Camille

TABLE OF CONTENTS

CONSERVING ENERGY BY ENVIRONMENTALLY ACCEPTABLE PRACTICES IN MAINTAINING AND PROCURING TRANSMISSION POLES

Objective III

Objective IV

Objective V

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*Empire State Electric Energy Research Corporation

*New York State Electric and Gas Corporation

*Pacific Gas and Electric

*Pacific Power Corporation

*Portland General Electric Company

WESTERN WOOD PRESERVERS INSTITUTE

J.H. Baxter & Company

McFarland-Cascade Company

Taylor Lumber and Treating Company

***CSI, Inc.**

***ISK Biotech**

***Osmose Wood Preserving, Inc.**

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

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SUMMARY

The Cooperative continues to actively address a diverse array of issues related to the effective use of wood utility poles.

The trials to evaluate the effectiveness of MITC-Fume are now in their seventh year and continue to show that methylisothiocyanate (MITC) levels in MITC-Fume treatments remain higher than comparable metham sodium treatments. The levels of chemical are, however, declining, suggesting that this treatment may need replenishment in 3 to 5 years. Trials with the solid wood fumigant Basamid continue to show that MITC release can be enhanced by addition of small amounts of copper. Field trials suggest that these additives become less important with time. As a result, unamended Basamid may be suitable for treatment where the risk of immediate decay is not high, but the utility wishes to protect against future attack.

Field trials with various water-diffusible internal treatments continue to show that these treatments move more slowly through Douglas-fir heartwood than do fumigants. Boron levels in pole sections treated with fused borate rods remain at levels that will protect against fungal attack 6 years after treatment. Similar trials with a boron/fluoride rod indicate that neither fluoride or boron levels in the poles are adequate for wood protection 2 years after treatment. While the dosages tested were relatively low, the volumes of chemical were similar to the liquid volumes normally applied during internal remedial treatment. We will sample these poles next year to ensure that our measurements accurately reflect the chemical levels present.

Trials to evaluate the effects of glycol on boron movement from fused borate rods suggest that glycol enhanced boron diffusion to only a slight extent. This effect was most pronounced at lower moisture contents. This trial was established to identify methods for improving boron movement in drier wood. In addition, moisture measurements in these poles suggest the internal wood moisture content varies widely both seasonally and positionally. While elevated moisture levels can negatively affect the movement of gaseous fumigants, excess moisture is critical for diffusion of boron or fluoride and its absence around the treatment site can markedly reduce the efficacy of rod treatments. These poles will continue to be monitored to assess both boron movement and seasonal changes in moisture content.

Trials to identify safe, effective and easily used systems for protecting wood exposed during field fabrication are continuing. Boron and fluoride continue to provide excellent protection to field drilled bolt holes. These treatments are safe and easy to apply, and have provided protection in our field test for 14 years. Trials of similar formulations on simulated decking are also reported to provide additional information on the ability of boron and fluoride to protect exposed Douglas-fir heartwood.

Efforts to improve the effectiveness of through boring as a method for enhancing the treatment of Douglas-fir poles are continuing. This past year, we evaluated preservative distribution around through bored holes as a means of developing optimum through boring patterns that maximized treatment while minimizing potential strength effects. These trials suggest the diamond shaped through boring zone of effect is relatively narrow. This information will be used in the coming year to construct optimum patterns for poles of various classes. The goal of this project is to develop a standard through boring pattern that would permit automation of the process. This would create the potential for cost savings on new poles.

Trials to evaluate the durability of western redcedar are nearly complete. These trials were initiated because of concerns that second growth western redcedar might be less durable than poles cut from older trees. As expected, cedar varied widely in its resistance to fungal attack. This resistance, however, was not related to tree age, suggesting that there might not be a difference between so-called "old-growth" and "second growth" material. These data will be more thoroughly analyzed once the final set of trials are completed. In addition, we are evaluating more rapid methods for assessing cedar durability by measuring tropolone content. Tropolones are an important component of the extractives that make cedar heartwood so durable.

Field trials of various externally applied supplemental groundline treatments are continuing at sites in Oregon, California, and New York. Trials in Corvallis, Oregon, have shown that various copper naphthenate, fluoride or boron based systems are at least as effective as the pentachlorophenol (penta) based systems that were formerly used for this purpose. Penta concentrations in one system have now declined below a protective level, while the copper based systems continue to remain at a protective level. Field trials in California are following similar trends and indicate that the alternative systems will provide comparable performance.

Fungus cellar trials of copper naphthenate treated western redcedar stakes continue to show that this chemical provides excellent protection to cedar sapwood. Weathered wood that was treated with copper naphthenate continues to perform more poorly than freshly sawn wood treated to similar retention levels. Variations in permeability likely account for these differences.

A new Wood Pole Maintenance Manual has been completed and is now ready for distribution. This update of the 1979 publication includes more information on initial pole procurement and closely follows the video by the same name that we produced in 1994.

OBJECTIVE I
DEVELOP SAFER CHEMICALS FOR CONTROLLING INTERNAL DECAY OF WOOD POLES

Improvements in specification, treatment and inspection have combined to markedly enhance the performance of wood poles in North America. Despite these steps, however, a percentage of poles in a population will eventually develop problems with decay or insect attack. In reality, this damage is no different than that which might occur with steel (which can corrode), concrete (which spalls), or any other material. Proper combinations of specification, treatment and quality control reduce the risk of such damage occurring, regardless of material, but they cannot completely prevent damage. As a result, utilities must perform regular inspections of their pole system to maintain system integrity and safety.

One of the advantages of wood for supporting overhead lines is the relative ease with which insect and fungal damage can be controlled. A wide array of treatments have been developed for remedially arresting decay and these systems have contributed, to a great measure, in the continued use of wood poles. Probably, the most important of the remedial treatments have been those designed to control internal decay of thin sapwood species. In these instances, checks through a well-treated shell of preservative permit the entry of moisture and fungal spores into the untreated wood within the pole. Eventually, decay fungi hollow out the pole near the groundline, leaving only the outer preservative treated shell to support the design load. The development of fumigants for arresting this decay in the late 1960's provided one of the first widely effective methods for economically prolonging the service life of internally decayed poles. As a result, nearly 90% of utilities in North America use fumigants as part of their pole maintenance programs, saving over one billion dollars per year in replacement costs.

Despite their widespread use, fumigants pose a challenge to users. Two of the three formulations registered with the U.S. Environmental Protection Agency for wood application are liquids (Table I-1), that can be spilled during application. One of these liquids, chloropicrin, is highly volatile and applicators must wear respirators when applying this chemical. In these times of heightened environmental sensitivity, the image of workers applying chemicals to poles while wearing respirators is difficult to explain to customers. The other liquid fumigant, metham sodium (32.7% sodium n-methyl-di-thiocarbamate), is caustic. The third fumigant registered for wood use (methyl-isothiocyanate) is a solid at room temperature, but it too is caustic and must be contained in either aluminum or glass capsules prior to application. Despite their widespread effectiveness, the drawbacks associated with each of these chemicals has encouraged a search for safer internal remedial treatments. In Objective I, we will present data on the currently registered fumigants along with information of formulations currently under evaluation. In addition, we will present information on the performance of various water-diffusible remedial treatments.

A. EVALUATE PREVIOUSLY ESTABLISHED TESTS OF VOLATILE REMEDIAL INTERNAL TREATMENTS

Over the past 20 years, a variety of field trials have been established to evaluate the efficacy of various remedial treatments (Table I-2). Many of these trials lasted only a few years, but several have been maintained for longer periods to develop data on long term performance of the more commercially important remedial treatments. Such data can be invaluable when making decisions concerning the efficacy of the various treatments. In this section, we describe results from those trials involving volatile chemicals. In last year's report (pages 5-9), we reported on

Table I-1. Characteristics of internal remedial treatments for wood poles.

Trade Name	Active Ingredient	Concentration %	Toxicity (LD_{50})	Manufacturer
Timber Fume	Trichloronitromethane	96	205 mg/kg	Osmose Wood Preserving Great Lakes Chemical Co.
Wood Fume	Sodium n-methyldithiocarbamate	32.1	1700-1800 mg/kg	Osmose Wood Preserving
ISK	Sodium n-methyldithiocarbamate			ISK Biotech Inc.
Vorlex	20% methylisothiocyante 80% chlorinated C_3 hydrocarbons	99	538 mg/kg	NorAm Chemical Co.
MITC-FUME	methylisothiocyante	96	305 mg/kg	Osmose Wood Preserving
Impel Rods	boron	99		CSI Inc.
Pole Saver	sodium octaborate tetrahydrate	58.2		Preschem Ltd.
PATOX Rods	sodium fluoride	24.3		

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

Test Site	Chemicals Evaluated	Date Installed	1995-96 Activity
Peavy Arboretum	Field drilled bolt hole treatments	1981	Inspected
Peavy Arboretum	Cedar pole sprays	1981	None
Dorena Tap (BPA)	Encapsulated Chloropicrin	1982	None
Hamburg Line (NYSEG)	Encapsulated MITC	1982	None
Alderwood Tap (BPA)	Encapsulated MITC	1987	None
Peavy Arboretum	Encapsulated MITC (MITC-Fume)	1987	Inspected
Peavy Arboretum	Basamid	1988	Inspected
Peavy Arboretum	Copper naphthenate/boron	1989	None
Peavy Arboretum	Impel Rods	1989	Inspected
Hilo, Hawaii (CSI)	Impel Rods	1990	None
Central Lincoln (CLPUD)	Encapsulated MITC	1990	None
Peavy Arboretum	Gelled NaMDC	1992	None
Pacific Power, Corvallis	Basamid	1993	Inspected
Peavy Arboretum	Boron/Fluoride Rods	1993	Inspected
San Jose, CA	Metham-sodium	1996	Installed

the final inspections of Douglas-fir poles treated with allyl alcohol in 1977 and with methylisothiocyanate (MITC) in 1983. These trials have since been discontinued owing to the inadvertent remedial treatment of many poles by a commercial contractor. In the following section, we describe the results obtained from trials of non-volatile remedial treatments.

1. ***New York field test of encapsulated fumigants*:** The field test of gelatin encapsulated MITC established in 1983 in chromated copper arsenate treated Douglas-fir poles in the New York State Electric and Gas system was last evaluated in 1992.

2. ***Treatment of through-bored Douglas-fir poles with gelatin encapsulated MITC or chloropicrin*:** The Douglas-fir poles treated with gelatin encapsulated chloropicrin or MITC in 1982 was last inspected in 1990.

3. ***Above ground treatment with gelatin encapsulated or pelletized MITC*:** The trial evaluating gelatin encapsulated and pelletized MITC in above ground applications was last evaluated in 1990 and was not sampled this year.

4. ***Seven year performance of glass-encapsulated methylisothiocyanate*:** The control of internal decay in wood products with volatile chemicals (fumigants) continues to represent a simple, economical method for extending the useful life of wood. For many years, the chemicals used for fumigant treatment were all liquids with varying degrees of volatility. This risk of spills and concerns about handling safety encouraged research to develop less volatile fumigants. Among the first chemicals identified for this purpose was methylisothiocyanate (MITC), a chemical which is solid at room temperature, but sublimes directly to a gas. MITC is the active ingredient of metham sodium, the most commonly used fumigant for wood applications. Its availability in a highly pure (96% active ingredient) solid form made it highly attractive for wood pole applications (Morrell and Corden, 1986), but the caustic nature of MITC made it difficult to handle. Preliminary trials suggested that gelatin capsules could be used to contain MITC prior to application (Zahora and Corden, 1985), but the process was never commercialized because of the cost of gelatin. Field trials, however, indicated that this encapsulation process provided excellent control against spills with no adverse effects on chemical performance.

Subsequently, MITC was encapsulated in borosilicate glass tubes plugged with Teflon caps for commercial application. Field trials were established to evaluate the effect of glass encapsulation on the rate of MITC release, residual MITC in the wood, and the ability of these MITC concentrations to inhibit decay fungi. Results of these trials were reported 3 years after test initiation (Morrell, et al., 1992). This paper describes the results of continued monitoring of these trials.

The methods follow those described previously (Morrell et al., 1992). Briefly, the two series of tests were established. Small scale trials in which eight 25 cm diameter by 75 cm long Douglas-fir (*Pseudotsuga menziesii* (Mirb) Franco) pole sections were end coated with elastomeric paint. One half of these sections were air seasoned to a moisture content below 25%; others were used while the wood remained above the fiber saturation point. A single 19 mm diameter by 205 mm long hole was drilled at a 45 degree angle near the center of the pole and a single MITC-Fume tube (ampule) containing 30 g of MITC was inserted, open side downward. The holes were plugged with rubber stoppers. Sets of three pole sections per moisture content were stored at 5°C (cold room), outdoors at ambient temperature (outdoors), or at 32°C and 90% relative humidity (hot wet room). At periodic intervals, the plugs were removed and the ampules were weighed to assess chemical loss over time. At the conclusion of the test, three increment cores were removed from equidistant sites around the pole section 15 cm below the treatment hole. The outer and inner 25 mm of each core were placed into tubes containing 5 ml of ethyl acetate and extracted for 48 hours at room temperature. The extracts were analyzed for residual MITC by gas chromatography using a flame photometric detector as previously described (Zahora and Morrell, 1989). MITC levels were quantified by comparison with prepared standards and expressed as ug of chemical per oven-dried gram of wood.

Field Trials: Equal numbers of Douglas-fir (*Pseudotsuga menziesii* (Mirb.) Franco) and southern pine (*Pinus taeda* L) pole sections (25 to 30 cm in diameter by 3.6 m long) were pressure treated with chromated copper arsenate to a retention of 6.4 kg/m^3, then painted with an elastomeric paint to retard fumigant loss. The poles were set to a depth of 0.9 m at a site located near Corvallis, Oregon. A series of 2, 4, 6, or 8 holes, 1.9 cm in diameter by 205 mm long were drilled in each group of six poles. Each hole received a MITC-Fume vial inserted with the open end downward and was plugged with a tight fitting preservative treated dowel. An additional set of five poles per species was treated with 500 ml of metham sodium equally distributed among three holes drilled as described for the MITC Fume. A final set of five poles received no chemical treatment.

The ability of MITC to diffuse through the wood was analyzed using combinations of bioassays and chemical assays. Over the entire study, the poles were assessed using closed tube bioassays, culturing of increment cores for fungi, and extraction for chemical analysis of residual MITC.

The poles were sampled 1, 2, 3, 5, and 7 years after installation by removing two 150 mm long increment cores, 180 degrees apart, from each test pole 0.3 m below groundline, and 3 increment cores 120 degree apart from sites 0, 0.3, 0.9, and 1.5 m above the highest treatment hole. The inner and outer 25 mm of each core was placed in separate tubes containing actively growing cultures of *Postia placenta* on malt agar slants. The tubes were capped and incubated in an inverted position so that the fungus was above the wood sample resting inside the cap. Radial growth of the fungus was measured after 2 to 3 weeks and this growth rate was compared to that of similar tubes without wood to provide a measure of the ability of the fumigant treated wood to inhibit decay fungi. This method has high sensitivity to MITC (Zahora and Morrell, 1988).

The middle section from each closed tube sample was placed on malt agar in a petri dish and observed over a 1 month period for evidence of fungal growth. Any fungi growing from the wood were examined for characteristics typical of basidiomycetes, a group of fungi containing many important wood decayers. The presence of non-basidomycetes was also noted.

The inner and outer 25 mm section of a second core from each site was placed into 5 ml of ethyl acetate and extracted for 48 hours prior to analysis. Chemical analysis was performed in a manner similar to that described for the small pole sections.

MITC release rates from the glass ampules in pole sections stored under varying conditions continued to show that temperature had a marked effect on the length of time that the chemical remained in the ampule. Ampules from poles stored under hot wet conditions exhibited chemical loss within one year after treatment, while those stored at 5°C continue to retain nearly one third of the original chemical (Figure I-1). Ampules in poles which were originally treated while green and then stored outdoors, continue to retain small amounts of chemical, while no MITC remains in vials from poles treated dry and stored in the same manner. The effect of moisture content on release was perplexing since one would expect that any moisture variations would equilibrate over time. One might expect that MITC sorption would be affected by higher MC's (Zahora and Morrell, 1989), but this effect should disappear as the log sections equilibrated to their ambient moisture levels. The difference between wet and dry treated pole sections has continued over the 7 year test period. A smaller, but similar trend was noted with the pole sections stored at 5°C.

MITC levels in pole sections 7 years after application of a single ampule of MITC-Fume ranged from below the limit of detection to

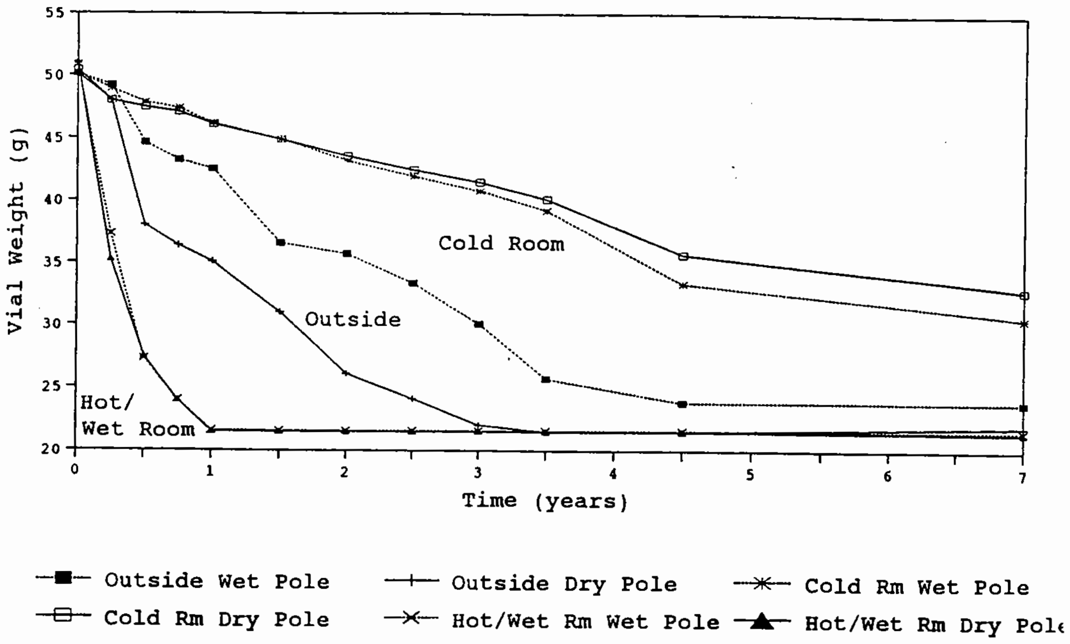


Figure I-1. Rate of MITC loss from glass encapsulated MITC placed in air dry or green Douglas-fir poles which were subsequently exposed under hot/wet, ambient, or cold conditions for 7 years.

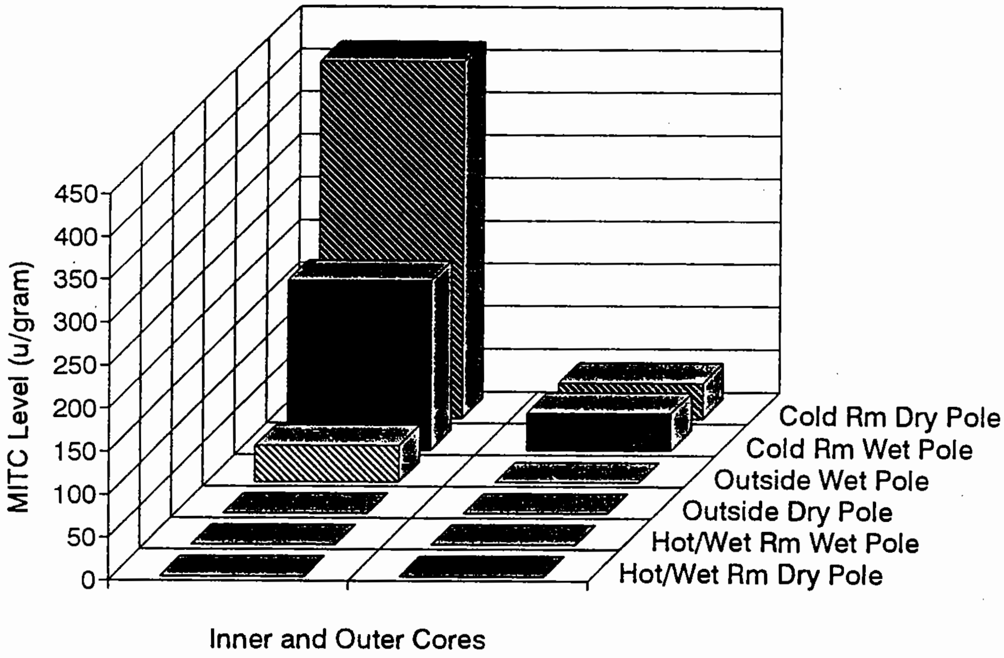


Figure I-2. Residual MITC in the inner or outer 25 mm of increment cores removed from Douglas-fir poles treated with glass encapsulated MITC and exposed for 7 years under hot/wet, ambient, and cold conditions.

over 400 ug/g oven dried wood (Figure I-2). MITC was virtually absent from pole sections exposed under hot wet conditions, nor was MITC detected in poles which were seasoned before treatment and exposure under ambient conditions. MITC was detected at low levels in the inner zone of pole sections treated when wet and exposed under ambient conditions, but was absent from the outer zones of the same pole sections. MITC was present in both assay zones in poles exposed at 5°C. MITC levels were higher in the inner zone, reflecting the original orientation of the tube opening towards the pole center and the loss of chemical nearer the surface. Chemical levels were again higher in poles which were treated while the wood was dry, following the weight loss trends from the ampules.

The original dosages applied to the poles were relatively low (0.2 kg MITC/m^3 of wood volume) which translates to approximately 0.04 % by weight. The final concentration 7 years after treatment approached this level in the inner zone of the cold stored poles, but the remainder of the samples had lost a majority of the chemical over the test period. These results suggest that caution must be exercised when contemplating prolonging the retreatment cycle with MITC based formulations under warmer exposure conditions.

Field Trials: Closed tube bioassays of inner zones of cores removed from the poles at selected times after MITC or metham sodium treatment suggest that the protective effects of these treatments have declined markedly between the 3 and 7 year sampling points for both wood species (Table I-3). There was little evidence of residual fungitoxicity in samples removed from sites 0.3, 0.9, and 1.5 m above the highest treatment sites regardless of dosage 5 or 7 years after treatment. A low level of inhibition appeared to be present in the inner zones of cores removed from the upper edge of the treatment zone at the same sampling times. The degrees of inhibition tended to improve slightly with increasing MITC dosage, but the differences were sometimes slight. A similar trend was noted 0.3 m below the lowest treatment hole. These results suggest that the protective effect of MITC has declined away from the original treatment zone, but that this chemical continues to provide protection to the treatment zone 7 years after chemical application.

Culturing of increment cores from the various treatments suggest that all of the treatments continue to inhibit colonization by decay fungi 7 years after chemical application (Table I-4). Basidiomycetes were virtually absent in non-fumigant treated southern pine poles, although one isolate was obtained from 1.5 m above the groundline on a single control pole. Colonization of Douglas-fir controls occurred more frequently over the test period at all of the sampling heights, but there was not consistent progression in degree of fungal colonization over time at a given location.

Basidiomycete isolations in southern pine poles treated with MITC or metham sodium were generally low over the 7 year test period. Only 7 of 375 cores (1.9 %) removed from the fumigant treated southern pine poles 7 years after treatment contained basidiomycetes, indicating that both chemicals were performing well. Basidiomycete levels in Douglas-fir poles receiving fumigants were equally low, with only 3 of 375 (0.8 %) of the cores taken 7 years after treatment containing these fungi.

The levels of non-decay fungi present in the cores generally increased with time following treatment and with distance away from the treatment zone, reflecting the higher tolerance of many of these fungi for chemicals. Virtually all cores contained some type of non-decay fungi 7 years after treatment. The role of these fungi in fumigant performance is unknown. Some of these fungi can inhibit growth by decay fungi and help prolong fumigant protection (Giron and Morrell, 1989). Many other non-decay fungi are known to detoxify preservatives (Zabel and Morrell, 1992), although their potential effects on fumigants are not known.

MITC levels present in the wood 5 and 7 years after treatment were generally lower than those found in the same poles at earlier sampling points (Table I-5). MITC levels in the outer zones of the samples were low regardless of distance from the treatment zone, and these

Table 1-3. Incidence of fungal growth, as measured by closed-tube bioassays of increment core segments, in southern pine and Douglas-fir poles 12, 24, 36, 60, and 84 months after treatment with MITC-Fume® or metham-sodium.[a]

Vertical distance from treatment zone	Core segment tested[c]	Months after treatment	Fungal growth (as % of control)[b]									
			Southern pine					Douglas-fir				
			MITC-Fume®				Metham-sodium	MITC-Fume®				Metham-sodium
			60 g	120 g	180 g	240 g	500 ml	60 g	120 g	180 g	240 g	500 ml
-0.3 m	Outer	12	12	0	0	0	23	34	25	4	0	77
		24	17	0	20	0	100	16	6	20	0	20
		36	55	41	33	32	78	25	21	20	22	82
		60	74	99	71	79	73	90	79	74	91	80
		84	59	68	79	108	97	76	91	92	102	71
	Inner	12	0	0	0	0	14	0	12	0	0	49
		24	0	0	0	0	0	0	0	0	0	16
		36	14	1	3	0	7	1	14	13	16	69
		60	51	28	52	1	28	71	45	53	61	57
		84	33	67	14	17	47	44	60	86	95	66
0.0 m	Outer	12	16	3	11	0	40	0	0	0	0	10
		24	0	7	30	0	100	16	0	0	0	12
		36	38	12	24	10	69	19	21	26	21	76
		60	76	82	87	72	90	85	47	75	77	58
		84	75	77	69	73	98	73	77	93	94	81
	Inner	12	0	0	0	0	0	0	0	0	0	0
		24	0	0	0	0	0	0	10	0	0	0
		36	13	3	7	3	5	8	2	1	0	82
		60	47	53	36	1	26	73	46	66	47	46
		84	57	60	34	27	57	40	83	84	76	54
0.3 m	Outer	12	80	0	21	41	63	65	32	4	0	67
		24	83	36	33	33	100	40	23	0	0	0
		36	51	25	28	27	67	24	19	15	7	91
		60	79	96	85	68	89	94	91	74	69	48
		84	78	88	87	88	83	68	75	91	94	79
	Inner	12	40	0	0	0	45	16	12	0	0	15
		24	0	0	13	0	13	16	13	0	0	33
		36	5	6	19	1	23	8	20	14	3	84
		60	76	66	83	33	67	92	75	71	62	75
		84	85	80	73	57	82	63	70	93	93	79
0.9 m	Outer	12	100	73	95	100	90	79	64	27	19	70
		24	90	77	94	100	100	43	43	23	24	60
		36	101	77	63	85	84	37	31	29	13	83
		60	96	102	101	85	89	88	82	69	77	68
		84	97	93	79	103	98	64	67	95	98	84
	Inner	12	60	33	92	100	86	27	26	22	8	39
		24	57	63	35	48	60	20	0	16	0	33
		36	78	49	43	36	50	38	54	41	15	90
		60	89	99	89	79	86	79	103	80	82	79
		84	94	91	83	86	99	63	64	96	191	87

Table 1-3. Incidence of fungal growth, as measured by closed-tube bioassays of increment core segments, in southern pine and Douglas-fir poles 12, 24, 36, 60, and 84 months after treatment with MITC-Fume® or metham-sodium.[a]

Vertical distance from treatment zone	Core segment tested[c]	Months after treatment	Fungal growth (as % of control)[b]									
			Southern pine					Douglas-fir				
			MITC-Fume®				Metham-sodium	MITC-Fume®				Metham-sodium
			60 g	120 g	180 g	240 g	500 ml	60 g	120 g	180 g	240 g	500 ml
1.5 m	Outer	12	100	100	100	100	100	63	100	62	48	86
		24	97	100	100	100	87	53	47	60	100	100
		36	88	91	89	85	93	74	71	72	86	92
		60	98	99	108	90	98	93	102	93	90	54
		84	100	83	79	97	111	68	66	97	102	86
	Inner	12	100	100	100	50	97	95	100	68	50	84
		24	100	94	80	57	70	77	43	30	67	67
		36	99	83	74	61	57	76	74	75	77	102
		60	97	93	95	76	86	76	107	75	93	73
		84	93	113	71	81	90	66	74	98	95	90

[a] Cores were removed from selected locations at different vertical distances above and below the treatment site.

[b] Values represent the growth of *Postia placenta* in tubes containing treated-wood cores as a percentage of its growth in tubes to which wood cores were not added. Complete inhibition (0% growth) represents fungitoxic chemical levels.

[c] Outer – 2.5 cm from pole surface; Inner – 12.5 to 15.0 cm from pole surface.

Table 1-4. Incidence of decay and nondecay fungi in southern pine and Douglas-fir poles 6, 12, 24, 36, 60, and 84 months after treatment with MITC-Fume® or metham-sodium.[a]

Chemical treatment		Percentage of cores containing decay (nondecay) fungi[b]																							
		-0.3 m				0.0 m					0.3 m					0.9 m					1.5 m				
	Dosage ^{c}	24 mo	36 mo	60 mo	84 mo	12 mo	24 mo	36 mo	60 mo	84 mo	12 mo	24 mo	36 mo	60 mo	84 mo	12 mo	24 mo	36 mo	60 mo	84 mo	12 mo	24 mo	36 mo	60 mo	84 mo
SOUTHERN PINE																									
MITC-Fume®	60	0 (50)	0 (67)	0 (50)	0(83)	0 (67)	(0)	0 (17)	0 (17)	0(83)	0 (100)	0 (100)	0 (39)	6 (22)	0(78)	0 (100)	0 (100)	0 (83)	0 (39)	0(100)	0 (100)	0 (100)	0 (88)	0 (61)	0(100)
	120	0 (50)	0 (42)	0 (33)	0(75)	0 (83)	0 (17)	0 (8)	8 (17)	0(92)	0 (100)	0 (83)	0 (17)	5 (28)	0(83)	0 (100)	0 (100)	0 (56)	0 (61)	0(100)	0 (100)	0 (100)	0 (56)	0 (39)	0(94)
	180	0 (28)	0 (57)	0 (25)	0(100)	0 (30)	0 (57)	0 (14)	0 (33)	8(92)	0 (100)	0 (100)	0 (67)	0 (33)	6(78)	0 (100)	0 (100)	0 (52)	0 (56)	0(89)	0 (100)	0 (100)	0 (52)	0 (50)	0(100)
	240	0 (0)	0 (58)	0 (33)	8(92)	0 (50)	0 (0)	0 (17)	0 (8)	8(83)	0 (100)	0 (100)	0 (38)	6 (28)	6(89)	0 (100)	0 (100)	0 (94)	6 (33)	0(100)	0 (100)	0 (100)	0 (94)	6 (94)	0(100)
Metham-sodium	500	0 (40)	0 (70)	0 (30)	0(75)	0 (40)	0 (40)	0 (40)	0 (20)	0(83)	0 (100)	0 (80)	0 (73)	0 (33)	0(83)	0 (100)	0 (100)	0 (93)	7 (53)	0(83)	0 (100)	0 (100)	0 (87)	8 (53)	0(85)
Control	- - -	0 (100)	0 (92)	0 (25)	0(100)	0 (100)	0 (100)	0 (83)	0 (50)	0(100)	0 (100)	0 (100)	0 (83)	0 (72)	0(100)	0 (100)	0 (100)	0 (89)	0 (72)	0(100)	0 (100)	0 (100)	0 (83)	6 (61)	0(100)
DOUGLAS-FIR																									
MITC-Fume®	60	0 (0)	0 (42)	0 (0)	0(92)	0 (25)	0 (33)	0 (0)	0 (8)	0(75)	0 (33)	0 (50)	0 (0)	0 (11)	0(72)	0 (50)	0 (100)	0 (17)	0 (17)	6(83)	0 (100)	0 (100)	6 (39)	0 (22)	0(89)
	120	0 (57)	0 (17)	0 (8)	0(83)	0 (29)	0 (29)	0 (0)	0 (8)	0(83)	0 (71)	0 (100)	0 (17)	0 (11)	6(72)	0 (64)	7 (100)	0 (10)	0 (17)	0(94)	10 (40)	0 (100)	10 (29)	0 (22)	0(89)
	180	0 (50)	0 (17)	0 (9)	0(92)	0 (16)	0 (17)	0 (8)	0 (0)	0(75)	0 (58)	0 (67)	0 (10)	0 (11)	0(94)	0 (75)	0 (67)	0 (17)	0 (11)	0(94)	0 (71)	0 (67)	0 (22)	0 (28)	0(94)
	240	0 (33)	0 (33)	0 (8)	0(100)	0 (29)	0 (17)	0 (0)	0 (17)	0(92)	0 (25)	0 (67)	0 (8)	0 (22)	0(72)	0 (8)	0 (100)	0 (0)	0 (17)	0(83)	25 (75)	0 (100)	0 (13)	0 (0)	0(100)
Metham-sodium	500	0 (60)	0 (40)	0 (30)	0(75)	0 (60)	0 (40)	10 (50)	0 (20)	0(67)	0 (40)	10 (50)	13 (7)	0 (33)	0(67)	10 (50)	10 (80)	13 (7)	7 (53)	0(78)	0 (40)	10 (80)	0 (0)	0 (53)	6(83)
Control	- - -	33 (100)	33 (75)	0 (25)	0(100)	0 (100)	33 (100)	42 (67)	0 (25)	8(100)	0 (50)	25 (100)	28 (50)	17 (44)	44(100)	8 (33)	8 (100)	28 (50)	0 (39)	22(100)	0 (33)	0 (100)	6 (6)	0 (33)	22(100)

[a] Core were removed from selected locations at different vertical distances above and below the treatment zone. The middle segment of cores was used for this analysis.

[b] Values reflect an average of 15 total cores per dosage/position. Figures in parentheses represent nondecay fungi isolated from the same cores.

results were reflected by the low inhibitory levels in the closed tube bioassays. Chemical levels in the inner zones of the samples varied more widely (Figure I-3). As might be expected, the highest chemical levels were at the site nearest the treatment zone. MITC levels in this zone increased with increasing MITC dosage, although the changes were not proportional to the increasing dosages. Chemical levels in the inner zones of southern pine samples were generally higher than those found for a comparable dosage in Douglas-fir. The reasons for this variation are unclear. Southern pine is about 100 times more permeable than Douglas-fir heartwood (Siau, 1995). As a result, southern pine might be expected to lose volatile chemicals more rapidly. Differences in MITC sorption, however, might alter this relationship.

MITC levels in poles treated with metham sodium were generally near those found in poles receiving 2 ampules of MITC-Fume suggesting that these treatments might perform similarly. Previous studies have shown that MITC levels in metham sodium treated poles tend to decline rapidly after treatment, reflecting the relatively low concentration of active ingredient applied per hole and the low decomposition efficiency found with metham sodium in many wood species (Helsing et al., 1984; Morrell, 1994; Morrell et al., in press). Closed tube bioassays of these poles suggest that the measured chemical levels are only marginally inhibitory to potential decay fungi.

The results suggest that the levels of MITC away from the treatment zone of poles treated 7 years earlier with MITC Fume have declined to levels where they are no longer capable of protecting the wood from fungal attack. Levels within the treatment zone would be expected to be higher than those found away from this zone and these levels will be the subject of a subsequent evaluation.

5. *Effect of selected additives on MITC release from Basamid in Douglas-fir poles*: The remedial treatment of wood poles to arrest and prevent fungal deterioration of wood poles saves millions of dollars annually. In North America, fumigants remain the primary chemicals used for this purpose, but there are ever increasing concerns about the handling features of these chemicals. Ideally, a fumigant would remain non-volatile until applied. Solid methylisothiocyanate most closely approaches this goal, but its caustic nature requires that it be encapsulated prior to application and its tendency to remain in the encapsulating tubes for several years after application continues to raise concerns. As a result, there is a continuing need for improved volatile treatments for wood poles.

One potential treatment is Basamid (3,5-dimethyltetrahydro 1,3,5,2H-thiadiazine-2-thione). This chemical is a solid crystalline material which slowly decomposes to produce MITC and a variety of other sulfur compounds. Preliminary field tests of Basamid suggested that the decomposition rate was too slow to be effective for controlling established decay fungi (Eslyn and Highley, 1985), but subsequent trials indicated that the rate of decomposition could be markedly improved by addition of bivalent metals, particularly copper (Forsyth and Morrell, 1995). Decomposition also improves with increasing pH, but this approach would be difficult given the low pH of most wood species (Morrell et al., 1988). In 1990, a series of trials was established to evaluate the ability of various materials to accelerate decomposition of Basamid to MITC. The results of these trials were reported 24 months after treatment (Forsyth and Morrell, 1993). These trials have also been monitored for an additional 4 years and the results are reported here.

The methods followed those previously described (Forsyth and Morrell, 1993). Briefly, Douglas-fir pole sections (*Pseudotsuga menziesii* (Mirb.) Franco) (250-300 mm in diameter by 1.6 m long) were capped to limit moisture uptake and three 22 mm diameter by 305 mm long holes were drilled at 60 degree angles with 100 mm vertical spacings around the center. Each hole received 50 g of Basamid alone or amended with selected additives (Table I-6). Control poles received either no chemical or 150 ml of metham sodium (32.7% sodium n-methyl-dithio-carbamate). Each treatment was replicated on 5 poles which were

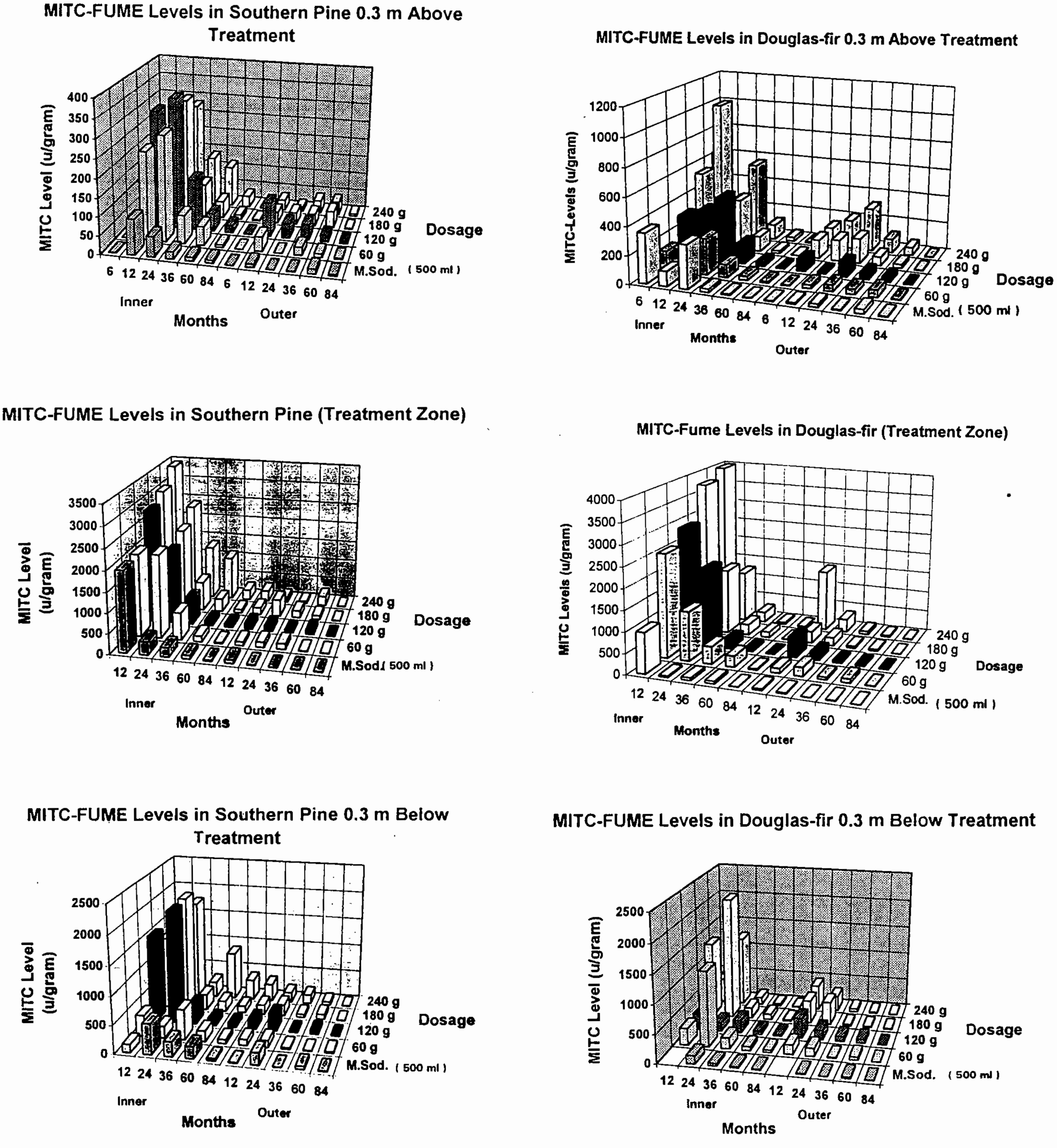


Figure I-3. Residual MITC in Douglas-fir (a-c) and southern pine (d-f) poles treated with 60, 120, 180, or 240 g of glass-encapsulated MITC or 500 ml of metham sodium at the top of the treatment zone and 0.3 m above or below the treatment zone.

Table 1-5. Residual MITC content, as measured by gas chromatographic analysis of increment cores, in southern pine and Douglas-fir poles 6, 12, 24, 36, 60, and 84 months after treatment with MITC-Fume® or metham-sodium.[a]

VERTICAL DISTANCE FROM TREATMENT ZONE	CORE SEGMENT TESTED[c]	MONTHS AFTER TREATMENT	Residual MITC (µg/g of wood)[b]									
			Southern pine					DOUGLAS-FIR				
			MITC-FUME®				METHAM-SODIUM	MITC-FUME®				METHAM-SODIUM
			60 g	120 g	180 g	240 g	500 ml	60 g	120 g	180 g	240 g	500 ml
-0.3 m	Outer	12	105	179	170	320	10	164	346	401	439	–
		24	125	306	204	185	213	140	168	404	273	15
		36	30	31	56	163	2	18	81	28	55	2
		60	14	70	86	61	56	58	65	24	18	26
		84	27	20	4	14	13	4	0	14	4	5
	Inner	12	369	1534	1282	1644	147	292	270	1327	441	--
		24	203	1996	2028	1754	535	1322	154	2161	1240	143
		36	536	368	284	277	257	186	219	182	127	44
		60	187	120	188	854	212	68	58	95	36	26
		84	73	72	121	372	43	41	26	19	9	17
0.0 m	Outer	12	93	147	169	275	85	119	485	280	1500	41
		24	127	120	426	140	18	219	200	192	322	31
		36	138	62	176	62	1	61	59	51	78	3
		60	10	107	92	235	15	99	36	44	37	18
		84	8	13	7	8	12	12	6	4	12	2
	Inner	12	2031	2777	3009	3425	1986	2525	2879	3745	3985	978
		24	2054	1798	2033	2381	319	1191	1928	1600	1242	34
		36	675	673	736	1332	227	418	223	260	251	68
		60	137	131	330	1085	93	267	70	135	46	64
		84	29	81	85	256	26	30	14	14	8	12
0.3 m	Outer	6	0	1	3	2	0	5	84	132	132	4
		12	38	94	30	29	9	26	12	149	206	11
		24	T	40	33	13	T	46	94	177	311	22
		36	21	42	34	36	2	37	48	63	99	8
		60	9	17	46	37	13	51	31	26	56	30
		84	3	6	3	6	5	7	4	5	6	5
	Inner	6	1	14	12	6	2	132	296	534	624	352
		12	239	316	212	184	96	128	349	1052	262	105
		24	285	353	322	281	54	256	459	363	554	306
		36	77	139	91	135	19	92	142	108	107	24
		60	51	48	47	112	10	29	30	18	28	10
		84	7	19	12	31	8	10	7	2	9	4
0.9 m	Outer	6	0	0	0	0	0	0	2	0	0	0
		12	T	12	13	10	0	34	94	25	34	10
		24	T	T	T	T	0	84	60	40	72	T
		36	1	4	6	5	T	26	40	17	20	4
		60	6	6	5	15	8	21	30	18	28	10
		84	2	4	1	5	4	3	1	2	4	3
	Inner	6	0	0	0	0	0	2	115	4	2	2
		12	T	12	9	T	0	24	198	26	31	102
		24	T	T	T	46	0	149	117	92	165	49
		36	2	12	12	8	T	34	26	28	48	8
		60	8	7	15	15	8	12	22	12	16	15

Table 1-5. Residual MITC content, as measured by gas chromatographic analysis of increment cores, in southern pine and Douglas-fir poles 6, 12, 24, 36, 60, and 84 months after treatment with MITC-Fume® or metham-sodium.[a]

Vertical distance from treatment zone	Core segment tested[c]	Months after treatment	Residual MITC (µg/g of wood)[b]									
			Southern pine					Douglas-fir				
			MITC-Fume®				Metham-sodium	MITC-Fume®				Metham-sodium
			60 g	120 g	180 g	240 g	500 ml	60 g	120 g	180 g	240 g	500 ml
		84	1	5	2	5	2	2	3	1	3	2
1.5 m	Outer	6	0	0	0	0	0	0	0	0	0	0
		12	0	0	0	0	0	5	T	T	T	T
		24	0	0	0	0	0	T	T	T	49	0
		36	0	T	T	2	T	3	3	T	4	T
		60	7	24	3	11	7	9	15	7	16	16
		84	2	4	6	1	3	3	2	2	3	6
	Inner	6	0	0	0	0	0	0	0	0	0	0
		12	0	0	0	0	0	T	T	T	21	0
		24	0	0	0	0	0	T	T	T	120	0
		36	0	T	T	2	T	3	6	3	2	T
		60	5	4	4	12	9	9	9	7	12	14
		84	1	6	3	2	2	2	4	1	1	2

[a] Cores were removed from selected locations at different vertical distances above and below the treatment site.

[b] T - trace amount of MITC present but not quantifiable.

[c] Outer -- 2.5 cm from pole surface; Inner -- 12.5 to 15.0 cm from pole surface.

exposed outside out of ground contact on racks near Corvallis, Oregon.

MITC content was measured at 6, 12, 24, 36, 60, and 72 months after treatment by removing 150 mm long increment cores from three sites equidistant around the pole 150 mm and 450 mm above and below the treatment zone. The cores were divided in half and each half was placed in a test tube containing 5 ml of ethyl acetate. The cores were extracted for 48 hours before the extracts were analyzed for MITC by gas chromatography as previously described (Zahora and Morrell, 1988).

MITC levels over the first 6 months were generally highest in poles receiving metham sodium, reflecting the tendency of this formulation to decompose shortly after treatment to produce MITC. MITC was virtually absent from these same poles 4 or 5 years after application, illustrating the ephemeral nature of this treatment (Table I-6).

MITC levels in poles receiving Basamid alone were initially far lower than those associated with metham sodium but rose steadily over the first year after treatment and have remained consistently higher over the 6 year test period.

The addition of powdered pH 12 buffer in conjunction with Basamid treatment initially appeared to be associated with increased MITC levels, a finding which was consistent with laboratory trials (Morrell et al., 1988; Forsyth and Morrell, 1995). Over the six-year period, however, MITC levels in buffer treatments have declined to levels similar to those found in non-buffer treatments. The absence of a long term effect with buffer addition may be due to the acidity of wood and the relatively small amounts of buffer applied. While higher percentages of buffer might enhance activity, the cost of higher levels may not justify the increase in MITC production.

The inclusion of various additives produced somewhat variable effects on residual MITC levels. A number of these compounds were included because previous studies suggested that they would enhance Basamid decomposition. In most cases, however, these additives had only a temporary influence or no effect on MITC levels. The exception was copper sulfate, which produced a marked effect on MITC levels. Initially, MITC levels were greatest when buffer was present, although this effect has gradually declined with time and average MITC levels are currently higher in Basamid plus copper sulfate treatments without buffer.

The relative effectiveness of Basamid in comparison with metham sodium has frequently been questioned. Bioassays have shown that Basamid decomposes in wood at rates which are eventually toxic to many wood inhabiting fungi, but the rates of control are somewhat slower than found with metham sodium (Highley and Eslyn, 1990). The addition of copper sulfate, and to a lesser extent, the presence of pH 12 buffer resulted in average MITC levels approaching those found with metham sodium. MITC levels in Basamid treatments generally remained elevated for far longer periods (Figure I-4). This provides for both a rapid chemical kill, as is found with metham sodium, and a prolonged protective effect more typical of chloropicrin or MITC Fume. The ability to deliver this effect using a non-volatile, crystalline chemical markedly enhances the safety of the remedial treatment process.

Basamid treatment resulted in residual MITC levels that were initially lower than those found with metham sodium. Eventually, MITC levels in nearly all Basamid treatments exceeded those found with metham sodium. With the exception of copper sulfate, additives had little consistent positive effect on MITC levels and their potential benefit in enhancing Basamid effectiveness is questionable. Copper sulfate provided the most consistent improvement in MITC levels and its inclusion in Basamid treatments for wood merits further evaluation.

6. ***Treatment of Douglas-fir transmission poles with Basamid and copper***: The initial field trials using untreated Douglas-fir poles exposed above ground indicated that the addition of copper compounds markedly enhanced the

TABLE I-6. MITC distribution in Douglas-fir pole sections 0.5 to 6 years after internal treatment with metham-sodium or Basamid amended with amended additives.

