone of retreated poles for evidence of decay. It must be noted, however, that most of the poles which are retreated in this fashion would normally have some residual preservative from the initial butt treatment which would combine to provide enhanced protection. In our trials we selected wood which had not previously received preservative treatment to minimize the potential for variation between samples.

The efficacy of copper naphthenate on these samples will continue to be monitored at regular intervals.

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3.2	2.7	9.6	9.1	9.0	8.8	2.6	10.0	9.2	9.2	9.0
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