Treatment	pH 12[b]	Year	ug MITC/OD g wood								
			+45 cm[a]		+15 cm		-15 cm		-45 cm		
			Outer	Inner	Outer	Inner	Outer	Inner	Outer	Inner	Mean[d]
Metham-sodium	-	0.5	-	-	113.3	195.6	173.4	104.2	-	-	147
	-	1	9.6	79.1	29.9	80.4	19.8	54.5	12.2	34.5	40
	-	2	8.4	15.7	5.0	21.3	5.3	14.3	2.3	5.0	10
	-	3	1.7	3.7	5.3	10.6	4.3	3.5	2.5	3.1	4
	-	4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.7	0
	-	6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0
Basamid Alone	-	0.5	-	-	9.5	16.6	12.9	19.9	-	-	14
	-	1	5.2	13.7	9.7	10.8	5.9	26.5	1.1	5.6	10
	-	2	2.6	3.7	4.1	8.1	6.1	7.7	3.8	3.1	5
	-	3	11.6	14.8	6.0	20.0	15.3	60.7	9.7	12.4	18
	-	4	1.2	6.9	29	21.9	13.4	87.9	16.6	13.5	21
	-	6	2.3	4.0	12.4	35.0	17.5	86.0	23.2	37.1	27
	+	0.5	-	-	9.3	14.6	16.4	100.5	-	-	44
	+	1	0.0	5.7	0.2	13.5	11.0	44.8	0.1	10.8	11
	+	2	0.0	0.6	0.0	7.2	3.6	32.5	1.7	8.3	7
	+	3	3.1	5.8	10.9	21.9	24.9	49.0	9.3	16.6	18
	+	4	0.0	3.8	12.7	15.5	10.7	43.3	6.8	23.1	15
	+	6	1.1	1.8	10.1	29.2	7.3	15.5	24.2	58.4	18
Basamid plus $CuSO_4$	-	0.5	-	-	15.9	45.9	10.2	39.1	-	-	27
	-	1	20.8	17.8	11.2	45.7	13.5	48.6	0.0	3.9	20
	-	2	5.9	9.1	10.3	47/1	11.7	66.7	0.4	6.8	20
	-	3	3.4	12.7	34.1	104.9	43.1	95.2	14.5	5.4	39
	-	4	4.1	24.7	19.6	87.3	27.2	106.9	6.8	25.3	38
	-	6	10.3	27.6	34.8	120.4	27.9	86.0	13.3	25.6	43
Basamid plus $CuSO_4$	+	0.5	-	-	55.3	58.1	90.5	95.4	-	-	75
	+	1	8.2	76.3	22.0	120.8	21.4	203.1	6.7	64.3	65
	+	2	49.2	47.6	69.9	63.9	99.7	96.5	95.8	124.5	81
	+	3	50.1	48.5	60.7	59.4	72.1	69.6	79.9	78.9	65
	+	4	3.4	15.7	13.8	44.3	17.5	62.5	12.0	46.1	27
	+	6	3.9	11.3	7.8	38.5	20.3	46.4	9.4	17.0	19
Basamid plus glucose	-	0.5	-	-	7.6	13.2	1.3	20.5	-	-	11
	-	1	0.5	0.2	1.7	17.1	4.8	32.8	2.6	3.7	8
	-	2	0.0	0.0	2.7	13.8	7.8	30.9	0.0	3.5	7
	-	3	2.2	7.8	33.2	62.1	35.2	112.4	160	30.0	8
	-	4	2.4	13.1	7.9	57.6	30.3	84.7	11.5	28.5	30
	-	6	2.0	4.0	10.4	28.1	21.9	83.7	17.4	49.9	27
	+	0.5	-	-	16.6	37.1	17.6	62.8	-	-	33
	+	1	1.8	20.0	6.8	76.9	81.7	14.2	33.1	21.6	32
	+	2	0.6	1.9	9.0	33.5	21.2	54.5	2.3	5.0	16
	+	3	1.2	3.9	9.3	29.4	48.7	91.8	9.0	23.9	27
	+	4	2.2	4.2	10.4	18.4	27.5	62.0	2.9	2.5	16
	+	6	5.4	5.9	17.8	39.9	20.7	40.8	5.9	10.4	18

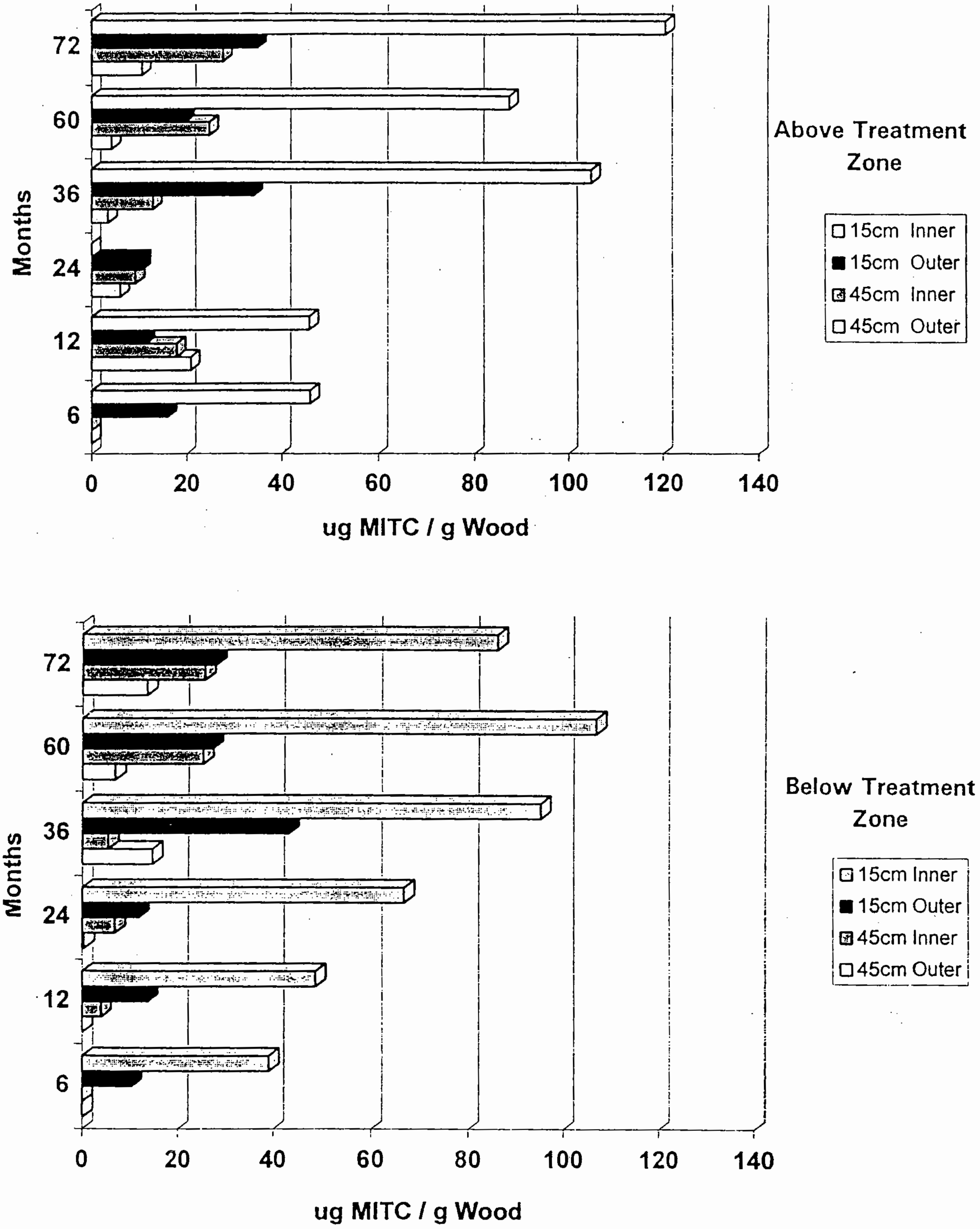
Treatment	pH 12[b]	Year	ug MITC/OD g wood								
			+45 cm[c]		+15 cm		-15 cm		-45 cm		Mean[d]
			Outer	Inner	Outer	Inner	Outer	Inner	Outer	Inner	
Basamid plus lignin	-	0.5	-	-	0.2	5.5	1.3	23.2	-	-	8
	-	1	1.4	2.8	2.9	24.9	4.8	93.1	2.1	14.0	18
	-	2	1.5	2.5	4.0	17.8	15.5	52.1	3.1	18.7	14
	-	3	2.3	6.6	8.7	20.8	16.0	33.0	3.7	5.8	12
	-	4	4.9	4.8	3.6	6.0	9.7	30.7	1.6	8.3	9
	-	6	-	-	-	-	-	-	-	-	-
	+	0.5	-	-	3.3	27.0	4.2	41.3	-	-	19
	+	1	3.2	17.4	7.0	63.6	16.1	79.6	5.5	3.0	24
	+	2	0.0	1.6	1.2	26.4	7.7	50.7	0.0	9.8	12
	+	3	2.1	1.6	19.3	13.5	35.3	28.9	3.1	9.2	14
	+	4	0.0	8.5	6.9	46.8	5.6	52.7	4.3	10.8	17
	+	6	1.0	3.4	6.0	30.8	14.7	48.4	4.1	7.6	15
Basamid plus boron	-	0.5	-	-	9.5	17.9	18.9	33.1	-	-	20
	-	1	0.4	11.3	6.6	30.8	15.0	49.6	0.1	5.2	15
	-	2	0.6	1.6	4.5	12.7	5.8	25.5	1.2	2.9	7
	-	3	0.3	0.3	7.6	17.9	21.6	27.1	2.6	2.6	10
	-	4	2.3	5.6	13.4	20.7	31.9	55.4	4.1	17.5	19
	-	6	5.2	10.9	21.6	45.2	35.0	69.9	5.7	20.8	27
	+	0.5	-	-	7.0	11.6	8.0	30.4	-	-	14
	+	1	0.0	11.8	7.7	24.2	17.2	33.5	1.0	5.6	13
	+	2	0.2	1.1	3.5	13.0	9.2	29.3	2.0	5.8	8
	+	3	29.2	54.5	8.8	17.7	66.5	33.8	11.3	49.1	34
	+	4	2.9	2.3	2.0	9.3	8.0	38.8	1.6	11.9	10
	+	6	3.4	7.4	15.2	32.6	20.2	43.8	5.9	9.4	17
Basamid plus ethanol	-	0.5	-	-	3.0	6.0	0.1	12.0	-	-	5
	-	1	0.0	2.1	0.4	15.3	0.2	7.3	0.0	0.0	3
	-	2	0.0	0.5	1.8	4.7	1.8	6.3	0.4	0.2	2
	-	3	0.1	0.8	1.0	8.4	3.0	12.5	0.7	1.4	4
	-	4	6.7	4.7	8.3	23.9	14.2	24.1	2.3	7.1	11
	-	6	2.9	3.2	2.2	16.8	4.4	9.3	2.2	7.9	6
Basamid plus acetone	-	0.5	-	-	1.2	4.4	1.0	8.2	-	-	4
	-	1	4.3	18.3	9.3	17.0	15.2	26.1	15.6	12.9	15
	-	2	0.0	0.0	2.8	8.3	7.2	16.0	0.9	1.3	5
	-	3	2.0	4.2	9.3	27.3	14.0	38.2	7.0	15.3	14
	-	4	0.0	0.0	2.4	25.8	14.4	181.2	10.1	18.1	32
	-	6	1.9	3.2	5.3	24.8	27.4	124.7	5.1	12.8	26
Basamid plus methanol	-	0.5	-	-	2.8	7.2	0.8	16.0	-	-	8
	-	1	0.0	0.1	0.0	3.7	0.2	9.5	0.3	0.6	2
	-	2	0.0	0.5	0.8	3.3	2.6	8.6	0.0	0.1	2
	-	3	0.2	0.9	9.6	11.6	19.0	28.7	7.2	5.0	10
	-	4	0.0	0.0	0.9	7.0	0.0	44.1	2.0	4.4	7
	-	6	0.0	0.0	5.4	13.0	1.5	9.4	0.0	3.1	4

Treatment	pH 12[b]	Year	ug MITC/OD g wood								
			+45 cm[a]		+15 cm		-15 cm		-45 cm		
			Outer	Inner	Outer	Inner	Outer	Inner	Outer	Inner	Mean[d]
Basamid plus water	-	0.5	-	-	1.0	3.0	1.6	14.8	-	-	5
	-	1	0.0	1.2	0.0	2.3	0.4	8.3	0.0	0.0	2
	-	2	0.3	2.0	1.5	7.3	5.1	22.1	2.6	7.7	6
	-	3	0.0	0.2	1.6	6.0	9.6	79.8	6.2	5.5	14
	-	4	3.3	8.1	3.4	14.6	11.3	80.7	2.6	7.0	16
	-	6	0.6	1.4	9.9	23.3	16.3	122.5	11.1	50.6	30

[a] Values are distance above (+) and below (-) treatment zone. Cores were broken in half and analyzed separately as "outer" and "inner" segments. Values represent mean of 15 core segments. Mean values for all 120 core segments within each treatment group.

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

[c] "-" indicates no core was taken at this location.



Figure, I-4. Residual MITC 15 or 45 cm above (A) or below (B) the treatment zone of Douglas-fir pole sections 6 to 72 months after treatment with basamid plus copper sulfate.

decomposition of Basamid (Forsyth and Morrell, 1994). These tests were performed in untreated wood and might not be representative of a full scale pole with an oil-treated shell. To develop this information, a series of three 19 mm diameter by 375 mm long steeply sloping holes were drilled into pentachlorophenol-treated Douglas-fir transmission poles. These holes began at groundline and moved upward at 150 mm intervals and 120 degrees around the pole. Poles received 200 or 400 g of powdered Basamid with or without 1% copper sulfate. An additional set of poles received 500 g of metham sodium to serve as treated controls. Each treatment was replicated on 5 poles.

Basamid and metham sodium must both decompose to methylisothiocyanate (MITC) to become effective as a fungicide. MITC levels were measured in wood samples to assess decomposition efficiency. Increment cores were removed from three equidistant sites 0, 1, 2, and 3 m above the highest treatment hole. These poles were originally through-bored, making sampling below the lowest fumigant treatment site impractical. The outer, preservative-treated shell from each core was discarded, then the inner and outer 25 mm of each core was individually placed into test tubes containing 5 ml of ethyl acetate. The cores were extracted for a minimum of 48 hours, then the extracts were analyzed for residual MITC by gas chromatography. The remainder of the core was cultured for the presence of decay fungi.

MITC levels were generally low in both 200 g Basamid treatments as well as the 400 g Basamid treatment without copper in comparison with the metham sodium control (Table I-7). MITC levels in 400 g treatments with copper were similar to those found with metham sodium. Metham sodium is generally considered to be a fairly short term treatment which results in detectable MITC for 2 to 3 years. MITC levels then decline fairly rapidly after that point and there is little evidence of protection in Douglas-fir poles 5 to 7 years after treatment. MITC levels increased in the groundline zone of all Basamid treatments 2 years after application. While levels were sometimes higher when copper was added to the holes, the differences were generally small and inconsistent. As a result, the benefits of copper may not be initially evident. As expected, MITC levels were higher near the groundline, reflecting the proximity to the treatment holes. MITC levels were somewhat variable 1 m above the treatment zone (Figure I-7). MITC levels were exceedingly low 2 and 3 m above the treatment zone regardless of treatment suggesting that the protective zone for this treatment was 1 m above or below the original treatment sites (Figure I-5).

Culturing revealed that a single decay fungus was isolated from metham sodium treated poles at the time of treatment while none have been isolated from any Basamid treatments at either sampling point (Table I-8).

The results indicate that Basamid is decomposing at levels at least comparable to metham sodium and should be a viable field treatment for controlling internal decay of Douglas-fir poles.

7. Effect of glycol and moisture on diffusion of boron from fused boron rods: Last year (95 Annual Report, Pages 41-43), we reported on the establishment of trials to evaluate the effects of glycol on movement of boron from fused boron rods. Thirty Douglas-fir poles (25 to 30 cm in diameter by 3.6 m long) were treated with pentachlorophenol in P9 Type A solvent and installed to a depth of 0.6 m at our Corvallis test site. Three 17.5 mm diameter by 267 mm long holes were drilled at 45 degree angles into the pole, 75 mm above the groundline. The poles received the combinations of boron rod and ethylene glycol (Table I-9).

The treatment holes were plugged with tight fitting wooden dowels. The treatments delivered 220 to 224 g of boric acid equivalent (BAE) to each pole.

One year after treatment the poles were sampled for both boron and moisture content by removing duplicate sets of increment cores from three equidistant sites around each pole - 300 mm, 0, 150 mm and 300 mm above the groundline. The outer, pentachlorophenol

Table I-7. Residual MITC in pentachlorophenol treated Douglas-fir transmission poles 1 and 2 years after internal treatment with 200 or 400 g of Basamid alone or amended with 1% (wt.) of copper sulfate as compared with similar poles receiving 500 ml of metham-sodium.

Chemical	Years	Copper Sulfate Added	Dosage (g)	Residual MITC (μg/g oven dried wood)[a]							
				Distance above treatment zone (m)							
				0		1 m		2 m		3 m	
				inner	outer	inner	outer	inner	outer	inner	outer
Metham-sodium	1	-	500	21	30	57	38	1	--	1	--
	2	–		47	16	13	10	4	2	3	4
Basamid	1	–	400	4	22	16	56	1	–	–	1
	2	–		51	39	7	4	4	3	5	3
	1	+	400	25	24	31	64	–	–	–	1
	2	+		62	33	11	3	6	4	3	3
Basamid	1	–	200	3	7	3	16	–	–	1	–
	2	–		72	54	11	6	2	1	4	8
	1	+	200	12	14	26	42	–	1	2	–
	2	+		69[b]	150[b]	8	2	2	2	3	6

[a] Values reflect means of 15 samples per position for Basamid and 30 for metham sodium. Core positions reflect inner and outer 25 mm of each increment core; (-) signifies no MITC detected.

[b] Data may represent an artifact.

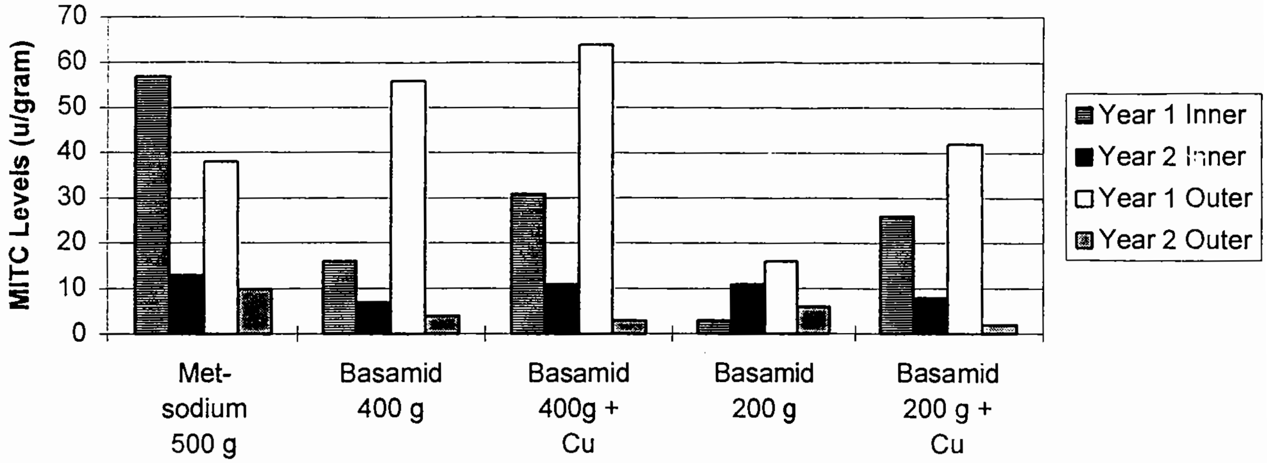
Table I-8. Fungal colonization in Douglas-fir poles 2 years after treatment with metham sodium or basamid with and without copper sulfate.

Treatment	Dosage (g)	Cu	Cores with Decay (DF) and Non-Decay (F) Fungi %[a]									
			1993		1995 -- Distance from Treatment Hole (m)							
					0		1		2		3	
			DF	F	DF	F	DF	F	DF	F	DF	F
Metham sodium	500 ml	-	3	23	0	10	0	20	0	20	0	10
Basamid	400 g	-	0	33	0	13	0	13	0	13	0	13
Basamid + Cu	400 g	+	0	33	0	13	0	13	0	20	0	20
Basamid	200 g	-	0	0	0	7	0	27	0	20	0	13
Basamid + Cu	200 g	+	0	20	0	7	0	27	0	13	0	20

*1993

[a] Initial samples were shavings from the treatment hole. DF=decay fungi, F=all other fungi. Values represent 15 samples/treatment.

Residual MITC of Inner and Outer Cores 1 m above Treatment Zone of Douglas-fir Transmission Poles 1 & 2 Years after Treatment



Residual MITC of Inner and Outer Cores in the Treatment Zone of Douglas-fir Transmission Poles 1 & 2 Years after Treatment

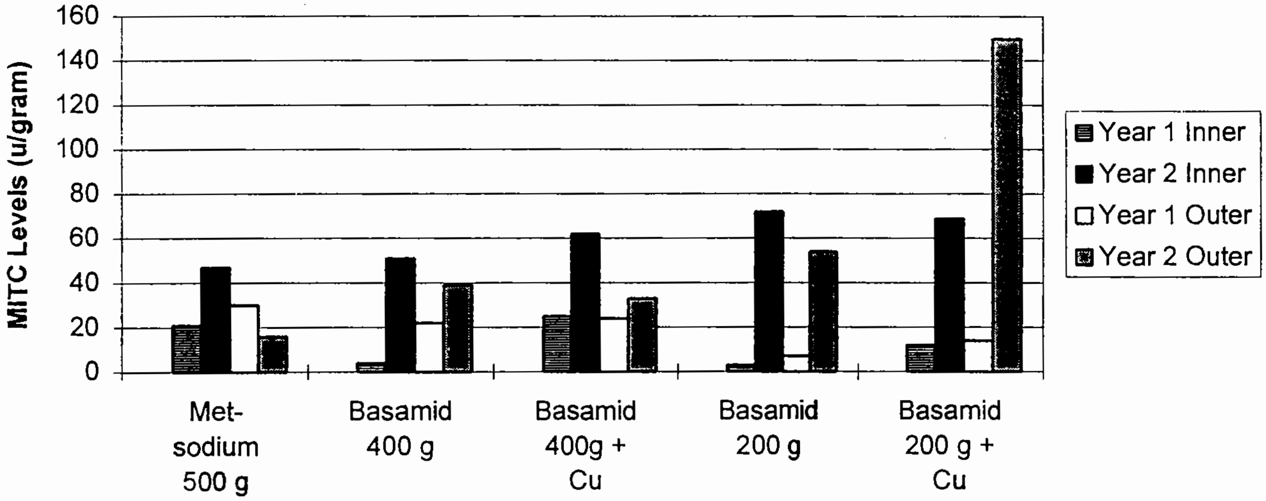


Figure I-5. Residual MITC in Douglas-fir transmission poles 1 to 2 years after treatment with 200 or 400 g of Basamid with or without copper sulfate in comparison with 500 g of metham sodium.

treated shell from each core was discarded. The cores for boron analysis were divided into three equal zones and air-dried for several days. The cores were then oven dried at 54°C for 24 hours and cores from the same sampling height for a given pole were combined before being ground to pass a 20 mesh screen. The resulting wood dust was extracted and analyzed for boron content by Ion Coupled Spectroscopy (ICP) on a blind sample basis by CSI, Inc.

Boron levels in poles receiving only rods were generally low (<0.1% BAE) 1 year after treatment (Table I-10), even at the groundline, where moisture levels should be adequate for boron diffusion. Boron levels in rod-only treatments increased from outer to inner sampling zones, but the differences were slight. The addition of glycol, either alone or with small amounts of boron, resulted in far higher levels of boron in the wood in all but a few treatments (Figure I-6). Boron levels were highest in the inner zone at groundline in poles receiving Boracol 40. Boron levels at groundline were similar to one another and slightly lower than Boracol 40 in poles receiving either Boracol 20 or glycol. Poles receiving Timbor or Boracare had slightly lower boron levels in the inner zone near groundline. Boron levels were slightly more variable 150 or 300 mm above the groundline, reflecting natural variation in moisture content. For example, boron levels at sites 150 mm above the groundline were highest with the boron rod plus Timbor treatment, while levels were highest with Boracare plus boron rods 300 mm above the groundline.

Interestingly, boron levels 300 mm below ground were higher than those 150 or 300 mm above ground, but did not exceed those at groundline for most treatments. Boron levels in the outer zone, however, were slightly elevated, suggesting that boron might be diffusing towards the pole surface. The test poles are exposed on a site which is extremely wet in the winter and this high moisture level may encourage boron loss. Further sampling will be necessary to confirm these trends.

The cores removed for moisture content analysis were divided into three equal segments (inner, middle and outer) and each segment was immediately placed in a tared glass test tube which was tightly capped to retard moisture loss. The tubes were then returned to the laboratory and weighed. Subtraction of the tare weight yielded an initial wet weight. The tubes containing cores were then oven-dried for 24 hours at 105° C and the cores were weighed. The weight wet and final oven dry weight were then used to determine wood moisture content.

Moisture contents of the poles varied from 14 to 89%, although most of the values were between 20 and 40%. These initial moisture samples were taken during the winter when wood moisture contents would be expected to be elevated. Most rainfall at the Corvallis test site falls between November and April. This past year, rainfall levels exceeded 150 cm, about 50 above normal. In addition, the test site soil tends to become water-logged during the winter months further enhancing conditions for increased wood moisture levels. Average moisture readings for all cores tended to be highest below the groundline, then declined slightly at groundline and remained similar further upward (Figure I-6). Moisture contents were generally highest in the inner zone and tended to vary between the middle and outer zones. The heavy oil shell surrounding these poles should minimize wide fluctuations in moisture since nearly all incoming moisture will likely move through checks into the surrounding wood. Thus, the differences between inner and outer zones should be less extreme than would be found with untreated wood in similar exposures. Given the ratio of check surface area to wood volume in an environment where excessive water was present, one would expect the inner zones to absorb more moisture since they contain a correspondingly lower volume of wood.

Moisture contents did not differ among most treatments, although moisture levels were significantly higher for the boron rod/boracol 20 (Treatment D) at the 300 mm above ground sampling site (Table I-11). The reasons for the increased moisture level in this treatment are unclear and will require additional sampling to determine if this difference is real or an artifact.

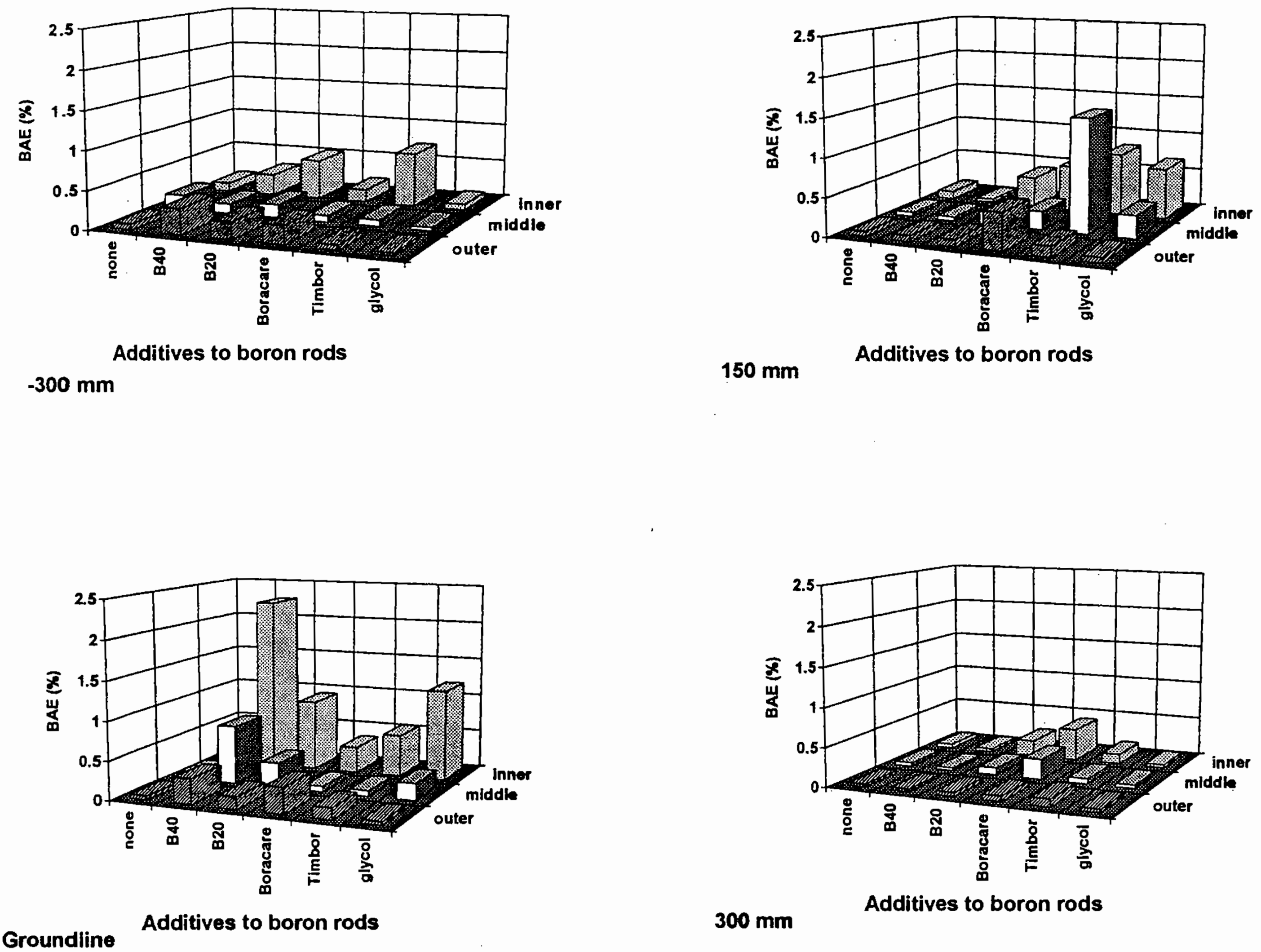
Table I-9. Boron rod/glycol treatments applied to Douglas-fir poles in 1995.

TREATMENT	REPS	DOSAGE (g)	
		BORON ROD (g)	ADDITIVE
A	5	152	-
B	5	152	ethylene glycol (140 g)
C	5	91	Boracol 40 (199 g)
D	5	125	Boracol 20 (183 g)
E	5	125	10 % Boracare (177 g)
F	5	140	10 % Timbor (170 g)

Table I-10. Residual boron in Douglas-fir poles 1 year after treatment with combinations of boron and glycol.

Treatment	Boron Concentration (%BAE)											
	-300mm			0			150mm			300mm		
	inner	middle	outer	inner	middle	outer	inner	middle	outer	inner	middle	outer
Rods only	0.111 (0.090)	0.180 (0.267)	0.072 (0.026	0.292 (0.381)	0.077 (0.048)	0.053 (0.026)	0.099 (0.059	0.050 (0.013)	0.067 (0.035)	0.051 (0.026)	0.045 (0.013)	0.035 (0.019)
Rods + B40	0.274 (0.306)	0.123 (0.082)	0.329 (0.510)	2.261 (1.655)	0.755 (0.537)	0.328 (0.437)	0.042 (0.023)	0.049 (0.006)	0.080 (0.050)	0.040 (0.024)	0.033 (0.020)	0.034 (0.022)
Rods + B20	0.518 (0.890)	0.169 (0.129)	0.222 (0.150)	0.917 (1.119)	0.322 (0.416)	0.161 (0.174)	0.397 (0.205)	0.161 (0.139	0.096 (0.071)	0.201 (0.278)	0.090 (0.074)	0.052 (0.012)
Rods + Boracare (25 g/hole)	0.162 (0.216)	0.081 (0.039)	0.239 (0.355)	0.338 (0.296)	0.071 (0.036)	0.337 (0.466)	0.597 (0.492)	0.237 (0.219)	0.486 (0.804)	0.907 (0.239)	0.259 (0.380)	0.073 (0.038)
Rods + Timbor (25 g/hole)	0.700 (1.091)	0.083 (0.045)	0.065 (0.036)	0.545 (0.522)	0.072 (0.035)	0.145 (0.126)	0.809 (0.666)	1.473 (2.448)	0.140 (0.160)	0.122 (0.047)	0.065 (0.020)	0.100 (0.064)
Rods + ethylene glycol	0.071 (0.058)	0.042 (0.013)	0.036 (0.021)	1.182 (1.780)	0.218 (0.239)	0.047 (0.032)	0.650 (0.704)	0.300 (0.305)	0,070 (0.039)	0.038 (0.022)	0.042 (0.009)	0.044 (0.008)

a Where locations represent distance above or below the groundline. Inner, middle, and outer zones represent thirds of a 15 mm long increment core. B20=Boracol 20, B40=Boracol 40.



-300 mm

150 mm

Groundline

300 mm

Figure I-6. Residual boron levels in the inner, middle, and outer thirds of increment cores removed from sites 300 mm below groundline, at groundline, and 150 or 300 mm above groundline, in Douglas-fir poles 1 year after treatment with boron rods and selected treatment additives.

Table I-11. Wood moisture contents at selected zones in Douglas-fir poles 1 year after treatment with combinations of boron and glycol.

	Wood Moisture Content (%)											
	-300mm			0			150mm			300mm		
Treatment	Inner	Middle	Outer	Inner	Middle	Outer	Inner	Middle	Outer	Inner	Middle	Outer
A	53	41	41	35	29	32	28	27	29	27	28	29
B	42	35	39	31	24	28	24	26	26	22	23	24
C	37	40	37	38	27	25	27	21	22	25	22	24
D	38	35	37	36	26	26	31	25	26	38	34	30
E	37	32	37	32	25	27	30	26	23	26	26	24
F	35	37	35	33	28	27	30	29	27	27	28	27

Values represent means of 9 replicates per position per treatment. See Table *** for key to treatments.

Moisture levels in all treatments were generally higher at the below ground sampling site. Average moisture contents of all treatments from this zone were above 30%, suggesting that conditions were adequate for both boron diffusion and fungal growth. Moisture contents in the groundline samples varied more widely. Samples from the inner zones were generally above 30%, again indicating that conditions were suitable for diffusion and fungal attack. Average moisture levels in the middle and inner zones were between 24 and 32%, with the majority of samples falling below 28%. Moisture contents of samples from inner zones of cores removed 150 mm above the groundline ranged from 24 to 31%, with three of six averages at or above 30%. Moisture contents further into cores for this zone were much lower ranging from 21 to 29%. Moisture levels were generally lower in samples removed from sites 300 mm above the groundline, with the exception of the boron rod/boracol 20 treatment. Average moisture contents for all three sampling depths with the treatment were at or above 30%. It is unclear why the moisture contents in this particular treatment are so elevated as noted above and we will continue to sample poles in this treatment to develop more comprehensive moisture content data.

8. Seasonal moisture distribution in Douglas-fir poles: Last year, we reported on an effort to track internal moisture contents of Douglas-fir poles seasonally using permanent sampling sites installed to various depths both above and below the groundline of poles treated with combinations of boron rod and glycol (95 Annual Report, pages 43,48). Briefly, pins were set 25, 75, or 150 mm into the poles, 150 mm below groundline as well as at groundline and 150 or 300 mm above this zone. The pins were sealed into the wood using epoxy resin and a rubber cap was placed over each pin to protect it from weathering. Resistance was measured monthly by attaching clips to the pins using a 30 volt AC power supply across each electrode. The results at 25 and 75 mm were compared with similar readings taken using a conventional resistance-type moisture meter. Last year, we reported that resistance declined with distance above ground and with time after installation. These measurements were taken during the drier summer months and appeared to reflect actual moisture conditions.

We have continued measuring these test sites through the winter to better understand the rate at which moisture contents change in the interior of a pole. This information is useful for predicting potential decay hazard, but more importantly, can be useful for predicting the potential distribution of water-diffusible biocides such as boron or fluoride.

Resistance readings in poles remained low in June, increased slightly in July, then returned to a lower level in August, suggesting that the resistance might provide a useful method for measuring seasonal moisture changes. Resistance readings taken in December, however, were uniformly low (Figure I-8,9). While this initially suggested that moisture levels in the poles had risen rapidly in response to the onset of the wet season, further examination of the pins indicated that many of the sites were extremely wet. Apparently as moisture ran down the pole, it entered the pin holes where it rapidly altered resistance. Resistance-type meter readings at sites adjacent to the pins indicated that wood moisture contents in these zones easily exceeded 30% in December, even 90 mm below the surface. Moisture measurements 25 mm away from these sampling sites, however, resulted in moisture contents between 17 and 21%. As a result of the inability to maintain resistance pin integrity with the wood, we abandoned this effort and instead removed additional increment cores during boron sampling of the test poles.(Objective I-7)

9. Chemical movement of a fluoride/boron rod through Douglas-fir poles: While boron rods have received the most widespread attention as a water diffusible remedial treatment, a boron/fluoride rod is also available outside the U.S. This formulation consists of 24.3% sodium fluoride and 58.2% sodium

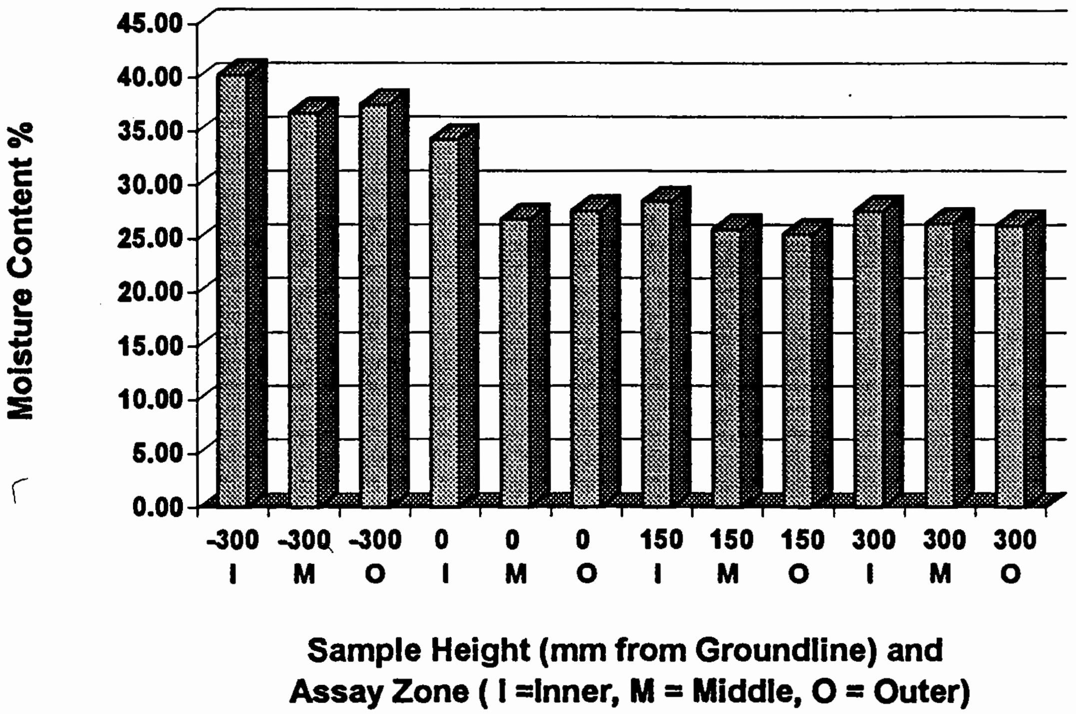


Figure I-7. Average moisture content of increment cores removed from selected heights above or below groundline of Douglas-fir poles 1 year after installation.

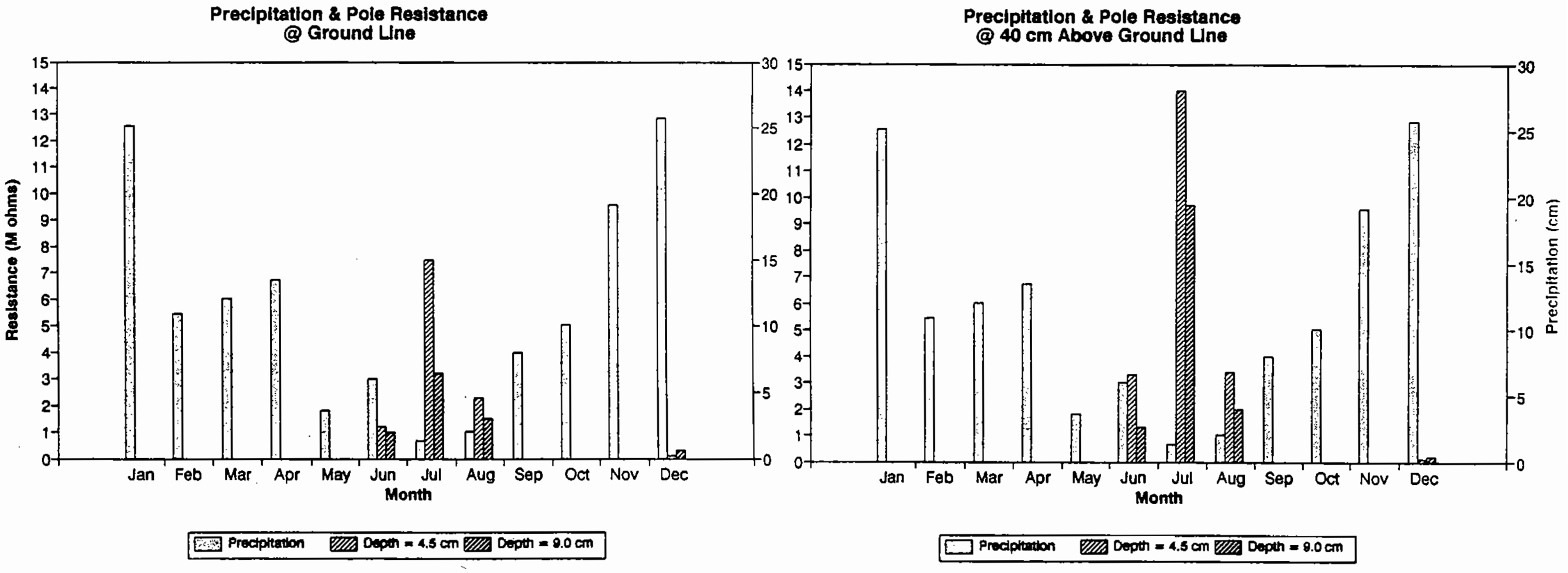


Figure I-8. Resistance measurements at selected depths in Douglas-fir poles at groundline or 400 mm above that zone vs precipitation.

octaborate tetrahydrate in a chalk-like rod.

This formulation has been reported to move well through various Eucalyptus species, but there are no data on the performance of this system in coniferous woods such as Douglas-fir.

Douglas-fir poles (3.6 m long x 250-300 mm in diameter) treated with pentachlorophenol in oil, were set in the ground to a depth of 0.3 m. A series of 3 holes (19 mm in diameter x 250 mm long) were drilled at steep sloping angles beginning at groundline, moving upward at 150 mm intervals, and around the pole at 90 or 120 degrees. A total of 70.5 or 141 g of boron/fluoride rod was equally distributed among the three holes which were plugged with tight-fitting wood dowels.

Boron and fluoride levels in the poles were assessed annually by removing increment cores from 3 equidistant sites around each pole: 300 mm below, 300 mm above, and 800 mm above the groundline. The outer, treated zone from each core was discarded, and the inner and outer 25 mm of each core were segregated. Core segments from the same location at a given sampling height were combined for the five poles in each treatment group and ground to pass a 20 mesh screen. One half of the sample was hot-water-extracted and analyzed for boron content using the azomethine H-method. The remainder of each sample was hot-water-extracted and analyzed for fluoride content using a specific ion electrode.

Fluoride levels were low at all sampled locations (Table I-13). None of the levels approached those required for protection against fungal attack (Figure I-10) (Becker, 1976). Boron levels were also generally low at all locations although the levels were much higher than those found with fluoride. Boron is generally effective against decay fungi at levels between 0.25 and 0.5% BAE. Using this range, all sampling sites 300 mm below ground were at or above 0.25% BAE. Three were above this level 300 mm above groundline and none were above this level 600 mm above ground 1 year after treatment (Figure I-11).

Boron levels were above 0.25% in only two sampling sites 2 years after treatment. The relatively light chemical loadings found in this test are perplexing, given the generally good movement of both boron and fluoride through most wood species. Furthermore, boron levels have generally increased in Douglas-fir poles between 1 and 3 years after treatment in other tests with boron rods. The levels of both boron and fluoride present in the formulation tested are much lower than those found with the borate rods. This lower dosage level apparently results in ineffective levels of either chemical unless higher dosages of chemical are applied.

10. Effect of glycol and moisture content on diffusion of boron from fused boron rods: Although we have established a variety of boron rod field trials, the results from these tests have indicated that boron movement through Douglas-fir appears to be slower than through other wood species. While the reasons for these differences remain unknown, it is clear that methods must be identified for accelerating boron movement through this wood species. One approach to enhancing movement is the addition of glycol to the boron at the time of application. Previous trials in Europe suggest that glycol enhances boron diffusion through drier wood, thereby producing more effective control under moisture regimes which would normally not be conducive to this treatment.

To study these effects, 38 by 88 by 150 mm long blocks were pressure soaked with water and conditioned to one of three moisture contents (15, 30, or 60%). The blocks were then dipped in molten wax to retard further changes in MC and the wood was stored for an additional 4 weeks at 5°C to encourage more even distribution of moisture.

A single 9.5 or 11.1 mm by 60 mm long hole was drilled at the midpoint of the 39 mm wide face of each block and a measured amount of boron alone or with Boracol 20, Boracol 40, Boracare (diluted 1:1 with water), 10% Timbor, or glycol was added to each hole. The holes were plugged with ~~rubber serum caps~~ wooden dowels and incubated at room temperature for ~~4~~, 8, or ~~16~~ 12 weeks.

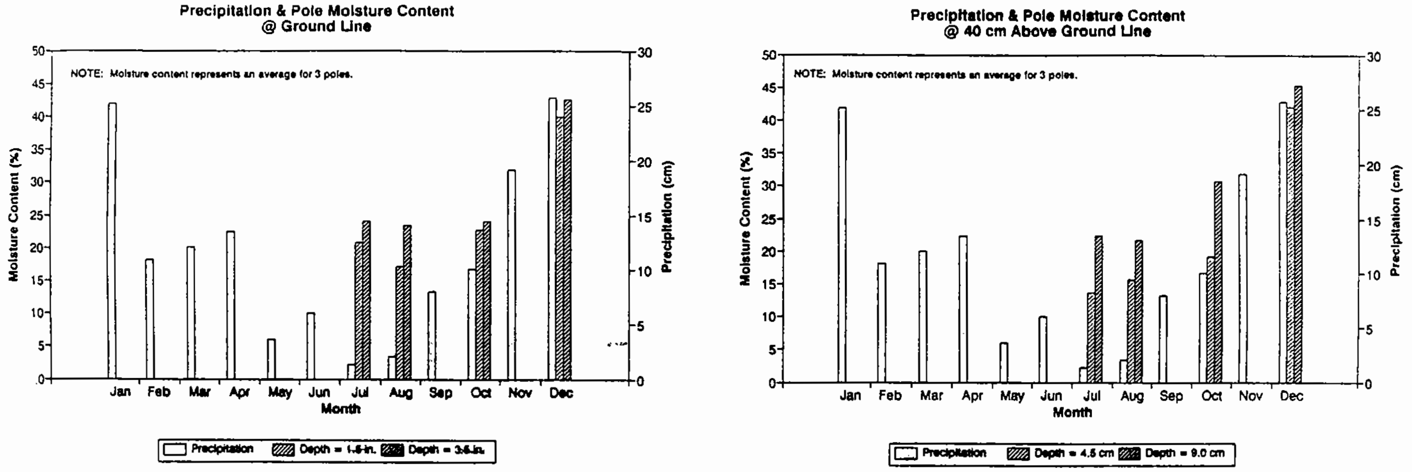


Figure I-9. Moisture content 45 or 90 mm from the wood surface of Douglas-fir poles at groundline or 400 mm above that zone vs precipitation.

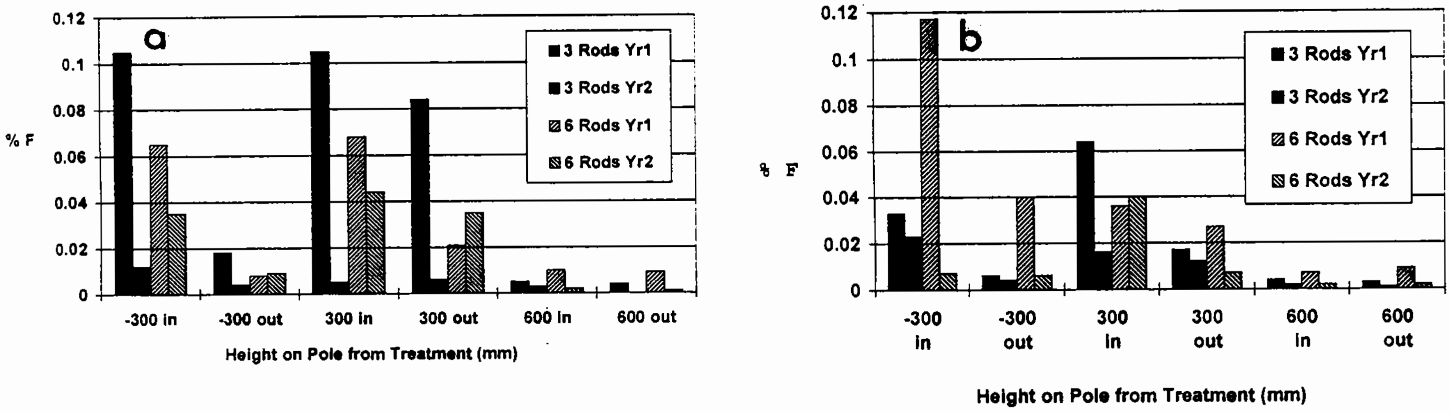
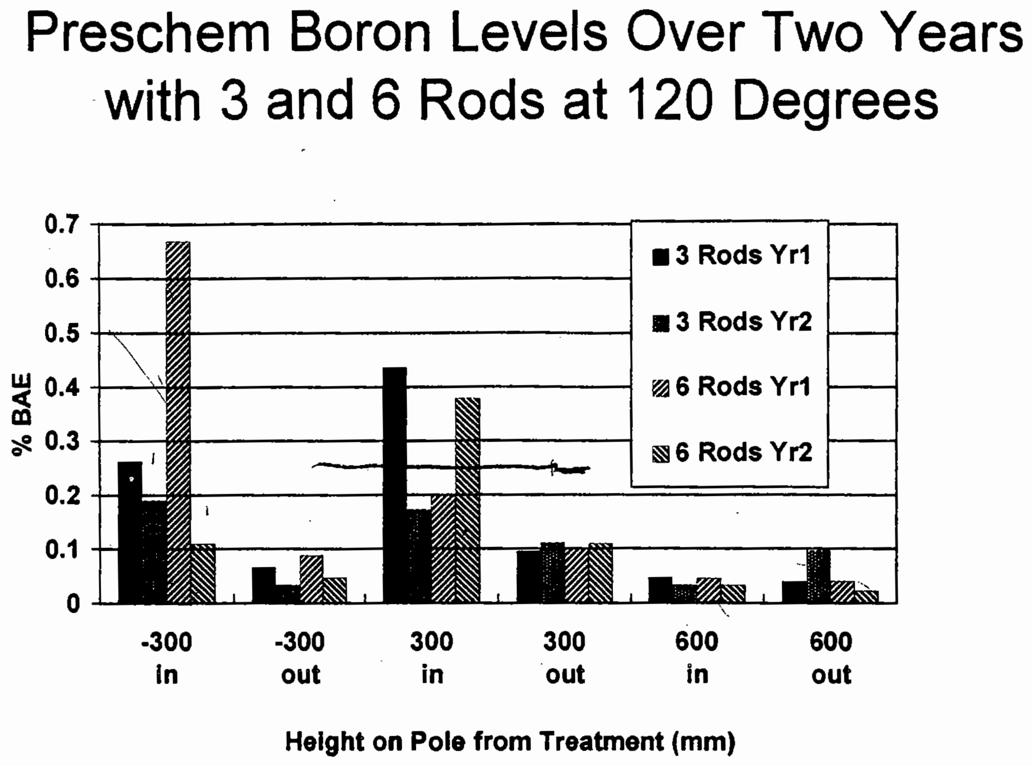


Figure I-10. Residual fluoride levels in Douglas-fir heartwood ~~blocks~~ poles 2 years after treatment with a boron/fluoride rod. a) 90 degree spacing, b) 120 degree spacing.



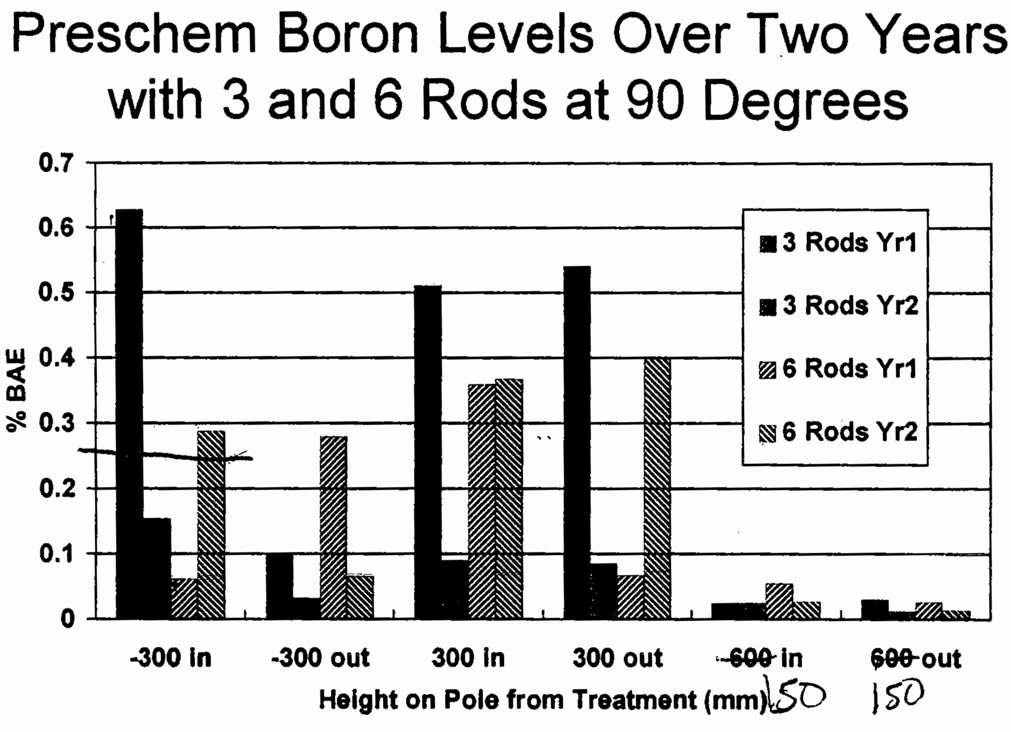


Figure I-1.1. Residual boron levels in Douglas-fir poles 1 or 2 years after treatment with 70.5 or 141 g (3 or 6 rods) of a boron/fluoride formulation.

Table I-12. Residual boron and fluoride at selected locations above or below the groundline in Douglas-fir poles 1 and 2 years after treatment with fluoride/boron rods.

Dosage	Application Pattern (Degrees)[a]	Years	Residual Chemical (% F or BAE)[b] Distance from Treatment Zone											
			-300mm				300 mm				600 mm			
			Outer		Inner		Outer		Inner		Outer		Inner	
			F	BAE	F	BAE	F	BAE	F	BAE	F	BAE	F	BAE
70.5	90	1	0.02	0.10	0.11	0.63	0.08	0.54	0.11	0.51	<0.01	0.03	0.01	0.02
		2	<0.01	0.03	0.01	0.15	<0.01	0.09	<0.01	0.09	<0.01	0.01	<0.01	0.03
	120	1	0.01	0.06	0.03	0.26	0.02	0.09	0.06	0.49	<0.01	0.04	<0.01	0.05
		2	<0.01	0.03	0.02	0.19	0.01	0.11	0.02	0.17	<0.01	0.10	<0.01	0.03
141.0	90	1	0.01	0.28	0.07	0.06	0.02	0.07	0.07	0.36	0.01	0.03	0.01	0.05
		2	0.01	0.07	0.04	0.29	0.04	0.40	0.04	0.38	<0.01	0.01	<0.01	0.03
	120	1	0.04	0.09	0.12	0.67	0.03	0.10	0.04	0.20	0.01	0.04	0.01	0.05
		2	0.01	0.05	0.01	0.11	0.01	0.11	0.04	0.38	<0.01	0.02	<0.01	0.03
0		1	--	0.01	--	0.08	--	0.04	--	0.01	--	0.01	--	0.01
		2	<0.01	0.01	<0.01	0.01	<0.01	0.01	<0.01	0.01	<0.01	0.01		

a Application patterns were holes at 90 or 120 degree intervals around the pole.

b Values represent composite analyses of 5 poles/treatment. BAE represents boric acid equivalent.

At each time point, four blocks per chemical treatment/moisture content combination were sampled by cutting a series of 5 mm thick sections 10, 25, 45, and 60 mm from the original treatment hole. These sections were oven dried overnight (54°C), sanded lightly to remove any possible boron carryover from sawing, and sprayed with a curcumin/salicylic acid indicator specific for boron.

The laboratory trials are still in progress and results are only available for three treatments at the selected moisture levels (2.1 g of rod plus 1.1, 2.2, or 3.3 g of glycol) after 8 and 12 weeks.

Boron movement in blocks treated with varying combination so boron and glycol was minimal in blocks maintained at 15% MC. Low levels of boron were detected 10 and 25 mm away from the treatment site in blocks (8 weeks after receiving 2.1 g of rod plus 3.3 g ethylene glycol but boron was not detected at any site 12 weeks after treatment with the same method (Figure I-12). Boron requires free moisture for movement and this glycol could not completely compensate for the absence of moisture in the test blocks.

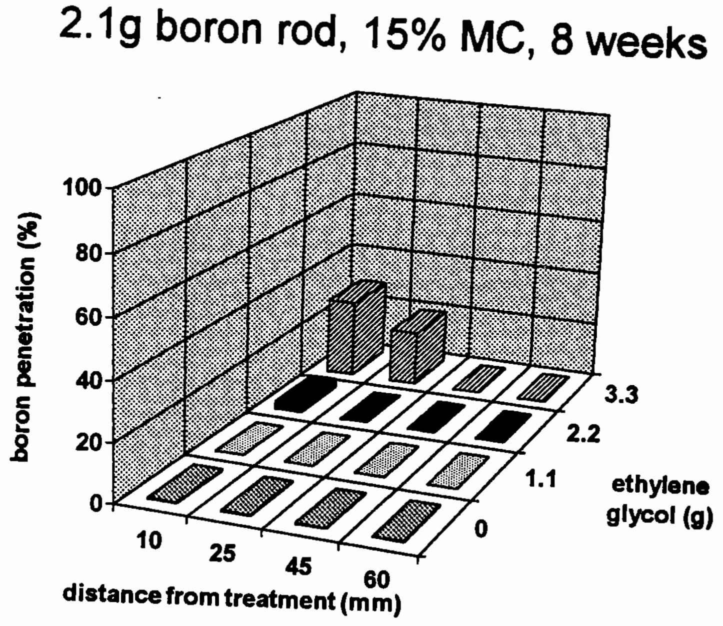
Boron movement was markedly improved in blocks maintained at 30% MC (Figure I-13). Boron distribution was generally low (< 20% of cross-section) in samples receiving only 2.1 g of boron rod 8 weeks earlier. Boron distribution improved markedly in this same treatment after an additional 4 weeks of incubation. Average percent penetration ranged from 70% 10 mm from the treatment hole to 15% 60 mm from this zone. Simultaneous addition of glycol markedly increased boron penetration in the test blocks. Average boron penetration 10 mm from the treatment hole ranged from 90 to 99% 8 weeks after treatment. Curiously, the degree of penetration declined slightly with increasing glycol content at the 8 week sampling point. This trend disappeared at the 12 week time point, suggesting that high variations between individual blocks may have accounted for these differences.

Boron distribution in blocks receiving 2.1 g of boron rod and maintained at 60% MC was virtually complete at all locations sampled both 8 and 12 weeks after treatment (Figure I-14). As a result, the addition of ethylene glycol produced no noticeable effect on boron movement. Previous studies (Morrell et al., 1990; Smith and Williams, 1969) have clearly demonstrated the importance of moisture for boron movement through wood. Glycol is definitely unnecessary for initial movement of boron through moisture wood. The effect of glycol on subsequent boron distribution and longevity of the treatment, however, is not known. Chemical analysis of the wafers examined in these tests should help to better delineate these effects.

11. Ability of fused borate rods to diffuse through Douglas-fir heartwood: While a majority of our research has evaluated volatile remedial chemicals, there are many instances where less volatile chemicals may provide equivalent protection. One currently available formulation employs sodium octaborate tetrahydrate in a fused borate rod. These glass-like rods release boron when moistened, and thus boron can then diffuse to control decay fungi present in the wood.

We have evaluated a series of field trials in Oregon, New York, and Hawaii. These sites are sampled periodically to assess boron movement. This past year we sampled three trials at the Corvallis test site. Samples from two of these trials are still being analyzed, but the results of the third are presented below.

In 1990, a trial was established to evaluate the efficacy of fused borate rods in Douglas-fir heartwood. Fifty Douglas-fir pole sections (1.05 m long by 25 to 30 cm in diameter) were surface dried and dipped for 5 minutes in a 2.0% solution of chromated copper arsenate Type C. The dipped poles were stored under cover for 24 hours to allow the fixation process to proceed, then air-dried. A 1.9 cm diameter hole was drilled through each pole section 40 cm from the top and a galvanized bolt with a slot cut perpendicular to the threads was inserted into the hole. A 1.9 cm diameter by 20 cm long hole was then drilled 15 cm directly above the bolt hole. The holes



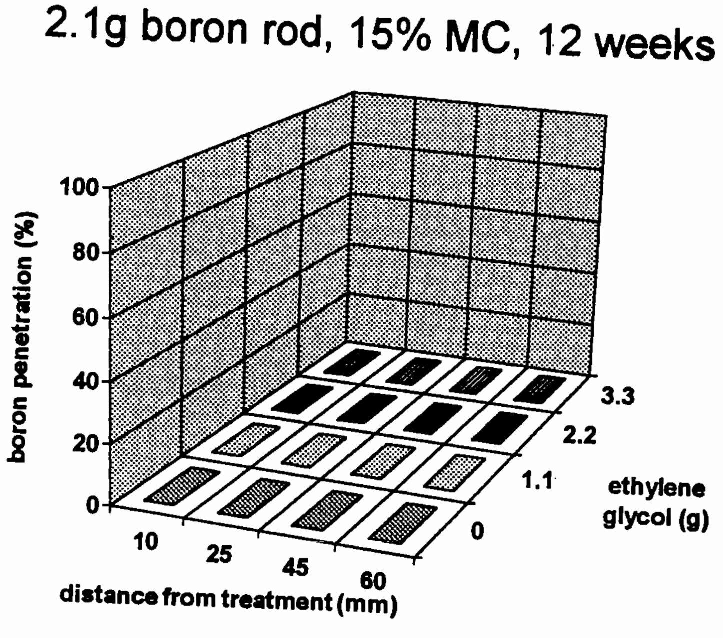
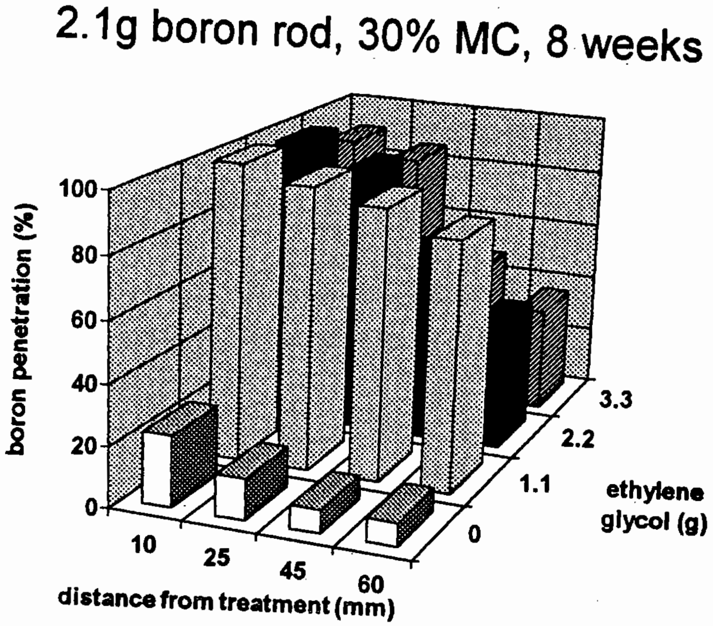


Figure I-12. Distribution of boron in Douglas-fir heartwood blocks maintained at 15% 8 or 12 weeks after treatment with combinations of boron rod and ethylene glycol.



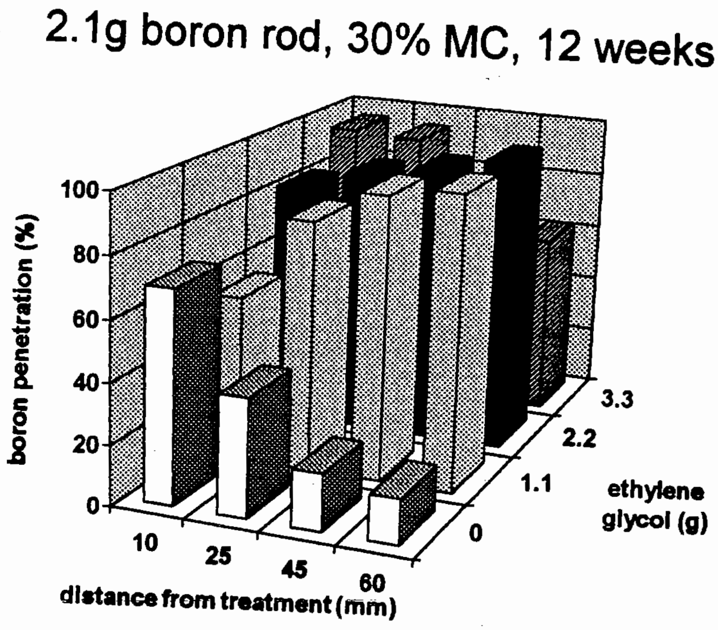
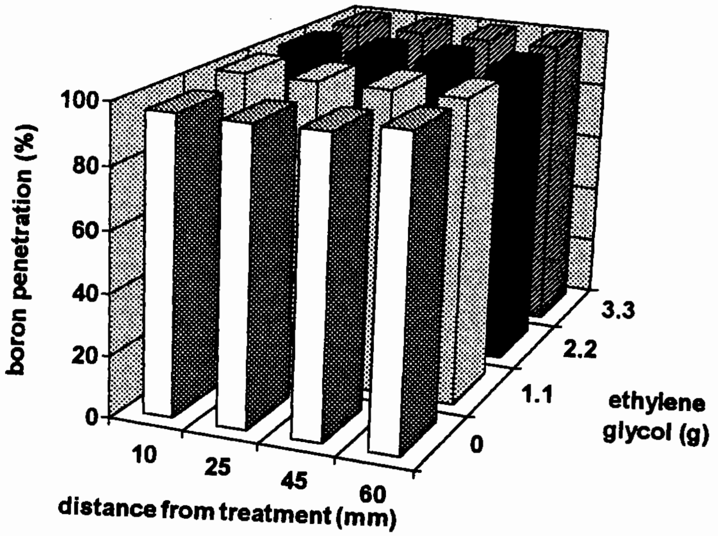


Figure I-13. Distribution of boron in Douglas-fir heartwood blocks maintained at 30% MC eight or twelve weeks after treatment with combinations of boron rod and ethylene glycol.


2.1g boron rod, 60% MC, 8 weeks

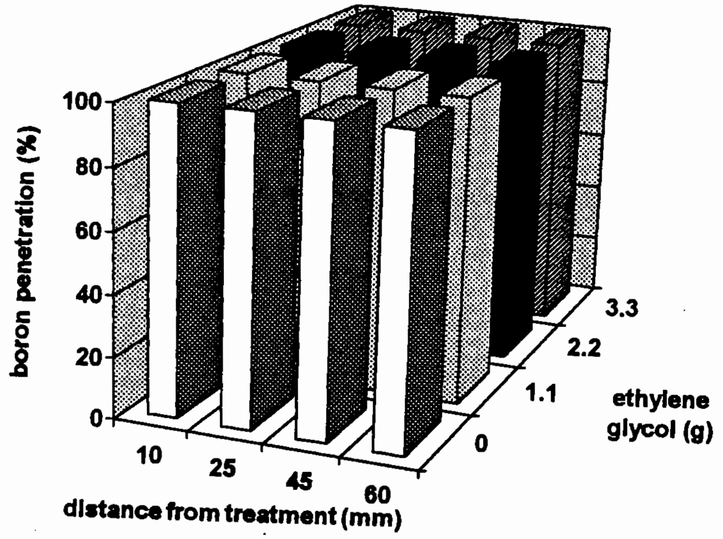

2.1g boron rod, 60% MC, 12 weeks

Figure I-14. Distribution of boron in Douglas-fir heartwood blocks maintained at 60% MC eight or twelve weeks after treatment with combination of boron rod and ethylene glycol.

Table I-13. Distribution of boron at selected distances from the treatment site in Douglas-fir heartwood blocks at 15, 30, or 60% MC 8 weeks after receiving 1.58 or 2.1 g of boron rod and combination of ethylene glycol.

		15% MC				30% MC				60% MC			
Boron Rod	Addition	Distance from Treatment Hole (mm)[1]											
	Glycol (g)	10	25	45	60	10	25	45	60	10	25	45	60
		8 weeks after treatment											
2.1	0	0.4 (0.70)	0.3 (0.43)	0.3 (0.43)	0.3 (0.43)	23.5 (26.69)	13.4 (22.91)	7.6 (13.86)	7.6 (12.92)	96.3 (6.50)	96.3 (6.50)	96.9 (5.56)	100.0 (0.00)
2.1	1.1	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	99.4 (1.65)	94.4 (9.82)	90.4 (17.46)	83.1 (26.45)	100.0 (0.00)	100.0 (0.00)	100.0 (0.00)	100.0 (0.00)
2.1	2.2	3.0 (2.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	97.5 (6.61)	90.0 (13.23)	65.6 (32.92)	43.1 (35.51)	100.0 (0.00)	100.0 (0.00)	100.0 (0.00)	100.0 (0.00)
2.1	3.3	27.9 (30.39)	9.3 19.25	0.00 (0.00)	0.00 (0.00)	90.0 (26.46)	85.6 (24.93)	47.5 (32.02)	35.6 (27.32)	100.0 (0.00)	100.0 (0.00)	100.0 (0.00)	100.0 (0.00)
	Boracol 40												
1.58	1.65	28.1 (7.04)	5.6 (9.82)	0.00 (0.00)	0.00 (0.00)	96.3 (6.50)	50.3 (28.84)	30.3 (37.95)	24.5 (37.18)	100.0 (0.00)	100.0 (0.00)	100.0 (0.00)	100.0 (0.00)
	Glycol (g)	12 weeks after treatment .											
2.1	0	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	70.0 (25.37)	39.0 (32.95)	18.8 (20.73)	15.0 (18.71)	100.0 (0.00)	100.0 (0.00)	100.0 (0.00)	100.0 (0.00)
2.1	1.1	21.1 (12.31)	9.4 (10.14)	0.00 (0.00)	0.10 (0.33)	55.1 (39.01)	83.5 (26.99)	94.8 (4.09)	98.1 (3.48)	100.0 (0.00)	100.0 (0.00)	100.0 (0.00)	100.0 (0.00)
2.1	2.2	0.5 (0.50)	0.9 (0.93)	10.3 (8.69)	20.9 (20.13)	82.3 (9.11)	89.1 (7.36)	93.3 (6.55)	98.9 (1.69)	100.0 (0.00)	99.8 (0.66)	99.1 (1.69)	98.5 (3.28)
2.1	3.3	33.8 (26.07)	14.6 (10.66)	1.3 (1.30)	1.6 (1.73)	95.0 (8.66)	93.8 (8.20)	73.8 (21.03)	61.9 (19.99)	100.0 (0.00)	100.0 (0.00)	99.8 (0.66)	100.0 (0.00)

1. Averages are of 8 measurements.
2. Numbers below averages represent one standard deviation.

Forsyth, P.G and J.J. Morrell. 1995. Decomposition of Basamid in Douglas-fir heartwood: Laboratory studies of a potential wood fumigant. Wood and Fiber Science 27:183-197.

Forsyth, P.G. and J.J. Morrell. 1993. Preliminary field trials using the solid fumigant Basamid amended with selected additives. Forest Products Journal 43(2):41-44.

Giron, M.Y. and J.J. Morrell. 1989. Interactions between microfungi isolated from fumigant-treated Douglas-fir heartwood and *Postia placenta* and *Postia carbonica*. Material und Organismen 24:39-49.

Helsing, G.G., J.J. Morrell, and R.D. Graham. 1984. Evaluations of fumigants for control of internal decay in pressure-treated Douglas-fir poles and piles. Holzforschung 38:277-280.

Highley, T.L. 1991. Movement and persistence of Dazomet and pelletized methylisothiocyanate in wrapped Douglas-fir and southern pine timbers. International Research Group on Wood Preservation, Document No. IRG/WP/1496. Stockholm, Sweden. 5 pp.

Morrell, J.J., C.M. Sexton, and S. Lebow. 1988. The effect of pH on decomposition of Mylone (Dazomet) to fungitoxic methylisothiocyanate in wood. Wood and Fiber Science 20(4):422-430.

Morrell, J.J. 1994. Decomposition of metham sodium to methylisothiocyanate as affected by wood species, temperature, and moisture content. Wood and Fiber Science 26:62-69.

Morrell, J.J. and M.E. Corden. 1986. Controlling wood deterioration with fumigants: A review. Forest Products Journal 36(10):26-34.

Morrell, J.J., M.A. Newbill, and C.M. Sexton. 1992. Remedial treatment of Douglas-fir and southern pine poles with methylisothiocyanate. Forest Products Journal 42(10):47-54.

Morrell, J.J., P.F. Schneider, and P.G. Forsyth. 1996. Performance of gelled and pelletized metham sodium as internal remedial treatments for Douglas-fir poles. Forest Products Journal.

Siau, J.F. 1995. Wood: Influence of moisture on physical properties. Department of Wood Science and Forest Products, Virginia Polytechnic Institute and State University, Blacksburg, Virginia. 227 pages.

Zabel, R.A. and J.J. Morrell. 1992. Wood microbiology: Decay and its prevention. Academic Press, San Diego, CA. 476 p.

Zahora, A.R. and M.E. Corden. 1985. Gelatin encapsulation of methylisothiocyanate for control of wood-decay fungi. Forest Products Journal 35(7/8):64-69.

Zahora, A.R. and J.J. Morrell. 1988. A note on the sensitivity of a closed tube bioassay to volatile methylisothiocyanate in fumigant-treated wood, Wood and Fiber Science 20:91-96.

Zahora, A.R. and J.J. Morrell. 1989. Diffusion and sorption of the fumigant methylisothiocyanate in Douglas-fir wood. Wood and Fiber Science 21:55-66.

Table I-14. Average retention of boron in Douglas-fir pole sections exposed in Corvallis, Oregon or Hilo, Hawaii, for 1 year after treatment with fused borate rods[a]

Dosage (g)	Boron Content (kg/m³)									
	90° from treatment 7.5 cm below treatment				90° from treatment 22.5 cm below treatment				in line 7.5 cm above treatment	
	Outer		Inner		Outer		Inner		Combined	
	1 yr	6 yr	1 yr	6 yr	1 yr	6 yr	1 yr	6 yr	1 yr	6 yr
Corvallis, Oregon										
40	0.05 (0.03)	0.30 (0.17)	0.55 (1.03)	0.99 (1.23)	0.05 (0.04)	0.30 (0.18)	0.06 (0.09)	0.38 (0.29)	0.26 (0.30)	0.26 (0.25)
80	0.04 (0.03)	0.24 (0.17)	0.04 (0.02)	0.64 (0.73)	0.02 (0.02)	0.13 (0.13)	0.06 (0.10)	0.30 (0.29)	0.70 (0.63)	0.78 (1.34)
Hilo, Hawaii										
40	0.03 (0.09)	--	0.25 (0.57)	--	0.01 (0.01)	--	0.01 (0.01)	--	0.69 (1.87)	--
80	0.08 (0.09)	--	0.01 (0.01)	--	0.01 (0.04)	--	<0.01 (0.01)	--	0.62 (0.88)	--

[a] Values represent means of 10 replicates per treatment. Figure in parentheses represent one standard deviation. Untreated control poles contained 0.002 kg/m³ of boron.

received 40 or 80 g of fused borate rod (1 or 2 rods) and were plugged with a tight fitting wood dowel. The pole sections were capped with plywood to limit end-grain wetting and exposed on a rack above-ground in either Corvallis, Oregon or Hilo, Hawaii. The Corvallis site is a typical Pacific Northwest location receiving approximately 112 cm of rainfall per year, primarily in the winter months. The Hilo site is an extremely wet, humid site receiving over 400 cm of rainfall per year.

The poles were sampled 1 and 6 years after treatment by removing increment cores from two sites 90 degrees around from and 7.5 cm below the bolt hole. The cores were segmented into zones corresponding to the outer and inner 5 cm. The segments were ground to pass a 20 mesh screen and analyzed for residual boron content by extraction and Ion Coupled Plasma Spectroscopic analysis. In addition, one core was removed from a site 7.5 cm above the treatment. This core was ground as one sample and similarly analyzed. A second set of cores was removed from sites 71.5 cm below each bolt hole and cultured on malt extract agar for the presence of decay fungi.

Culturing of increment cores revealed that none of the poles were infested by decay fungi in the zone near the bolt hole. Chemical analysis revealed that boron levels at all locations were less than 0.7 kg/m^3 (Table I-14). It is difficult to determine the exact threshold of boron for fungal control; however, previous studies on hardwoods suggest that a threshold ranging from 0.6 to 1.2 kg/m^3 (as boron) will prevent colonization by basidiomycetes. These levels are present only in the zone above the original treatment hole 1 year after treatment.

As expected, boron levels in the inner zone were higher than those nearer to the surface, although these differences were sometimes slight after 1 year. Chemical levels in pole sections exposed at Hilo tended to be lower than those in similar sections exposed in Corvallis. Since Hilo receives considerably more precipitation, boron leaching losses might account for these differences. Generally, chemical levels below the treatment holes were lower than those found in the single core removed from above the treatment hole. This difference is perplexing since we considered downward movement to be the more likely pathway for movement of this chemical. Chemical dosage also appeared to have only a minimal effect on subsequent boron levels. The absence of a dosage effect 1 year after treatment suggested that the rate of boron release from the two treatments was similar. In general, however, the boron levels present in these pole sections 1 year after treatment were far lower than would be required to effectively arrest established internal decay fungi and suggest that considerable caution should be exercised in the application of this chemical.

Boron levels 6 years after treatment were generally higher below the treatment hole than those removed 5 years earlier, although the levels varied widely among the samples. Boron levels were slightly higher in samples receiving the lower dosage, a trend that was also noted 1 year after treatment. Chemical levels were higher in the inner zone of the samples. This difference was greatest in samples removed from the site 7.5 cm below the treatment hole, and least in samples removed 22.5 cm below the treatment hole in poles treated with 40 g of boron rod.

These results indicate that application of boron rods results in boron levels that provide protection to field drilled bolt holes for periods of up to 5 years. These treatments may be ideal in preventing above-ground damage. Boron diffusion might be too slow to protect against actively growing decay fungi, but it might be ideal for application to freshly exposed wood where decay fungi have not yet become established.

LITERATURE CITED

Eslyn, W.E. and T.L. Highley. 1985. Efficacy of various fumigants in the eradication of decay fungi implanted in Douglas-fir timbers. Phytopathology 75(5):588-592.

OBJECTIVE II
IDENTIFY SAFER CHEMICALS FOR PROTECTING EXPOSED WOOD SURFACES IN POLES

INTRODUCTION

Making all cuts on a pole prior to treatment should be a major component of a utility specification since any damage to the original treated shell provides an avenue for invasion by fungi and insects. There are times, however, when field fabrication can become necessary. For many years field exposed wood was protected by topical application of pentachlorophenol in diesel oil. This practice, however, was widely ignored because line personnel disliked getting their gloves soiled with the preservative and because it was difficult to confirm if the treatments had, in fact, been applied. Yet, previous studies have shown that decay in above ground locations is endemic in many utilities. This damage is destined to grow as utilities are forced to share the zone beneath the energized segment of a pole with an increasing array of cable and telecommunications entities. Thus, the need for a simple, safe method for protecting field-drilled bolt holes and other damage of poles should remain a critical objective.

A. EVALUATION OF TREATMENTS FOR PROTECTING FIELD DRILLED BOLT HOLES

Trials to evaluate the effectiveness of various treatments for protecting exposed heartwood in Douglas-fir poles are continuing. Fourteen years ago, a series of Douglas-fir pole sections was treated with pentachlorophenol in heavy oil by Boultonizing to produce a relatively shallow shell of treatment.

A series of eight 25 mm diameter holes was drilled at 90 degree angles into the poles beginning 600 mm above the groundline and extending upward at 450 mm intervals to within 450 mm of the top. The holes on a given pole were treated with 10% pentachlorophenol in diesel oil, powdered ammonium bifluoride (ABF), powdered disodium octaborate tetrahydrate (Boron), or 40% boron in ethylene glycol (Boracol). Each chemical was replicated in eight holes on each of four poles. An additional set of 4 poles did not receive 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 (PATOX) were used to attach the bolts to these poles. Holes were drilled in an additional eight poles that received no chemical treatment. The bolt holes were filled with galvanized metal hardware and either metal or plastic gain plates. For the first 5 years, increment cores were only removed from 4 of the control poles at sites directly below the gain plate on one side of the pole and from sites directly above the washer on the opposite side. These cores were cultured on malt extract agar and observed for the growth of basidiomycetes, a class of fungi that includes many important wood decayers. Once a sufficient level of fungal colonization was present in the control sample, the remainder of the poles were sampled in the same manner.

The levels of fungal colonization in the poles has never been high, with levels in control poles ranging from 3 to 17% of the cores cultured (Table II-1). Colonization was initially highest in control poles, but the degree of colonization has steadily risen in poles receiving PATOX washers reflecting the inability of the chemicals in the washer to migrate for appreciable distances into the bolt hole.

The penta control treatment initially provided some protection to the holes, but these levels declined and colonization in these poles did not differ markedly from that of the control. Two of the three diffusible treatments continue to provide excellent protection against fungal attack, while colonization levels in the Boracol treatment have increased in the past 2 years. Both ABF and boron continue to provide protection against fungal attack (Figure

Table II-1. Basidomycetes and other fungi found in preservative-treated Douglas-fir poles 6 to 14 years after bolt holes were drilled and treated in the field as shown by cultures from increment cores

Field Treatment[a]	Percentage of cores containing...																	
	Basidiomycetes									Other Fungi								
	6 yr	7 yr	8 yr	9 yr	10 yr	11 yr	12 yr	13 yr	14 yr	6 yr	7 yr	8 yr	9 yr	10 yr	11 yr	12 yr	13 yr	14 yr
Ammonium bifluoride (n = 32)	0	2	0	2	2	2	2	2	5	5	2	16	42	9	47	39	38	38
Boracol® (n = 32)	0	2	0	0	3	0	3	8	9	18	27	33	66	16	70	42	59	80
Patox® washer	5	5	8	14	13	11	8	14	14	12	22	31	66	27	55	45	48	38
Pentachlorophenol (n = 32)	2	2	8	5	6	5	6	10	8	25	17	25	51	25	80	61	67	47
Boron (n = 32)	0	0	0	2	2	2	0	3	0	11	25	25	37	14	75	39	59	67
Control (n = 64)	3	9	17	9	8	11	3	5	9	30	26	46	70	33	86	55	81	68

[a] Figures - parenthesis represent number of cores cultured/treatment.

II-1). In both instances, the diffusible nature of the treatment probably helps to provide protection deeper in the wood than would be possible with penta.

The results continue to demonstrate the benefits of diffusible boron and fluoride for protecting field-drilled bolt holes. As utilities continue to face an onslaught of potential users for portions of their poles, the inclusion of such treatments in specifications for these users would provide excellent protection against potential internal decay in this zone.

B. PROTECTION OF JOINTS IN DOUGLAS-FIR PIERS

The protection techniques for piers and other large dimension timbers are similar to those used to protect utility poles from field damage. In 1979, five simulated piers of Douglas-fir were constructed in an open field at the Peavy Arboretum test site. Each structure was supported by nine creosoted piles that were equally spaced in a 3.6 m square area. Each simulated pier was constructed with eight pairs of abutting caps measuring 25 cm by 25 cm by 2.1 m long, 10 pairs of abutting stringers measuring 10 cm by 25 cm by 2.1 m long, and eight sets of three abutting decking planks measuring 10 by 25 cm by 1.6 m long (Figure II-2). Eight of the caps were center-kerfed to minimize check development and the kerfs were oriented downward. The structures were built to enable various protective measures to be assessed, as well as to create combinations of exposed end-grain and untreated butt joints.

At the time of installation, nine different treatments were applied to the top surfaces of the caps, stringers, and decking planks in the structures (Table II-2).

Each specific treatment was applied to one half of the five structures. One half of one pier remained as an untreated control. The same preservative was applied to each underlying stringer cap as well as to the four sets of three abutting deck planks in that half of the structure. A supplemental treatment of FCAP, ABF and Polybor® was applied 2 years after installation to decking laid over roofing felt. A total of 3.5 liters of each preservative was sprayed onto the top surface, into seasoning checks, and into butt joints of the decking planks.

Each half of a structure was evaluated for the presence of decay fungi annually for the first 6 years by removing increment cores from various locations and placing these onto malt extract agar in petri dishes. The cores were observed for fungal growth and any fungi were examined for characteristics of basidiomycetes, a class of fungi containing many important wood decayers. Two cores were removed from the underside of each cap adjacent to the creosote support planks, one from each end. Four cores were removed from every fourth stringer on a rotating basis so that each stringer was evaluated every fourth year. Two cores were removed from the stringer directly under the overlaying decking plank, and two cores were removed at the stringer/cap junction.

In addition, decking planks were sampled in three locations: (1) junction of abutting decking planks, (2) decking/stringer junction, and (3) midspan between two stringers. One core was removed from one of these locations in each decking plank, rotating to another location each year, so that after 3 years each of the planks had been sampled in all three locations.

The presence of decay fungi in caps varied widely between kerfed and nonkerfed members over the first 6 years of the test, but these differences were much smaller after 13 or 16 years (Table I-3). Kerfing has previously been found to control the development of deep checks on utility poles in service (Helsing and Graham, 1976). These poles, however, have a preservative-treated shell which can protect against invasion. It would appear that this shell is essential for long-term performance of kerfed materials even in the above ground exposures in this test. Of the topical chemicals evaluated for protecting the caps, FCAP and ABF both appeared to provide the most consistent protection, while oilborne penta and copper-8 provided much lower levels of protection. These differences probably reflect the inability of the oilbased materials to move far beyond the wood surface. FCAP and ABF both have the ability

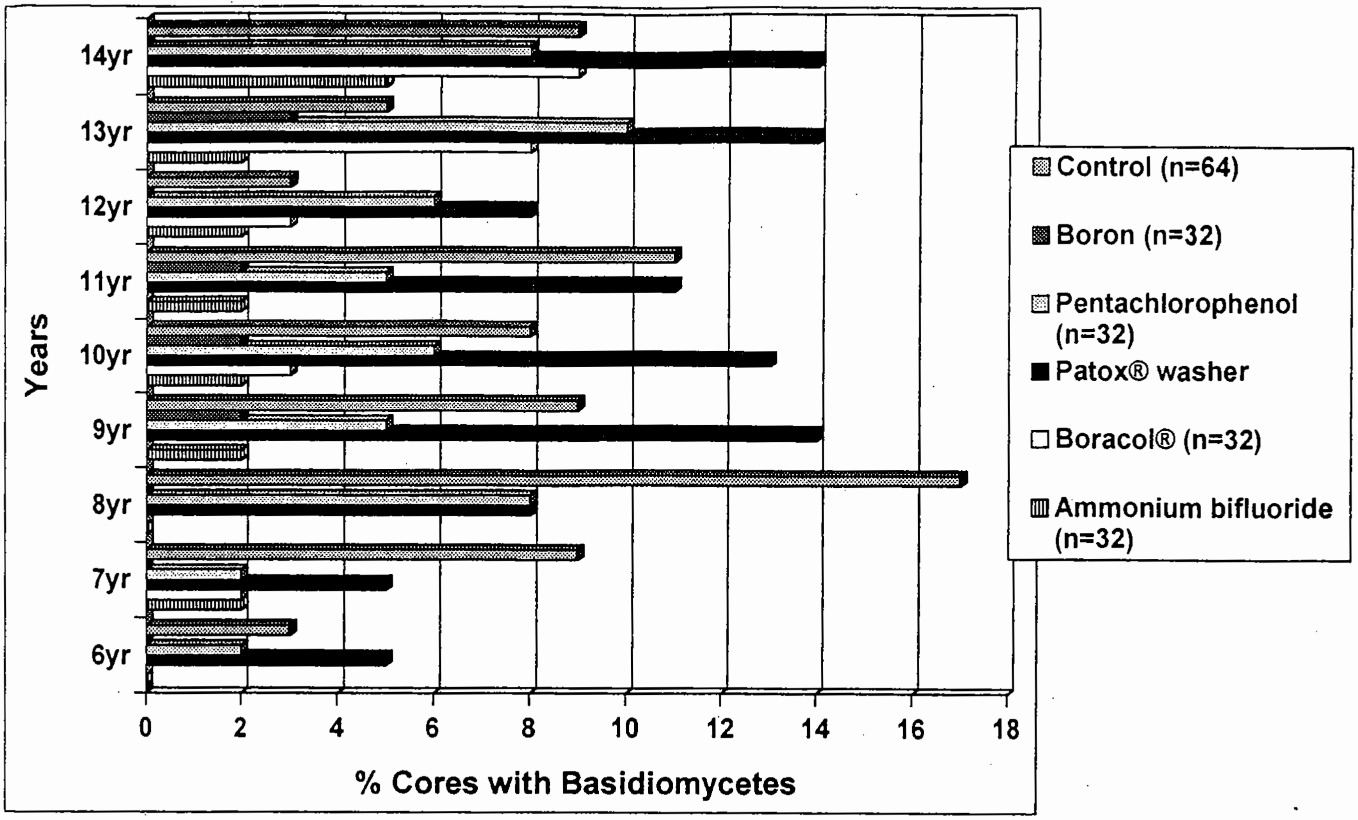


Figure II-1. Colonization of field drilled bolt holes in Douglas-fir poles by basidiomycetes 6 to 14 years after application of various topical preservatives or chemically impregnated washers.

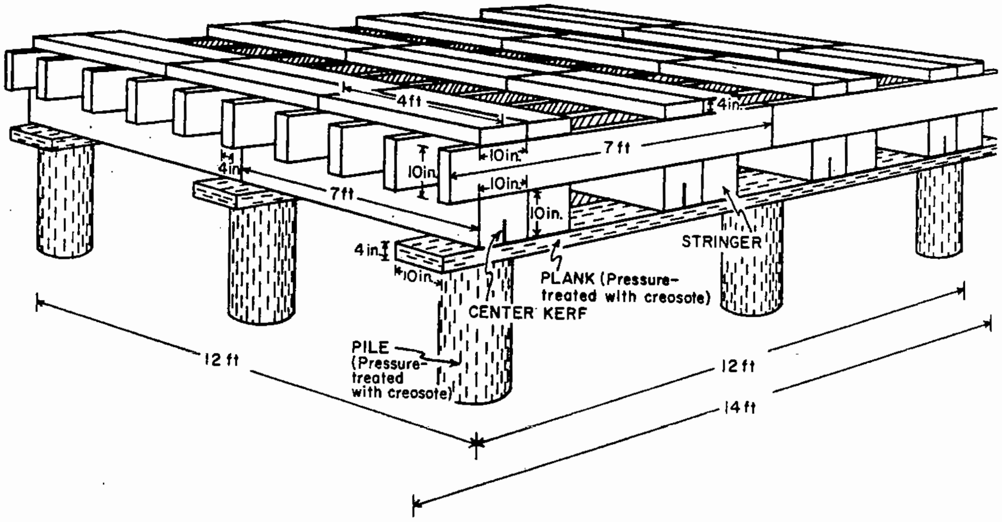


Figure II-2. Schematic of simulated pier.

Table II-2. Treatments applied to the top surfaces of caps, stringers, and decking planks in structures.

Treatment	**Carrier**	**Concentration (%)**
Pentachlorophenol (penta)	Oil	10
Copper-8-quinolinolate (copper-8)	Oil	1 (Cu basis)
Fluor-chrome-arsenic-phenol (FCAP) (as a slurry)	Water	12
Ammonium bifluoride (ABF)	Water	20
Polybor®	Water	9
FCAP in roofing felt[a]	Water	2
ABF in roofing felt[a]	Water	20
Polybor® in roofing felt[a]	Water	9
Roofing felt alone[a]	–	–

[a] Felt was applied beneath the stringers and beneath the decking planks.

Table II-3. Percentage of increment cores containing Basidiomycetes 1 to 16 years after initial treatment of kerfed and nonkerfed Douglas-fir caps in five simulated piers.

	Kerfed (%)					Nonkerfed (%)				
Treatment	1 yr	4 yr	6 yr	13 yr	16 yr	1 yr	4 yr	6 yr	13 yr	16 yr
Pentachlorophenol	25	25	13	38	75	0	37	50	75	50
Copper-8-quinolinolate	0	0	0	25	25	25	37	13	75	25
FCAP	0	0	13	13	0	0	0	0	13	0
ABF	0	0	0	25	25	0	0	0	13	13
Polybor®	0	25	50	25	13	13	37	50	38	50
FCAP-flooded felt	0	0	25	0	0	0	0	13	0	13
Polybor® - flooded felt	0	0	0	13	13	0	0	13	0	13
Felt alone	0	0	0	25	25	0	0	13	13	13
Control	0	13	25	25	50	0	50	88	38	50

to migrate with moisture to protect wood in checks that opened following treatment. It is interesting to note that Polybor®, which contains disodium octaborate tetrahydrate, provided little long term protection. These results differ from those found with the field drilled bolt hole test. The differences may reflect the higher exposure of the caps to leaching.

The effect of water trapping joints on the development of decay is illustrated by the differences in fungal colonization of decking at the mid-span and the point where the deck contacted the stringer (Table II-4). Fungal isolations were generally lower at the mid-span, reflecting the absence of water trapping sites and the dependence on the development of checks for colonization by decay fungi. Interestingly, the levels of fungal colonization near abutting deck boards were relatively low, perhaps reflecting the ability of these boards to dry periodically. Of the chemicals evaluated, the water diffusible systems provided the best protection near the joint, while protection at mid-span was more variable. For example, penta provided excellent protection for the first 6 years, but sampling at 13 and 16 years revealed substantial fungal attack. Copper-8 has provided variable protection, while ABF and FCAP flooded felt have provided complete protection against fungal attack in this zone. The mid-span should have a lower risk of fungal attack, making it more likely that less effective chemicals might still perform well under these conditions.

The degree of colonization in the stringers was generally low 13 years after installation, regardless of treatment with the exception of penta-treated stringers, which continued to experience higher levels of colonization (Table II-5). It was interesting to note that with Copper-8, another oilborne chemical, far lower levels of attack were observed throughout the test. The basis for this variable performance is unclear. The relatively low levels of fungal attack in control stringers after 13 years may reflect the presence of pockets of advanced decay. Basidiomycetes are often difficult to isolate from wood in the advanced stages of decay.

The results suggest that combinations of topical treatments and kerfing can delay, but not completely prevent colonization of large wood members by decay fungi. Periodic replenishment of biocides might improve their performance, although such applications would be difficult and costly.

LITERATURE CITED

Eslyn, W.E. and T.L. Highley. 1985. Efficacy of various fumigants in the eradication of decay fungi implanted in Douglas-fir timbers. Phytopathology 75:588-592.

Graham, R.D. and E.M. Estep. 1966. Effect of incising and saw kerfs on checking of pressure-treated Douglas-fir spar crossarms. Proc. Am. Wood Preserv. Assoc. 62:155-158.

Graham, R.D. 1983. Improving the performance of wood poles. Proc. American Wood Preserver's Assoc. 79:222-228.

Helsing, G.G., J.J. Morrell, and R.D. Graham. 1984. Evaluations of fumigants for control of internal decay in pressure-treated Douglas-fir poles and piles. Holzforschung 38(5):277-280.

Helsing, G.G. and R.D. Graham. 1976. Saw kerfs reduce checking and prevent internal decay in pressure-treated Douglas-fir poles. Holzforschung 30(6):184-186.

Helsing, G.G. and R.D. Graham. 1981. Control of wood rot in waterfront structures. Oregon State Univ. Extension Marine Advisory Program SG55. Corvallis, Oregon.

Helsing, G.G., J.J. Morrell, and R.D. Graham. 1986. Service life of Douglas-fir piles: Methods for protecting cut-off tops from decay. Forest Prod. J. 36(2):21-24.

Highley, T.L. 1983. Protecting piles from decay: End treatments. Int. J. Wood Preserv. 3(2):73-76.

Table II-4. Effect of water-trapping joints on the percentage of increment cores containing Basidiomycetes 2 to 16 years after initial treatment of Douglas-fir decking in five simulated piers.[a]

Treatment	Butt joint				Decking/stringer junction				Decking midspan			
	2 yr	6 yr	13 yr	16 yr	2 yr	6 yr	13 yr	16 yr	2 yr	6 yr	13 yr	16 yr
Pentachlorophenol	25	0	0	25	0	25	75	40	0	0	75	33
Copper-8-quinolinolate	0	25	0	0	0	25	0	0	0	25	0	25
FCAP	0	25	0	0	0	50	25	25	0	50	25	0
ABF	0	0	0	0	0	25	0	25	0	25	0	0
Polybor®	0	50	25	25	0	75	50	25	0	0	0	75
FCAP-flooded felt[b,c]	0	0	0	0	0	0	0	0	0	25	0	0
ABF-flooded felt[b,c]	0	25	0	0	0	0	0	0	0	0	0	33
Polybor®-flooded felt[b,c]	0	0	0	0	0	25	25	0	0	25	25	33
Felt alone[b]	25	50	25	25	0	25	25	25	25	50	50	50
Control	25	25	0	0	0	25	50	50	0	50	25	25

[a] To evaluate each treatment, one core was removed from each of 12 decking planks at the butt joint, decking/stringer junction, or decking midspan. The sampling was rotated annually between the three locations until all areas were sampled in each of the planks.

[b] Felt was applied between decking and stringer, and between stringer and cap.

[c] After 2 years, a second treatment was applied.

Table II-5. Percentage of increment cores containing Basidiomycetes 1 to 16 years after initial treatment of Douglas-fir stringers and decking in five simulated piers.

	Stringers (%)				Decking (%)				
Treatment	1 yr	4 yr	6 yr	13 yr	1 yr	4 yr	6 yr	13 yr	16 yr
Pentachlorophenol	30	20	25	30	0	25	8	30	33
Copper-8-quinolinolate	5	5	5	5	0	17	25	0	8
FCAP	0	10	0	5	0	8	42	17	8
ABF	0	5	0	5	8	0	16	0	8
Polybor®	5	40	20	15	8	25	42	25	42
FCAP-flooded felt[a]	0	5	0	15	0	0	8	0	0
ABF-flooded felt[a]	5	0	0	10	8	0	8	0	8
Polybor®-flooded felt[a]	0	10	10	15	33	8	24	17	8
Felt alone[a]	0	20	30	15	25	25	42	33	33
Control	10	25	25	10	17	25	33	25	25

[a] Felt was applied between decking and stringer, and between stringer and cap.

Highley, T.L. 1980. In-place treatments for control of decay in waterfront structures. Forest Prod. J. 30(9):49-51.

Highley, T.L. 1984. In-place treatments from waterborne preservatives for control of decay in hardwoods and softwoods above ground. Mater. u. Org. 19(2):95-104.

Highley, T.L. and T.C. Scheffer. 1978. Controlling decay in above-water parts of waterfront structures. Forest Prod. J. 28(2):40-43.

Highley, T.L. and T.C. Scheffer. 1975. In-place treatment of simulated waterfront structures for decay control. Mater u. Org. 10:57-66.

Lebow, S.T. and J.J. Morrell. 1989. Penetration of boron in Douglas-fir and western hemlock lumber. Forest Prod. J. 39(1):67-70.

Morrell, J.J., M.A. Newbill, G.G. Helsing, and R.D. Graham. 1987. Preventing decay in piers of nonpressure-treated Douglas-fir. Forest Prod. J. 37(7/8):31-34.

Morrell, J.J., R.D. Graham, M.E. Corden, C.M. Sexton, and B.R. Kropp. 1989. Ammonium bifluoride treatment of air-seasoning Douglas-fir poles. Forest Prod. J. 39(1):51-54.

Morrell, J.J., M. Newbill, and R.D. Graham. 1990. Evaluation of protective treatment for field-drilled bolt holes. Forest Prod. J. 40(11/12):49-50.

U.S. Navy. 1965. Marine biology operational handbook: Inspection, repair, and preservation of waterfront structures. NAVDOCKS NO-311. Bureau of Yards and Docks, Washington, D.C.

OBJECTIVE III
EVALUATE PROPERTIES AND DEVELOP IMPROVED SPECIFICATIONS FOR WOOD POLES

A. IMPROVED THROUGH-BORING PATTERNS FOR INITIAL TREATMENT OF POLES

Through-boring is an excellent method for improving treatment of pole sections where decay is most likely to occur. The process produces complete or near complete penetration of the heartwood of thin sapwood species. Through-boring has been used by utilities in the western U.S. since the early 1960s and has markedly reduced the incidence of internal decay at groundline.

While through-boring is an excellent method for improving treatment, there is no standard boring pattern. The use of a standard pattern could optimize treatment while minimizing the number of holes. In addition, a single boring pattern would allow for process automation, potentially reducing pole costs. The development of a standard boring pattern requires the development of data on the performance of through-bored poles already in service, and the effect of varying patterns in relative distribution of treatment.

The variation in preservative distribution in through-bored Douglas-fir poles was investigated in a series of in-service poles located in western Oregon. Increment cores were removed from sites located between the through-boring holes. Each core was sprayed with penta-check and the penetration was mapped on each core. Penetration was reported as percent penetration/core. The results of this study showed that most poles had 90% or more penetration, although cores from some poles had as little as 70% penetration. Visual examination of cores showed no evidence of decay in any of the untreated zones along the cores, nor did culturing indicate that any viable decay fungi were present. These results indicated that through-boring was an excellent method for preventing internal decay.

Subsequently, a series of tests were established in which through-boring patterns were varied to determine how far apart the holes could be located and still produce adequate penetration. The results indicated that the distances between holes in the currently used patterns could be markedly increased without adversely affecting penetration. Retention analysis indicated that pentachlorophenol levels were well above the threshold for fungal attack even in the innermost sample analyzed.

The past year we initiated a study to identify the distribution of preservative around individual through-boring holes. These data will be used to construct an optimum through-boring pattern that insures a high percentage of penetration, but minimizes the number of holes required. A series of Douglas-fir pole sections (24 m long by 250-300 mm in diameter) were air-seasoned. Individual 10.5 mm diameter holes were drilled on one face of each pole section at 0.6 m intervals from one end of each section. The poles were then treated with pentachlorophenol in P-9 (Type A) oil using a cycle typically used for pole treatment.

The preservative distribution around each treatment hole was assessed by removing a series of increment cores from sites around each treatment hole (Figure III-1). Preservative penetration along each core was mapped on a visual basis and the cores were retained for later analysis.

Average penetration declined slightly from the outer to inner zones of increment cores removed from sites around the through-boring holes (Figure III-2). Penetration, however was rarely complete, a trend that was surprising in light of the normally thorough distribution of preservative in the through-bored zone.

Maps of pentachlorophenol distribution patterns around the through-bored hole showed that chemical penetration extended 150 to 225 mm above and below the treatment hole in the outer 50 cm of core (Figures III-3. Penetration on either side of the

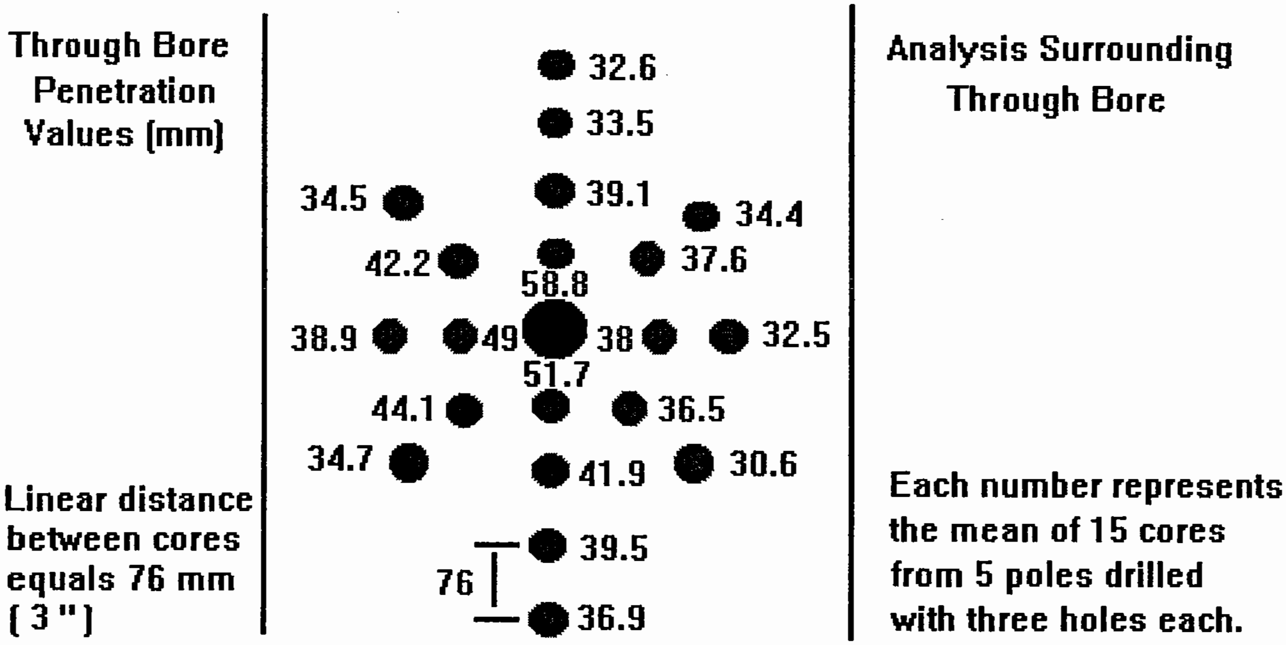


Figure III-1. Increment core sampling pattern employed to evaluate preservative penetration around the through bored holes in Douglas-fir poles.

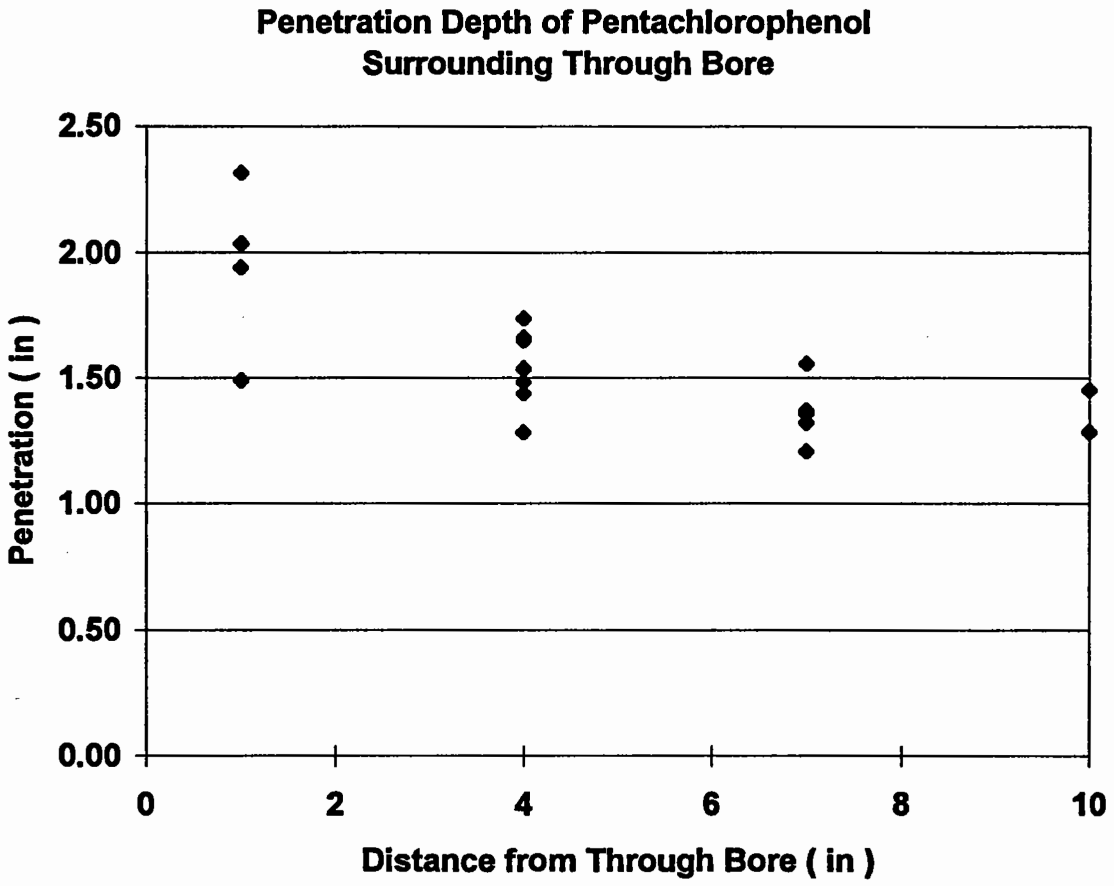


Figure III-2 Average penetration of pentachlorophenol in cores removed from selected locations around through-bored holes in Douglas-fir poles. Values represent means of 10 replicates per data point.

hole rarely extended beyond 150 mm from the treatment hole. Penetration around the through-bored hole in the heartwood was much lower, particularly radially from the hole. Penetration tended to be limited to a 75 mm radial zone around individual treatment holes farther into the wood (Figure III-3). While penetration sometimes extended 225 mm above or below the hole, this degree of penetration was somewhat inconsistent. As a result, using a lower degree of penetration would probably be more prudent in identifying patterns that optimize preservative penetration while minimizing strength.

One problem that was experienced in the current study was a difficulty in clearly delineating heartwood penetration. A portion of this difficulty occurred because of the light oil used for treatment. We plan to evaluate additional samples treated with creosote to determine if penetration patterns are similar.

The results from these two trials will be used to develop more widely spaced patterns that still produce good treatment.

B. EFFECT OF SOURCE ON DURABILITY OF WESTERN REDCEDAR HEARTWOOD

Western redcedar has a naturally durable heartwood surrounded by a thin (<25 mm) thick sapwood shell. The durable heartwood of this species has permitted its use with either no supplemental treatment or treatment of the butt only in a variety of environments with excellent results. Average service in excess of 80 years has been reported for this species and poles removed from service after 40 to 60 years retain strength at or near their original design values. Such enviable performance has made western redcedar the long sought after choice for supporting utility lines despite a higher initial cost.

Recently, however, questions concerning the durability of this wood species have arisen among utility users, who have experienced sporadic early failures of cedar poles under conditions that normally would be considered low or moderately susceptible to decay. These failures have raised concerns that the durability of the cedar source is changing as the industry increasingly shifts to younger trees grown under more silviculturally aggressive conditions. There is no question that the durability of second growth of some species declines markedly in comparison to original "old growth" trees. Notable examples of this effect include bald cypress and coast redwood. The reasons for these changes are not well understood, but their effects have important implications for the use of these species. Complicating this issue is the inherent variability of naturally durable woods. Natural durability can vary widely between trees of the same species as well as with tree height and location in the cross section. Typically, the most recently formed heartwood is most durable and durability declines as the heartwood ages. Finally, further complicating the western redcedar durability issue, is the allowance of some internal decay in poles of this species. Western redcedar is the only pole species in which decay is permitted, as a result of the belief that fungi causing decay in living trees are unable to survive the seasoning and treatment processes. Data for this premise are hard to come by owing to the difficulty of isolating fungi from western redcedar heartwood even when visible decay is present.

In order to better understand the distribution of relative durability within western redcedar poles currently being produced, we undertook the following survey:

Six western redcedar pole yards were sampled with the cooperation of the Western Redcedar Association. At each site, 50 poles were randomly selected and a single 5-10 cm thick cross-section was cut from the butt end of each pole. The pertinent data on pole source was recorded and the discs were shipped to Oregon State University.

Upon arrival, the section age of each was determined by sanding the surface and counting rings. A series of 1 cm cubes was then cut from three locations across each section--just inside the heart/sap interface, midway across the heartwood and immediately adjacent to the pith. These cubes were numbered, oven-dried (54°C) and weighed (nearest 0.001 g). The cubes were then soaked to saturation, placed in plastic

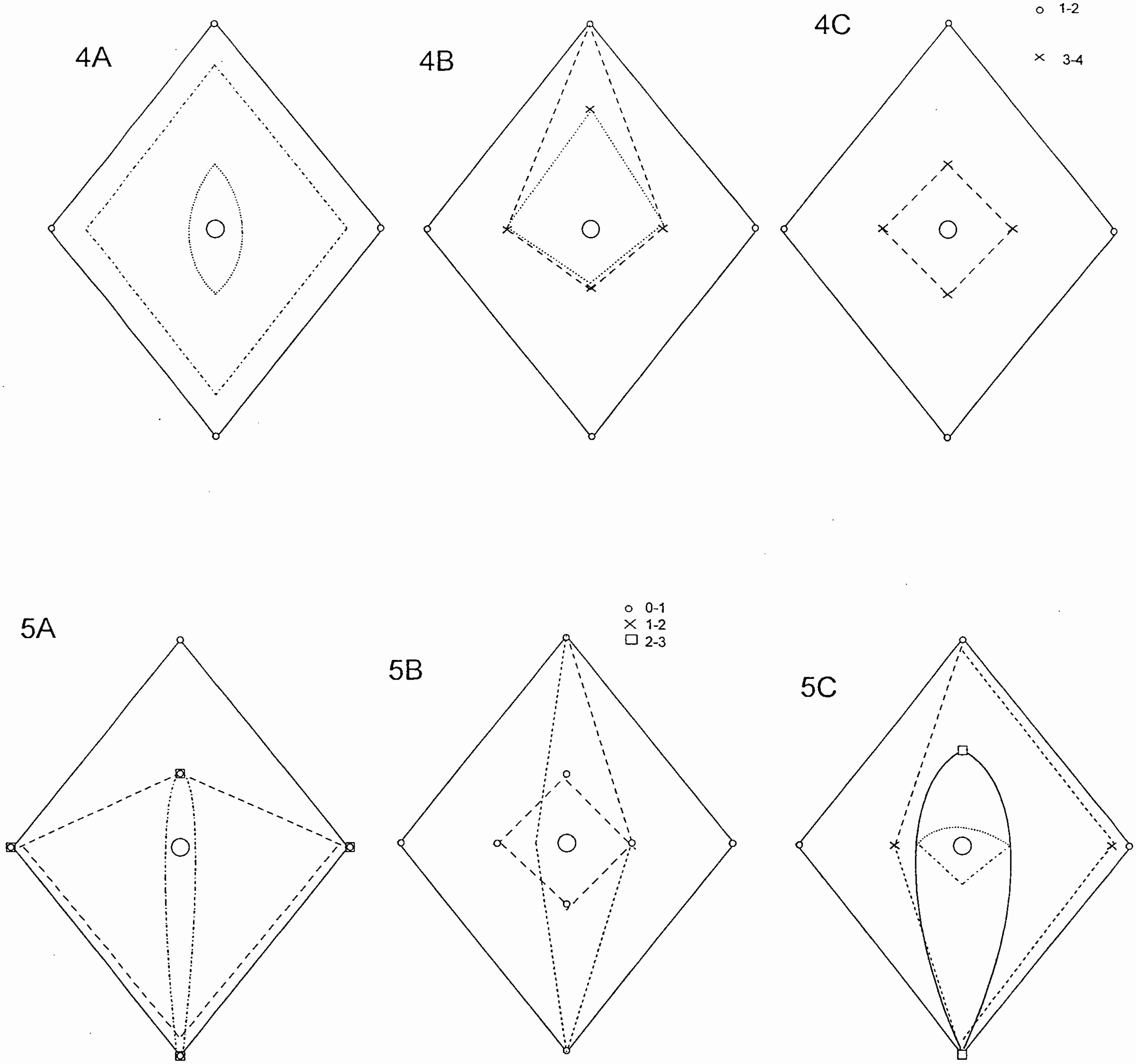
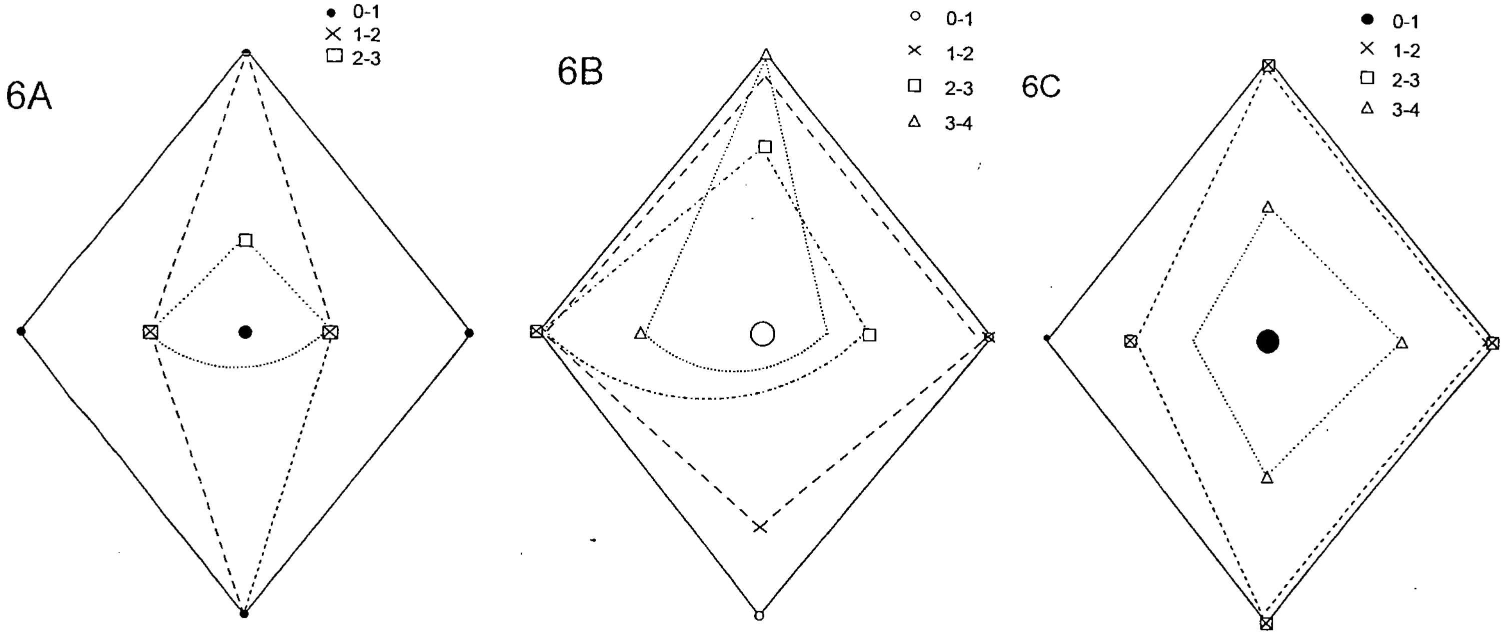


Figure III-3. Examples of pentachlorophenol penetration patterns around through-bored holes in Douglas-fir poles. Distances from the through-bolter hole are in inches.

Figure III-3. Continued.



bags and sterilized by exposure to 2.5 MRADS from a cobalt 60 source. The cubes were then evaluated using a modified soil block procedure in which 114 ml glass jars were half-filled with moist forest loam and a 15x15x3 mm thick western hemlock wafer was placed on the soil surface. The jars were capped and autoclaved for 45 minutes at 121°C, cooled overnight, and autoclaved for an additional 15 minutes. After cooling, the edge of each wood wafer was inoculated with a 3 mm diameter disk of agar cut from the actively growing edge of a culture of *Postia placenta* (Fr.) M. Larson and Lombard. The jars were incubated at 28°C until the wafers were thoroughly colonized, then two sterile cubes were added to each bottle. The bottles were incubated for 12 weeks at 28°C, then each cube was scraped clear and weighed to ensure that the moisture levels were suitable for fungal growth. The cubes were oven-dried (54°C) and weighed (nearest 0.001 g) to determine wood weight lost as a result of fungal exposure.

Decay tests have been completed on five of the six samples and the sixth will be sampled shortly. As might be expected from a sample of this size (300 cross sections), the results vary widely. These results are being presented in a series of graphs by site so that users can begin to see the array of possible durability levels found within western redcedar. Currently, sites are presented by code until sources can be confirmed and the data can be thoroughly analyzed.

As expected for naturally durable woods, weight losses varied widely among and between sites (Figures III-4). Weight losses ranged from 0 to nearly 50%, although most weight losses were less than 10%. Weight losses were generally lowest in samples from Site 1. Samples from Sites 2 and 3 were geographically similar and, if source affects durability, we would expect weight losses for these sites to be similar. In fact, weight losses from these two sites were similar. Weight losses appeared to be slightly higher in samples from Site 4.

Research was also conducted on the effect of cross-section location on durability. Previous studies suggest that the most recently formed heartwood should be most durable, while wood closest to the pith has the lowest durability. This did not appear to be the case with the present data. Although many samples from the outer heartwood experienced lower weight losses, there was no consistent trend with position.

In previous studies, the concept of old growth (>100 years) compared to second growth was related to durability. Tree ages in the current study ranged from 40 to 330 years. The relationship between age and durability was examined for all blocks and for blocks by position. Generally, weight losses were poorly correlated with tree age (r^2 = 0.0007 to 0.001) indicating that heartwood durability is not changing as treaters moved to second growth poles. This would be critical since the ability to supply poles 100 years or older will ultimately become more difficult. The initial results indicate that second growth trees are no less durable than old growth western redcedar. It will be important, however, to continue to evaluating durability as poles increasingly come from more heavily managed forests.

We still have one set of pole sections in test. Once these are completed, we will begin a more detailed analysis of the data and compare these results with previous decay tests performed 40 years ago by T.C. Scheffer, then at the U.S. Forest Products Laboratory.

C. RELATIONSHIP BETWEEN TROPOLONE CONTENT OF INCREMENT CORES AND DECAY RESISTANCE IN WESTERN REDCEDAR[a]

Western redcedar (*Thuja plicata* Donn) is a valuable commercial species in the northwestern United States and Canada. One of its most important characteristics is high decay resistance, which is due to the presence of toxic extractives in the heartwood. While a number of heartwood extractives have been shown to be toxic to fungi, the tropolones are the most important; they are comparable to pentachlorophenol in toxicity (Barton and

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[a] This section represents a portion of a thesis by Jeffrey DeBell.

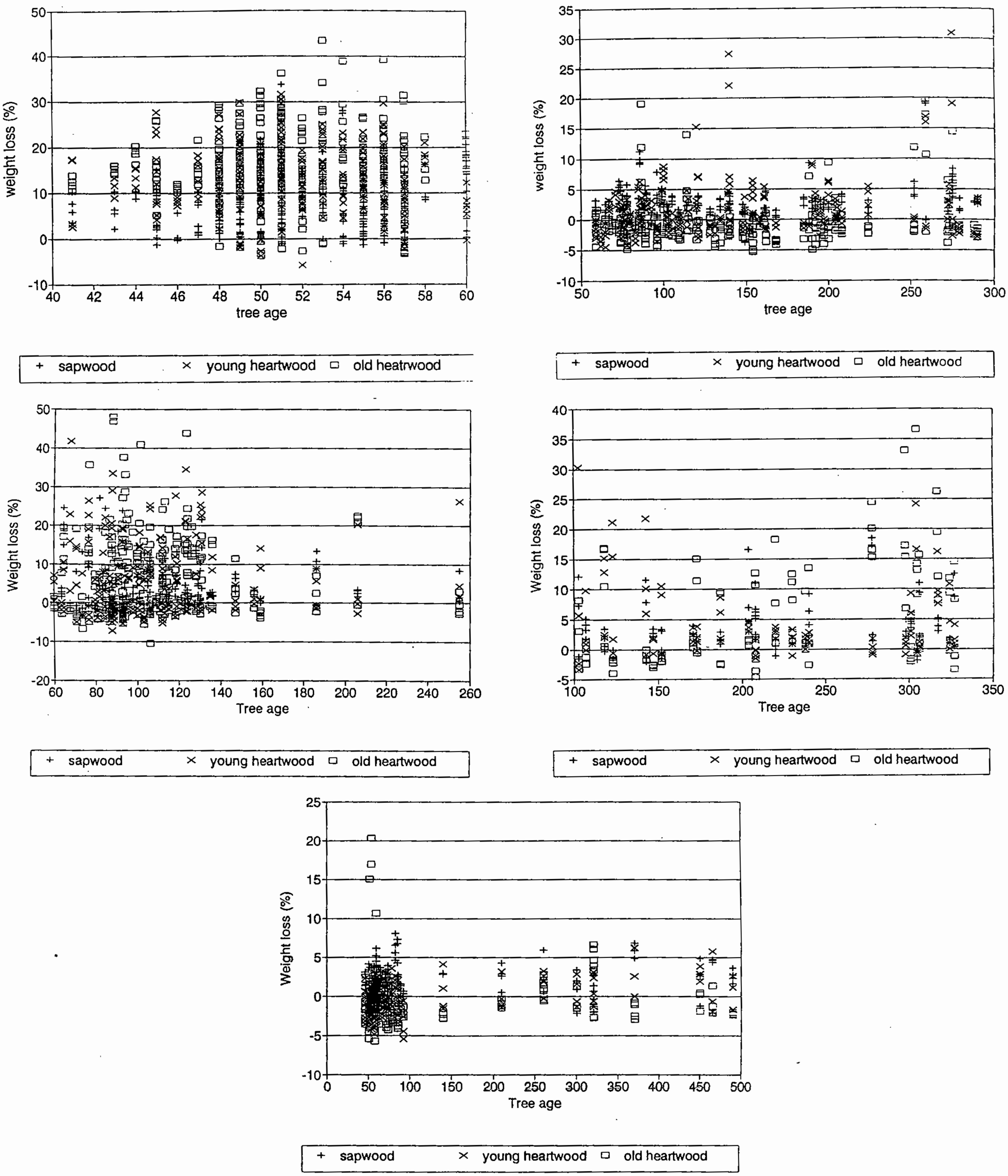


Figure III-4. Tree age vs weight losses of western redcedar heartwood cubes removed from selected zones of the cross-section of trees taken from five sites in the Pacific Northwest.

MacDonald 1971; Rennerfelt 1948; Rudman 1962,1963). Five tropolones have been identified in western redcedar. Of these, β-thujaplicin, γ-thujaplicin, and β-thujaplicinol are the most important in terms of quantity, together making up 98% of the total tropolone content (Barton and MacDonald 1971; Frazier 1987).

If tropolones are primarily responsible for the decay resistance of western redcedar, then it should be possible to use tropolone content of the wood as an indicator of decay resistance. Tropolone content can be assessed in days; the standard method of assessing decay resistance is the soil block test, which takes 12-16 weeks. Nault (1988) noted that measurement of tropolones using gas chromatography can be accomplished with very small samples, making it possible to use increment cores to assess tropolone content of standing trees. This procedure would be particularly useful for studying tropolone content in situations where destructive sampling of trees is undesirable.

Techniques have been developed for measuring thujaplicin content using gas chromatography (Johnson and Cserjesi 1975,1980; Nault 1987,1988). These techniques require extraction in a soxhlet apparatus; this restricts the number of samples that can be processed at one time to the number of soxhlet setups available. For some studies, it would be desirable to use a method that allows efficient handling of large numbers of samples.

Our objective was to modify the techniques for measuring thujaplicins to allow efficient handling of large numbers of increment cores or similar sized samples. We then examined the relationship between measurements of tropolone content using the modified extraction procedure and decay resistance in soil block tests.

Wood Samples: Material for this study came from western redcedar trees growing near Clatskanie, Oregon, on the Oregon State University College of Forestry's Blodgett Tract. Disks were cut every 2m from breast height (1.37m) to the top of 11 trees. The disks were air dried in the lab. A drill equipped with a 9.5mm plug cutter was used to remove two plugs, parallel to the stem axis and oriented side by side tangentially, from the outermost heartwood of each disk (Figure III-5). A second pair of plugs was removed approximately 1.5 cm from the pith. One of the plugs from each pair was used for tropolone analysis, while the other was used in the decay tests.

Tropolone Measurements: We modified the extraction technique of Johnson and Cserjesi (1980) by replacing soxhlet extraction with cold extraction in centrifuge tubes. The benefit of this modification was the ability to process larger numbers of samples. The disadvantage was that complete extraction was not possible. Thus, the method is suitable for studying relative differences in tropolone content between wood samples rather than absolute tropolone content.

Pure samples of γ-thujaplicin and β-thujaplicinol were provided by Forintek Canada Corporation. β-thujaplicin was purchased under the name Hinokitiol from a commercial supplier (TCI America). Tropolone contents were determined by comparison with prepared solutions of these known compounds. Tropolone content was expressed as a percentage of air-dried wood weight.

Each redcedar plug was cut into pieces and ground in a small Wiley mill to pass through a 30-mesh screen. Approximately 0.5 g of wood meal from each sample was weighed and placed in 50 ml plastic centrifuge tube, along with 9 ml of acetone and 1 ml of an internal standard solution (3,4,5-trimethoxyphenol in acetone, about 0.35 mg/ml). The tube was capped and allowed to sit overnight (16 hours) at room temperature (23-25°C). The sample was then centrifuged for 5 minutes, and the supernatant was transferred by Pasteur pipet to a clean 50ml plastic centrifuge tube.

The samples were evaporated to about 1 ml by blowing air through a small hoses into the tube. When the volume of the sample was reduced to about 1 ml, the solution was transferred it to a small glass vial, and evaporated to dryness using air as described above. When the sample was dry, 0.2 ml of B.S.A. (N,O-bis (trimethylsilyl) acetamide) was added, and the sample was placed in a

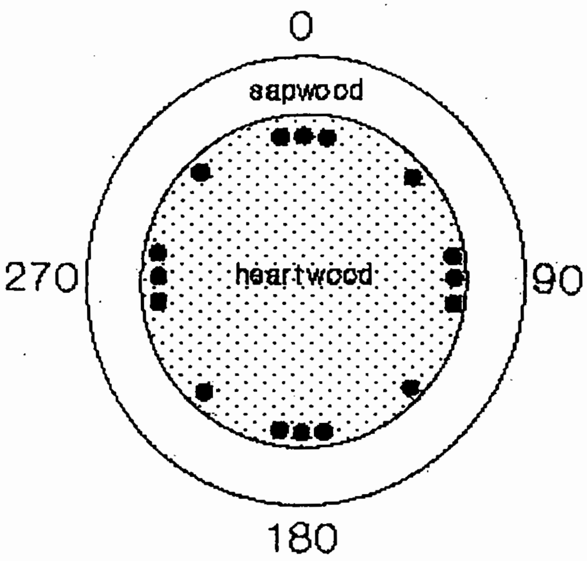


Figure III-5. Locations of plugs removed from western redcedar disks to evaluate cross-section variation in tropolone content.

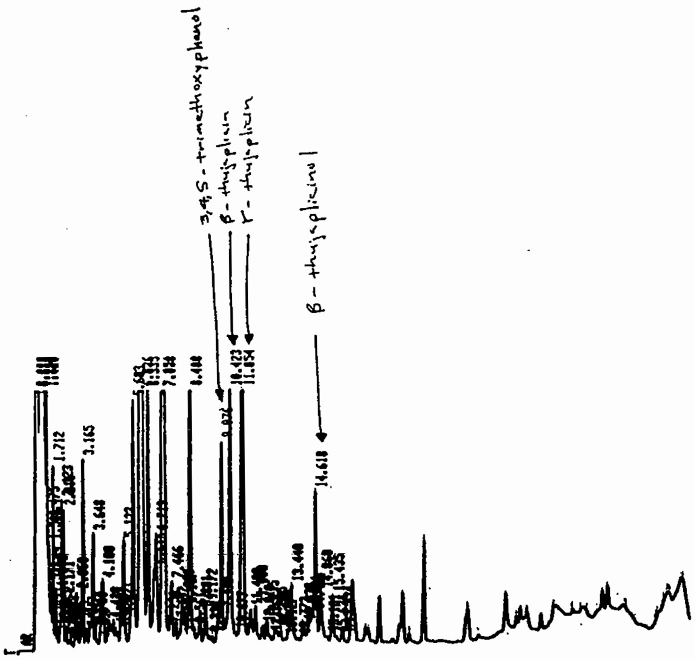


Figure III-6. Sample chromatogram of western redcedar heartwood extract.

warming tray at 70°C for 10 minutes. A needle and syringe were then used to transfer the solution to an autosampler vial, which was capped and placed in the autosampler tray to await injection into the gas chromatograph. One microliter injections were made.

A Hewlett Packard HP-5890 gas chromatograph equipped with a flame ionization detector and an autosampler was used for analysis. The column was a Supelco SPB-5 (30m x 0.75mm). Hydrogen was the carrier gas, with a flow rate of 15 ml/min. The initial oven temperature of 125°C was held for 4 minutes, then raised at 5°C/minute to 200°C. Injector temperature was 250°C and the detector temperature was 250°C. Retention times for the internal standard and tropolone were as follows 3,4,5-trimethoxyphenol: 9.9 min; β-thujaplicin: 10.4 min; γ-thujaplicin: 11.0 min; β-thujaplicinol: 14.6 min (Figure III-6).

Additional Samples Run: The precision of the analytical method was assessed by extracting 5 subsamples of a single cedar heartwood sample and by examining 5 injections from a single extract. Also, the variations in tropolone content in an individual stem were assessed by analyzing 16 plugs from a single cross-section.

Soil Block Tests: Soil block tests were performed using procedures described by Scheffer et al. (1987). Briefly, 113 ml glass bottles were half-filled with moist forest loam and a single 15x15x3 mm thick alder (*Alnus rubra*) feeder strip was placed on the soil surface. Water was added to raise the moisture content to 100% (wet basis), then the jars were loosely capped prior to autoclaving for 45 minutes at 121°C. After cooling, the feeder strips were inoculated with 3mm diameter disks of agar cut from the actively growing edge of cultures of *Poria placenta*, a fungus which causes brown rot of many coniferous species. The bottles were incubated at 28°C until the feeder strips were throughly colonized by the test fungus. The cedar heartwood plugs were oven dried (54°C), weighed, and sealed in plastic bags and subjected to 2.5 mrads of ionizing radiation from a cobalt 60 source. The plugs were placed on the feeder strips (1/bottle) and the jars were then incubated at 28°C for 16 weeks. The plugs were removed, scraped clean of adhering mycelium prior to oven drying (54°C), and weighed. Weight loss was used as the measure of decay resistance.

A. Small-scale analysis:

Consistency of Method: Multiple injections from a single sample of cedar extract and extractions of 5 subsamples from a single batch of cedar meal produced uniform results with coefficients of variation of 1.9% and 4.5%, respectively. These low levels of variation attest to the consistency of the method.

Variation in Tropolone Content Around the Stem: Tropolone content around the circumference of a disk was fairly uniform, averaging between 0.2 and 0.3% (Figure III-7). However, samples from the 180 degree position contained nearly double the tropolone content of samples from the rest of the disk. There were no apparent reasons for these variations.

For the most part, a single increment core should be a reliable indicator of tropolone content at a given height in a tree. The similarity between tropolone contents at positions where clusters of three samples were taken increased our confidence that the method gave consistent results. It also suggested that where increment cores are used, the cores should be removed from points at least 90 degrees apart, since taking two cores near the same point may do little to improve the estimate of the average tropolone content at that height in the tree.

B. Relationship of Tropolone Measurements to Soil Block Tests: Tropolone content of the wood samples ranged from 0 to 1.2% (weight basis). Weight losses ranged from 0 to 70% (Figure III-8). Weight losses were variable for samples with tropolone content of <0.10%, but averaged 21%. Weight losses were less variable for samples with tropolone contents between 0.10% and 0.24%, averaging 9%. Samples with tropolone content of 0.25% and greater had consistently high decay resistance. Average weight loss was 4%; only 3 out of the

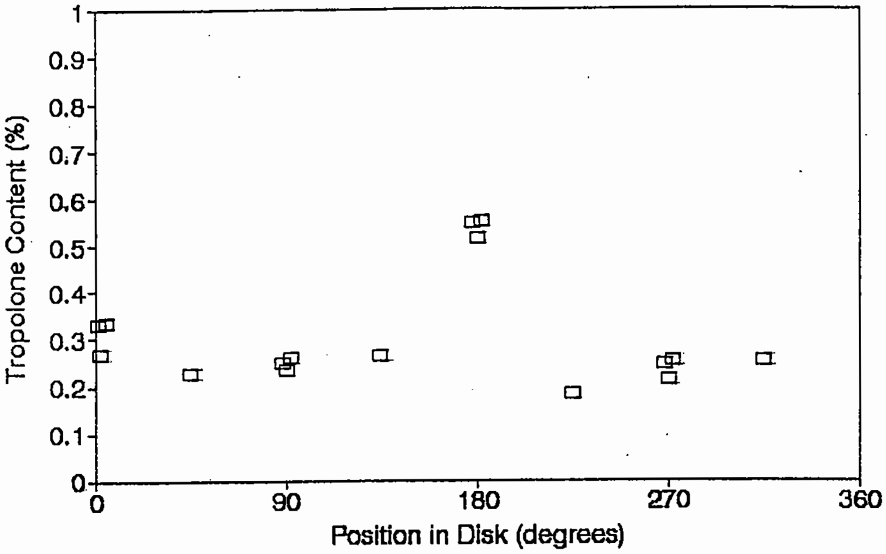


Figure III-7. Effect of sampling position on tropolone content in a single western redcedar disk (see Figure III-5 for sampling pattern).

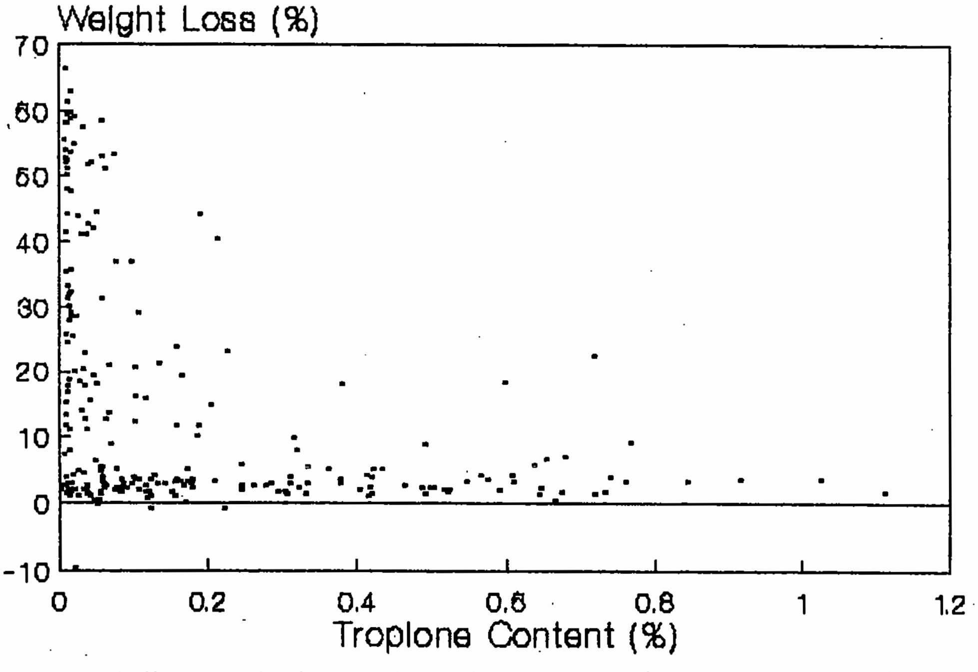


Figure III-8. Relationship between tropolone content and decay resistance (measured by weight loss in soil block tests) for plugs cut from western redcedar heartwood.

59 samples with high tropolone content had more than 10% weight loss.

We are unsure of the reasons for the variability in weight loss in samples with low tropolone levels. One possibility is that other substances in the heartwood prevented significant decay in some samples. However, there were no obvious patterns in the chromatograms to suggest any major differences between low tropolone samples. Differences in tropolone distribution might influence the results, since the extract and decay samples were removed from adjacent locations; however, the initial multiple sample of a single disk (Figure III-8) suggests that these differences should be minimal. The variability of the soil block test may also influence the results since individual decay tests can sometimes vary widely.

The modified tropolone analysis method gave consistent results, and could handle large numbers of samples fairly efficiently. A single increment core should provide a reasonable estimate of tropolone content for a given height in the tree. The method we used provides relative tropolone content rather than absolute content, and is useful for comparing differences between wood samples rather than establishing absolute tropolone content for a given sample. High decay resistance can be expected when tropolone content reaches 0.25% as measured by this modified method.

LITERATURE CITED

Barton, G.M. and B.F. MacDonald. 1971. The chemistry and utilization of western red cedar. Canadian For. Serv. Publ. No. 1023. 31 pp.

Frazier, C.E. 1987. The essential oil of western red cedar, (*Thuja plicata*). M.S. Thesis. Univ. of Washington. Seattle, WA. 112 pp.

Johnson, E.L. and A.J. Cserjesi. 1975. Gas-liquid chromatography of some tropolone-TMS ethers. J. Chromatog. 107(2):388.

Johnson, E.L. and A.J. Cserjesi. 1980. Weathering effect on thujaplicin concentration in western redcedar shakes. For. Prod. J. 30(6):52-53.

Nault, J. 1987. A capillary gas chromatographic method for thujaplicins in western redcedar extractives. Wood Sci. Technol. 21(4):311-316.

Nault, J. 1988. Radial distribution of thujaplicins in old growth and second growth western red cedar (*Thuja plicata* Donn). Wood Sci. Tech. 22(1):73-80.

Rennerfelt, E. 1948. Investigations of thujaplicin, a fungicidal substance in the heartwood of *Thuja plicata* D. Don. Physiologia Plantarum 1(3):245-254.

Rudman, P. 1962. The causes of natural durability in timber. IX. The antifungal activity of heartwood extractives in a wood substrate. Holzforschung 16(3):74-77.

Rudman, P. 1963. The causes of natural durability in timber. Part XI. Some tests on the fungi toxicity of wood extractives and related compounds. Holzforschung 17(2):54-57.

Scheffer, T.C., J.J. Morrell and M.A. Newbill. 1987. Shellrot control in western redcedar: potential replacements for pentachlorophenol spray. For. Prod. J. 37(7/8):51-54.

OBJECTIVE IV
PERFORMANCE OF EXTERNAL GROUNDLINE BANDAGES

Initial preservative treatment using pressure processes produces well-treated barriers that resist fungal and insect attack in terrestrial exposures. In some species, or in some exposures, this protective effect declines with time permitting degradation of the outer surface of the pole, typically by the action of soft rot fungi (Zabel et al., 1985). This damage can have a dramatic negative impact on pole strength, thereby shortening service life and decreasing system reliability. Surface decay is generally controlled by application of preservative pastes to the wood surface. The effectiveness of this approach to pole maintenance has long been known (Panek et al., 1961; Leutritz and Lumsden, 1962; Harkom et al., 1948; DeGroot, 1981; Henningsson et al., 1988; Chudnoff et al., 1977; Ziobro et al., 1987; Smith and Cockroft, 1967). For many years, the biocides used in these systems included oilborne chemicals such as creosote or pentachlorophenol and water-based fungicides such as sodium dichromate, dinitrophenol, and sodium fluoride. The oil-based biocide was presumed to provide supplemental protection against renewed fungal attack from the surrounding soil, while the water-based materials diffused for short distances into the wood to arrest growth of fungi which had already become established in the pole. The final resolution of the rebuttable presumption against registration (RPAR) process by the U.S. Environmental Protection Agency led to the designation of creosote, pentachlorophenol (penta) and the inorganic arsenicals as restricted use pesticides which could only be used by certified applicators. These activities, coupled with desires by many utilities to move to less toxic biocides encouraged a widespread effort to reformulate external groundline preservative systems using combinations of copper naphthenate, sodium fluoride, or boron. While each of these biocides is a proven wood preservative, their performance as external groundline preservatives was untested. In order to develop comparative information, the following test was performed.

A. *EVALUATION OF FORMULATIONS IN DOUGLAS-FIR TEST POLES AT CORVALLIS, OREGON*

Freshly peeled sections of Douglas-fir (*Pseudotsuga menziesii* (Mirb.) Franco) (1.8 m long and 25 to 30 cm in diameter) were air-seasoned for 6 months before use. Five sections each were treated with one of six external preservative systems:

CUNAP WRAP® (CSI, Inc., Charlotte, NC), containing 2.0 percent copper naphthenate (as Cu) on an absorbent pad.

CuRap20® (ISK Biotech, Memphis, TN), a paste containing 18.16 percent amine-based copper naphthenate and 40 percent sodium tetraborate decahydrate.

COP-R-NAP® (Osmose Wood Preserving, Inc., Buffalo, NY), a paste containing 19.25 percent copper naphthenate.

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

POLNU 15-15® (ISK Biotech), a grease containing 12.9 percent pentachlorophenol, 15 percent creosote, and 1.5 percent chlorinated phenols.

POLNU® (ISK Biotech), a grease containing 10.2 percent pentachlorophenol.

The POLNU systems were included to provide comparisons between new formulations and those used previously.

The pastes were applied according to the manufacturer's directions. All but the self-contained CUNAP WRAP were covered with polyethylene wrap before being set 45 cm deep in the ground at the Peavy Arboretum test site, near Corvallis, Oregon. 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 precipitation per year, 81 percent of which falls between October and March. Average monthly temperatures range from 3.9° to 11.7°C during that period and rarely exceed 30°C or fall below 0°C at other times. The soil is an Olympic silty clay and is slightly acidic (pH 5.4). During the winter months, the water table rises to within 15 cm of the soil surface. Over the first 3 years of the study, however, rainfall was below average.

Preservative distribution was assessed 18, 30, 42, 54, and 66 months after treatment. Either 2 cm diameter plugs or increment cores were removed from three equidistant sites around each pole section, 15 cm below the groundline. Cores were removed initially, but as the poles became wetter and internally decayed, it was difficult to obtain solid cores, so plugs were substituted. Multiple increment cores were required from each site to produce an equivalent volume of wood. 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 with an Asoma 8620 x-ray fluorescence analyzer (XRF) (Asoma Instruments, Austin, TX). Borate was analyzed by the azomethine-H method described in AWPA Standard A2, Method 16 (AWPA, 1995a). Fluoride analyses were performed on blind samples by R. Ziobro (Osmose Wood Preserving, Inc.) according to AWPA Standard A2 Method 7 (AWPA, 1995b).

The condition of the untreated posts has declined considerably over the 5.5-year test, but the wrapped sections retained sufficient integrity for sampling purposes. Levels of all wrap components were initially well above the thresholds for fungal attack and declined markedly with distance from the wood surface (Table IV-1). For example, penta levels at 18 months in the outer 4 mm in both POLNU and POLNU 15-15 treated posts ranged from 3.36 to 6.24 kg/m^3, well above the reported threshold of 2.4 kg/m^3 (Figure IV-1). Penta levels farther from the surface declined precipitously, with little or no penta being detected beyond 16 mm from the surface. Penta levels in the outer zone also declined with time, with levels in the POLNU declining below the threshold 66 months after chemical application.

Copper levels in formulations containing copper naphthenate initially followed trends similar to those found for the penta based systems with declining levels with distance from the surface and time after treatment, but these levels in the outer zone had not yet declined below the purported threshold against non-copper tolerant fungi (0.64 kg/m^3 Cu) 66 months after treatment (Figure IV-2). In addition to these trends, there appeared to be slight differences in copper levels with the four copper based systems. Copper levels in the outer 4 mm of posts 66 months after treatment, have declined most substantially in CUNAP WRAP®, COP-R-NAP® and CuRap20® treatments, although these levels all remained above the threshold for protection against fungal attack. Copper levels in COP-R-PLASTIC® treated poles continue to remain over ten times higher than those in the remaining three copper naphthenate treatments, and show no signs of declining.

One other interesting aspect of the copper naphthenate systems was the inability of the water soluble, amine-based copper naphthenate in CuRap20® to move more readily into the wood. In previous trials using green southern pine posts, this chemical moved for substantial distances from the wood surface (West et al., 1992). In the current trial, however, the posts were partially seasoned prior to chemical application. Perhaps inability of the copper naphthenate to migrate reflects this lower initial moisture level.

Levels of boron in posts receiving CuRap20® were initially well above the

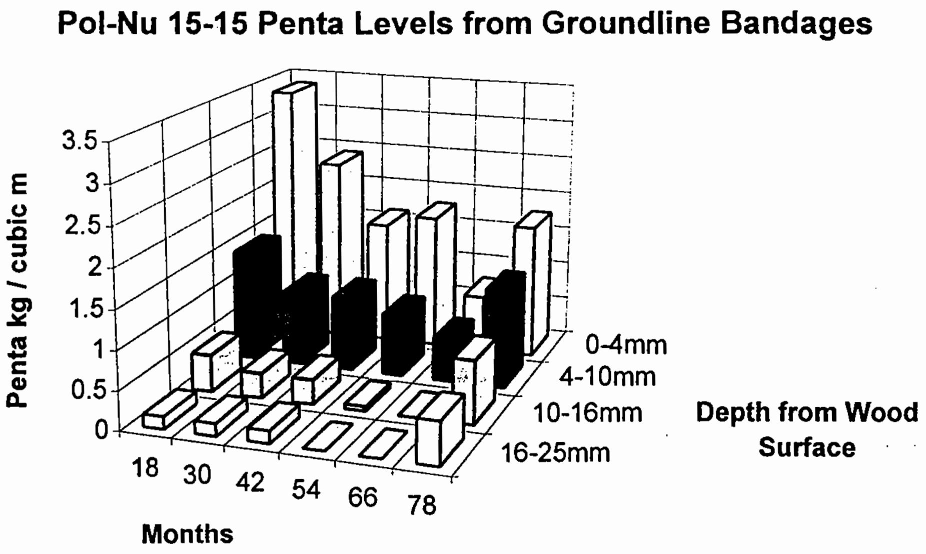
Table IV-1. Chemical content at selected depths from the wood surface of Douglas-fir posts 18, 30, 42, 54, 66, and 78 months after treatment with selected groundline bandage systems.

Chemical Treatment	Exposure Period (months)	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/m^3)				(kg/m^3)				(%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	–	–	–	–	–	–	–	–	–	–	–	–
	54	1.61	1.01	0.61	0.31	–	–	–	–	–	–	–	–	–	–	–	–
	66	1.54	1.23	1.71	0.51	–	–	–	–	–	–	–	–	–	–	–	–
	78 (n = 5)	1.17	1.00	0.59	0.43	–	–	–	–	–	–	–	–	–	–	–	–
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	–	–	–	–	–	–	–	–	–	–	–	–
	54	1.45	0.52	0.30	0.15	–	–	–	–	–	–	–	–	–	–	–	–
	66	1.14	0.67	0.52	0.28	–	–	–	–	–	–	–	–	–	–	–	–
	78 (n = 1)	0.99	0.78	0.61	0.37	–	–	–	–	–	–	–	–	–	–	–	–
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	–	–	–	–
	54	2.10	0.34	0.60	0	–	–	–	–	0.12	0.10	0.11	0.08	–	–	–	–
	66	1.43	0.32	0	0	–	–	–	–	0.07	0.05	0.04	0.05	–	–	–	–
	78 (n = 4)	2.09	0.52	0.15	0.09	–	–	–	–	0.04	0.03	0.03	0.03	–	–	–	–
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
	54	2.65	0.70	0.24	0.11	–	–	–	–	–	–	–	–	0.73	0.37	0.28	0.27
	66	3.63	1.13	0.47	0.15	–	–	–	–	–	–	–	–	1.45	0.55	0.39	0.19
	78 (n = 5)	2.51	0.71	0.28	0.12	–	–	–	–	–	–	–	–	0.75	0.30	0.21	0.19
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	–	–	–	–	–	–	–	–
	54	–	–	–	–	1.76	0.80	0.06	0	–	–	–	–	–	–	–	–
	66	–	–	–	–	0.73	0.56	0	0	–	–	–	–	–	–	–	–
	78 (n = 4)	–	–	–	–	1.75	1.27	0.81	0.55	–	–	–	–	–	–	–	–

Chemical Treatment	Exposure Period (months)	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)			
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	–	–	–	–	–	–	–	–
	54	–	–	–	–	3.04	1.28	0.32	0	–	–	–	–	–	–	–	–
	66	–	–	–	–	1.98	1.03	0.20	0	–	–	–	–	–	–	–	–
	78 (n=4)	–	–	–	–	2.70	2.08	1.23	0.68	–	–	–	–	–	–	–	–

[a] By distance (mm) from wood surface.

n = Number of poles sampled with plugs. Pole number reduced at 78 months due to advanced decay. Number of poles sampled equals five unless otherwise noted.



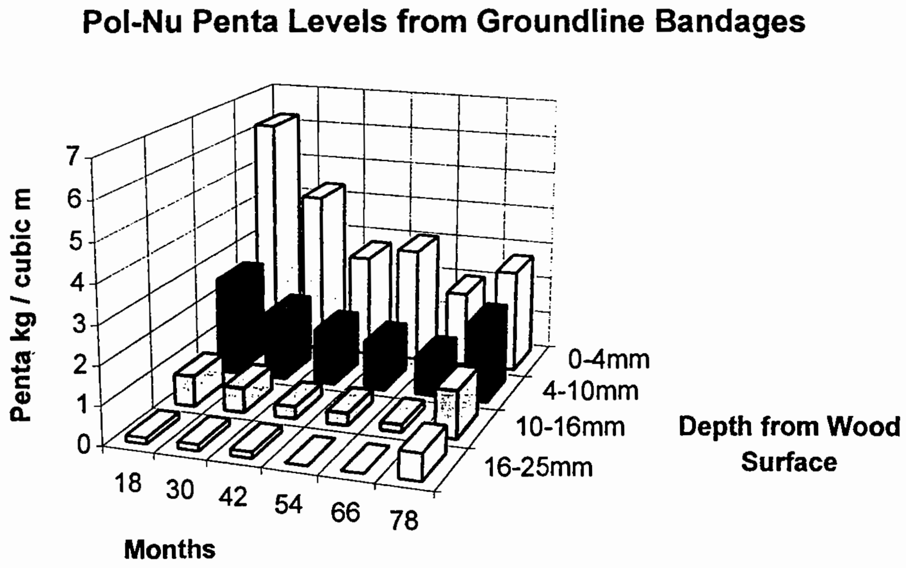
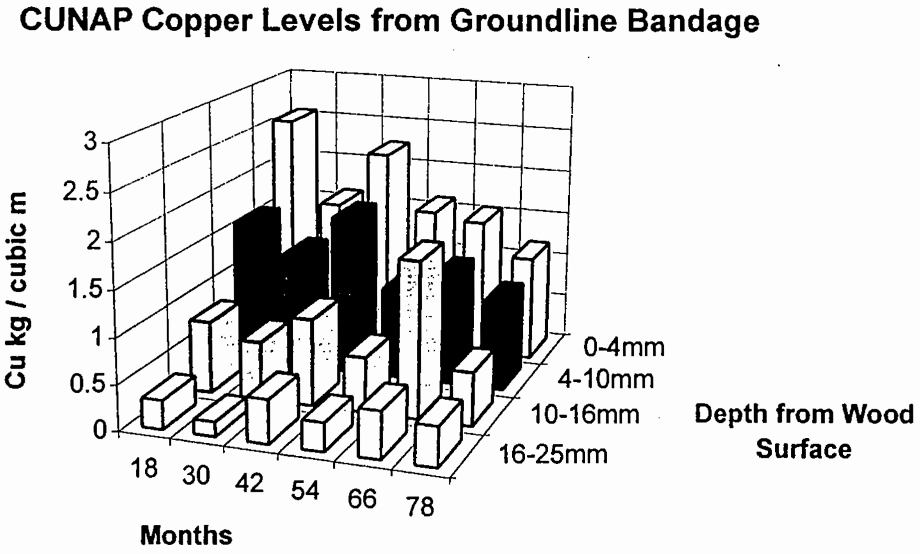


Figure IV-1. Residual levels of pentachlorophenol in Douglas-fir poles treated with POLNU® and POLNU 15-15® groundline bandage systems.



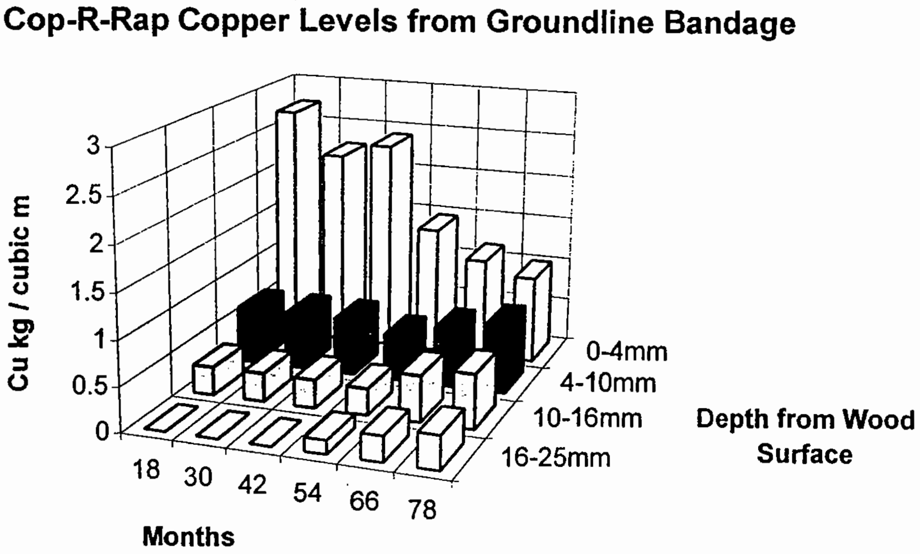


Figure IV-2. Residual levels of copper naphthenate (as Cu) in Douglas-fir poles treated with (a) CUNAP WRAP®, (b) COP-R-Rap groundline bandage systems.

reported threshold for fungal attack (0.25% BAE) 18 months after treatment to a depth of 25 mm, but these levels rapidly declined over the remaining test period (Figure IV-3). At present, boron levels in the posts are similar to those found naturally in Douglas-fir. Boron has been widely used as a fungicide and insecticide because of its well known ability to migrate through normally impermeable woods with moisture. This characteristic, must be considered a negative, particularly under the test conditions employed. Suggestions have been made that boron might diffuse from the surface far into the wood to provide supplemental internal protection, however, amortizing the levels assayed at 1 year across a pole 350 mm in diameter would result in boron levels far below those required for fungal protection. Thus, the boron in CuRap20® should be viewed as a temporary supplement to copper naphthenate in this formulation.

Fluoride in COP-R-PLASTIC® treated pole sections behaved markedly different from boron in CuRap20® tested pole sections (Figure IV-3). Fluoride levels were similar to those for boron 18 months after treatment, but declined much more slowly over the remaining 48 months of the test. Fluoride is generally more toxic to decay fungi than boron and its ability to remain in the posts under a high leaching exposure suggests that the combination of fluoride and copper naphthenate in this formulation should provide excellent long-term surface protection (Becker, 1976).

One factor which complicates the assessment of external bandages is the role of the preservative present from the original treatment. In the present tests, untreated posts were used to provide a direct comparison of efficacy of the various formulations without a complicating initial treatment. In practice, these treatments are applied over the existing biocide to supplement protection. For example, it is likely that residual chemical loadings from the initial pressure treatment coupled with the declining levels of the two POLNU formulations would continue to protect the wood surface. Further studies to better understand the performance of these formulations are underway on in-service Douglas-fir, western redcedar, Ponderosa and southern pine poles in New York and California, as are laboratory trials to determine the thresholds for boron/fluoride/copper naphthenate mixtures. This information will help utilities make more informed decisions concerning the frequency of retreatment with these systems.

All of the alternative external preservative systems continue to provide protection to Douglas-fir posts which is equivalent or greater than that provided by penta based formulations. Further studies are underway to more fully delineate the protective role of these systems.

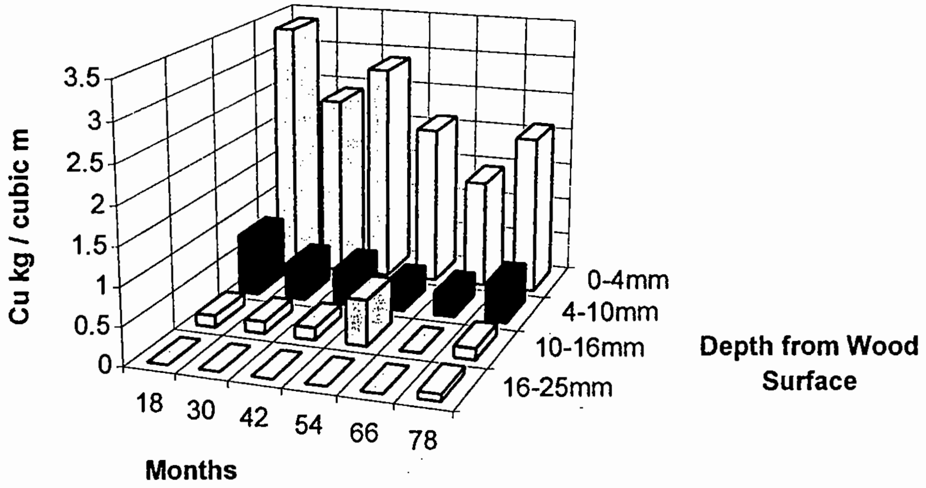
B. EVALUATION OF SELECTED GROUNDLINE BANDAGE SYSTEMS IN DOUGLAS-FIR, WESTERN REDCEDAR, AND PONDEROSA PINE POLES IN MERCED, CALIFORNIA

While controlled field trials using otherwise untreated Douglas-fir have provided excellent data for the various chemicals and have demonstrated the comparable performance of these newer systems, it is also desirable to generate data on groundline bandages on in-service poles of other species exposed at alternative sites.

The Merced area in Northern California was selected for this purpose because it tends to be slightly drier than Corvallis, experiences higher temperatures, and, most importantly, the cooperation utility in this area had three wood species available for evaluation.

A total of 27 Douglas fir, 27 western redcedar, and 15 Ponderosa pine poles was presampled by removing plugs from three equidistant locations around the groundline. The outer 25 mm of each plug was removed and plugs from a single pole were combined prior to being ground to pass a 20 mesh screen. The resulting powder was analyzed for pentachlorophenol using an Asoma 8620 x-ray fluorescence analyzer. These results were then used to partition the poles into three equal groups so that each group contained poles with similar ranges of preservative retentions (Table IV-2).

CuRAP 20 Copper Levels from Groundline Bandage



COP-R-PLASTIC Copper Levels from Groundline Bandages

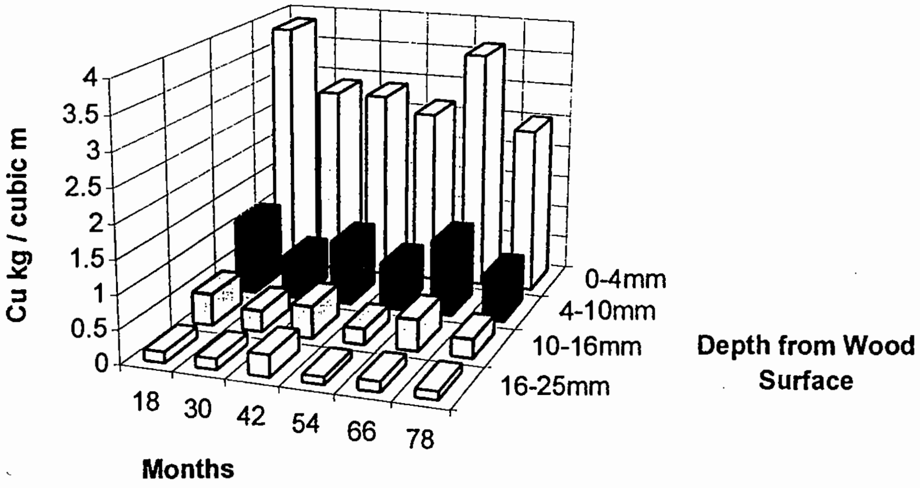


Figure IV-3. Residual levels of copper naphthenate (as Cu) in Douglas-fir poles treated with CuRap20 or Cop-R-Plastic groundline bandage systems.

Table IV-2. Retentions of pentachlorophenol in the outer 2.5 cm of Douglas-fir, western redcedar, and ponderosa pine poles prior to groundline preservative treatment.

Pole #	Species	Retention (kg/m^3)	Treatment	Pole#	Species	Retention (kg/m^3)	Treatment
2/6	DF	.563	PATOX II	4/14	WRC	.370	CUNAP
2/7	DP	.386	DUNAP	4/15	WRC	.285	CUNAP
2/8	DF	.331	CURAP	4/16	WRC	.221	PATOX II
2/9	DP	.427	PATOX II	5/0	WRC	.618	PATOX II
2/10	DF	.505	CUNAP	5/1	WRC	.592	PATOX II
2/11	DF	.402	CUNAP	5/2	WRC	.372	CURAP 20
2/13	DF	.472	CURAP 20	5/3	WRC	1.639	CUNAP
2/14	DF	1.027	CURAP 20	5/4	WRC	.397	PATOX II
2/16	DF	.398	CURAP 20	5/5	WRC	.400	CUNAP
2/17	DF	.278	CUNAP	5/6	WRC	.198	PATOX II
2/18	DF	1.548	PATOX II	5/7	WRC	.244	CUNAP
2/19	DF	1.413	CUNAP	5/8	WRC	1/111	CUNAP
3/0	DF	.224	PATOX II	5/11	WRC	.153	CUNAP
3/1	DF	.791	CURAP 20	5/12	WRC	.837	CUNAP
3/2	DF	.657	PATOX II	5/13	WRC	.203	CUNAP
3/3	DF	.696	CURAP 20	5/14	WRC	.738	CURAP 20
3/4	DF	.487	CURAP 20	5/15	WRC	1.395	PATOX II
3/5	DF	.828	CUNAP	5/16	WRC	.419	CUNAP
3/11	DF	.394	PATOX II	L9/0	WRC	.104	CUNAP
3/12	DF	.794	PATOX II	L9/2	WRC	.025	CURAP 20
4/3	DF	.290	CURAP 20	L9/3	WRC	.110	CURAP 20
4/4	DF	.653	CUNAP	L9/4	WRC	.168	CURAP 20
4/5	DF	.481	PATOX II	L9/6	WRC	.076	PATOX II
4/8	DF	.779	CUNAP	L9/8	WRC	.110	CUNAP
4/9	DF	.914	PATOX II	L10/1	WRC	.154	PATOX II
4/12	DF	.557	CURAP 20	L10/2	WRC	.234	CUNAP
4/13	DF	.479	CUNAP	L10/3	WRC	.139	PATOX II
1	PP	.552	CURAP 20	9	PP	.569	CUNAP
2	PP	.478	PATOX II	10	PP	.357	CUNAP
3	PP	.774	PATOX II	11	PP	.304	PATOX II
4	PP	.535	CUNAP	12	PP	.523	CURAP 20
5	PP	.582	CURAP 20	13	PP	.333	CUNAP
6	PP	.819	CUNAP	14	PP	1.009	PATOX II
7	PP	.722	PATOX II	15	PP	.458	CURAP 20
8	PP	.762	CURAP 20				

1. Where DF= Douglas-fir, WRC= Western redcedar, and PP= Ponderosa pine.

Poles in a selected group were excavated to a depth of 45 cm and one of three groundline bandage systems was applied according to manufacturer's specifications.

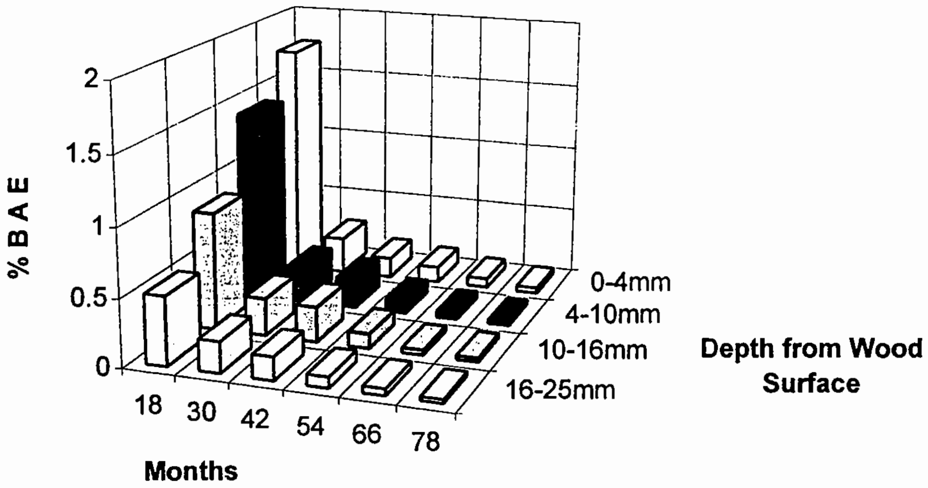
CUNAP® and CuRap20® were the same formulations evaluated on untreated Douglas-fir poles at the Corvallis test site, while PATOX II (Osmose Wood Preserving Inc., Buffalo, NY), was a newer formulation containing 70.3% sodium fluoride as the only active ingredient.

The ability of the three formulations to move into the selected wood species was assessed 1-, 2-, 3-, and 5 years after application by removing three increment cores from equidistant points around each pole approximately 15 cm below groundline. These cores were divided into zones corresponding to 0 to 4, 4 to 10, 10 to 16 and 16 to 24 mm from the wood surface. Samples from the same zone from a respective treatment group were combined prior to grinding to pass a 20 mesh screen. Samples from poles treated with CuRap20® or CUNAP WRAP® were analyzed for residual copper content by x-ray fluorescence. Samples treated with boron were analyzed by hot water extraction followed by the Azomethine H method (AWPA, 1995). Samples treated with PATOX II were analyzed on a blind sample basis by Osmose Wood Preserving, Inc. using the method described in AWPA Standard A2-94, Method 7 (AWPA, 1995).

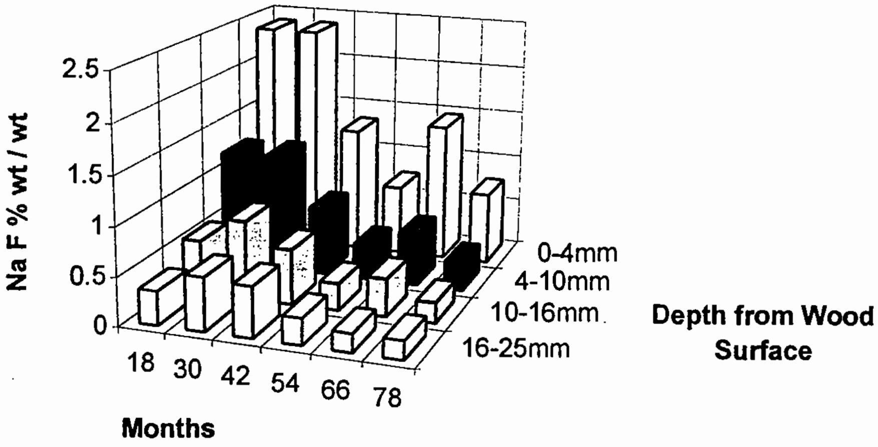
The copper levels in the two formulations containing copper naphthenate varied widely (Figure IV-5,6). Copper in CuRap20® treated poles was initially higher than that found in poles treated with CUNAP WRAP® and these trends have continued over the 5-year test period. Copper levels in both treatments were highest 1 to 2 years after treatment, then steadily declined. The threshold for protection of wood against fungal attack using copper naphthenate where copper tolerant fungi are not prevalent varies from 0.3 to 0.7 kg/m^3 (as Cu). Based upon this range, copper levels in the outer zone remain at or above the threshold for both systems, although the levels in CuRap20® treated poles are far in excess of this range implying that this treatment may provide a longer residual protective period under the test conditions. Copper levels in CUNAP WRAP® treatments were slightly higher in Douglas-fir poles 5 years after treatment. Penetration of copper naphthenate into the various pole species varied, reflecting the permeability of each wood. This was particularly true for CUNAP WRAP®. The gradient of copper from outer to inner assaying zones was relatively shallow in Ponderosa pine, and dropped off more sharply in the other two species. Ponderosa pine is considerably more permeable that either Douglas-fir or western redcedar. This effect was not present in CuRap20®. The copper naphthenate in CuRap is amine based and initially water soluble, while CUNAP WRAP® is oil soluble. Differences in interactions with the wood or the moisture present in the wood may account for the differential movement.

Boron levels in CuRap20® treated poles were well above the threshold for decay prevention 1 and 2 years after treatment, then declined to near the threshold at 3 years (Figure IV-5). Boron levels [5 years after treatment] have rebounded in Douglas-fir and western redcedar but continue to decline in Ponderosa pine. In the earlier field tests on Douglas-fir pole sections, boron levels steadily declined over the test period, reflecting the sensitivity of the fungicide to water. The Corvallis test site has a high water table which encourages leaching and presents a formidable challenge to the use of boron in the groundline. The Merced site is much drier, lacks the high water table, and potentially represents a less severe leaching exposure. The reasons for the sudden increase in boron levels is unclear, although it may represent differences in seasonal rainfall. Boron levels in the four sampling zones were uniform for Ponderosa pine and western redcedar and exhibited a slight outer to inner gradient in Douglas-fir. Boron distribution should become reasonably uniform in these poles as the chemical diffuses across the pole with moisture.

Fluoride levels in PATOX II treated poles indicate that levels remain well above the threshold in the two outer assay zones (Figure IV-6). Fluoride levels remain highest in western

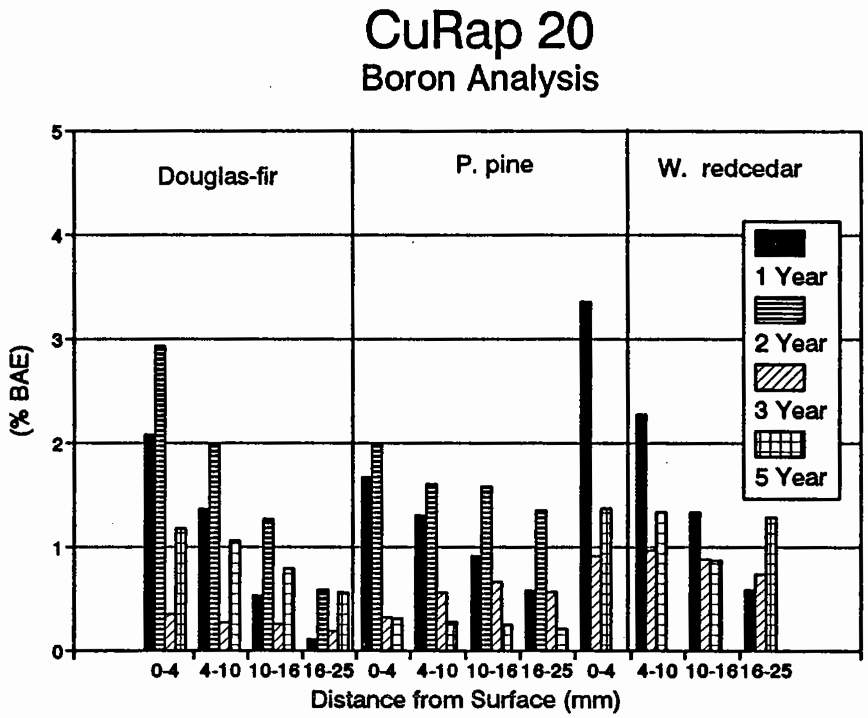


CuRAP 20 Boron Levels from Groundline Bandages



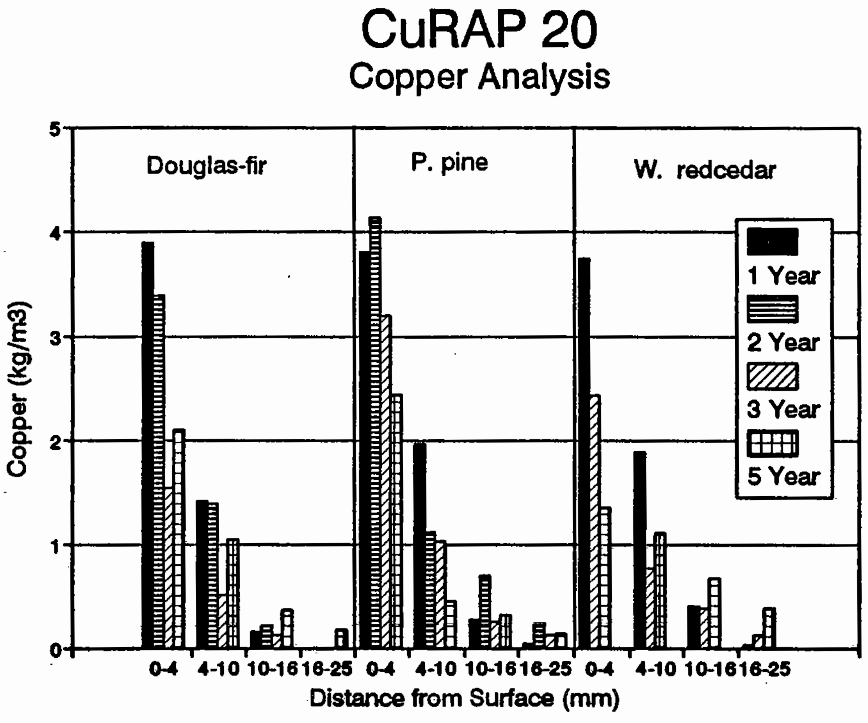
COP-R-PLASTIC Sodium Fluoride Levels from Groundline Bandages

Figure IV-4. Residual levels of boron or fluoride in Douglas-fir poles treated with CuRap20® or COP-R-PLASTIC®, respectively.



CuRap 20

Boron Analysis



CuRAP 20

Copper Analysis

Figure IV-5. Residual levels of copper or boron in Ponderosa pine, western redcedar, or Douglas-fir poles 3 years after treatment with CuRap20®.

redcedar, while levels in Ponderosa pine and Douglas-fir appear similar. Unlike boron, fluoride levels continue to exhibit a concentration gradient from the surface inward, suggesting that the chemical distribution has not yet equilibrated.

While the results appear similar to those found with Douglas-fir poles at the Corvallis site, subtle differences have emerged. Boron appears to remain for longer periods in the California poles, while the fluoride levels are similar at both sites. Copper levels in CuRap20® are similar in both sites on the outer assay zone, but are higher in the next zone in the California poles. Copper levels in CUNAP WRAP®-treated poles in California have never approached the levels found in Corvallis. These results illustrate the need to assess systems on a multitude of sites with varying environmental characteristics to develop estimated service life data.

Despite these differences, chemical levels in poles receiving all three treatments remain adequate for protecting the surface against fungal attack five years after treatment.

C. EVALUATION OF GROUNDLINE BANDAGE SYSTEMS ON WESTERN REDCEDAR AND SOUTHERN PINE POLES IN NEW YORK

In order to generate additional data on groundline bandage systems on the southern pine, the species most often receiving this treatment, a field test was established in Binghamton, New York. Western redcedar and southern pine distribution poles ranging in age from 5 to 60 years were treated with CUNAP WRAP®, CuRap20®, or PATOX II as described earlier. This test was only installed in October of last year and will be sampled shortly.

Outcomes of This Objective

- Reformulated groundline bandages performing similarly to earlier systems

- Boron is most susceptible to loss, although rate of loss varies with site conditions

- Copper levels vary widely with site and formulation

LITERATURE CITED

American Wood-Preservers' Association. 1995a. Book of Standards. Standard A2-94. Standard methods for analysis of waterborne preservatives and fire-retardant formulations. Method 7. Determination of the fluoride in wood and solutions. AWPA, Woodstock, MD.

American Wood-Preservers' Association. 1995b. Book of Standards. Standard A2-94. Standard methods for analysis of waterborne preservatives and fire-retardant formulations. Method 16. Determination of boron in treated wood using Azomethine H or Carminic acid. AWPA, Woodstock, MD.

Becker, G. 1976. Treatment of wood by diffusion of salts. Doc. No. IRG/WP/358. Inter. Res. Group on Wood Preservation, Stockholm, Sweden.

Chudnoff, M., W.E. Eslyn, and R. Wawriw. 1977. Effectiveness of groundline treatment of creosoted pine poles under tropical exposures. Forest Prod. J. 28(4):28-32.

DeGroot, R.C. 1981. Groundline treatments of southern pine posts. Res. Pap. FPL-409. USDA Forest Service, Forest Prod. Lab., Madison, WI.

Harkom, J.F., M.J. Colleary, and H.P. Sedziak. 1948. Results of the examination of seven ground-line treatments and one butt treatment of eastern white cedar pole stubs after six years' service. IN: Proc. Am. Wood-Preservers' Association, 44:158-171.

Henningsson, B., H. Friis-Hansen, A. Kaarik, and M.-L. Edlund. 1988. Remedial groundline treatment of CCA poles in service: A progress report after 28 months' testing. Doc. No. IRG/WP/3481. Inter. Res. Group on Wood Preservation. Stockholm, Sweden.

Leutritz, J., Jr., and G.Q. Lumsden. 1962. The groundline treatment of standing southern pine poles. IN: Proc. Am. Wood-Preservers' Assoc. 58:79-86.

Morrell, J.J., A.E. Connelly, P.F. Schneider, P.G. Forsyth, and J.J. Morrell. 1996. Performance of external groundline bandages in Douglas-fir poles. Proceedings International Conference on Wood Poles and Piles. Fort Collins, CO, pp.

Morrell, J., Forsyth, P.G., and Newbill, M.A. 1994. Distribution of biocides in Douglas-fir poles 42 months after application of groundline preservative systems. For. Prod. J. 44(6):24-26.

Panek, E., J.O. Blew, Jr., and R.H. Baechler. 1961. Study of groundline treatments applied to five pole species. Rept. No. 2227. USDA Forest Service, Forest Prod. Lab., Madison, WI.

Smith, D.N. and R. Cockroft. 1967. The remedial treatment of telephone and electric transmission poles. Part 1. Treatment for external decay. Wood 32(9):35-40.

West, M.H., M.H. Freeman, and R.S. Gross. 1992. Remedial treatments with a borate-copper naphthenate paste. Proceedings International Conference on Wood Poles and Piles, Fort Collins, CO, p. 95-99.

Zabel, R.A., F.F. Lombard, C.J.K. Wang, and F.C. Terracina. 1985. Fungi associated with decay in treated southern pine utility poles in the eastern United States. Wood and Fiber Sci. 17:75-91.

Ziobro, R.J., W.S., McNamara, and J.F. Triana. 1987. Tropical field evaluations of groundline remedial treatments on soft rot attacked CCA-treated eucalyptus poles. Forest Prod. J. 37(3):42-45.

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TABLE OF CONTENTS

CONSERVING ENERGY BY ENVIRONMENTALLY ACCEPTABLE PRACTICES IN MAINTAINING AND PROCURING TRANSMISSION POLES

Objective III

Objective IV

Objective V

COOPERATORS

ELECTRIC UTILITIES

*Bonneville Power Administration

*Empire State Electric Energy Research Corporation

*New York State Electric and Gas Corporation

*Pacific Gas and Electric

*Pacific Power Corporation

*Portland General Electric Company

WESTERN WOOD PRESERVERS INSTITUTE

J.H. Baxter & Company

McFarland-Cascade Company

Taylor Lumber and Treating Company

***CSI, Inc.**

***ISK Biotech**

***Osmose Wood Preserving, Inc.**

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

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SUMMARY

The Cooperative continues to actively address a diverse array of issues related to the effective use of wood utility poles.

The trials to evaluate the effectiveness of MITC-Fume are now in their seventh year and continue to show that methylisothiocyanate (MITC) levels in MITC-Fume treatments remain higher than comparable metham sodium treatments. The levels of chemical are, however, declining, suggesting that this treatment may need replenishment in 3 to 5 years. Trials with the solid wood fumigant Basamid continue to show that MITC release can be enhanced by addition of small amounts of copper. Field trials suggest that these additives become less important with time. As a result, unamended Basamid may be suitable for treatment where the risk of immediate decay is not high, but the utility wishes to protect against future attack.

Field trials with various water-diffusible internal treatments continue to show that these treatments move more slowly through Douglas-fir heartwood than do fumigants. Boron levels in pole sections treated with fused borate rods remain at levels that will protect against fungal attack 6 years after treatment. Similar trials with a boron/fluoride rod indicate that neither fluoride or boron levels in the poles are adequate for wood protection 2 years after treatment. While the dosages tested were relatively low, the volumes of chemical were similar to the liquid volumes normally applied during internal remedial treatment. We will sample these poles next year to ensure that our measurements accurately reflect the chemical levels present.

Trials to evaluate the effects of glycol on boron movement from fused borate rods suggest that glycol enhanced boron diffusion to only a slight extent. This effect was most pronounced at lower moisture contents. This trial was established to identify methods for improving boron movement in drier wood. In addition, moisture measurements in these poles suggest the internal wood moisture content varies widely both seasonally and positionally. While elevated moisture levels can negatively affect the movement of gaseous fumigants, excess moisture is critical for diffusion of boron or fluoride and its absence around the treatment site can markedly reduce the efficacy of rod treatments. These poles will continue to be monitored to assess both boron movement and seasonal changes in moisture content.

Trials to identify safe, effective and easily used systems for protecting wood exposed during field fabrication are continuing. Boron and fluoride continue to provide excellent protection to field drilled bolt holes. These treatments are safe and easy to apply, and have provided protection in our field test for 14 years. Trials of similar formulations on simulated decking are also reported to provide additional information on the ability of boron and fluoride to protect exposed Douglas-fir heartwood.

Efforts to improve the effectiveness of through boring as a method for enhancing the treatment of Douglas-fir poles are continuing. This past year, we evaluated preservative distribution around through bored holes as a means of developing optimum through boring patterns that maximized treatment while minimizing potential strength effects. These trials suggest the diamond shaped through boring zone of effect is relatively narrow. This information will be used in the coming year to construct optimum patterns for poles of various classes. The goal of this project is to develop a standard through boring pattern that would permit automation of the process. This would create the potential for cost savings on new poles.

Trials to evaluate the durability of western redcedar are nearly complete. These trials were initiated because of concerns that second growth western redcedar might be less durable than poles cut from older trees. As expected, cedar varied widely in its resistance to fungal attack. This resistance, however, was not related to tree age, suggesting that there might not be a difference between so-called "old-growth" and "second growth" material. These data will be more thoroughly analyzed once the final set of trials are completed. In addition, we are evaluating more rapid methods for assessing cedar durability by measuring tropolone content. Tropolones are an important component of the extractives that make cedar heartwood so durable.

Field trials of various externally applied supplemental groundline treatments are continuing at sites in Oregon, California, and New York. Trials in Corvallis, Oregon, have shown that various copper naphthenate, fluoride or boron based systems are at least as effective as the pentachlorophenol (penta) based systems that were formerly used for this purpose. Penta concentrations in one system have now declined below a protective level, while the copper based systems continue to remain at a protective level. Field trials in California are following similar trends and indicate that the alternative systems will provide comparable performance.

Fungus cellar trials of copper naphthenate treated western redcedar stakes continue to show that this chemical provides excellent protection to cedar sapwood. Weathered wood that was treated with copper naphthenate continues to perform more poorly than freshly sawn wood treated to similar retention levels. Variations in permeability likely account for these differences.

A new Wood Pole Maintenance Manual has been completed and is now ready for distribution. This update of the 1979 publication includes more information on initial pole procurement and closely follows the video by the same name that we produced in 1994.

OBJECTIVE I
DEVELOP SAFER CHEMICALS FOR CONTROLLING INTERNAL DECAY OF WOOD POLES

Improvements in specification, treatment and inspection have combined to markedly enhance the performance of wood poles in North America. Despite these steps, however, a percentage of poles in a population will eventually develop problems with decay or insect attack. In reality, this damage is no different than that which might occur with steel (which can corrode), concrete (which spalls), or any other material. Proper combinations of specification, treatment and quality control reduce the risk of such damage occurring, regardless of material, but they cannot completely prevent damage. As a result, utilities must perform regular inspections of their pole system to maintain system integrity and safety.

One of the advantages of wood for supporting overhead lines is the relative ease with which insect and fungal damage can be controlled. A wide array of treatments have been developed for remedially arresting decay and these systems have contributed, to a great measure, in the continued use of wood poles. Probably, the most important of the remedial treatments have been those designed to control internal decay of thin sapwood species. In these instances, checks through a well-treated shell of preservative permit the entry of moisture and fungal spores into the untreated wood within the pole. Eventually, decay fungi hollow out the pole near the groundline, leaving only the outer preservative treated shell to support the design load. The development of fumigants for arresting this decay in the late 1960's provided one of the first widely effective methods for economically prolonging the service life of internally decayed poles. As a result, nearly 90% of utilities in North America use fumigants as part of their pole maintenance programs, saving over one billion dollars per year in replacement costs.

Despite their widespread use, fumigants pose a challenge to users. Two of the three formulations registered with the U.S. Environmental Protection Agency for wood application are liquids (Table I-1), that can be spilled during application. One of these liquids, chloropicrin, is highly volatile and applicators must wear respirators when applying this chemical. In these times of heightened environmental sensitivity, the image of workers applying chemicals to poles while wearing respirators is difficult to explain to customers. The other liquid fumigant, metham sodium (32.7% sodium n-methyl-di-thiocarbamate), is caustic. The third fumigant registered for wood use (methyl-isothiocyanate) is a solid at room temperature, but it too is caustic and must be contained in either aluminum or glass capsules prior to application. Despite their widespread effectiveness, the drawbacks associated with each of these chemicals has encouraged a search for safer internal remedial treatments. In Objective I, we will present data on the currently registered fumigants along with information of formulations currently under evaluation. In addition, we will present information on the performance of various water-diffusible remedial treatments.

A. EVALUATE PREVIOUSLY ESTABLISHED TESTS OF VOLATILE REMEDIAL INTERNAL TREATMENTS

Over the past 20 years, a variety of field trials have been established to evaluate the efficacy of various remedial treatments (Table I-2). Many of these trials lasted only a few years, but several have been maintained for longer periods to develop data on long term performance of the more commercially important remedial treatments. Such data can be invaluable when making decisions concerning the efficacy of the various treatments. In this section, we describe results from those trials involving volatile chemicals. In last year's report (pages 5-9), we reported on

Table I-1. Characteristics of internal remedial treatments for wood poles.

Trade Name	Active Ingredient	Concentration %	Toxicity (LD_{50})	Manufacturer
Timber Fume	Trichloronitromethane	96	205 mg/kg	Osmose Wood Preserving Great Lakes Chemical Co.
Wood Fume	Sodium n-methyldithiocarbamate	32.1	1700-1800 mg/kg	Osmose Wood Preserving
ISK	Sodium n-methyldithiocarbamate			ISK Biotech Inc.
Vorlex	20% methylisothiocyante 80% chlorinated C_3 hydrocarbons	99	538 mg/kg	NorAm Chemical Co.
MITC-FUME	methylisothiocyante	96	305 mg/kg	Osmose Wood Preserving
Impel Rods	boron	99		CSI Inc.
Pole Saver	sodium octaborate tetrahydrate	58.2		Preschem Ltd.
PATOX Rods	sodium fluoride	24.3		

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

Test Site	Chemicals Evaluated	Date Installed	1995-96 Activity
Peavy Arboretum	Field drilled bolt hole treatments	1981	Inspected
Peavy Arboretum	Cedar pole sprays	1981	None
Dorena Tap (BPA)	Encapsulated Chloropicrin	1982	None
Hamburg Line (NYSEG)	Encapsulated MITC	1982	None
Alderwood Tap (BPA)	Encapsulated MITC	1987	None
Peavy Arboretum	Encapsulated MITC (MITC-Fume)	1987	Inspected
Peavy Arboretum	Basamid	1988	Inspected
Peavy Arboretum	Copper naphthenate/boron	1989	None
Peavy Arboretum	Impel Rods	1989	Inspected
Hilo, Hawaii (CSI)	Impel Rods	1990	None
Central Lincoln (CLPUD)	Encapsulated MITC	1990	None
Peavy Arboretum	Gelled NaMDC	1992	None
Pacific Power, Corvallis	Basamid	1993	Inspected
Peavy Arboretum	Boron/Fluoride Rods	1993	Inspected
San Jose, CA	Metham-sodium	1996	Installed

the final inspections of Douglas-fir poles treated with allyl alcohol in 1977 and with methylisothiocyanate (MITC) in 1983. These trials have since been discontinued owing to the inadvertent remedial treatment of many poles by a commercial contractor. In the following section, we describe the results obtained from trials of non-volatile remedial treatments.

1. *New York field test of encapsulated fumigants*: The field test of gelatin encapsulated MITC established in 1983 in chromated copper arsenate treated Douglas-fir poles in the New York State Electric and Gas system was last evaluated in 1992.

2. *Treatment of through-bored Douglas-fir poles with gelatin encapsulated MITC or chloropicrin*: The Douglas-fir poles treated with gelatin encapsulated chloropicrin or MITC in 1982 was last inspected in 1990.

3. *Above ground treatment with gelatin encapsulated or pelletized MITC*: The trial evaluating gelatin encapsulated and pelletized MITC in above ground applications was last evaluated in 1990 and was not sampled this year.

4. *Seven year performance of glass-encapsulated methylisothiocyanate*: The control of internal decay in wood products with volatile chemicals (fumigants) continues to represent a simple, economical method for extending the useful life of wood. For many years, the chemicals used for fumigant treatment were all liquids with varying degrees of volatility. This risk of spills and concerns about handling safety encouraged research to develop less volatile fumigants. Among the first chemicals identified for this purpose was methylisothiocyanate (MITC), a chemical which is solid at room temperature, but sublimes directly to a gas. MITC is the active ingredient of metham sodium, the most commonly used fumigant for wood applications. Its availability in a highly pure (96% active ingredient) solid form made it highly attractive for wood pole applications (Morrell and Corden, 1986), but the caustic nature of MITC made it difficult to handle. Preliminary trials suggested that gelatin capsules could be used to contain MITC prior to application (Zahora and Corden, 1985), but the process was never commercialized because of the cost of gelatin. Field trials, however, indicated that this encapsulation process provided excellent control against spills with no adverse effects on chemical performance.

Subsequently, MITC was encapsulated in borosilicate glass tubes plugged with Teflon caps for commercial application. Field trials were established to evaluate the effect of glass encapsulation on the rate of MITC release, residual MITC in the wood, and the ability of these MITC concentrations to inhibit decay fungi. Results of these trials were reported 3 years after test initiation (Morrell, et al., 1992). This paper describes the results of continued monitoring of these trials.

The methods follow those described previously (Morrell et al., 1992). Briefly, the two series of tests were established. Small scale trials in which eight 25 cm diameter by 75 cm long Douglas-fir (*Pseudotsuga menziesii* (Mirb) Franco) pole sections were end coated with elastomeric paint. One half of these sections were air seasoned to a moisture content below 25%; others were used while the wood remained above the fiber saturation point. A single 19 mm diameter by 205 mm long hole was drilled at a 45 degree angle near the center of the pole and a single MITC-Fume tube (ampule) containing 30 g of MITC was inserted, open side downward. The holes were plugged with rubber stoppers. Sets of three pole sections per moisture content were stored at 5°C (cold room), outdoors at ambient temperature (outdoors), or at 32°C and 90% relative humidity (hot wet room). At periodic intervals, the plugs were removed and the ampules were weighed to assess chemical loss over time. At the conclusion of the test, three increment cores were removed from equidistant sites around the pole section 15 cm below the treatment hole. The outer and inner 25 mm of each core were placed into tubes containing 5 ml of ethyl acetate and extracted for 48 hours at room temperature. The extracts were analyzed for residual MITC by gas chromatography using a flame photometric detector as previously described (Zahora and Morrell, 1989). MITC levels were quantified by comparison with prepared standards and expressed as ug of chemical per oven-dried gram of wood.

Field Trials: Equal numbers of Douglas-fir (*Pseudotsuga menziesii* (Mirb.) Franco) and southern pine (*Pinus taeda* L) pole sections (25 to 30 cm in diameter by 3.6 m long) were pressure treated with chromated copper arsenate to a retention of 6.4 kg/m^3, then painted with an elastomeric paint to retard fumigant loss. The poles were set to a depth of 0.9 m at a site located near Corvallis, Oregon. A series of 2, 4, 6, or 8 holes, 1.9 cm in diameter by 205 mm long were drilled in each group of six poles. Each hole received a MITC-Fume vial inserted with the open end downward and was plugged with a tight fitting preservative treated dowel. An additional set of five poles per species was treated with 500 ml of metham sodium equally distributed among three holes drilled as described for the MITC Fume. A final set of five poles received no chemical treatment.

The ability of MITC to diffuse through the wood was analyzed using combinations of bioassays and chemical assays. Over the entire study, the poles were assessed using closed tube bioassays, culturing of increment cores for fungi, and extraction for chemical analysis of residual MITC.

The poles were sampled 1, 2, 3, 5, and 7 years after installation by removing two 150 mm long increment cores, 180 degrees apart, from each test pole 0.3 m below groundline, and 3 increment cores 120 degree apart from sites 0, 0.3, 0.9, and 1.5 m above the highest treatment hole. The inner and outer 25 mm of each core was placed in separate tubes containing actively growing cultures of *Postia placenta* on malt agar slants. The tubes were capped and incubated in an inverted position so that the fungus was above the wood sample resting inside the cap. Radial growth of the fungus was measured after 2 to 3 weeks and this growth rate was compared to that of similar tubes without wood to provide a measure of the ability of the fumigant treated wood to inhibit decay fungi. This method has high sensitivity to MITC (Zahora and Morrell, 1988).

The middle section from each closed tube sample was placed on malt agar in a petri dish and observed over a 1 month period for evidence of fungal growth. Any fungi growing from the wood were examined for characteristics typical of basidiomycetes, a group of fungi containing many important wood decayers. The presence of non-basidomycetes was also noted.

The inner and outer 25 mm section of a second core from each site was placed into 5 ml of ethyl acetate and extracted for 48 hours prior to analysis. Chemical analysis was performed in a manner similar to that described for the small pole sections.

MITC release rates from the glass ampules in pole sections stored under varying conditions continued to show that temperature had a marked effect on the length of time that the chemical remained in the ampule. Ampules from poles stored under hot wet conditions exhibited chemical loss within one year after treatment, while those stored at 5°C continue to retain nearly one third of the original chemical (Figure I-1). Ampules in poles which were originally treated while green and then stored outdoors, continue to retain small amounts of chemical, while no MITC remains in vials from poles treated dry and stored in the same manner. The effect of moisture content on release was perplexing since one would expect that any moisture variations would equilibrate over time. One might expect that MITC sorption would be affected by higher MC's (Zahora and Morrell, 1989), but this effect should disappear as the log sections equilibrated to their ambient moisture levels. The difference between wet and dry treated pole sections has continued over the 7 year test period. A smaller, but similar trend was noted with the pole sections stored at 5°C.

MITC levels in pole sections 7 years after application of a single ampule of MITC-Fume ranged from below the limit of detection to

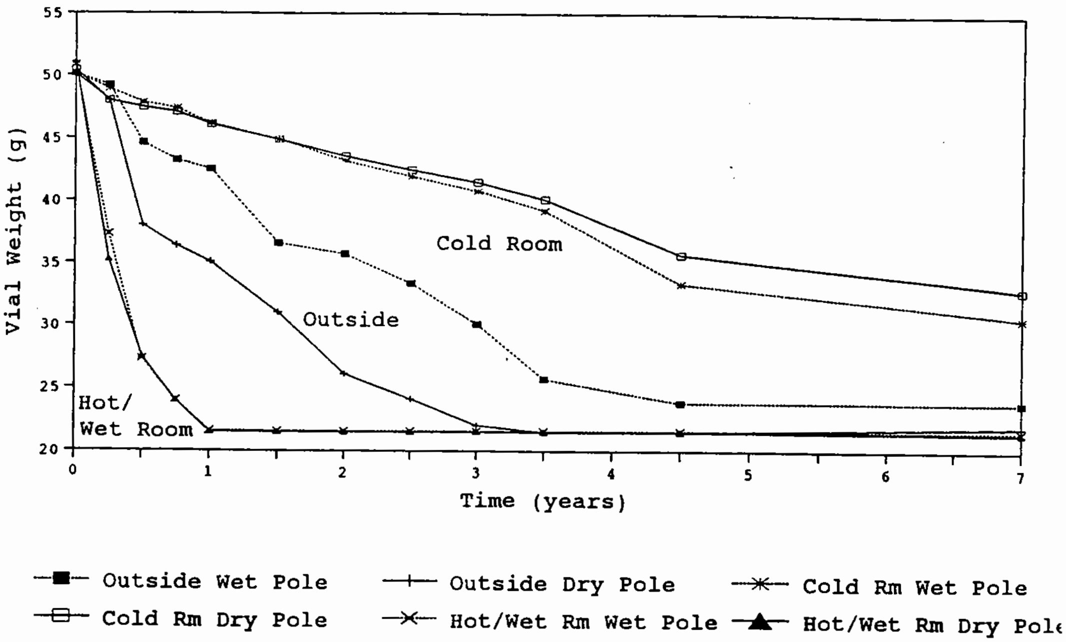


Figure I-1. Rate of MITC loss from glass encapsulated MITC placed in air dry or green Douglas-fir poles which were subsequently exposed under hot/wet, ambient, or cold conditions for 7 years.

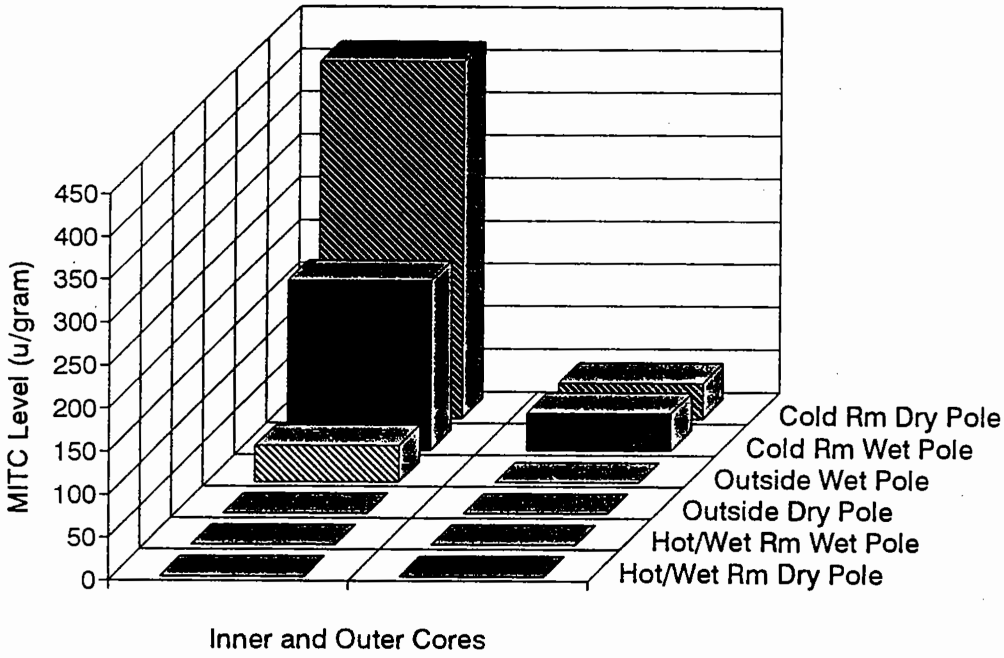


Figure I-2. Residual MITC in the inner or outer 25 mm of increment cores removed from Douglas-fir poles treated with glass encapsulated MITC and exposed for 7 years under hot/wet, ambient, and cold conditions.

over 400 ug/g oven dried wood (Figure I-2). MITC was virtually absent from pole sections exposed under hot wet conditions, nor was MITC detected in poles which were seasoned before treatment and exposure under ambient conditions. MITC was detected at low levels in the inner zone of pole sections treated when wet and exposed under ambient conditions, but was absent from the outer zones of the same pole sections. MITC was present in both assay zones in poles exposed at 5°C. MITC levels were higher in the inner zone, reflecting the original orientation of the tube opening towards the pole center and the loss of chemical nearer the surface. Chemical levels were again higher in poles which were treated while the wood was dry, following the weight loss trends from the ampules.

The original dosages applied to the poles were relatively low (0.2 kg MITC/m^3 of wood volume) which translates to approximately 0.04 % by weight. The final concentration 7 years after treatment approached this level in the inner zone of the cold stored poles, but the remainder of the samples had lost a majority of the chemical over the test period. These results suggest that caution must be exercised when contemplating prolonging the retreatment cycle with MITC based formulations under warmer exposure conditions.

Field Trials: Closed tube bioassays of inner zones of cores removed from the poles at selected times after MITC or metham sodium treatment suggest that the protective effects of these treatments have declined markedly between the 3 and 7 year sampling points for both wood species (Table I-3). There was little evidence of residual fungitoxicity in samples removed from sites 0.3, 0.9, and 1.5 m above the highest treatment sites regardless of dosage 5 or 7 years after treatment. A low level of inhibition appeared to be present in the inner zones of cores removed from the upper edge of the treatment zone at the same sampling times. The degrees of inhibition tended to improve slightly with increasing MITC dosage, but the differences were sometimes slight. A similar trend was noted 0.3 m below the lowest treatment hole. These results suggest that the protective effect of MITC has declined away from the original treatment zone, but that this chemical continues to provide protection to the treatment zone 7 years after chemical application.

Culturing of increment cores from the various treatments suggest that all of the treatments continue to inhibit colonization by decay fungi 7 years after chemical application (Table I-4). Basidiomycetes were virtually absent in non-fumigant treated southern pine poles, although one isolate was obtained from 1.5 m above the groundline on a single control pole. Colonization of Douglas-fir controls occurred more frequently over the test period at all of the sampling heights, but there was not consistent progression in degree of fungal colonization over time at a given location.

Basidiomycete isolations in southern pine poles treated with MITC or metham sodium were generally low over the 7 year test period. Only 7 of 375 cores (1.9 %) removed from the fumigant treated southern pine poles 7 years after treatment contained basidiomycetes, indicating that both chemicals were performing well. Basidiomycete levels in Douglas-fir poles receiving fumigants were equally low, with only 3 of 375 (0.8 %) of the cores taken 7 years after treatment containing these fungi.

The levels of non-decay fungi present in the cores generally increased with time following treatment and with distance away from the treatment zone, reflecting the higher tolerance of many of these fungi for chemicals. Virtually all cores contained some type of non-decay fungi 7 years after treatment. The role of these fungi in fumigant performance is unknown. Some of these fungi can inhibit growth by decay fungi and help prolong fumigant protection (Giron and Morrell, 1989). Many other non-decay fungi are known to detoxify preservatives (Zabel and Morrell, 1992), although their potential effects on fumigants are not known.

MITC levels present in the wood 5 and 7 years after treatment were generally lower than those found in the same poles at earlier sampling points (Table I-5). MITC levels in the outer zones of the samples were low regardless of distance from the treatment zone, and these

Table 1-3. Incidence of fungal growth, as measured by closed-tube bioassays of increment core segments, in southern pine and Douglas-fir poles 12, 24, 36, 60, and 84 months after treatment with MITC-Fume® or metham-sodium.[a]

Vertical distance from treatment zone	Core segment tested[c]	Months after treatment	Fungal growth (as % of control)[b]									
			Southern pine					Douglas-fir				
			MITC-Fume®				Metham-sodium	MITC-Fume®				Metham-sodium
			60 g	120 g	180 g	240 g	500 ml	60 g	120 g	180 g	240 g	500 ml
-0.3 m	Outer	12	12	0	0	0	23	34	25	4	0	77
		24	17	0	20	0	100	16	6	20	0	20
		36	55	41	33	32	78	25	21	20	22	82
		60	74	99	71	79	73	90	79	74	91	80
		84	59	68	79	108	97	76	91	92	102	71
	Inner	12	0	0	0	0	14	0	12	0	0	49
		24	0	0	0	0	0	0	0	0	0	16
		36	14	1	3	0	7	1	14	13	16	69
		60	51	28	52	1	28	71	45	53	61	57
		84	33	67	14	17	47	44	60	86	95	66
0.0 m	Outer	12	16	3	11	0	40	0	0	0	0	10
		24	0	7	30	0	100	16	0	0	0	12
		36	38	12	24	10	69	19	21	26	21	76
		60	76	82	87	72	90	85	47	75	77	58
		84	75	77	69	73	98	73	77	93	94	81
	Inner	12	0	0	0	0	0	0	0	0	0	0
		24	0	0	0	0	0	0	10	0	0	0
		36	13	3	7	3	5	8	2	1	0	82
		60	47	53	36	1	26	73	46	66	47	46
		84	57	60	34	27	57	40	83	84	76	54
0.3 m	Outer	12	80	0	21	41	63	65	32	4	0	67
		24	83	36	33	33	100	40	23	0	0	0
		36	51	25	28	27	67	24	19	15	7	91
		60	79	96	85	68	89	94	91	74	69	48
		84	78	88	87	88	83	68	75	91	94	79
	Inner	12	40	0	0	0	45	16	12	0	0	15
		24	0	0	13	0	13	16	13	0	0	33
		36	5	6	19	1	23	8	20	14	3	84
		60	76	66	83	33	67	92	75	71	62	75
		84	85	80	73	57	82	63	70	93	93	79
0.9 m	Outer	12	100	73	95	100	90	79	64	27	19	70
		24	90	77	94	100	100	43	43	23	24	60
		36	101	77	63	85	84	37	31	29	13	83
		60	96	102	101	85	89	88	82	69	77	68
		84	97	93	79	103	98	64	67	95	98	84
	Inner	12	60	33	92	100	86	27	26	22	8	39
		24	57	63	35	48	60	20	0	16	0	33
		36	78	49	43	36	50	38	54	41	15	90
		60	89	99	89	79	86	79	103	80	82	79
		84	94	91	83	86	99	63	64	96	191	87

Table 1-3. Incidence of fungal growth, as measured by closed-tube bioassays of increment core segments, in southern pine and Douglas-fir poles 12, 24, 36, 60, and 84 months after treatment with MITC-Fume® or metham-sodium.[a]

Vertical distance from treatment zone	Core segment tested[c]	Months after treatment	Fungal growth (as % of control)[b]									
			Southern pine					Douglas-fir				
			MITC-Fume®				Metham-sodium	MITC-Fume®				Metham-sodium
			60 g	120 g	180 g	240 g	500 ml	60 g	120 g	180 g	240 g	500 ml
1.5 m	Outer	12	100	100	100	100	100	63	100	62	48	86
		24	97	100	100	100	87	53	47	60	100	100
		36	88	91	89	85	93	74	71	72	86	92
		60	98	99	108	90	98	93	102	93	90	54
		84	100	83	79	97	111	68	66	97	102	86
	Inner	12	100	100	100	50	97	95	100	68	50	84
		24	100	94	80	57	70	77	43	30	67	67
		36	99	83	74	61	57	76	74	75	77	102
		60	97	93	95	76	86	76	107	75	93	73
		84	93	113	71	81	90	66	74	98	95	90

[a] Cores were removed from selected locations at different vertical distances above and below the treatment site.

[b] Values represent the growth of *Postia placenta* in tubes containing treated-wood cores as a percentage of its growth in tubes to which wood cores were not added. Complete inhibition (0% growth) represents fungitoxic chemical levels.

[c] Outer – 2.5 cm from pole surface; Inner – 12.5 to 15.0 cm from pole surface.

Table 1-4. Incidence of decay and nondecay fungi in southern pine and Douglas-fir poles 6, 12, 24, 36, 60, and 84 months after treatment with MITC-Fume® or metham-sodium.[a]

Chemical treatment	Percentage of cores containing decay (nondecay) fungi[b]																								
		-0.3 m				0.0 m					0.3 m					0.9 m					1.5 m				
	Dosage[c]	24 mo	36 mo	60 mo	84 mo	12 mo	24 mo	36 mo	60 mo	84 mo	12 mo	24 mo	36 mo	60 mo	84 mo	12 mo	24 mo	36 mo	60 mo	84 mo	12 mo	24 mo	36 mo	60 mo	84 mo
SOUTHERN PINE																									
MITC-Fume®	60	0 (50)	0 (67)	0 (50)	0(83)	0 (67)	(0)	0 (17)	0 (17)	0(83)	0 (100)	0 (100)	0 (39)	6 (22)	0(78)	0 (100)	0 (100)	0 (83)	0 (39)	0(100)	0 (100)	0 (100)	0 (88)	0 (61)	0(100)
	120	0 (50)	0 (42)	0 (33)	0(75)	0 (83)	0 (17)	0 (8)	8 (17)	0(92)	0 (100)	0 (83)	0 (17)	5 (28)	0(83)	0 (100)	0 (100)	0 (56)	0 (61)	0(100)	0 (100)	0 (100)	0 (56)	0 (39)	0(94)
	180	0 (28)	0 (57)	0 (25)	0(100)	0 (30)	0 (57)	0 (14)	0 (33)	8(92)	0 (100)	0 (100)	0 (67)	0 (33)	6(78)	0 (100)	0 (100)	0 (52)	0 (56)	0(89)	0 (100)	0 (100)	0 (52)	0 (50)	0(100)
	240	0 (0)	0 (58)	0 (33)	8(92)	0 (50)	0 (0)	0 (17)	0 (8)	8(83)	0 (100)	0 (100)	0 (38)	6 (28)	6(89)	0 (100)	0 (100)	0 (94)	6 (33)	0(100)	0 (100)	0 (100)	0 (94)	6 (94)	0(100)
Metham-sodium	500	0 (40)	0 (70)	0 (30)	0(75)	0 (40)	0 (40)	0 (40)	0 (20)	0(83)	0 (100)	0 (80)	0 (73)	0 (33)	0(83)	0 (100)	0 (100)	0 (93)	7 (53)	0(83)	0 (100)	0 (100)	0 (87)	8 (53)	0(85)
Control	- - -	0 (100)	0 (92)	0 (25)	0(100)	0 (100)	0 (100)	0 (83)	0 (50)	0(100)	0 (100)	0 (100)	0 (83)	0 (72)	0(100)	0 (100)	0 (100)	0 (89)	0 (72)	0(100)	0 (100)	0 (100)	0 (83)	6 (61)	0(100)
DOUGLAS-FIR																									
MITC-Fume®	60	0 (0)	0 (42)	0 (0)	0(92)	0 (25)	0 (33)	0 (0)	0 (8)	0(75)	0 (33)	0 (50)	0 (0)	0 (11)	0(72)	0 (50)	0 (100)	0 (17)	0 (17)	6(83)	0 (100)	0 (100)	6 (39)	0 (22)	0(89)
	120	0 (57)	0 (17)	0 (8)	0(83)	0 (29)	0 (29)	0 (0)	0 (8)	0(83)	0 (71)	0 (100)	0 (17)	0 (11)	6(72)	0 (64)	7 (100)	0 (10)	0 (17)	0(94)	10 (40)	0 (100)	10 (29)	0 (22)	0(89)
	180	0 (50)	0 (17)	0 (9)	0(92)	0 (16)	0 (17)	0 (8)	0 (0)	0(75)	0 (58)	0 (67)	0 (10)	0 (11)	0(94)	0 (75)	0 (67)	0 (17)	0 (11)	0(94)	0 (71)	0 (67)	0 (22)	0 (28)	0(94)
	240	0 (33)	0 (33)	0 (8)	0(100)	0 (29)	0 (17)	0 (0)	0 (17)	0(92)	0 (25)	0 (67)	0 (8)	0 (22)	0(72)	0 (8)	0 (100)	0 (0)	0 (17)	0(83)	25 (75)	0 (100)	0 (13)	0 (0)	0(100)
Metham-sodium	500	0 (60)	0 (40)	0 (30)	0(75)	0 (60)	0 (40)	10 (50)	0 (20)	0(67)	0 (40)	10 (50)	13 (7)	0 (33)	0(67)	10 (50)	10 (80)	13 (7)	7 (53)	0(78)	0 (40)	10 (80)	0 (0)	0 (53)	6(83)
Control	- - -	33 (100)	33 (75)	0 (25)	0(100)	0 (100)	33 (100)	42 (67)	0 (25)	8(100)	0 (50)	25 (100)	28 (50)	17 (44)	44(100)	8 (33)	8 (100)	28 (50)	0 (39)	22(100)	0 (33)	0 (100)	6 (6)	0 (33)	22(100)

[a] Core were removed from selected locations at different vertical distances above and below the treatment zone. The middle segment of cores was used for this analysis.
[b] Values reflect an average of 15 total cores per dosage/position. Figures in parentheses represent nondecay fungi isolated from the same cores.

results were reflected by the low inhibitory levels in the closed tube bioassays. Chemical levels in the inner zones of the samples varied more widely (Figure I-3). As might be expected, the highest chemical levels were at the site nearest the treatment zone. MITC levels in this zone increased with increasing MITC dosage, although the changes were not proportional to the increasing dosages. Chemical levels in the inner zones of southern pine samples were generally higher than those found for a comparable dosage in Douglas-fir. The reasons for this variation are unclear. Southern pine is about 100 times more permeable than Douglas-fir heartwood (Siau, 1995). As a result, southern pine might be expected to lose volatile chemicals more rapidly. Differences in MITC sorption, however, might alter this relationship.

MITC levels in poles treated with metham sodium were generally near those found in poles receiving 2 ampules of MITC-Fume suggesting that these treatments might perform similarly. Previous studies have shown that MITC levels in metham sodium treated poles tend to decline rapidly after treatment, reflecting the relatively low concentration of active ingredient applied per hole and the low decomposition efficiency found with metham sodium in many wood species (Helsing et al., 1984; Morrell, 1994; Morrell et al., in press). Closed tube bioassays of these poles suggest that the measured chemical levels are only marginally inhibitory to potential decay fungi.

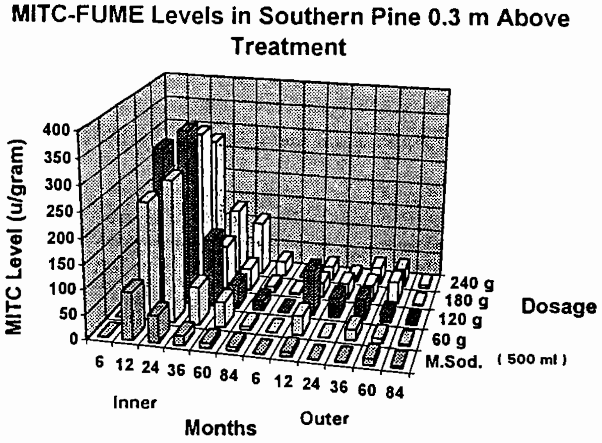
The results suggest that the levels of MITC away from the treatment zone of poles treated 7 years earlier with MITC Fume have declined to levels where they are no longer capable of protecting the wood from fungal attack. Levels within the treatment zone would be expected to be higher than those found away from this zone and these levels will be the subject of a subsequent evaluation.

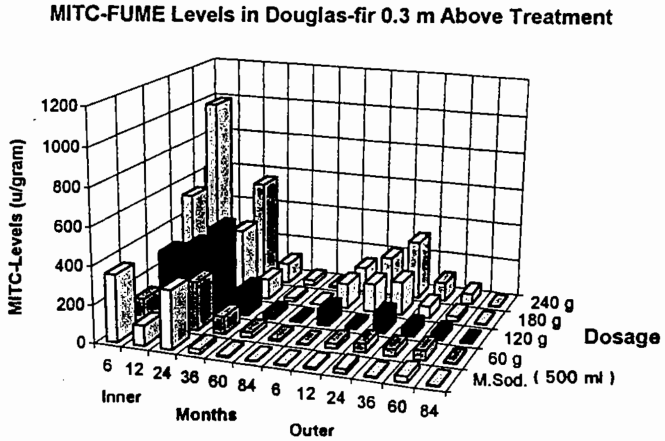
5. *Effect of selected additives on MITC release from Basamid in Douglas-fir poles*:

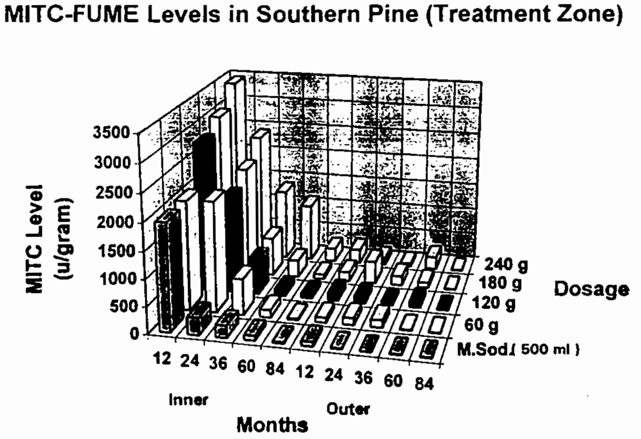
The remedial treatment of wood poles to arrest and prevent fungal deterioration of wood poles saves millions of dollars annually. In North America, fumigants remain the primary chemicals used for this purpose, but there are ever increasing concerns about the handling features of these chemicals. Ideally, a fumigant would remain non-volatile until applied. Solid methylisothiocyanate most closely approaches this goal, but its caustic nature requires that it be encapsulated prior to application and its tendency to remain in the encapsulating tubes for several years after application continues to raise concerns. As a result, there is a continuing need for improved volatile treatments for wood poles.

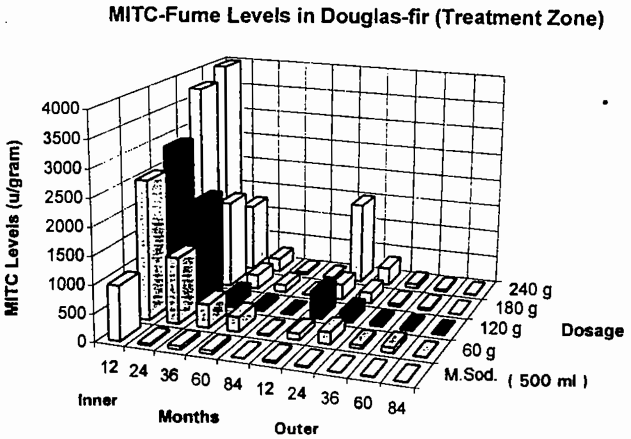
One potential treatment is Basamid (3,5-dimethyltetrahydro 1,3,5,2H-thiadiazine-2-thione). This chemical is a solid crystalline material which slowly decomposes to produce MITC and a variety of other sulfur compounds. Preliminary field tests of Basamid suggested that the decomposition rate was too slow to be effective for controlling established decay fungi (Eslyn and Highley, 1985), but subsequent trials indicated that the rate of decomposition could be markedly improved by addition of bivalent metals, particularly copper (Forsyth and Morrell, 1995). Decomposition also improves with increasing pH, but this approach would be difficult given the low pH of most wood species (Morrell et al., 1988). In 1990, a series of trials was established to evaluate the ability of various materials to accelerate decomposition of Basamid to MITC. The results of these trials were reported 24 months after treatment (Forsyth and Morrell, 1993). These trials have also been monitored for an additional 4 years and the results are reported here.

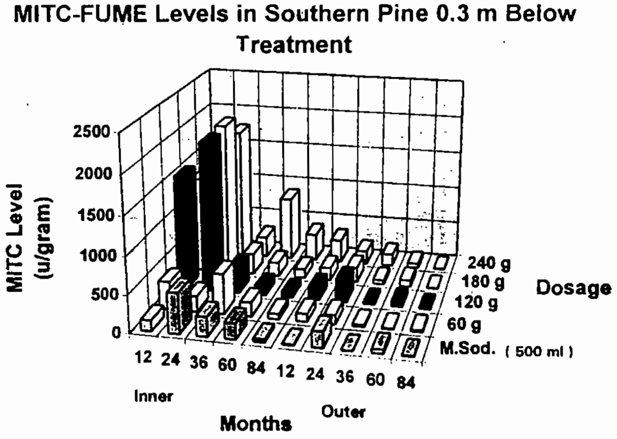
The methods followed those previously described (Forsyth and Morrell, 1993). Briefly, Douglas-fir pole sections (*Pseudotsuga menziesii* (Mirb.) Franco) (250-300 mm in diameter by 1.6 m long) were capped to limit moisture uptake and three 22 mm diameter by 305 mm long holes were drilled at 60 degree angles with 100 mm vertical spacings around the center. Each hole received 50 g of Basamid alone or amended with selected additives (Table I-6). Control poles received either no chemical or 150 ml of metham sodium (32.7% sodium n-methyl-dithio-carbamate). Each treatment was replicated on 5 poles which were


MITC-FUME Levels in Southern Pine 0.3 m Above Treatment


MITC-FUME Levels in Douglas-fir 0.3 m Above Treatment


MITC-FUME Levels in Southern Pine (Treatment Zone)


MITC-Fume Levels in Douglas-fir (Treatment Zone)


MITC-FUME Levels in Southern Pine 0.3 m Below Treatment

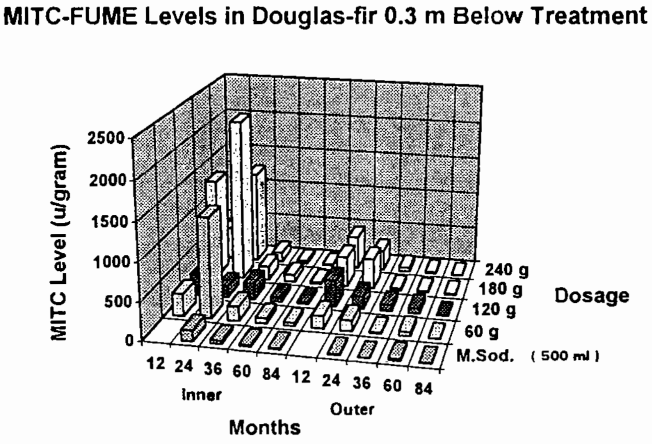

MITC-FUME Levels in Douglas-fir 0.3 m Below Treatment

Figure I-3. Residual MITC in Douglas-fir (a-c) and southern pine (d-f) poles treated with 60, 120, 180, or 240 g of glass-encapsulated MITC or 500 ml of metham sodium at the top of the treatment zone and 0.3 m above or below the treatment zone.

Table 1-5. Residual MITC content, as measured by gas chromatographic analysis of increment cores, in southern pine and Douglas-fir poles 6, 12, 24, 36, 60, and 84 months after treatment with MITC-Fume® or metham-sodium.[a]

VERTICAL DISTANCE FROM TREATMENT ZONE	CORE SEGMENT TESTED[c]	MONTHS AFTER TREATMENT	Residual MITC (µg/g of wood)[b]									
			Southern pine					DOUGLAS-FIR				
			MITC-FUME®				METHAM-SODIUM	MITC-FUME®				METHAM-SODIUM
			60 g	120 g	180 g	240 g	500 ml	60 g	120 g	180 g	240 g	500 ml
-0.3 m	Outer	12	105	179	170	320	10	164	346	401	439	--
		24	125	306	204	185	213	140	168	404	273	15
		36	30	31	56	163	2	18	81	28	55	2
		60	14	70	86	61	56	58	65	24	18	26
		84	27	20	4	14	13	4	0	14	4	5
	Inner	12	369	1534	1282	1644	147	292	270	1327	441	--
		24	203	1996	2028	1754	535	1322	154	2161	1240	143
		36	536	368	284	277	257	186	219	182	127	44
		60	187	120	188	854	212	68	58	95	36	26
		84	73	72	121	372	43	41	26	19	9	17
0.0 m	Outer	12	93	147	169	275	85	119	485	280	1500	41
		24	127	120	426	140	18	219	200	192	322	31
		36	138	62	176	62	1	61	59	51	78	3
		60	10	107	92	235	15	99	36	44	37	18
		84	8	13	7	8	12	12	6	4	12	2
	Inner	12	2031	2777	3009	3425	1986	2525	2879	3745	3985	978
		24	2054	1798	2033	2381	319	1191	1928	1600	1242	34
		36	675	673	736	1332	227	418	223	260	251	68
		60	137	131	330	1085	93	267	70	135	46	64
		84	29	81	85	256	26	30	14	14	8	12
0.3 m	Outer	6	0	1	3	2	0	5	84	132	132	4
		12	38	94	30	29	9	26	12	149	206	11
		24	T	40	33	13	T	46	94	177	311	22
		36	21	42	34	36	2	37	48	63	99	8
		60	9	17	46	37	13	51	31	26	56	30
		84	3	6	3	6	5	7	4	5	6	5
	Inner	6	1	14	12	6	2	132	296	534	624	352
		12	239	316	212	184	96	128	349	1052	262	105
		24	285	353	322	281	54	256	459	363	554	306
		36	77	139	91	135	19	92	142	108	107	24
		60	51	48	47	112	10	29	30	18	28	10
		84	7	19	12	31	8	10	7	2	9	4
0.9 m	Outer	6	0	0	0	0	0	0	2	0	0	0
		12	T	12	13	10	0	34	94	25	34	10
		24	T	T	T	T	0	84	60	40	72	T
		36	1	4	6	5	T	26	40	17	20	4
		60	6	6	5	15	8	21	30	18	28	10
		84	2	4	1	5	4	3	1	2	4	3
	Inner	6	0	0	0	0	0	2	115	4	2	2
		12	T	12	9	T	0	24	198	26	31	102
		24	T	T	T	46	0	149	117	92	165	49
		36	2	12	12	8	T	34	26	28	48	8
		60	8	7	15	15	8	12	22	12	16	15

Table 1-5. Residual MITC content, as measured by gas chromatographic analysis of increment cores, in southern pine and Douglas-fir poles 6, 12, 24, 36, 60, and 84 months after treatment with MITC-Fume® or metham-sodium.[a]

VERTICAL DISTANCE FROM TREATMENT ZONE	CORE SEGMENT TESTED[c]	MONTHS AFTER TREATMENT	Residual MITC (µg/g of wood)[b]									
			Southern pine					DOUGLAS-FIR				
			MITC-FUME®				METHAM-SODIUM	MITC-FUME®				METHAM-SODIUM
			60 g	120 g	180 g	240 g	500 ml	60 g	120 g	180 g	240 g	500 ml
		84	1	5	2	5	2	2	3	1	3	2
1.5 m	Outer	6	0	0	0	0	0	0	0	0	0	0
		12	0	0	0	0	0	5	T	T	T	T
		24	0	0	0	0	0	T	T	T	49	0
		36	0	T	T	2	T	3	3	T	4	T
		60	7	24	3	11	7	9	15	7	16	16
		84	2	4	6	1	3	3	2	2	3	6
	Inner	6	0	0	0	0	0	0	0	0	0	0
		12	0	0	0	0	0	T	T	T	21	0
		24	0	0	0	0	0	T	T	T	120	0
		36	0	T	T	2	T	3	6	3	2	T
		60	5	4	4	12	9	9	9	7	12	14
		84	1	6	3	2	2	2	4	1	1	2

[a] Cores were removed from selected locations at different vertical distances above and below the treatment site.

[b] T - trace amount of MITC present but not quantifiable.

[c] Outer -- 2.5 cm from pole surface; Inner -- 12.5 to 15.0 cm from pole surface.

exposed outside out of ground contact on racks near Corvallis, Oregon.

MITC content was measured at 6, 12, 24, 36, 60, and 72 months after treatment by removing 150 mm long increment cores from three sites equidistant around the pole 150 mm and 450 mm above and below the treatment zone. The cores were divided in half and each half was placed in a test tube containing 5 ml of ethyl acetate. The cores were extracted for 48 hours before the extracts were analyzed for MITC by gas chromatography as previously described (Zahora and Morrell, 1988).

MITC levels over the first 6 months were generally highest in poles receiving metham sodium, reflecting the tendency of this formulation to decompose shortly after treatment to produce MITC. MITC was virtually absent from these same poles 4 or 5 years after application, illustrating the ephemeral nature of this treatment (Table I-6).

MITC levels in poles receiving Basamid alone were initially far lower than those associated with metham sodium but rose steadily over the first year after treatment and have remained consistently higher over the 6 year test period.

The addition of powdered pH 12 buffer in conjunction with Basamid treatment initially appeared to be associated with increased MITC levels, a finding which was consistent with laboratory trials (Morrell et al., 1988; Forsyth and Morrell, 1995). Over the six-year period, however, MITC levels in buffer treatments have declined to levels similar to those found in non-buffer treatments. The absence of a long term effect with buffer addition may be due to the acidity of wood and the relatively small amounts of buffer applied. While higher percentages of buffer might enhance activity, the cost of higher levels may not justify the increase in MITC production.

The inclusion of various additives produced somewhat variable effects on residual MITC levels. A number of these compounds were included because previous studies suggested that they would enhance Basamid decomposition. In most cases, however, these additives had only a temporary influence or no effect on MITC levels. The exception was copper sulfate, which produced a marked effect on MITC levels. Initially, MITC levels were greatest when buffer was present, although this effect has gradually declined with time and average MITC levels are currently higher in Basamid plus copper sulfate treatments without buffer.

The relative effectiveness of Basamid in comparison with metham sodium has frequently been questioned. Bioassays have shown that Basamid decomposes in wood at rates which are eventually toxic to many wood inhabiting fungi, but the rates of control are somewhat slower than found with metham sodium (Highley and Eslyn, 1990). The addition of copper sulfate, and to a lesser extent, the presence of pH 12 buffer resulted in average MITC levels approaching those found with metham sodium. MITC levels in Basamid treatments generally remained elevated for far longer periods (Figure I-4). This provides for both a rapid chemical kill, as is found with metham sodium, and a prolonged protective effect more typical of chloropicrin or MITC Fume. The ability to deliver this effect using a non-volatile, crystalline chemical markedly enhances the safety of the remedial treatment process.

Basamid treatment resulted in residual MITC levels that were initially lower than those found with metham sodium. Eventually, MITC levels in nearly all Basamid treatments exceeded those found with metham sodium. With the exception of copper sulfate, additives had little consistent positive effect on MITC levels and their potential benefit in enhancing Basamid effectiveness is questionable. Copper sulfate provided the most consistent improvement in MITC levels and its inclusion in Basamid treatments for wood merits further evaluation.

6. *Treatment of Douglas-fir transmission poles with Basamid and copper*: The initial field trials using untreated Douglas-fir poles exposed above ground indicated that the addition of copper compounds markedly enhanced the

TABLE I-6. MITC distribution in Douglas-fir pole sections 0.5 to 6 years after internal treatment with metham-sodium or Basamid amended with amended additives.

Treatment	pH 12[b]	Year	ug MITC/OD g wood								
			+45 cm[a]		+15 cm		-15 cm		-45 cm		
			Outer	Inner	Outer	Inner	Outer	Inner	Outer	Inner	Mean[d]
Metham-sodium	-	0.5	-	-	113.3	195.6	173.4	104.2	-	-	147
	-	1	9.6	79.1	29.9	80.4	19.8	54.5	12.2	34.5	40
	-	2	8.4	15.7	5.0	21.3	5.3	14.3	2.3	5.0	10
	-	3	1.7	3.7	5.3	10.6	4.3	3.5	2.5	3.1	4
	-	4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.7	0
	-	6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0
Basamid Alone	-	0.5	-	-	9.5	16.6	12.9	19.9	-	-	14
	-	1	5.2	13.7	9.7	10.8	5.9	26.5	1.1	5.6	10
	-	2	2.6	3.7	4.1	8.1	6.1	7.7	3.8	3.1	5
	-	3	11.6	14.8	6.0	20.0	15.3	60.7	9.7	12.4	18
	-	4	1.2	6.9	29	21.9	13.4	87.9	16.6	13.5	21
	-	6	2.3	4.0	12.4	35.0	17.5	86.0	23.2	37.1	27
	+	0.5	-	-	9.3	14.6	16.4	100.5	-	-	44
	+	1	0.0	5.7	0.2	13.5	11.0	44.8	0.1	10.8	11
	+	2	0.0	0.6	0.0	7.2	3.6	32.5	1.7	8.3	7
	+	3	3.1	5.8	10.9	21.9	24.9	49.0	9.3	16.6	18
	+	4	0.0	3.8	12.7	15.5	10.7	43.3	6.8	23.1	15
	+	6	1.1	1.8	10.1	29.2	7.3	15.5	24.2	58.4	18
Basamid plus $CuSO_4$	-	0.5	-	-	15.9	45.9	10.2	39.1	-	-	27
	-	1	20.8	17.8	11.2	45.7	13.5	48.6	0.0	3.9	20
	-	2	5.9	9.1	10.3	47/1	11.7	66.7	0.4	6.8	20
	-	3	3.4	12.7	34.1	104.9	43.1	95.2	14.5	5.4	39
	-	4	4.1	24.7	19.6	87.3	27.2	106.9	6.8	25.3	38
	-	6	10.3	27.6	34.8	120.4	27.9	86.0	13.3	25.6	43
Basamid plus $CuSO_4$	+	0.5	-	-	55.3	58.1	90.5	95.4	-	-	75
	+	1	8.2	76.3	22.0	120.8	21.4	203.1	6.7	64.3	65
	+	2	49.2	47.6	69.9	63.9	99.7	96.5	95.8	124.5	81
	+	3	50.1	48.5	60.7	59.4	72.1	69.6	79.9	78.9	65
	+	4	3.4	15.7	13.8	44.3	17.5	62.5	12.0	46.1	27
	+	6	3.9	11.3	7.8	38.5	20.3	46.4	9.4	17.0	19
Basamid plus glucose	-	0.5	-	-	7.6	13.2	1.3	20.5	-	-	11
	-	1	0.5	0.2	1.7	17.1	4.8	32.8	2.6	3.7	8
	-	2	0.0	0.0	2.7	13.8	7.8	30.9	0.0	3.5	7
	-	3	2.2	7.8	33.2	62.1	35.2	112.4	160	30.0	8
	-	4	2.4	13.1	7.9	57.6	30.3	84.7	11.5	28.5	30
	-	6	2.0	4.0	10.4	28.1	21.9	83.7	17.4	49.9	27
	+	0.5	-	-	16.6	37.1	17.6	62.8	-	-	33
	+	1	1.8	20.0	6.8	76.9	81.7	14.2	33.1	21.6	32
	+	2	0.6	1.9	9.0	33.5	21.2	54.5	2.3	5.0	16
	+	3	1.2	3.9	9.3	29.4	48.7	91.8	9.0	23.9	27
	+	4	2.2	4.2	10.4	18.4	27.5	62.0	2.9	2.5	16
	+	6	5.4	5.9	17.8	39.9	20.7	40.8	5.9	10.4	18

Treatment	pH 12[b]	Year	ug MITC/OD g wood								
			+45 cm[a]		+15 cm		-15 cm		-45 cm		Mean[d]
			Outer	Inner	Outer	Inner	Outer	Inner	Outer	Inner	
Basamid plus lignin	-	0.5	-	-	0.2	5.5	1.3	23.2	-	-	8
	-	1	1.4	2.8	2.9	24.9	4.8	93.1	2.1	14.0	18
	-	2	1.5	2.5	4.0	17.8	15.5	52.1	3.1	18.7	14
	-	3	2.3	6.6	8.7	20.8	16.0	33.0	3.7	5.8	12
	-	4	4.9	4.8	3.6	6.0	9.7	30.7	1.6	8.3	9
	-	6	-	-	-	-	-	-	-	-	-
	+	0.5	-	-	3.3	27.0	4.2	41.3	-	-	19
	+	1	3.2	17.4	7.0	63.6	16.1	79.6	5.5	3.0	24
	+	2	0.0	1.6	1.2	26.4	7.7	50.7	0.0	9.8	12
	+	3	2.1	1.6	19.3	13.5	35.3	28.9	3.1	9.2	14
	+	4	0.0	8.5	6.9	46.8	5.6	52.7	4.3	10.8	17
	+	6	1.0	3.4	6.0	30.8	14.7	48.4	4.1	7.6	15
Basamid plus boron	-	0.5	-	-	9.5	17.9	18.9	33.1	-	-	20
	-	1	0.4	11.3	6.6	30.8	15.0	49.6	0.1	5.2	15
	-	2	0.6	1.6	4.5	12.7	5.8	25.5	1.2	2.9	7
	-	3	0.3	0.3	7.6	17.9	21.6	27.1	2.6	2.6	10
	-	4	2.3	5.6	13.4	20.7	31.9	55.4	4.1	17.5	19
	-	6	5.2	10.9	21.6	45.2	35.0	69.9	5.7	20.8	27
	+	0.5	-	-	7.0	11.6	8.0	30.4	-	-	14
	+	1	0.0	11.8	7.7	24.2	17.2	33.5	1.0	5.6	13
	+	2	0.2	1.1	3.5	13.0	9.2	29.3	2.0	5.8	8
	+	3	29.2	54.5	8.8	17.7	66.5	33.8	11.3	49.1	34
	+	4	2.9	2.3	2.0	9.3	8.0	38.8	1.6	11.9	10
	+	6	3.4	7.4	15.2	32.6	20.2	43.8	5.9	9.4	17
Basamid plus ethanol	-	0.5	-	-	3.0	6.0	0.1	12.0	-	-	5
	-	1	0.0	2.1	0.4	15.3	0.2	7.3	0.0	0.0	3
	-	2	0.0	0.5	1.8	4.7	1.8	6.3	0.4	0.2	2
	-	3	0.1	0.8	1.0	8.4	3.0	12.5	0.7	1.4	4
	-	4	6.7	4.7	8.3	23.9	14.2	24.1	2.3	7.1	11
	-	6	2.9	3.2	2.2	16.8	4.4	9.3	2.2	7.9	6
Basamid plus acetone	-	0.5	-	-	1.2	4.4	1.0	8.2	-	-	4
	-	1	4.3	18.3	9.3	17.0	15.2	26.1	15.6	12.9	15
	-	2	0.0	0.0	2.8	8.3	7.2	16.0	0.9	1.3	5
	-	3	2.0	4.2	9.3	27.3	14.0	38.2	7.0	15.3	14
	-	4	0.0	0.0	2.4	25.8	14.4	181.2	10.1	18.1	32
	-	6	1.9	3.2	5.3	24.8	27.4	124.7	5.1	12.8	26
Basamid plus methanol	-	0.5	-	-	2.8	7.2	0.8	16.0	-	-	8
	-	1	0.0	0.1	0.0	3.7	0.2	9.5	0.3	0.6	2
	-	2	0.0	0.5	0.8	3.3	2.6	8.6	0.0	0.1	2
	-	3	0.2	0.9	9.6	11.6	19.0	28.7	7.2	5.0	10
	-	4	0.0	0.0	0.9	7.0	0.0	44.1	2.0	4.4	7
	-	6	0.0	0.0	5.4	13.0	1.5	9.4	0.0	3.1	4

Treatment	pH 12[b]	Year	ug MITC/OD g wood								Mean[d]
			+45 cm[a]		+15 cm		-15 cm		-45 cm		
			Outer	Inner	Outer	Inner	Outer	Inner	Outer	Inner	
Basamid plus water	-	0.5	-	-	1.0	3.0	1.6	14.8	-	-	5
	-	1	0.0	1.2	0.0	2.3	0.4	8.3	0.0	0.0	2
	-	2	0.3	2.0	1.5	7.3	5.1	22.1	2.6	7.7	6
	-	3	0.0	0.2	1.6	6.0	9.6	79.8	6.2	5.5	14
	-	4	3.3	8.1	3.4	14.6	11.3	80.7	2.6	7.0	16
	-	6	0.6	1.4	9.9	23.3	16.3	122.5	11.1	50.6	30

[a] Values are distance above (+) and below (-) treatment zone. Cores were broken in half and analyzed separately as “outer” and “inner” segments. Values represent mean of 15 core segments. Mean values for all 120 core segments within each treatment group.

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

[c] "-" indicates no core was taken at this location.

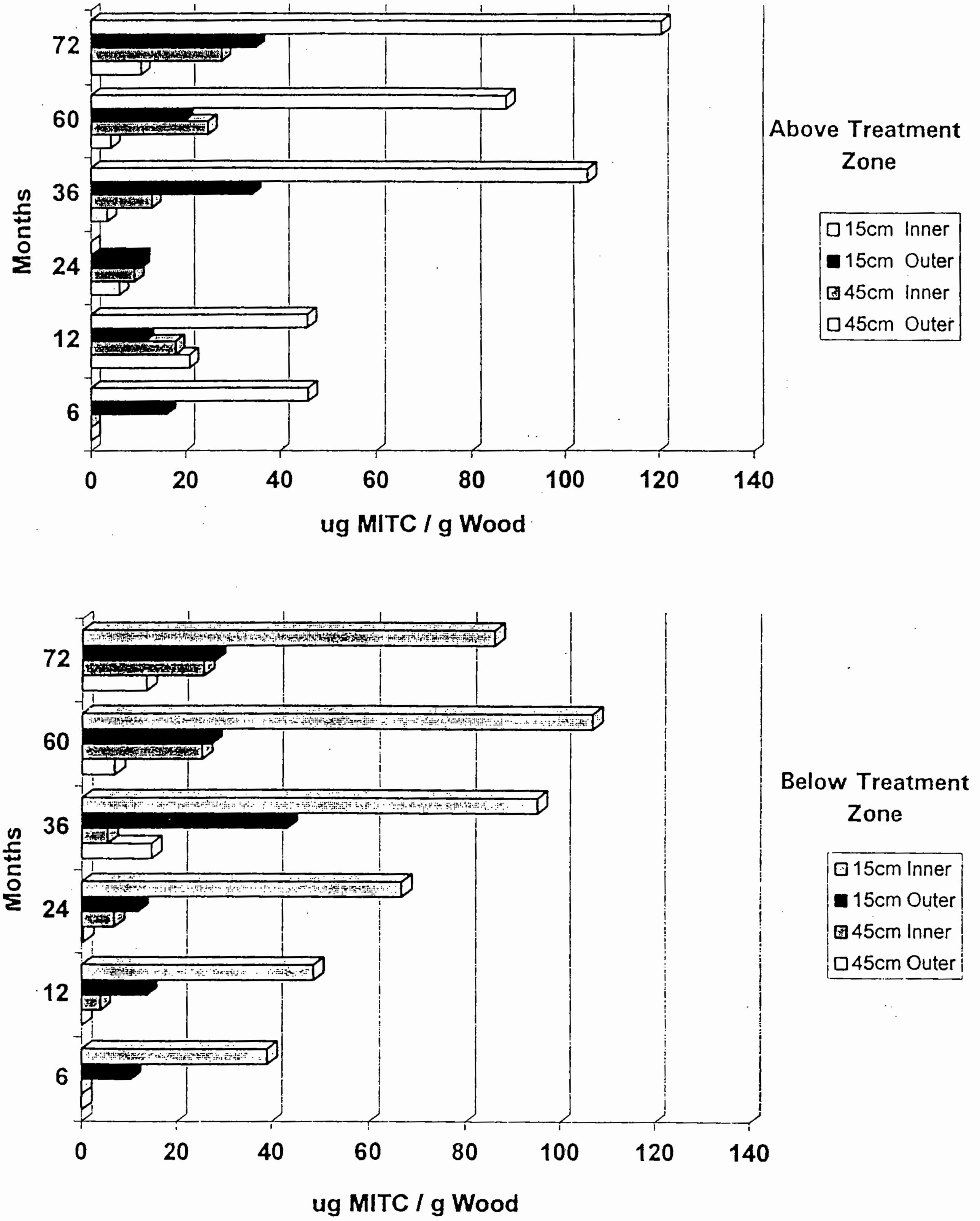


Figure I-4. Residual MITC 15 or 45 cm above (A) or below (B) the treatment zone of Douglas-fir pole sections 6 to 72 months after treatment with basamid plus copper sulfate.

decomposition of Basamid (Forsyth and Morrell, 1994). These tests were performed in untreated wood and might not be representative of a full scale pole with an oil-treated shell. To develop this information, a series of three 19 mm diameter by 375 mm long steeply sloping holes were drilled into pentachlorophenol-treated Douglas-fir transmission poles. These holes began at groundline and moved upward at 150 mm intervals and 120 degrees around the pole. Poles received 200 or 400 g of powdered Basamid with or without 1% copper sulfate. An additional set of poles received 500 g of metham sodium to serve as treated controls. Each treatment was replicated on 5 poles.

Basamid and metham sodium must both decompose to methylisothiocyanate (MITC) to become effective as a fungicide. MITC levels were measured in wood samples to assess decomposition efficiency. Increment cores were removed from three equidistant sites 0, 1, 2, and 3 m above the highest treatment hole. These poles were originally through-bored, making sampling below the lowest fumigant treatment site impractical. The outer, preservative-treated shell from each core was discarded, then the inner and outer 25 mm of each core was individually placed into test tubes containing 5 ml of ethyl acetate. The cores were extracted for a minimum of 48 hours, then the extracts were analyzed for residual MITC by gas chromatography. The remainder of the core was cultured for the presence of decay fungi.

MITC levels were generally low in both 200 g Basamid treatments as well as the 400 g Basamid treatment without copper in comparison with the metham sodium control (Table I-7). MITC levels in 400 g treatments with copper were similar to those found with metham sodium. Metham sodium is generally considered to be a fairly short term treatment which results in detectable MITC for 2 to 3 years. MITC levels then decline fairly rapidly after that point and there is little evidence of protection in Douglas-fir poles 5 to 7 years after treatment. MITC levels increased in the groundline zone of all Basamid treatments 2 years after application. While levels were sometimes higher when copper was added to the holes, the differences were generally small and inconsistent. As a result, the benefits of copper may not be initially evident. As expected, MITC levels were higher near the groundline, reflecting the proximity to the treatment holes. MITC levels were somewhat variable 1 m above the treatment zone (Figure I-7). MITC levels were exceedingly low 2 and 3 m above the treatment zone regardless of treatment suggesting that the protective zone for this treatment was 1 m above or below the original treatment sites (Figure I-5).

Culturing revealed that a single decay fungus was isolated from metham sodium treated poles at the time of treatment while none have been isolated from any Basamid treatments at either sampling point (Table I-8).

The results indicate that Basamid is decomposing at levels at least comparable to metham sodium and should be a viable field treatment for controlling internal decay of Douglas-fir poles.

7. Effect of glycol and moisture on diffusion of boron from fused boron rods: Last year (95 Annual Report, Pages 41-43), we reported on the establishment of trials to evaluate the effects of glycol on movement of boron from fused boron rods. Thirty Douglas-fir poles (25 to 30 cm in diameter by 3.6 m long) were treated with pentachlorophenol in P9 Type A solvent and installed to a depth of 0.6 m at our Corvallis test site. Three 17.5 mm diameter by 267 mm long holes were drilled at 45 degree angles into the pole, 75 mm above the groundline. The poles received the combinations of boron rod and ethylene glycol (Table I-9).

The treatment holes were plugged with tight fitting wooden dowels. The treatments delivered 220 to 224 g of boric acid equivalent (BAE) to each pole.

One year after treatment the poles were sampled for both boron and moisture content by removing duplicate sets of increment cores from three equidistant sites around each pole - 300 mm, 0, 150 mm and 300 mm above the groundline. The outer, pentachlorophenol

Table I-7. Residual MITC in pentachlorophenol treated Douglas-fir transmission poles 1 and 2 years after internal treatment with 200 or 400 g of Basamid alone or amended with 1% (wt.) of copper sulfate as compared with similar poles receiving 500 ml of metham-sodium.

Chemical	Years	Copper Sulfate Added	Dosage (g)	Residual MITC (µg/g oven dried wood)[a]							
				Distance above treatment zone (m)							
				0		1 m		2 m		3 m	
				inner	outer	inner	outer	inner	outer	inner	outer
Metham-sodium	1	-	500	21	30	57	38	1	--	1	--
	2	-		47	16	13	10	4	2	3	4
Basamid	1	-	400	4	22	16	56	1	--	--	1
	2	-		51	39	7	4	4	3	5	3
	1	+	400	25	24	31	64	--	--	--	1
	2	+		62	33	11	3	6	4	3	3
Basamid	1	-	200	3	7	3	16	--	--	1	--
	2	-		72	54	11	6	2	1	4	8
	1	+	200	12	14	26	42	--	1	2	--
	2	+		69[b]	150[b]	8	2	2	2	3	6

[a] Values reflect means of 15 samples per position for Basamid and 30 for metham sodium. Core positions reflect inner and outer 25 mm of each increment core; (-) signifies no MITC detected.

[b] Data may represent an artifact.

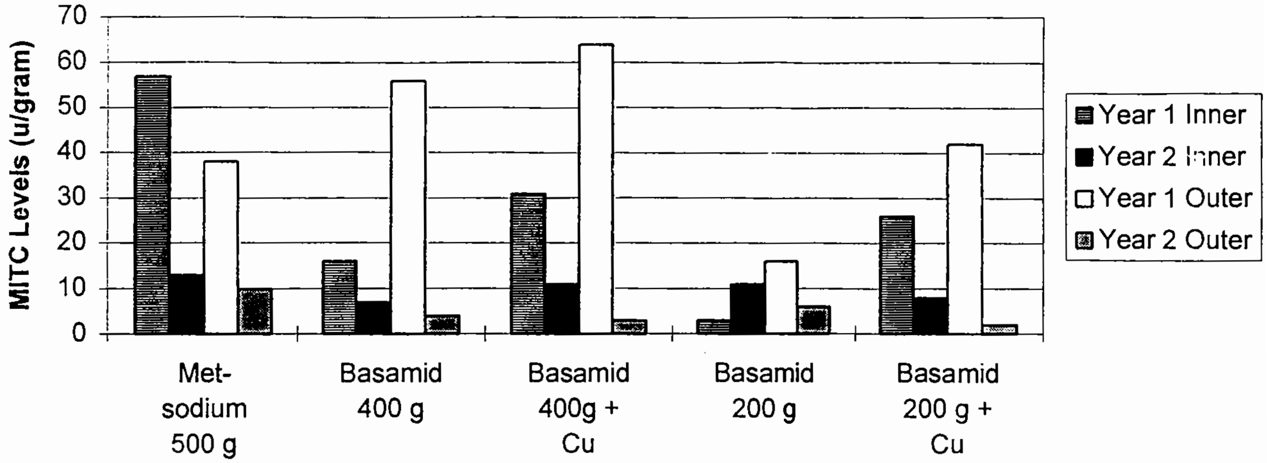
Table I-8. Fungal colonization in Douglas-fir poles 2 years after treatment with metham sodium or basamid with and without copper sulfate.

Treatment	Dosage (g)	Cu	Cores with Decay (DF) and Non-Decay (F) Fungi %[a]									
			1993		1995 -- Distance from Treatment Hole (m)							
					0		1		2		3	
			DF	F	DF	F	DF	F	DF	F	DF	F
Metham sodium	500 ml	-	3	23	0	10	0	20	0	20	0	10
Basamid	400 g	-	0	33	0	13	0	13	0	13	0	13
Basamid + Cu	400 g	+	0	33	0	13	0	13	0	20	0	20
Basamid	200 g	-	0	0	0	7	0	27	0	20	0	13
Basamid + Cu	200 g	+	0	20	0	7	0	27	0	13	0	20

*1993

[a] Initial samples were shavings from the treatment hole. DF=decay fungi, F=all other fungi. Values represent 15 samples/treatment.

Residual MITC of Inner and Outer Cores 1 m above Treatment Zone of Douglas-fir Transmission Poles 1 & 2 Years after Treatment



Residual MITC of Inner and Outer Cores in the Treatment Zone of Douglas-fir Transmission Poles 1 & 2 Years after Treatment

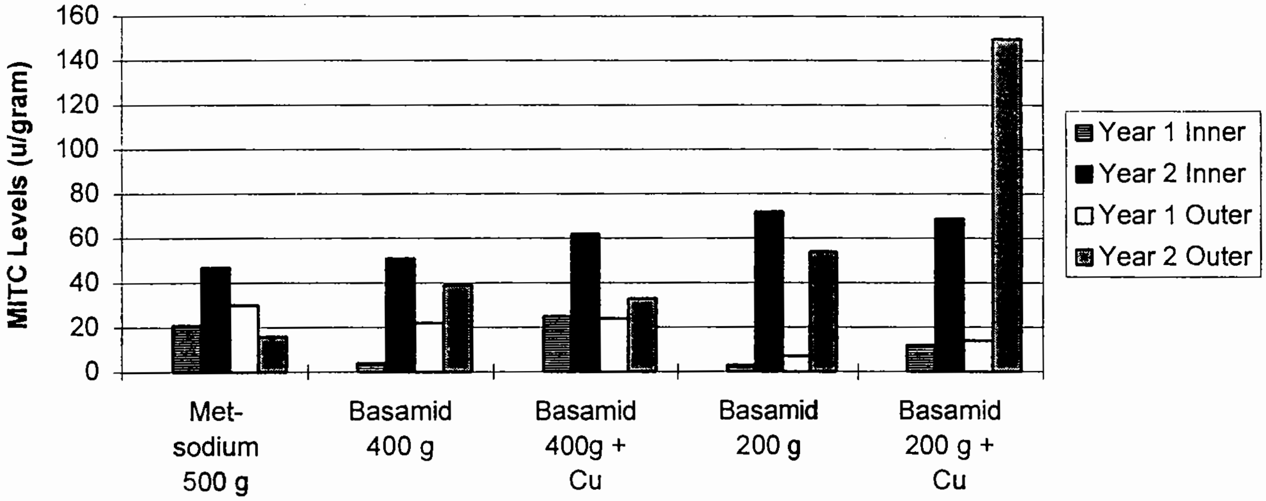


Figure I-5. Residual MITC in Douglas-fir transmission poles 1 to 2 years after treatment with 200 or 400 g of Basamid with or without copper sulfate in comparison with 500 g of metham sodium.

treated shell from each core was discarded. The cores for boron analysis were divided into three equal zones and air-dried for several days. The cores were then oven dried at 54°C for 24 hours and cores from the same sampling height for a given pole were combined before being ground to pass a 20 mesh screen. The resulting wood dust was extracted and analyzed for boron content by Ion Coupled Spectroscopy (ICP) on a blind sample basis by CSI, Inc.

Boron levels in poles receiving only rods were generally low (<0.1% BAE) 1 year after treatment (Table I-10), even at the groundline, where moisture levels should be adequate for boron diffusion. Boron levels in rod-only treatments increased from outer to inner sampling zones, but the differences were slight. The addition of glycol, either alone or with small amounts of boron, resulted in far higher levels of boron in the wood in all but a few treatments (Figure I-6). Boron levels were highest in the inner zone at groundline in poles receiving Boracol 40. Boron levels at groundline were similar to one another and slightly lower than Boracol 40 in poles receiving either Boracol 20 or glycol. Poles receiving Timbor or Boracare had slightly lower boron levels in the inner zone near groundline. Boron levels were slightly more variable 150 or 300 mm above the groundline, reflecting natural variation in moisture content. For example, boron levels at sites 150 mm above the groundline were highest with the boron rod plus Timbor treatment, while levels were highest with Boracare plus boron rods 300 mm above the groundline.

Interestingly, boron levels 300 mm below ground were higher than those 150 or 300 mm above ground, but did not exceed those at groundline for most treatments. Boron levels in the outer zone, however, were slightly elevated, suggesting that boron might be diffusing towards the pole surface. The test poles are exposed on a site which is extremely wet in the winter and this high moisture level may encourage boron loss. Further sampling will be necessary to confirm these trends.

The cores removed for moisture content analysis were divided into three equal segments (inner, middle and outer) and each segment was immediately placed in a tared glass test tube which was tightly capped to retard moisture loss. The tubes were then returned to the laboratory and weighed. Subtraction of the tare weight yielded an initial wet weight. The tubes containing cores were then oven-dried for 24 hours at 105° C and the cores were weighed. The weight wet and final oven dry weight were then used to determine wood moisture content.

Moisture contents of the poles varied from 14 to 89%, although most of the values were between 20 and 40%. These initial moisture samples were taken during the winter when wood moisture contents would be expected to be elevated. Most rainfall at the Corvallis test site falls between November and April. This past year, rainfall levels exceeded 150 cm, about 50 above normal. In addition, the test site soil tends to become water-logged during the winter months further enhancing conditions for increased wood moisture levels. Average moisture readings for all cores tended to be highest below the groundline, then declined slightly at groundline and remained similar further upward (Figure I-6). Moisture contents were generally highest in the inner zone and tended to vary between the middle and outer zones. The heavy oil shell surrounding these poles should minimize wide fluctuations in moisture since nearly all incoming moisture will likely move through checks into the surrounding wood. Thus, the differences between inner and outer zones should be less extreme than would be found with untreated wood in similar exposures. Given the ratio of check surface area to wood volume in an environment where excessive water was present, one would expect the inner zones to absorb more moisture since they contain a correspondingly lower volume of wood.

Moisture contents did not differ among most treatments, although moisture levels were significantly higher for the boron rod/boracol 20 (Treatment D) at the 300 mm above ground sampling site (Table I-11). The reasons for the increased moisture level in this treatment are unclear and will require additional sampling to determine if this difference is real or an artifact.

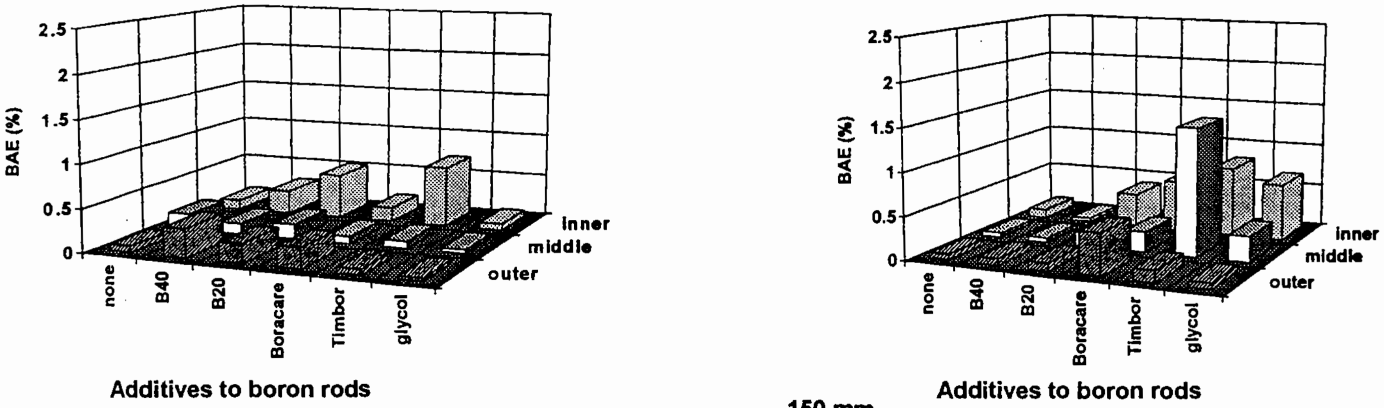
Table I-9. Boron rod/glycol treatments applied to Douglas-fir poles in 1995.

TREATMENT	REPS	DOSAGE (g)	
		BORON ROD (g)	ADDITIVE
A	5	152	-
B	5	152	ethylene glycol (140 g)
C	5	91	Boracol 40 (199 g)
D	5	125	Boracol 20 (183 g)
E	5	125	10 % Boracare (177 g)
F	5	140	10 % Timbor (170 g)

Table I-10. Residual boron in Douglas-fir poles 1 year after treatment with combinations of boron and glycol.

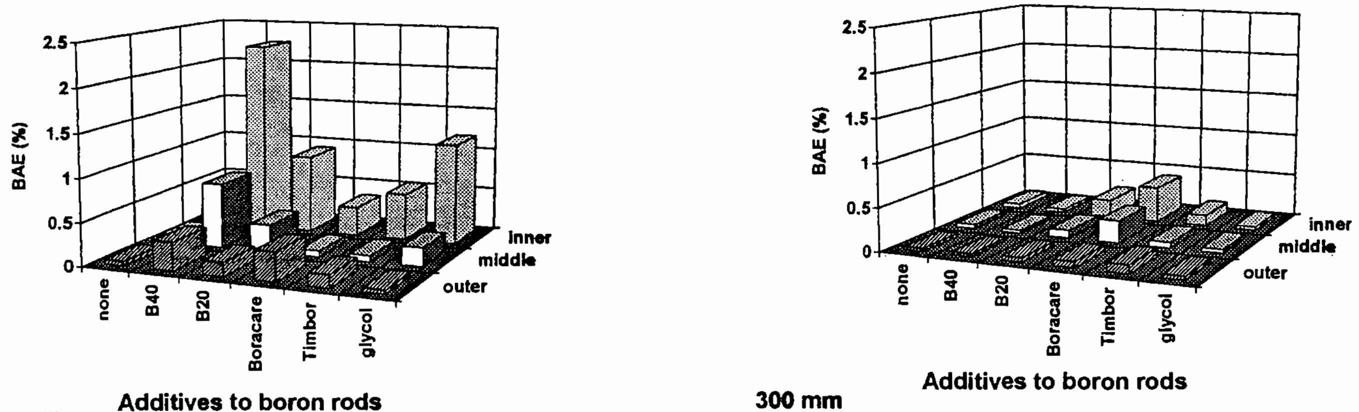
Treatment	Boron Concentration (%BAE)											
	-300mm			0			150mm			300mm		
	inner	middle	outer	inner	middle	outer	inner	middle	outer	inner	middle	outer
Rods only	0.111 (0.090)	0.180 (0.267)	0.072 (0.026	0.292 (0.381)	0.077 (0.048)	0.053 (0.026)	0.099 (0.059	0.050 (0.013)	0.067 (0.035)	0.051 (0.026)	0.045 (0.013)	0.035 (0.019)
Rods + B40	0.274 (0.306)	0.123 (0.082)	0.329 (0.510)	2.261 (1.655)	0.755 (0.537)	0.328 (0.437)	0.042 (0.023)	0.049 (0.006)	0.080 (0.050)	0.040 (0.024)	0.033 (0.020)	0.034 (0.022)
Rods + B20	0.518 (0.890)	0.169 (0.129)	0.222 (0.150)	0.917 (1.119)	0.322 (0.416)	0.161 (0.174)	0.397 (0.205)	0.161 (0.139	0.096 (0.071)	0.201 (0.278)	0.090 (0.074)	0.052 (0.012)
Rods + Boracare (25 g/hole)	0.162 (0.216)	0.081 (0.039)	0.239 (0.355)	0.338 (0.296)	0.071 (0.036)	0.337 (0.466)	0.597 (0.492)	0.237 (0.219)	0.486 (0.804)	0.907 (0.239)	0.259 (0.380)	0.073 (0.038)
Rods + Timbor (25 g/hole)	0.700 (1.091)	0.083 (0.045)	0.065 (0.036)	0.545 (0.522)	0.072 (0.035)	0.145 (0.126)	0.809 (0.666)	1.473 (2.448)	0.140 (0.160)	0.122 (0.047)	0.065 (0.020)	0.100 (0.064)
Rods + ethylene glycol	0.071 (0.058)	0.042 (0.013)	0.036 (0.021)	1.182 (1.780)	0.218 (0.239)	0.047 (0.032)	0.650 (0.704)	0.300 (0.305)	0,070 (0.039)	0.038 (0.022)	0.042 (0.009)	0.044 (0.008)

a Where locations represent distance above or below the groundline. Inner, middle, and outer zones represent thirds of a 15 mm long increment core. B20=Boracol 20, B40=Boracol 40.



-300 mm

150 mm



Groundline

300 mm

Figure I-6. Residual boron levels in the inner, middle, and outer thirds of increment cores removed from sites 300 mm below groundline, at groundline, and 150 or 300 mm above groundline, in Douglas-fir poles 1 year after treatment with boron rods and selected treatment additives.

Table I-11. Wood moisture contents at selected zones in Douglas-fir poles 1 year after treatment with combinations of boron and glycol.

	Wood Moisture Content (%)											
	-300mm			0			150mm			300mm		
Treatment	Inner	Middle	Outer	Inner	Middle	Outer	Inner	Middle	Outer	Inner	Middle	Outer
A	53	41	41	35	29	32	28	27	29	27	28	29
B	42	35	39	31	24	28	24	26	26	22	23	24
C	37	40	37	38	27	25	27	21	22	25	22	24
D	38	35	37	36	26	26	31	25	26	38	34	30
E	37	32	37	32	25	27	30	26	23	26	26	24
F	35	37	35	33	28	27	30	29	27	27	28	27

Values represent means of 9 replicates per position per treatment. See Table *** for key to treatments.

Moisture levels in all treatments were generally higher at the below ground sampling site. Average moisture contents of all treatments from this zone were above 30%, suggesting that conditions were adequate for both boron diffusion and fungal growth. Moisture contents in the groundline samples varied more widely. Samples from the inner zones were generally above 30%, again indicating that conditions were suitable for diffusion and fungal attack. Average moisture levels in the middle and inner zones were between 24 and 32%, with the majority of samples falling below 28%. Moisture contents of samples from inner zones of cores removed 150 mm above the groundline ranged from 24 to 31%, with three of six averages at or above 30%. Moisture contents further into cores for this zone were much lower ranging from 21 to 29%. Moisture levels were generally lower in samples removed from sites 300 mm above the groundline, with the exception of the boron rod/boracol 20 treatment. Average moisture contents for all three sampling depths with the treatment were at or above 30%. It is unclear why the moisture contents in this particular treatment are so elevated as noted above and we will continue to sample poles in this treatment to develop more comprehensive moisture content data.

***8. Seasonal moisture distribution in Douglas-fir poles*:** Last year, we reported on an effort to track internal moisture contents of Douglas-fir poles seasonally using permanent sampling sites installed to various depths both above and below the groundline of poles treated with combinations of boron rod and glycol (95 Annual Report, pages 43,48). Briefly, pins were set 25, 75, or 150 mm into the poles, 150 mm below groundline as well as at groundline and 150 or 300 mm above this zone. The pins were sealed into the wood using epoxy resin and a rubber cap was placed over each pin to protect it from weathering. Resistance was measured monthly by attaching clips to the pins using a 30 volt AC power supply across each electrode. The results at 25 and 75 mm were compared with similar readings taken using a conventional resistance-type moisture meter. Last year, we reported that resistance declined with distance above ground and with time after installation. These measurements were taken during the drier summer months and appeared to reflect actual moisture conditions.

We have continued measuring these test sites through the winter to better understand the rate at which moisture contents change in the interior of a pole. This information is useful for predicting potential decay hazard, but more importantly, can be useful for predicting the potential distribution of water-diffusible biocides such as boron or fluoride.

Resistance readings in poles remained low in June, increased slightly in July, then returned to a lower level in August, suggesting that the resistance might provide a useful method for measuring seasonal moisture changes. Resistance readings taken in December, however, were uniformly low (Figure I-8,9). While this initially suggested that moisture levels in the poles had risen rapidly in response to the onset of the wet season, further examination of the pins indicated that many of the sites were extremely wet. Apparently as moisture ran down the pole, it entered the pin holes where it rapidly altered resistance. Resistance-type meter readings at sites adjacent to the pins indicated that wood moisture contents in these zones easily exceeded 30% in December, even 90 mm below the surface. Moisture measurements 25 mm away from these sampling sites, however, resulted in moisture contents between 17 and 21%. As a result of the inability to maintain resistance pin integrity with the wood, we abandoned this effort and instead removed additional increment cores during boron sampling of the test poles.(Objective I-7)

***9. Chemical movement of a fluoride/boron rod through Douglas-fir poles*:** While boron rods have received the most widespread attention as a water diffusible remedial treatment, a boron/fluoride rod is also available outside the U.S. This formulation consists of 24.3% sodium fluoride and 58.2% sodium

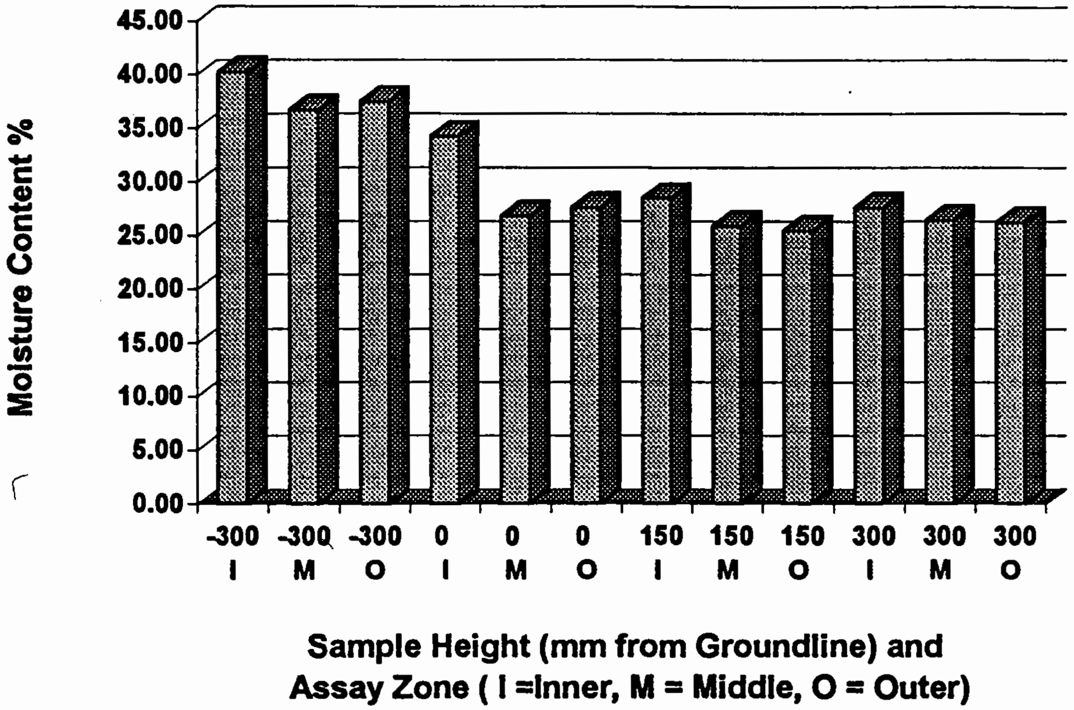


Figure I-7. Average moisture content of increment cores removed from selected heights above or below groundline of Douglas-fir poles 1 year after installation.

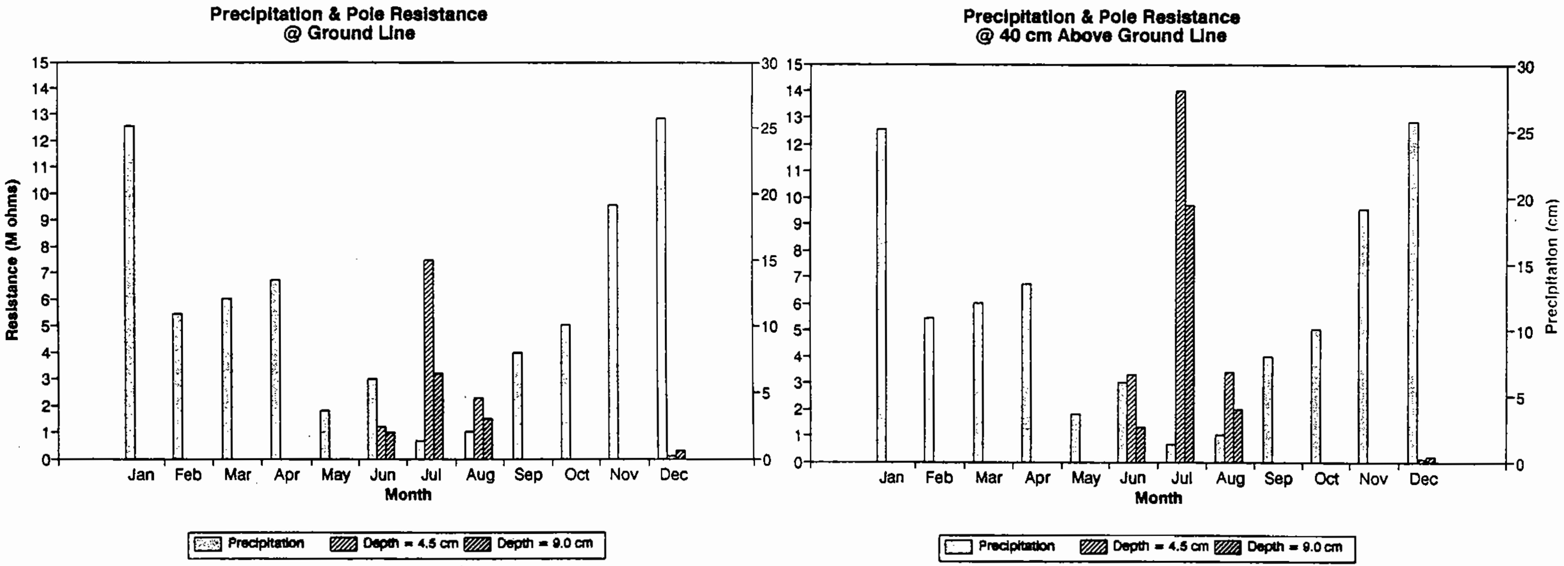


Figure I-8. Resistance measurements at selected depths in Douglas-fir poles at groundline or 400 mm above that zone vs precipitation.

octaborate tetrahydrate in a chalk-like rod.

This formulation has been reported to move well through various Eucalyptus species, but there are no data on the performance of this system in coniferous woods such as Douglas-fir.

Douglas-fir poles (3.6 m long x 250-300 mm in diameter) treated with pentachlorophenol in oil, were set in the ground to a depth of 0.3 m. A series of 3 holes (19 mm in diameter x 250 mm long) were drilled at steep sloping angles beginning at groundline, moving upward at 150 mm intervals, and around the pole at 90 or 120 degrees. A total of 70.5 or 141 g of boron/fluoride rod was equally distributed among the three holes which were plugged with tight-fitting wood dowels.

Boron and fluoride levels in the poles were assessed annually by removing increment cores from 3 equidistant sites around each pole: 300 mm below, 300 mm above, and 800 mm above the groundline. The outer, treated zone from each core was discarded, and the inner and outer 25 mm of each core were segregated. Core segments from the same location at a given sampling height were combined for the five poles in each treatment group and ground to pass a 20 mesh screen. One half of the sample was hot-water-extracted and analyzed for boron content using the azomethine H-method. The remainder of each sample was hot-water-extracted and analyzed for fluoride content using a specific ion electrode.

Fluoride levels were low at all sampled locations (Table I-13). None of the levels approached those required for protection against fungal attack (Figure I-10) (Becker, 1976). Boron levels were also generally low at all locations although the levels were much higher than those found with fluoride. Boron is generally effective against decay fungi at levels between 0.25 and 0.5% BAE. Using this range, all sampling sites 300 mm below ground were at or above 0.25% BAE. Three were above this level 300 mm above groundline and none were above this level 600 mm above ground 1 year after treatment (Figure I-11).

Boron levels were above 0.25% in only two sampling sites 2 years after treatment. The relatively light chemical loadings found in this test are perplexing, given the generally good movement of both boron and fluoride through most wood species. Furthermore, boron levels have generally increased in Douglas-fir poles between 1 and 3 years after treatment in other tests with boron rods. The levels of both boron and fluoride present in the formulation tested are much lower than those found with the borate rods. This lower dosage level apparently results in ineffective levels of either chemical unless higher dosages of chemical are applied.

10. Effect of glycol and moisture content on diffusion of boron from fused boron rods: Although we have established a variety of boron rod field trials, the results from these tests have indicated that boron movement through Douglas-fir appears to be slower than through other wood species. While the reasons for these differences remain unknown, it is clear that methods must be identified for accelerating boron movement through this wood species. One approach to enhancing movement is the addition of glycol to the boron at the time of application. Previous trials in Europe suggest that glycol enhances boron diffusion through drier wood, thereby producing more effective control under moisture regimes which would normally not be conducive to this treatment.

To study these effects, 38 by 88 by 150 mm long blocks were pressure soaked with water and conditioned to one of three moisture contents (15, 30, or 60%). The blocks were then dipped in molten wax to retard further changes in MC and the wood was stored for an additional 4 weeks at 5°C to encourage more even distribution of moisture.

A single 9.5 or 11.1 mm by 60 mm long hole was drilled at the midpoint of the 39 mm wide face of each block and a measured amount of boron alone or with Boracol 20, Boracol 40, Boracare (diluted 1:1 with water), 10% Timbor, or glycol was added to each hole. The holes were plugged with ~~rubber serum caps~~ wooden dowels and incubated at room temperature for ~~4~~, 8, or ~~16~~ 12 weeks.

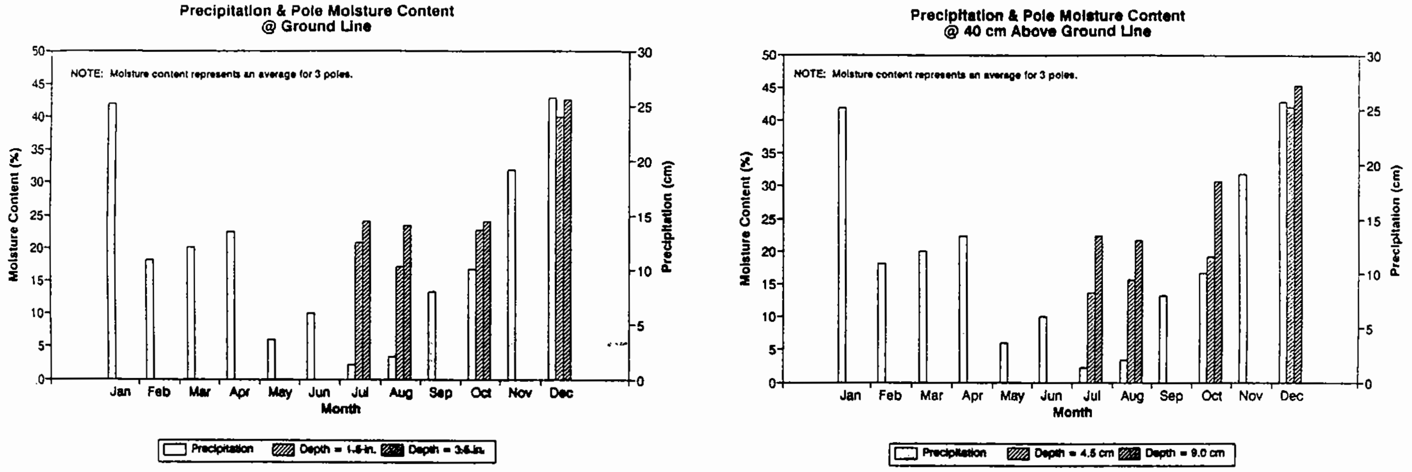


Figure I-9. Moisture content 45 or 90 mm from the wood surface of Douglas-fir poles at groundline or 400 mm above that zone vs precipitation.

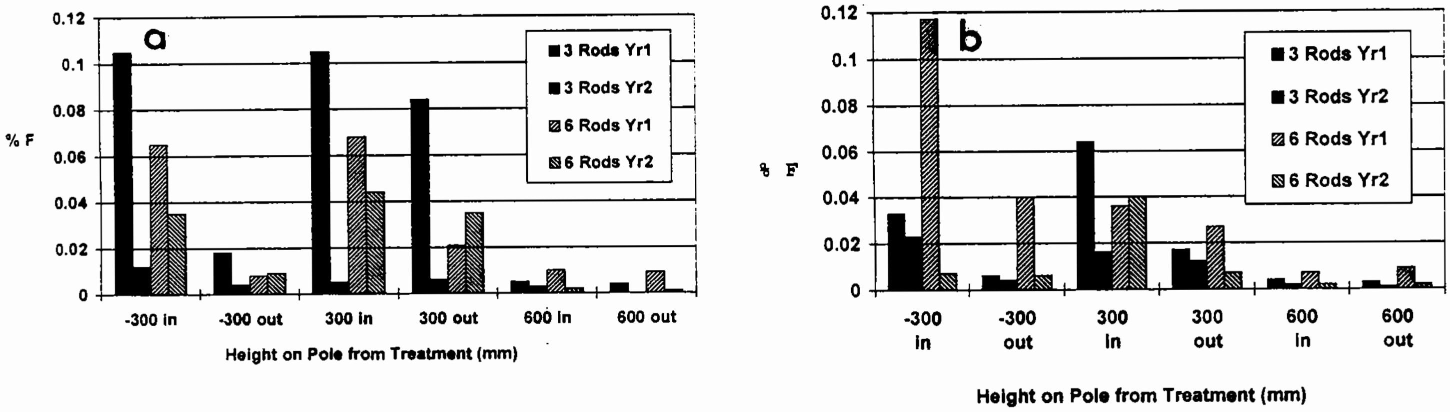
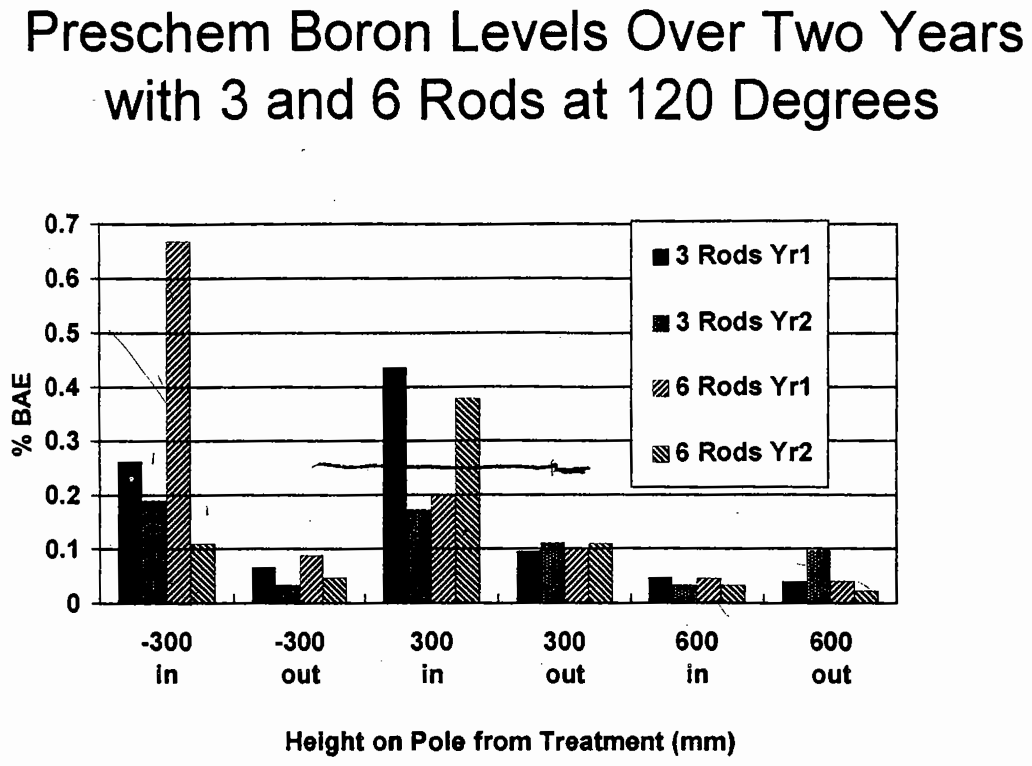
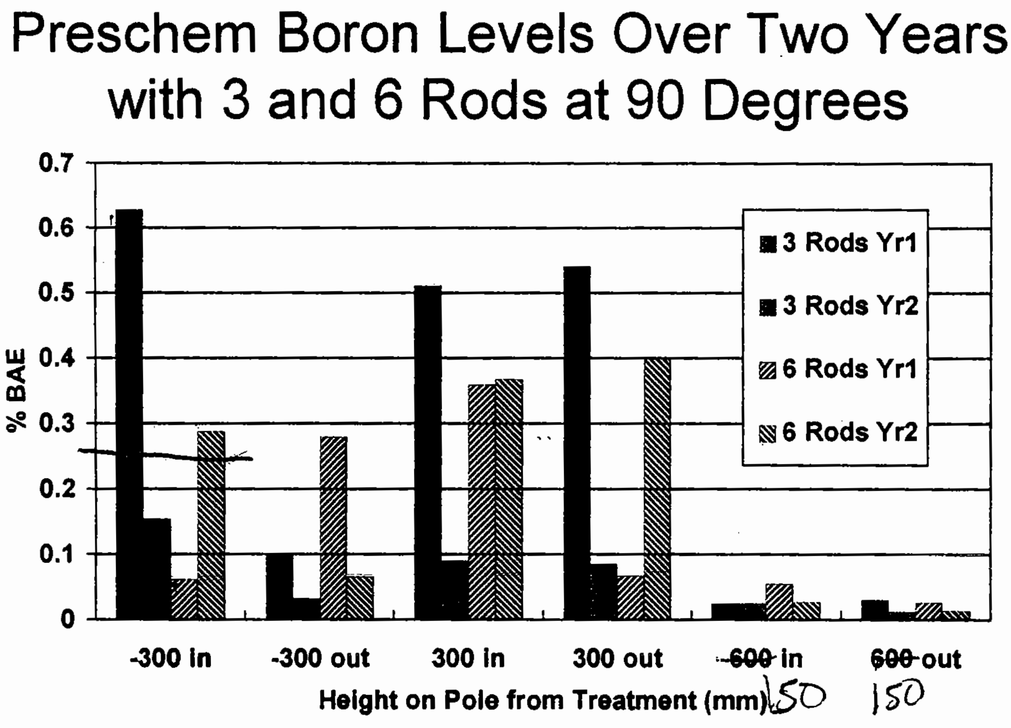


Figure I-10. Residual fluoride levels in Douglas-fir heartwood ~~blocks~~ poles 2 years after treatment with a boron/fluoride rod. a) 90 degree spacing, b) 120 degree spacing.



Preschem Boron Levels Over Two Years with 3 and 6 Rods at 120 Degrees



Preschem Boron Levels Over Two Years with 3 and 6 Rods at 90 Degrees

Figure I-11. Residual boron levels in Douglas-fir poles 1 or 2 years after treatment with 70.5 or 141 g (3 or 6 rods) of a boron/fluoride formulation.

Table I-12. Residual boron and fluoride at selected locations above or below the groundline in Douglas-fir poles 1 and 2 years after treatment with fluoride/boron rods.

Dosage	Application Pattern (Degrees)[a]	Years	Residual Chemical (% F or BAE)[b] Distance from Treatment Zone											
			-300mm				300 mm				600 mm			
			Outer		Inner		Outer		Inner		Outer		Inner	
			F	BAE	F	BAE	F	BAE	F	BAE	F	BAE	F	BAE
70.5	90	1	0.02	0.10	0.11	0.63	0.08	0.54	0.11	0.51	<0.01	0.03	0.01	0.02
		2	<0.01	0.03	0.01	0.15	<0.01	0.09	<0.01	0.09	<0.01	0.01	<0.01	0.03
	120	1	0.01	0.06	0.03	0.26	0.02	0.09	0.06	0.49	<0.01	0.04	<0.01	0.05
		2	<0.01	0.03	0.02	0.19	0.01	0.11	0.02	0.17	<0.01	0.10	<0.01	0.03
141.0	90	1	0.01	0.28	0.07	0.06	0.02	0.07	0.07	0.36	0.01	0.03	0.01	0.05
		2	0.01	0.07	0.04	0.29	0.04	0.40	0.04	0.38	<0.01	0.01	<0.01	0.03
	120	1	0.04	0.09	0.12	0.67	0.03	0.10	0.04	0.20	0.01	0.04	0.01	0.05
		2	0.01	0.05	0.01	0.11	0.01	0.11	0.04	0.38	<0.01	0.02	<0.01	0.03
0		1	--	0.01	--	0.08	--	0.04	--	0.01	--	0.01	--	0.01
		2	<0.01	0.01	<0.01	0.01	<0.01	0.01	<0.01	0.01	<0.01	0.01		

a Application patterns were holes at 90 or 120 degree intervals around the pole.

b Values represent composite analyses of 5 poles/treatment. BAE represents boric acid equivalent.

At each time point, four blocks per chemical treatment/moisture content combination were sampled by cutting a series of 5 mm thick sections 10, 25, 45, and 60 mm from the original treatment hole. These sections were oven dried overnight (54°C), sanded lightly to remove any possible boron carryover from sawing, and sprayed with a curcumin/salicylic acid indicator specific for boron.

The laboratory trials are still in progress and results are only available for three treatments at the selected moisture levels (2.1 g of rod plus 1.1, 2.2, or 3.3 g of glycol) after 8 and 12 weeks.

Boron movement in blocks treated with varying combination so boron and glycol was minimal in blocks maintained at 15% MC. Low levels of boron were detected 10 and 25 mm away from the treatment site in blocks (8 weeks after receiving 2.1 g of rod plus 3.3 g ethylene glycol but boron was not detected at any site 12 weeks after treatment with the same method (Figure I-12). Boron requires free moisture for movement and this glycol could not completely compensate for the absence of moisture in the test blocks.

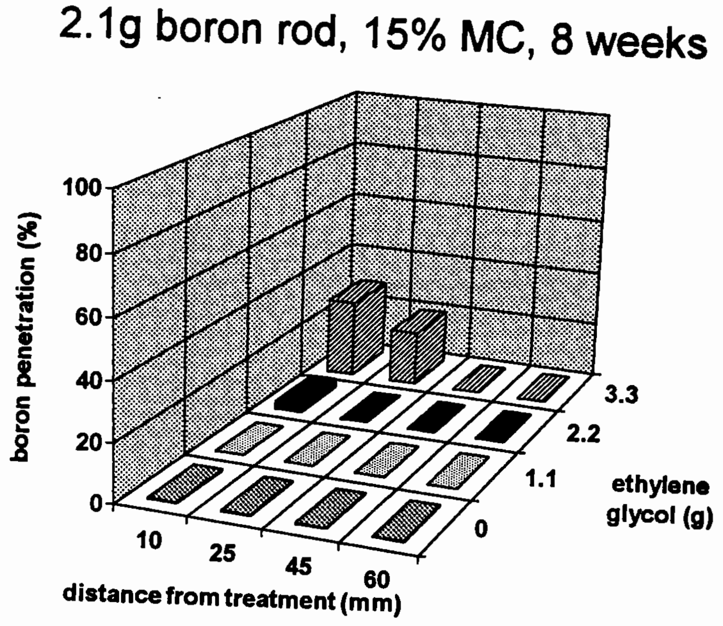
Boron movement was markedly improved in blocks maintained at 30% MC (Figure I-13). Boron distribution was generally low (<20% of cross-section) in samples receiving only 2.1 g of boron rod 8 weeks earlier. Boron distribution improved markedly in this same treatment after an additional 4 weeks of incubation. Average percent penetration ranged from 70% 10 mm from the treatment hole to 15% 60 mm from this zone. Simultaneous addition of glycol markedly increased boron penetration in the test blocks. Average boron penetration 10 mm from the treatment hole ranged from 90 to 99% 8 weeks after treatment. Curiously, the degree of penetration declined slightly with increasing glycol content at the 8 week sampling point. This trend disappeared at the 12 week time point, suggesting that high variations between individual blocks may have accounted for these differences.

Boron distribution in blocks receiving 2.1 g of boron rod and maintained at 60% MC was virtually complete at all locations sampled both 8 and 12 weeks after treatment (Figure I-14). As a result, the addition of ethylene glycol produced no noticeable effect on boron movement. Previous studies (Morrell et al., 1990; Smith and Williams, 1969) have clearly demonstrated the importance of moisture for boron movement through wood. Glycol is definitely unnecessary for initial movement of boron through moisture wood. The effect of glycol on subsequent boron distribution and longevity of the treatment, however, is not known. Chemical analysis of the wafers examined in these tests should help to better delineate these effects.

11. Ability of fused borate rods to diffuse through Douglas-fir heartwood: While a majority of our research has evaluated volatile remedial chemicals, there are many instances where less volatile chemicals may provide equivalent protection. One currently available formulation employs sodium octaborate tetrahydrate in a fused borate rod. These glass-like rods release boron when moistened, and thus boron can then diffuse to control decay fungi present in the wood.

We have evaluated a series of field trials in Oregon, New York, and Hawaii. These sites are sampled periodically to assess boron movement. This past year we sampled three trials at the Corvallis test site. Samples from two of these trials are still being analyzed, but the results of the third are presented below.

In 1990, a trial was established to evaluate the efficacy of fused borate rods in Douglas-fir heartwood. Fifty Douglas-fir pole sections (1.05 m long by 25 to 30 cm in diameter) were surface dried and dipped for 5 minutes in a 2.0% solution of chromated copper arsenate Type C. The dipped poles were stored under cover for 24 hours to allow the fixation process to proceed, then air-dried. A 1.9 cm diameter hole was drilled through each pole section 40 cm from the top and a galvanized bolt with a slot cut perpendicular to the threads was inserted into the hole. A 1.9 cm diameter by 20 cm long hole was then drilled 15 cm directly above the bolt hole. The holes



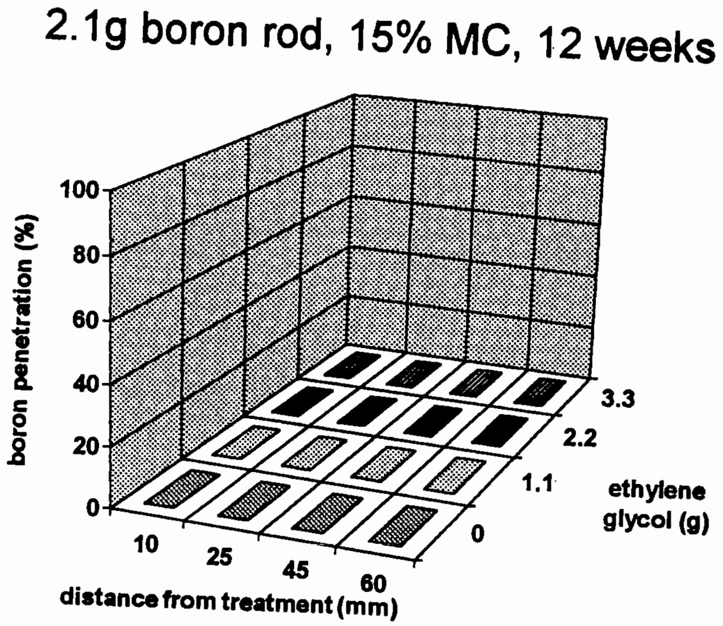
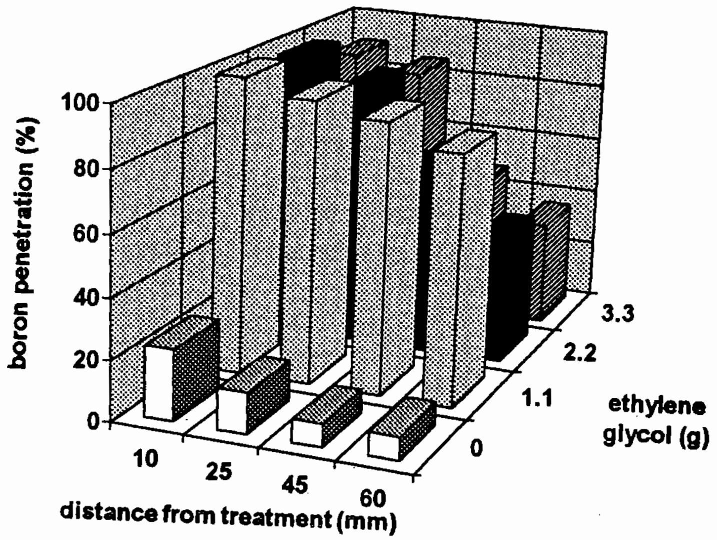
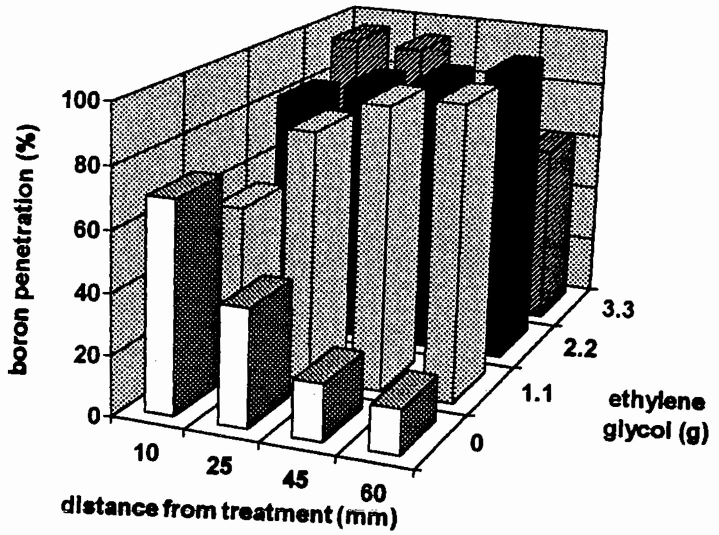


Figure I-12. Distribution of boron in Douglas-fir heartwood blocks maintained at 15% 8 or 12 weeks after treatment with combinations of boron rod and ethylene glycol.

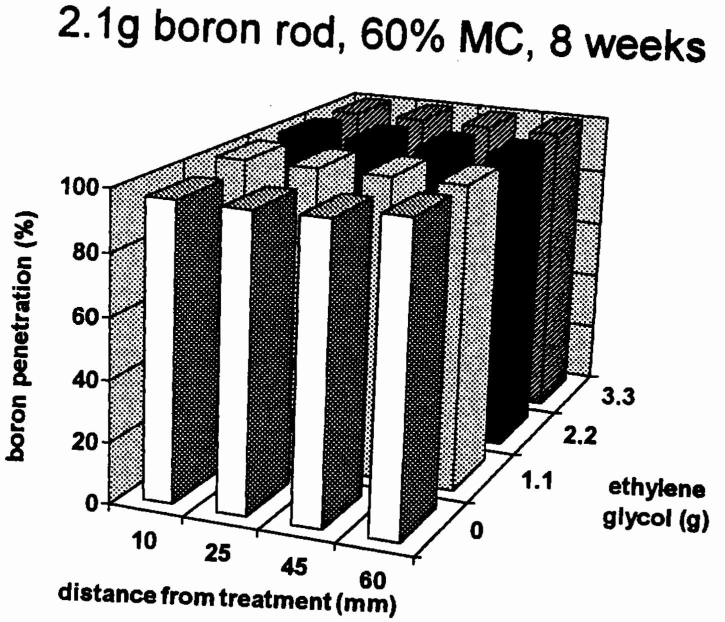


2.1g boron rod, 30% MC, 8 weeks



2.1g boron rod, 30% MC, 12 weeks

Figure I-13. Distribution of boron in Douglas-fir heartwood blocks maintained at 30% MC eight or twelve weeks after treatment with combinations of boron rod and ethylene glycol.


2.1g boron rod, 60% MC, 8 weeks

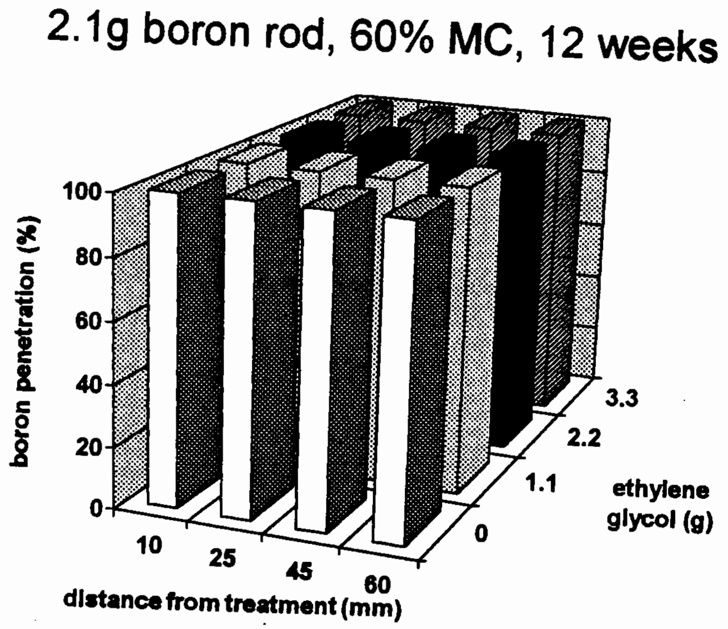

2.1g boron rod, 60% MC, 12 weeks

Figure I-14. Distribution of boron in Douglas-fir heartwood blocks maintained at 60% MC eight or twelve weeks after treatment with combination of boron rod and ethylene glycol.

Table I-13. Distribution of boron at selected distances from the treatment site in Douglas-fir heartwood blocks at 15, 30, or 60% MC 8 weeks after receiving 1.58 or 2.1 g of boron rod and combination of ethylene glycol.

		15% MC				30% MC				60% MC			
Boron Rod	Addition	Distance from Treatment Hole (mm)[1]											
	Glycol (g)	10	25	45	60	10	25	45	60	10	25	45	60
		8 weeks after treatment											
2.1	0	0.4 (0.70)	0.3 (0.43)	0.3 (0.43)	0.3 (0.43)	23.5 (26.69)	13.4 (22.91)	7.6 (13.86)	7.6 (12.92)	96.3 (6.50)	96.3 (6.50)	96.9 (5.56)	100.0 (0.00)
2.1	1.1	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	99.4 (1.65)	94.4 (9.82)	90.4 (17.46)	83.1 (26.45)	100.0 (0.00)	100.0 (0.00)	100.0 (0.00)	100.0 (0.00)
2.1	2.2	3.0 (2.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	97.5 (6.61)	90.0 (13.23)	65.6 (32.92)	43.1 (35.51)	100.0 (0.00)	100.0 (0.00)	100.0 (0.00)	100.0 (0.00)
2.1	3.3	27.9 (30.39)	9.3 19.25	0.00 (0.00)	0.00 (0.00)	90.0 (26.46)	85.6 (24.93)	47.5 (32.02)	35.6 (27.32)	100.0 (0.00)	100.0 (0.00)	100.0 (0.00)	100.0 (0.00)
	Boracol 40												
1.58	1.65	28.1 (7.04)	5.6 (9.82)	0.00 (0.00)	0.00 (0.00)	96.3 (6.50)	50.3 (28.84)	30.3 (37.95)	24.5 (37.18)	100.0 (0.00)	100.0 (0.00)	100.0 (0.00)	100.0 (0.00)
	Glycol (g)	12 weeks after treatment .											
2.1	0	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	70.0 (25.37)	39.0 (32.95)	18.8 (20.73)	15.0 (18.71)	100.0 (0.00)	100.0 (0.00)	100.0 (0.00)	100.0 (0.00)
2.1	1.1	21.1 (12.31)	9.4 (10.14)	0.00 (0.00)	0.10 (0.33)	55.1 (39.01)	83.5 (26.99)	94.8 (4.09)	98.1 (3.48)	100.0 (0.00)	100.0 (0.00)	100.0 (0.00)	100.0 (0.00)
2.1	2.2	0.5 (0.50)	0.9 (0.93)	10.3 (8.69)	20.9 (20.13)	82.3 (9.11)	89.1 (7.36)	93.3 (6.55)	98.9 (1.69)	100.0 (0.00)	99.8 (0.66)	99.1 (1.69)	98.5 (3.28)
2.1	3.3	33.8 (26.07)	14.6 (10.66)	1.3 (1.30)	1.6 (1.73)	95.0 (8.66)	93.8 (8.20)	73.8 (21.03)	61.9 (19.99)	100.0 (0.00)	100.0 (0.00)	99.8 (0.66)	100.0 (0.00)

1. Averages are of 8 measurements.
2. Numbers below averages represent one standard deviation.

Forsyth, P.G and J.J. Morrell. 1995. Decomposition of Basamid in Douglas-fir heartwood: Laboratory studies of a potential wood fumigant. Wood and Fiber Science 27:183-197.

Forsyth, P.G. and J.J. Morrell. 1993. Preliminary field trials using the solid fumigant Basamid amended with selected additives. Forest Products Journal 43(2):41-44.

Giron, M.Y. and J.J. Morrell. 1989. Interactions between microfungi isolated from fumigant-treated Douglas-fir heartwood and *Postia placenta* and *Postia carbonica*. Material und Organismen 24:39-49.

Helsing, G.G., J.J. Morrell, and R.D. Graham. 1984. Evaluations of fumigants for control of internal decay in pressure-treated Douglas-fir poles and piles. Holzforschung 38:277-280.

Highley, T.L. 1991. Movement and persistence of Dazomet and pelletized methylisothiocyanate in wrapped Douglas-fir and southern pine timbers. International Research Group on Wood Preservation, Document No. IRG/WP/1496. Stockholm, Sweden. 5 pp.

Morrell, J.J., C.M. Sexton, and S. Lebow. 1988. The effect of pH on decomposition of Mylone (Dazomet) to fungitoxic methylisothiocyanate in wood. Wood and Fiber Science 20(4):422-430.

Morrell, J.J. 1994. Decomposition of metham sodium to methylisothiocyanate as affected by wood species, temperature, and moisture content. Wood and Fiber Science 26:62-69.

Morrell, J.J. and M.E. Corden. 1986. Controlling wood deterioration with fumigants: A review. Forest Products Journal 36(10):26-34.

Morrell, J.J., M.A. Newbill, and C.M. Sexton. 1992. Remedial treatment of Douglas-fir and southern pine poles with methylisothiocyanate. Forest Products Journal 42(10):47-54.

Morrell, J.J., P.F. Schneider, and P.G. Forsyth. 1996. Performance of gelled and pelletized metham sodium as internal remedial treatments for Douglas-fir poles. Forest Products Journal.

Siau, J.F. 1995. Wood: Influence of moisture on physical properties. Department of Wood Science and Forest Products, Virginia Polytechnic Institute and State University, Blacksburg, Virginia. 227 pages.

Zabel, R.A. and J.J. Morrell. 1992. Wood microbiology: Decay and its prevention. Academic Press, San Diego, CA. 476 p.

Zahora, A.R. and M.E. Corden. 1985. Gelatin encapsulation of methylisothiocyanate for control of wood-decay fungi. Forest Products Journal 35(7/8):64-69.

Zahora, A.R. and J.J. Morrell. 1988. A note on the sensitivity of a closed tube bioassay to volatile methylisothiocyanate in fumigant-treated wood, Wood and Fiber Science 20:91-96.

Zahora, A.R. and J.J. Morrell. 1989. Diffusion and sorption of the fumigant methylisothiocyanate in Douglas-fir wood. Wood and Fiber Science 21:55-66.

Table I-14. Average retention of boron in Douglas-fir pole sections exposed in Corvallis, Oregon or Hilo, Hawaii, for 1 year after treatment with fused borate rods[a]

Dosage (g)	Boron Content (kg/m^3)									
	90° from treatment 7.5 cm below treatment				90° from treatment 22.5 cm below treatment				in line 7.5 cm above treatment	
	Outer		Inner		Outer		Inner		Combined	
	1 yr	6 yr	1 yr	6 yr	1 yr	6 yr	1 yr	6 yr	1 yr	6 yr
Corvallis, Oregon										
40	0.05 (0.03)	0.30 (0.17)	0.55 (1.03)	0.99 (1.23)	0.05 (0.04)	0.30 (0.18)	0.06 (0.09)	0.38 (0.29)	0.26 (0.30)	0.26 (0.25)
80	0.04 (0.03)	0.24 (0.17)	0.04 (0.02)	0.64 (0.73)	0.02 (0.02)	0.13 (0.13)	0.06 (0.10)	0.30 (0.29)	0.70 (0.63)	0.78 (1.34)
Hilo, Hawaii										
40	0.03 (0.09)	--	0.25 (0.57)	--	0.01 (0.01)	--	0.01 (0.01)	--	0.69 (1.87)	--
80	0.08 (0.09)	--	0.01 (0.01)	--	0.01 (0.04)	--	<0.01 (0.01)	--	0.62 (0.88)	--

[a] Values represent means of 10 replicates per treatment. Figure in parentheses represent one standard deviation. Untreated control poles contained 0.002 kg/m^3 of boron.

received 40 or 80 g of fused borate rod (1 or 2 rods) and were plugged with a tight fitting wood dowel. The pole sections were capped with plywood to limit end-grain wetting and exposed on a rack above-ground in either Corvallis, Oregon or Hilo, Hawaii. The Corvallis site is a typical Pacific Northwest location receiving approximately 112 cm of rainfall per year, primarily in the winter months. The Hilo site is an extremely wet, humid site receiving over 400 cm of rainfall per year.

The poles were sampled 1 and 6 years after treatment by removing increment cores from two sites 90 degrees around from and 7.5 cm below the bolt hole. The cores were segmented into zones corresponding to the outer and inner 5 cm. The segments were ground to pass a 20 mesh screen and analyzed for residual boron content by extraction and Ion Coupled Plasma Spectroscopic analysis. In addition, one core was removed from a site 7.5 cm above the treatment. This core was ground as one sample and similarly analyzed. A second set of cores was removed from sites 71.5 cm below each bolt hole and cultured on malt extract agar for the presence of decay fungi.

Culturing of increment cores revealed that none of the poles were infested by decay fungi in the zone near the bolt hole. Chemical analysis revealed that boron levels at all locations were less than 0.7 kg/m^3 (Table I-14). It is difficult to determine the exact threshold of boron for fungal control; however, previous studies on hardwoods suggest that a threshold ranging from 0.6 to 1.2 kg/m^3 (as boron) will prevent colonization by basidiomycetes. These levels are present only in the zone above the original treatment hole 1 year after treatment.

As expected, boron levels in the inner zone were higher than those nearer to the surface, although these differences were sometimes slight after 1 year. Chemical levels in pole sections exposed at Hilo tended to be lower than those in similar sections exposed in Corvallis. Since Hilo receives considerably more precipitation, boron leaching losses might account for these differences. Generally, chemical levels below the treatment holes were lower than those found in the single core removed from above the treatment hole. This difference is perplexing since we considered downward movement to be the more likely pathway for movement of this chemical. Chemical dosage also appeared to have only a minimal effect on subsequent boron levels. The absence of a dosage effect 1 year after treatment suggested that the rate of boron release from the two treatments was similar. In general, however, the boron levels present in these pole sections 1 year after treatment were far lower than would be required to effectively arrest established internal decay fungi and suggest that considerable caution should be exercised in the application of this chemical.

Boron levels 6 years after treatment were generally higher below the treatment hole than those removed 5 years earlier, although the levels varied widely among the samples. Boron levels were slightly higher in samples receiving the lower dosage, a trend that was also noted 1 year after treatment. Chemical levels were higher in the inner zone of the samples. This difference was greatest in samples removed from the site 7.5 cm below the treatment hole, and least in samples removed 22.5 cm below the treatment hole in poles treated with 40 g of boron rod.

These results indicate that application of boron rods results in boron levels that provide protection to field drilled bolt holes for periods of up to 5 years. These treatments may be ideal in preventing above-ground damage. Boron diffusion might be too slow to protect against actively growing decay fungi, but it might be ideal for application to freshly exposed wood where decay fungi have not yet become established.

LITERATURE CITED

Eslyn, W.E. and T.L. Highley. 1985. Efficacy of various fumigants in the eradication of decay fungi implanted in Douglas-fir timbers. Phytopathology 75(5):588-592.

OBJECTIVE II
IDENTIFY SAFER CHEMICALS FOR PROTECTING EXPOSED WOOD SURFACES IN POLES

INTRODUCTION

Making all cuts on a pole prior to treatment should be a major component of a utility specification since any damage to the original treated shell provides an avenue for invasion by fungi and insects. There are times, however, when field fabrication can become necessary. For many years field exposed wood was protected by topical application of pentachlorophenol in diesel oil. This practice, however, was widely ignored because line personnel disliked getting their gloves soiled with the preservative and because it was difficult to confirm if the treatments had, in fact, been applied. Yet, previous studies have shown that decay in above ground locations is endemic in many utilities. This damage is destined to grow as utilities are forced to share the zone beneath the energized segment of a pole with an increasing array of cable and telecommunications entities. Thus, the need for a simple, safe method for protecting field-drilled bolt holes and other damage of poles should remain a critical objective.

A. EVALUATION OF TREATMENTS FOR PROTECTING FIELD DRILLED BOLT HOLES

Trials to evaluate the effectiveness of various treatments for protecting exposed heartwood in Douglas-fir poles are continuing. Fourteen years ago, a series of Douglas-fir pole sections was treated with pentachlorophenol in heavy oil by Boultonizing to produce a relatively shallow shell of treatment.

A series of eight 25 mm diameter holes was drilled at 90 degree angles into the poles beginning 600 mm above the groundline and extending upward at 450 mm intervals to within 450 mm of the top. The holes on a given pole were treated with 10% pentachlorophenol in diesel oil, powdered ammonium bifluoride (ABF), powdered disodium octaborate tetrahydrate (Boron), or 40% boron in ethylene glycol (Boracol). Each chemical was replicated in eight holes on each of four poles. An additional set of 4 poles did not receive 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 (PATOX) were used to attach the bolts to these poles. Holes were drilled in an additional eight poles that received no chemical treatment. The bolt holes were filled with galvanized metal hardware and either metal or plastic gain plates. For the first 5 years, increment cores were only removed from 4 of the control poles at sites directly below the gain plate on one side of the pole and from sites directly above the washer on the opposite side. These cores were cultured on malt extract agar and observed for the growth of basidiomycetes, a class of fungi that includes many important wood decayers. Once a sufficient level of fungal colonization was present in the control sample, the remainder of the poles were sampled in the same manner.

The levels of fungal colonization in the poles has never been high, with levels in control poles ranging from 3 to 17% of the cores cultured (Table II-1). Colonization was initially highest in control poles, but the degree of colonization has steadily risen in poles receiving PATOX washers reflecting the inability of the chemicals in the washer to migrate for appreciable distances into the bolt hole.

The penta control treatment initially provided some protection to the holes, but these levels declined and colonization in these poles did not differ markedly from that of the control. Two of the three diffusible treatments continue to provide excellent protection against fungal attack, while colonization levels in the Boracol treatment have increased in the past 2 years. Both ABF and boron continue to provide protection against fungal attack (Figure

Table II-1. Basidomycetes and other fungi found in preservative-treated Douglas-fir poles 6 to 14 years after bolt holes were drilled and treated in the field as shown by cultures from increment cores

Field Treatment[a]	Percentage of cores containing...																	
	Basidiomycetes									Other Fungi								
	6 yr	7 yr	8 yr	9 yr	10 yr	11 yr	12 yr	13 yr	14 yr	6 yr	7 yr	8 yr	9 yr	10 yr	11 yr	12 yr	13 yr	14 yr
Ammonium bifluoride (n = 32)	0	2	0	2	2	2	2	2	5	5	2	16	42	9	47	39	38	38
Boracol® (n = 32)	0	2	0	0	3	0	3	8	9	18	27	33	66	16	70	42	59	80
Patox® washer	5	5	8	14	13	11	8	14	14	12	22	31	66	27	55	45	48	38
Pentachlorophenol (n = 32)	2	2	8	5	6	5	6	10	8	25	17	25	51	25	80	61	67	47
Boron (n = 32)	0	0	0	2	2	2	0	3	0	11	25	25	37	14	75	39	59	67
Control (n = 64)	3	9	17	9	8	11	3	5	9	30	26	46	70	33	86	55	81	68

[a] Figures - parenthesis represent number of cores cultured/treatment.

II-1). In both instances, the diffusible nature of the treatment probably helps to provide protection deeper in the wood than would be possible with penta.

The results continue to demonstrate the benefits of diffusible boron and fluoride for protecting field-drilled bolt holes. As utilities continue to face an onslaught of potential users for portions of their poles, the inclusion of such treatments in specifications for these users would provide excellent protection against potential internal decay in this zone.

B. PROTECTION OF JOINTS IN DOUGLAS-FIR PIERS

The protection techniques for piers and other large dimension timbers are similar to those used to protect utility poles from field damage. In 1979, five simulated piers of Douglas-fir were constructed in an open field at the Peavy Arboretum test site. Each structure was supported by nine creosoted piles that were equally spaced in a 3.6 m square area. Each simulated pier was constructed with eight pairs of abutting caps measuring 25 cm by 25 cm by 2.1 m long, 10 pairs of abutting stringers measuring 10 cm by 25 cm by 2.1 m long, and eight sets of three abutting decking planks measuring 10 by 25 cm by 1.6 m long (Figure II-2). Eight of the caps were center-kerfed to minimize check development and the kerfs were oriented downward. The structures were built to enable various protective measures to be assessed, as well as to create combinations of exposed end-grain and untreated butt joints.

At the time of installation, nine different treatments were applied to the top surfaces of the caps, stringers, and decking planks in the structures (Table II-2).

Each specific treatment was applied to one half of the five structures. One half of one pier remained as an untreated control. The same preservative was applied to each underlying stringer cap as well as to the four sets of three abutting deck planks in that half of the structure. A supplemental treatment of FCAP, ABF and Polybor® was applied 2 years after installation to decking laid over roofing felt. A total of 3.5 liters of each preservative was sprayed onto the top surface, into seasoning checks, and into butt joints of the decking planks.

Each half of a structure was evaluated for the presence of decay fungi annually for the first 6 years by removing increment cores from various locations and placing these onto malt extract agar in petri dishes. The cores were observed for fungal growth and any fungi were examined for characteristics of basidiomycetes, a class of fungi containing many important wood decayers. Two cores were removed from the underside of each cap adjacent to the creosote support planks, one from each end. Four cores were removed from every fourth stringer on a rotating basis so that each stringer was evaluated every fourth year. Two cores were removed from the stringer directly under the overlaying decking plank, and two cores were removed at the stringer/cap junction.

In addition, decking planks were sampled in three locations: (1) junction of abutting decking planks, (2) decking/stringer junction, and (3) midspan between two stringers. One core was removed from one of these locations in each decking plank, rotating to another location each year, so that after 3 years each of the planks had been sampled in all three locations.

The presence of decay fungi in caps varied widely between kerfed and nonkerfed members over the first 6 years of the test, but these differences were much smaller after 13 or 16 years (Table I-3). Kerfing has previously been found to control the development of deep checks on utility poles in service (Helsing and Graham, 1976). These poles, however, have a preservative-treated shell which can protect against invasion. It would appear that this shell is essential for long-term performance of kerfed materials even in the above ground exposures in this test. Of the topical chemicals evaluated for protecting the caps, FCAP and ABF both appeared to provide the most consistent protection, while oilborne penta and copper-8 provided much lower levels of protection. These differences probably reflect the inability of the oilbased materials to move far beyond the wood surface. FCAP and ABF both have the ability

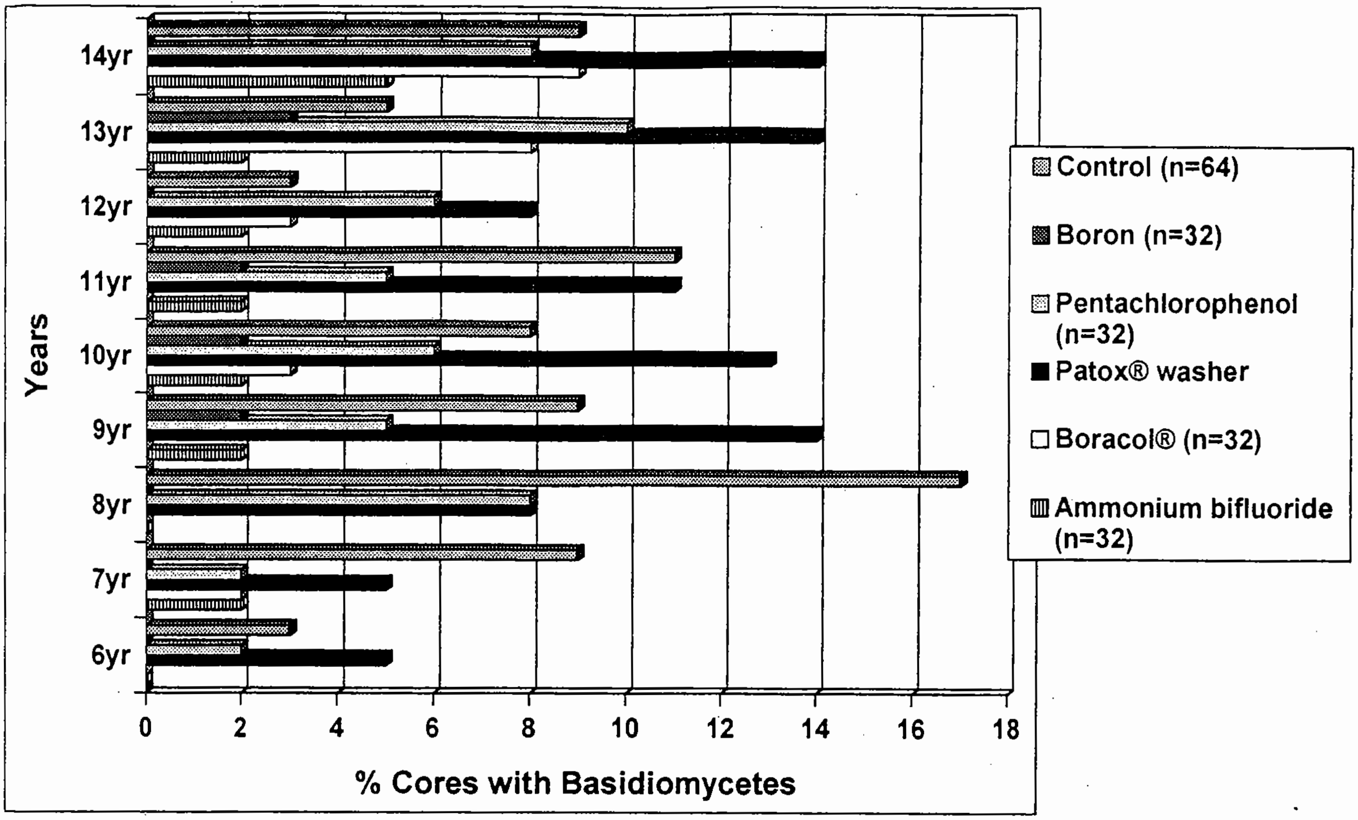


Figure II-1. Colonization of field drilled bolt holes in Douglas-fir poles by basidiomycetes 6 to 14 years after application of various topical preservatives or chemically impregnated washers.

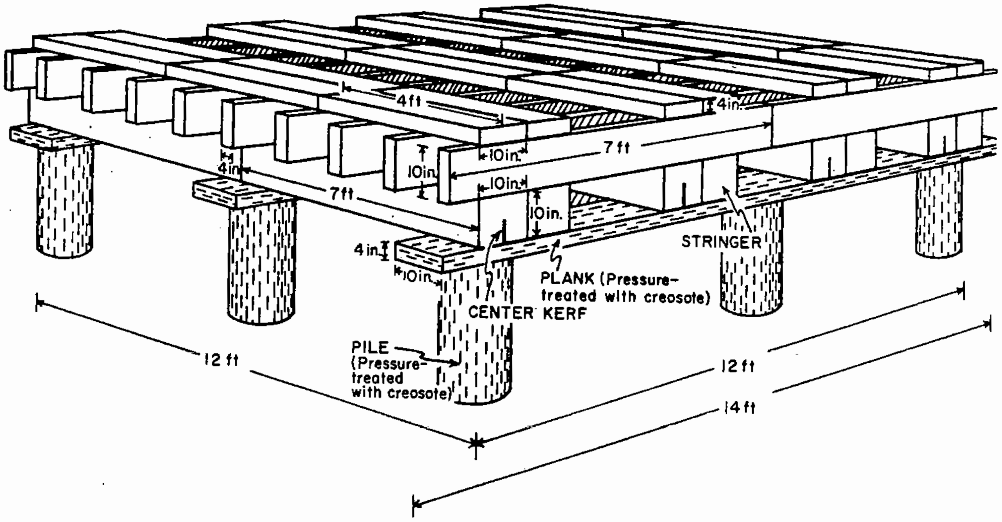


Figure II-2. Schematic of simulated pier.

Table II-2. Treatments applied to the top surfaces of caps, stringers, and decking planks in structures.

Treatment	**Carrier**	**Concentration (%)**
Pentachlorophenol (penta)	Oil	10
Copper-8-quinolinolate (copper-8)	Oil	1 (Cu basis)
Fluor-chrome-arsenic-phenol (FCAP) (as a slurry)	Water	12
Ammonium bifluoride (ABF)	Water	20
Polybor®	Water	9
FCAP in roofing felt[a]	Water	2
ABF in roofing felt[a]	Water	20
Polybor® in roofing felt[a]	Water	9
Roofing felt alone[a]	–	–

[a] Felt was applied beneath the stringers and beneath the decking planks.

Table II-3. Percentage of increment cores containing Basidiomycetes 1 to 16 years after initial treatment of kerfed and nonkerfed Douglas-fir caps in five simulated piers.

	Kerfed (%)					Nonkerfed (%)				
Treatment	1 yr	4 yr	6 yr	13 yr	16 yr	1 yr	4 yr	6 yr	13 yr	16 yr
Pentachlorophenol	25	25	13	38	75	0	37	50	75	50
Copper-8-quinolinolate	0	0	0	25	25	25	37	13	75	25
FCAP	0	0	13	13	0	0	0	0	13	0
ABF	0	0	0	25	25	0	0	0	13	13
Polybor®	0	25	50	25	13	13	37	50	38	50
FCAP-flooded felt	0	0	25	0	0	0	0	13	0	13
Polybor® - flooded felt	0	0	0	13	13	0	0	13	0	13
Felt alone	0	0	0	25	25	0	0	13	13	13
Control	0	13	25	25	50	0	50	88	38	50

to migrate with moisture to protect wood in checks that opened following treatment. It is interesting to note that Polybor®, which contains disodium octaborate tetrahydrate, provided little long term protection. These results differ from those found with the field drilled bolt hole test. The differences may reflect the higher exposure of the caps to leaching.

The effect of water trapping joints on the development of decay is illustrated by the differences in fungal colonization of decking at the mid-span and the point where the deck contacted the stringer (Table II-4). Fungal isolations were generally lower at the mid-span, reflecting the absence of water trapping sites and the dependence on the development of checks for colonization by decay fungi. Interestingly, the levels of fungal colonization near abutting deck boards were relatively low, perhaps reflecting the ability of these boards to dry periodically. Of the chemicals evaluated, the water diffusible systems provided the best protection near the joint, while protection at mid-span was more variable. For example, penta provided excellent protection for the first 6 years, but sampling at 13 and 16 years revealed substantial fungal attack. Copper-8 has provided variable protection, while ABF and FCAP flooded felt have provided complete protection against fungal attack in this zone. The mid-span should have a lower risk of fungal attack, making it more likely that less effective chemicals might still perform well under these conditions.

The degree of colonization in the stringers was generally low 13 years after installation, regardless of treatment with the exception of penta-treated stringers, which continued to experience higher levels of colonization (Table II-5). It was interesting to note that with Copper-8, another oilborne chemical, far lower levels of attack were observed throughout the test. The basis for this variable performance is unclear. The relatively low levels of fungal attack in control stringers after 13 years may reflect the presence of pockets of advanced decay. Basidiomycetes are often difficult to isolate from wood in the advanced stages of decay.

The results suggest that combinations of topical treatments and kerfing can delay, but not completely prevent colonization of large wood members by decay fungi. Periodic replenishment of biocides might improve their performance, although such applications would be difficult and costly.

LITERATURE CITED

Eslyn, W.E. and T.L. Highley. 1985. Efficacy of various fumigants in the eradication of decay fungi implanted in Douglas-fir timbers. Phytopathology 75:588-592.

Graham, R.D. and E.M. Estep. 1966. Effect of incising and saw kerfs on checking of pressure-treated Douglas-fir spar crossarms. Proc. Am. Wood Preserv. Assoc. 62:155-158.

Graham, R.D. 1983. Improving the performance of wood poles. Proc. American Wood Preserver's Assoc. 79:222-228.

Helsing, G.G., J.J. Morrell, and R.D. Graham. 1984. Evaluations of fumigants for control of internal decay in pressure-treated Douglas-fir poles and piles. Holzforschung 38(5):277-280.

Helsing, G.G. and R.D. Graham. 1976. Saw kerfs reduce checking and prevent internal decay in pressure-treated Douglas-fir poles. Holzforschung 30(6):184-186.

Helsing, G.G. and R.D. Graham. 1981. Control of wood rot in waterfront structures. Oregon State Univ. Extension Marine Advisory Program SG55. Corvallis, Oregon.

Helsing, G.G., J.J. Morrell, and R.D. Graham. 1986. Service life of Douglas-fir piles: Methods for protecting cut-off tops from decay. Forest Prod. J. 36(2):21-24.

Highley, T.L. 1983. Protecting piles from decay: End treatments. Int. J. Wood Preserv. 3(2):73-76.

Table II-4. Effect of water-trapping joints on the percentage of increment cores containing Basidiomycetes 2 to 16 years after initial treatment of Douglas-fir decking in five simulated piers.[a]

Treatment	Butt joint				Decking/stringer junction				Decking midspan			
	2 yr	6 yr	13 yr	16 yr	2 yr	6 yr	13 yr	16 yr	2 yr	6 yr	13 yr	16 yr
Pentachlorophenol	25	0	0	25	0	25	75	40	0	0	75	33
Copper-8-quinolinolate	0	25	0	0	0	25	0	0	0	25	0	25
FCAP	0	25	0	0	0	50	25	25	0	50	25	0
ABF	0	0	0	0	0	25	0	25	0	25	0	0
Polybor®	0	50	25	25	0	75	50	25	0	0	0	75
FCAP-flooded felt[b,c]	0	0	0	0	0	0	0	0	0	25	0	0
ABF-flooded felt[b,c]	0	25	0	0	0	0	0	0	0	0	0	33
Polybor®-flooded felt[b,c]	0	0	0	0	0	25	25	0	0	25	25	33
Felt alone[b]	25	50	25	25	0	25	25	25	25	50	50	50
Control	25	25	0	0	0	25	50	50	0	50	25	25

[a] To evaluate each treatment, one core was removed from each of 12 decking planks at the butt joint, decking/stringer junction, or decking midspan. The sampling was rotated annually between the three locations until all areas were sampled in each of the planks.

[b] Felt was applied between decking and stringer, and between stringer and cap.

[c] After 2 years, a second treatment was applied.

Table II-5. Percentage of increment cores containing Basidiomycetes 1 to 16 years after initial treatment of Douglas-fir stringers and decking in five simulated piers.

	Stringers (%)				Decking (%)				
Treatment	1 yr	4 yr	6 yr	13 yr	1 yr	4 yr	6 yr	13 yr	16 yr
Pentachlorophenol	30	20	25	30	0	25	8	30	33
Copper-8-quinolinolate	5	5	5	5	0	17	25	0	8
FCAP	0	10	0	5	0	8	42	17	8
ABF	0	5	0	5	8	0	16	0	8
Polybor®	5	40	20	15	8	25	42	25	42
FCAP-flooded felt[a]	0	5	0	15	0	0	8	0	0
ABF-flooded felt[a]	5	0	0	10	8	0	8	0	8
Polybor®-flooded felt[a]	0	10	10	15	33	8	24	17	8
Felt alone[a]	0	20	30	15	25	25	42	33	33
Control	10	25	25	10	17	25	33	25	25

[a] Felt was applied between decking and stringer, and between stringer and cap.

Highley, T.L. 1980. In-place treatments for control of decay in waterfront structures. Forest Prod. J. 30(9):49-51.

Highley, T.L. 1984. In-place treatments from waterborne preservatives for control of decay in hardwoods and softwoods above ground. Mater. u. Org. 19(2):95-104.

Highley, T.L. and T.C. Scheffer. 1978. Controlling decay in above-water parts of waterfront structures. Forest Prod. J. 28(2):40-43.

Highley, T.L. and T.C. Scheffer. 1975. In-place treatment of simulated waterfront structures for decay control. Mater u. Org. 10:57-66.

Lebow, S.T. and J.J. Morrell. 1989. Penetration of boron in Douglas-fir and western hemlock lumber. Forest Prod. J. 39(1):67-70.

Morrell, J.J., M.A. Newbill, G.G. Helsing, and R.D. Graham. 1987. Preventing decay in piers of nonpressure-treated Douglas-fir. Forest Prod. J. 37(7/8):31-34.

Morrell, J.J., R.D. Graham, M.E. Corden, C.M. Sexton, and B.R. Kropp. 1989. Ammonium bifluoride treatment of air-seasoning Douglas-fir poles. Forest Prod. J. 39(1):51-54.

Morrell, J.J., M. Newbill, and R.D. Graham. 1990. Evaluation of protective treatment for field-drilled bolt holes. Forest Prod. J. 40(11/12):49-50.

U.S. Navy. 1965. Marine biology operational handbook: Inspection, repair, and preservation of waterfront structures. NAVDOCKS NO-311. Bureau of Yards and Docks, Washington, D.C.

OBJECTIVE III
EVALUATE PROPERTIES AND DEVELOP IMPROVED SPECIFICATIONS FOR WOOD POLES

A. IMPROVED THROUGH-BORING PATTERNS FOR INITIAL TREATMENT OF POLES

Through-boring is an excellent method for improving treatment of pole sections where decay is most likely to occur. The process produces complete or near complete penetration of the heartwood of thin sapwood species. Through-boring has been used by utilities in the western U.S. since the early 1960s and has markedly reduced the incidence of internal decay at groundline.

While through-boring is an excellent method for improving treatment, there is no standard boring pattern. The use of a standard pattern could optimize treatment while minimizing the number of holes. In addition, a single boring pattern would allow for process automation, potentially reducing pole costs. The development of a standard boring pattern requires the development of data on the performance of through-bored poles already in service, and the effect of varying patterns in relative distribution of treatment.

The variation in preservative distribution in through-bored Douglas-fir poles was investigated in a series of in-service poles located in western Oregon. Increment cores were removed from sites located between the through-boring holes. Each core was sprayed with penta-check and the penetration was mapped on each core. Penetration was reported as percent penetration/core. The results of this study showed that most poles had 90% or more penetration, although cores from some poles had as little as 70% penetration. Visual examination of cores showed no evidence of decay in any of the untreated zones along the cores, nor did culturing indicate that any viable decay fungi were present. These results indicated that through-boring was an excellent method for preventing internal decay.

Subsequently, a series of tests were established in which through-boring patterns were varied to determine how far apart the holes could be located and still produce adequate penetration. The results indicated that the distances between holes in the currently used patterns could be markedly increased without adversely affecting penetration. Retention analysis indicated that pentachlorophenol levels were well above the threshold for fungal attack even in the innermost sample analyzed.

The past year we initiated a study to identify the distribution of preservative around individual through-boring holes. These data will be used to construct an optimum through-boring pattern that insures a high percentage of penetration, but minimizes the number of holes required. A series of Douglas-fir pole sections (24 m long by 250-300 mm in diameter) were air-seasoned. Individual 10.5 mm diameter holes were drilled on one face of each pole section at 0.6 m intervals from one end of each section. The poles were then treated with pentachlorophenol in P-9 (Type A) oil using a cycle typically used for pole treatment.

The preservative distribution around each treatment hole was assessed by removing a series of increment cores from sites around each treatment hole (Figure III-1). Preservative penetration along each core was mapped on a visual basis and the cores were retained for later analysis.

Average penetration declined slightly from the outer to inner zones of increment cores removed from sites around the through-boring holes (Figure III-2). Penetration, however was rarely complete, a trend that was surprising in light of the normally thorough distribution of preservative in the through-bored zone.

Maps of pentachlorophenol distribution patterns around the through-bored hole showed that chemical penetration extended 150 to 225 mm above and below the treatment hole in the outer 50 cm of core (Figures III-3. Penetration on either side of the

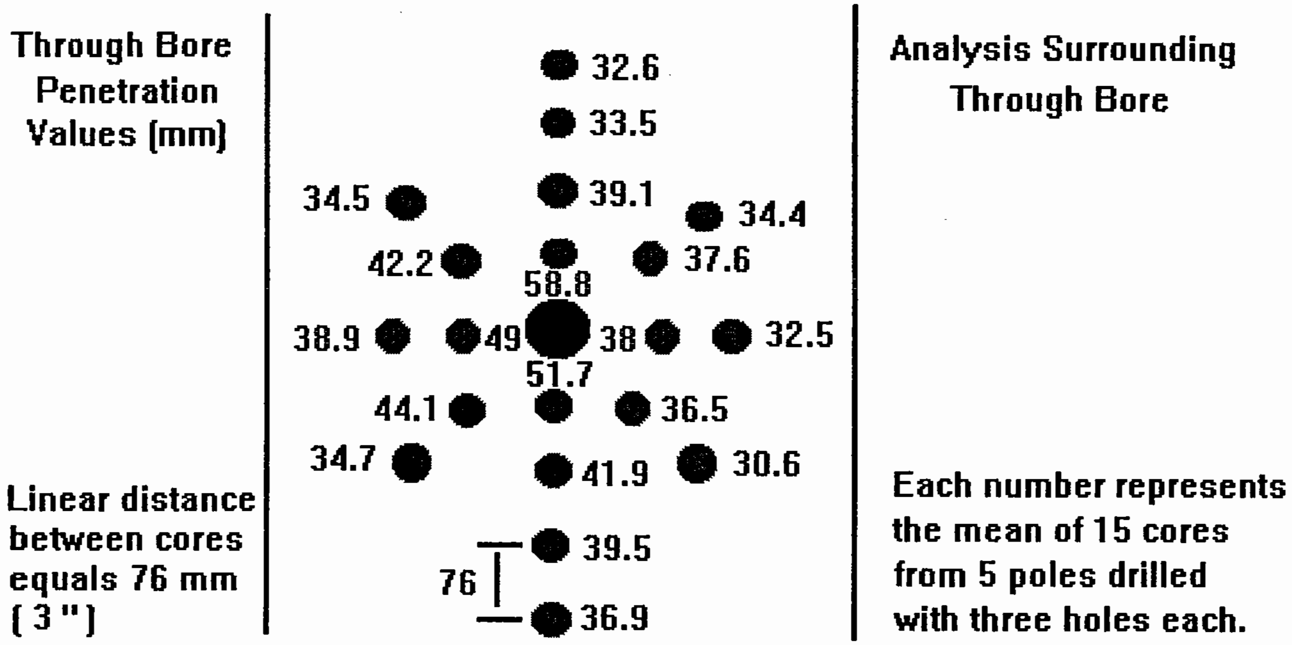


Figure III-1. Increment core sampling pattern employed to evaluate preservative penetration around the through bored holes in Douglas-fir poles.

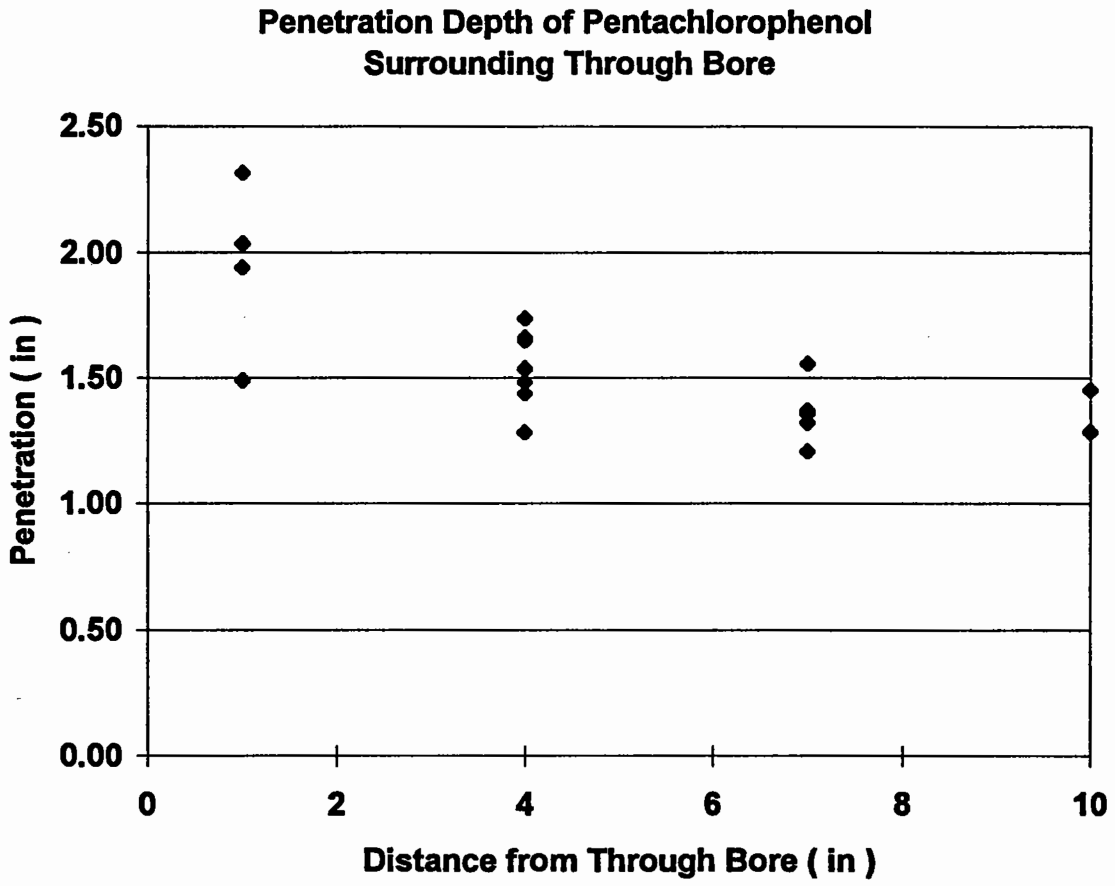


Figure III-2 Average penetration of pentachlorophenol in cores removed from selected locations around through-bored holes in Douglas-fir poles. Values represent means of 10 replicates per data point.

hole rarely extended beyond 150 mm from the treatment hole. Penetration around the through-bored hole in the heartwood was much lower, particularly radially from the hole. Penetration tended to be limited to a 75 mm radial zone around individual treatment holes farther into the wood (Figure III-3). While penetration sometimes extended 225 mm above or below the hole, this degree of penetration was somewhat inconsistent. As a result, using a lower degree of penetration would probably be more prudent in identifying patterns that optimize preservative penetration while minimizing strength.

One problem that was experienced in the current study was a difficulty in clearly delineating heartwood penetration. A portion of this difficulty occurred because of the light oil used for treatment. We plan to evaluate additional samples treated with creosote to determine if penetration patterns are similar.

The results from these two trials will be used to develop more widely spaced patterns that still produce good treatment.

B. EFFECT OF SOURCE ON DURABILITY OF WESTERN REDCEDAR HEARTWOOD

Western redcedar has a naturally durable heartwood surrounded by a thin (<25 mm) thick sapwood shell. The durable heartwood of this species has permitted its use with either no supplemental treatment or treatment of the butt only in a variety of environments with excellent results. Average service in excess of 80 years has been reported for this species and poles removed from service after 40 to 60 years retain strength at or near their original design values. Such enviable performance has made western redcedar the long sought after choice for supporting utility lines despite a higher initial cost.

Recently, however, questions concerning the durability of this wood species have arisen among utility users, who have experienced sporadic early failures of cedar poles under conditions that normally would be considered low or moderately susceptible to decay. These failures have raised concerns that the durability of the cedar source is changing as the industry increasingly shifts to younger trees grown under more silviculturally aggressive conditions. There is no question that the durability of second growth of some species declines markedly in comparison to original "old growth" trees. Notable examples of this effect include bald cypress and coast redwood. The reasons for these changes are not well understood, but their effects have important implications for the use of these species. Complicating this issue is the inherent variability of naturally durable woods. Natural durability can vary widely between trees of the same species as well as with tree height and location in the cross section. Typically, the most recently formed heartwood is most durable and durability declines as the heartwood ages. Finally, further complicating the western redcedar durability issue, is the allowance of some internal decay in poles of this species. Western redcedar is the only pole species in which decay is permitted, as a result of the belief that fungi causing decay in living trees are unable to survive the seasoning and treatment processes. Data for this premise are hard to come by owing to the difficulty of isolating fungi from western redcedar heartwood even when visible decay is present.

In order to better understand the distribution of relative durability within western redcedar poles currently being produced, we undertook the following survey:

Six western redcedar pole yards were sampled with the cooperation of the Western Redcedar Association. At each site, 50 poles were randomly selected and a single 5-10 cm thick cross-section was cut from the butt end of each pole. The pertinent data on pole source was recorded and the discs were shipped to Oregon State University.

Upon arrival, the section age of each was determined by sanding the surface and counting rings. A series of 1 cm cubes was then cut from three locations across each section--just inside the heart/sap interface, midway across the heartwood and immediately adjacent to the pith. These cubes were numbered, oven-dried (54°C) and weighed (nearest 0.001 g). The cubes were then soaked to saturation, placed in plastic

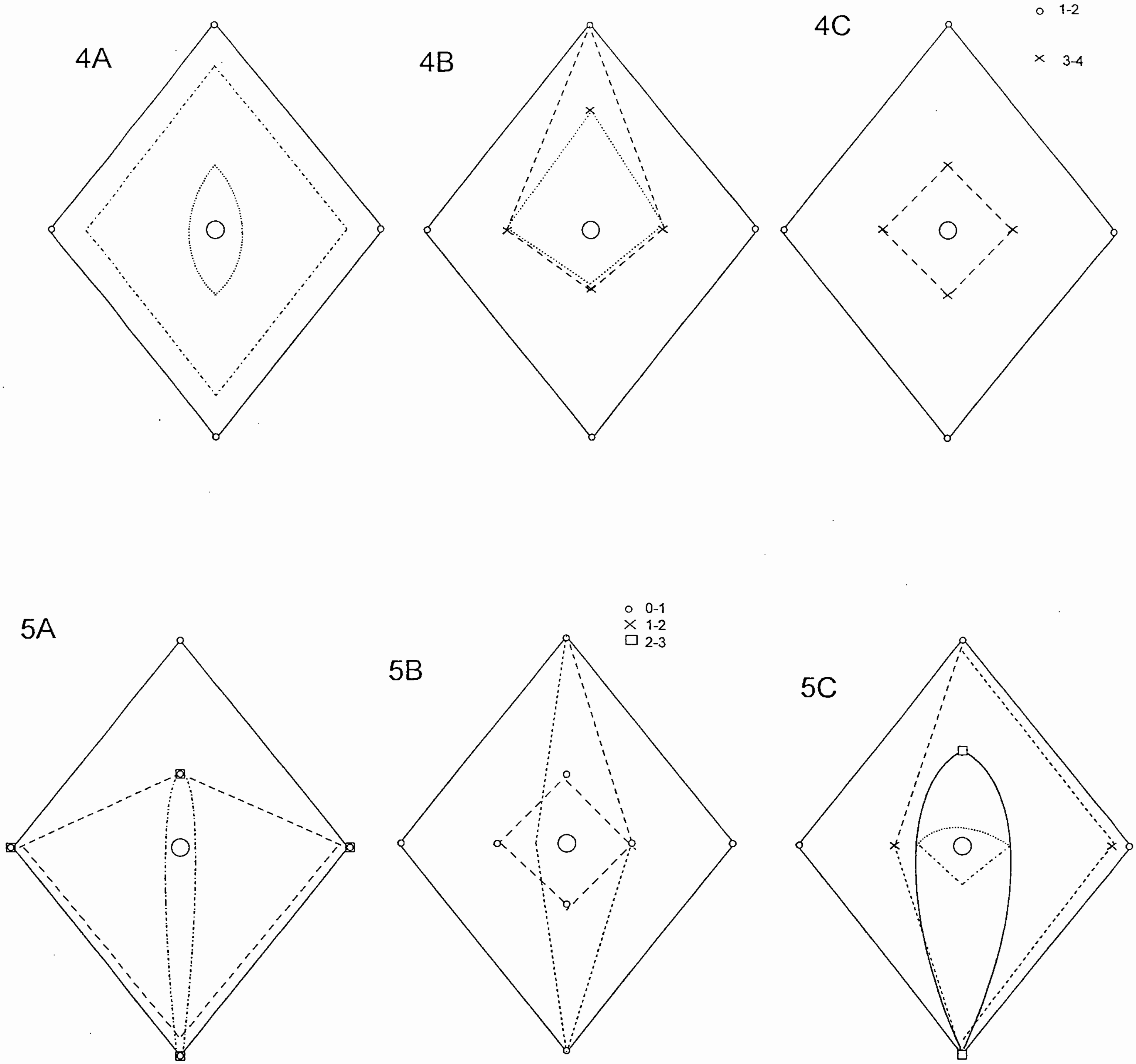
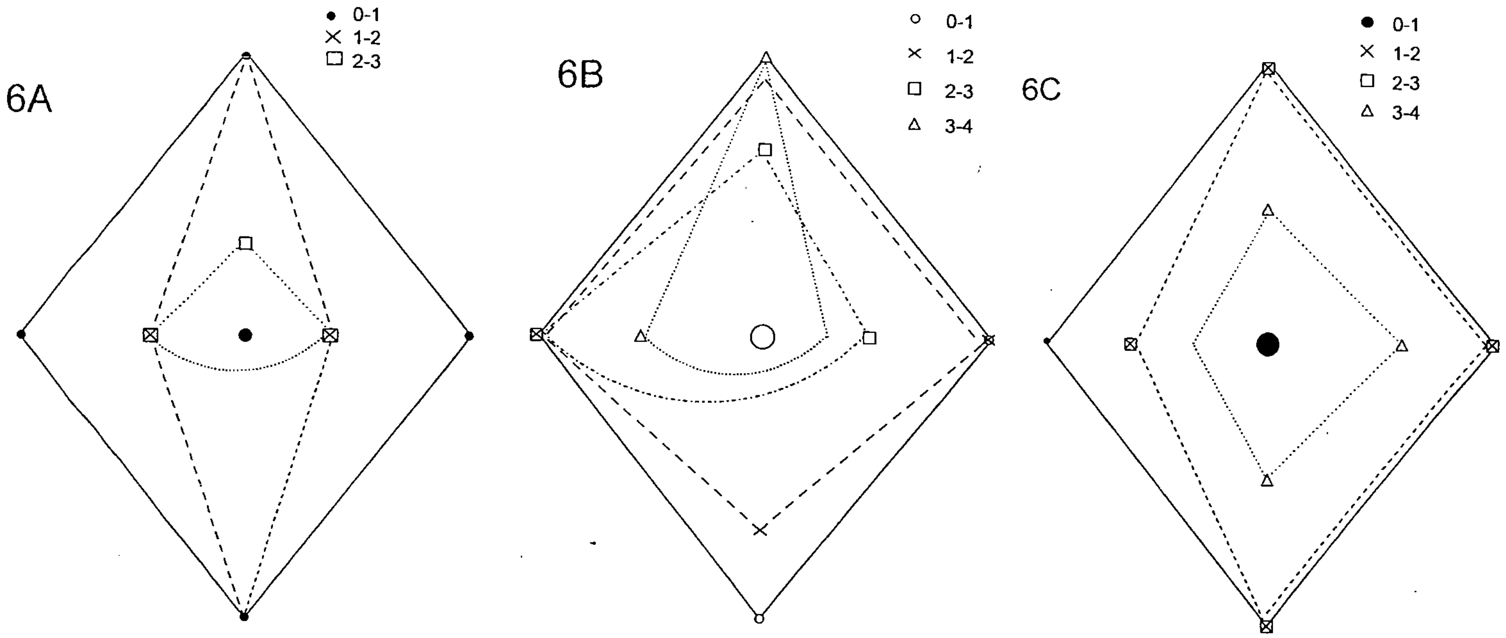


Figure III-3. Examples of pentachlorophenol penetration patterns around through-bored holes in Douglas-fir poles. Distances from the through-bolter hole are in inches.

Figure III-3. Continued.



bags and sterilized by exposure to 2.5 MRADS from a cobalt 60 source. The cubes were then evaluated using a modified soil block procedure in which 114 ml glass jars were half-filled with moist forest loam and a 15x15x3 mm thick western hemlock wafer was placed on the soil surface. The jars were capped and autoclaved for 45 minutes at 121°C, cooled overnight, and autoclaved for an additional 15 minutes. After cooling, the edge of each wood wafer was inoculated with a 3 mm diameter disk of agar cut from the actively growing edge of a culture of *Postia placenta* (Fr.) M. Larson and Lombard. The jars were incubated at 28°C until the wafers were thoroughly colonized, then two sterile cubes were added to each bottle. The bottles were incubated for 12 weeks at 28°C, then each cube was scraped clear and weighed to ensure that the moisture levels were suitable for fungal growth. The cubes were oven-dried (54°C) and weighed (nearest 0.001 g) to determine wood weight lost as a result of fungal exposure.

Decay tests have been completed on five of the six samples and the sixth will be sampled shortly. As might be expected from a sample of this size (300 cross sections), the results vary widely. These results are being presented in a series of graphs by site so that users can begin to see the array of possible durability levels found within western redcedar. Currently, sites are presented by code until sources can be confirmed and the data can be thoroughly analyzed.

As expected for naturally durable woods, weight losses varied widely among and between sites (Figures III-4). Weight losses ranged from 0 to nearly 50%, although most weight losses were less than 10%. Weight losses were generally lowest in samples from Site 1. Samples from Sites 2 and 3 were geographically similar and, if source affects durability, we would expect weight losses for these sites to be similar. In fact, weight losses from these two sites were similar. Weight losses appeared to be slightly higher in samples from Site 4.

Research was also conducted on the effect of cross-section location on durability. Previous studies suggest that the most recently formed heartwood should be most durable, while wood closest to the pith has the lowest durability. This did not appear to be the case with the present data. Although many samples from the outer heartwood experienced lower weight losses, there was no consistent trend with position.

In previous studies, the concept of old growth (>100 years) compared to second growth was related to durability. Tree ages in the current study ranged from 40 to 330 years. The relationship between age and durability was examined for all blocks and for blocks by position. Generally, weight losses were poorly correlated with tree age (r^2 = 0.0007 to 0.001) indicating that heartwood durability is not changing as treaters moved to second growth poles. This would be critical since the ability to supply poles 100 years or older will ultimately become more difficult. The initial results indicate that second growth trees are no less durable than old growth western redcedar. It will be important, however, to continue to evaluating durability as poles increasingly come from more heavily managed forests.

We still have one set of pole sections in test. Once these are completed, we will begin a more detailed analysis of the data and compare these results with previous decay tests performed 40 years ago by T.C. Scheffer, then at the U.S. Forest Products Laboratory.

C. RELATIONSHIP BETWEEN TROPOLONE CONTENT OF INCREMENT CORES AND DECAY RESISTANCE IN WESTERN REDCEDAR[a]

Western redcedar (*Thuja plicata* Donn) is a valuable commercial species in the northwestern United States and Canada. One of its most important characteristics is high decay resistance, which is due to the presence of toxic extractives in the heartwood. While a number of heartwood extractives have been shown to be toxic to fungi, the tropolones are the most important; they are comparable to pentachlorophenol in toxicity (Barton and

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[a] This section represents a portion of a thesis by Jeffrey DeBell.

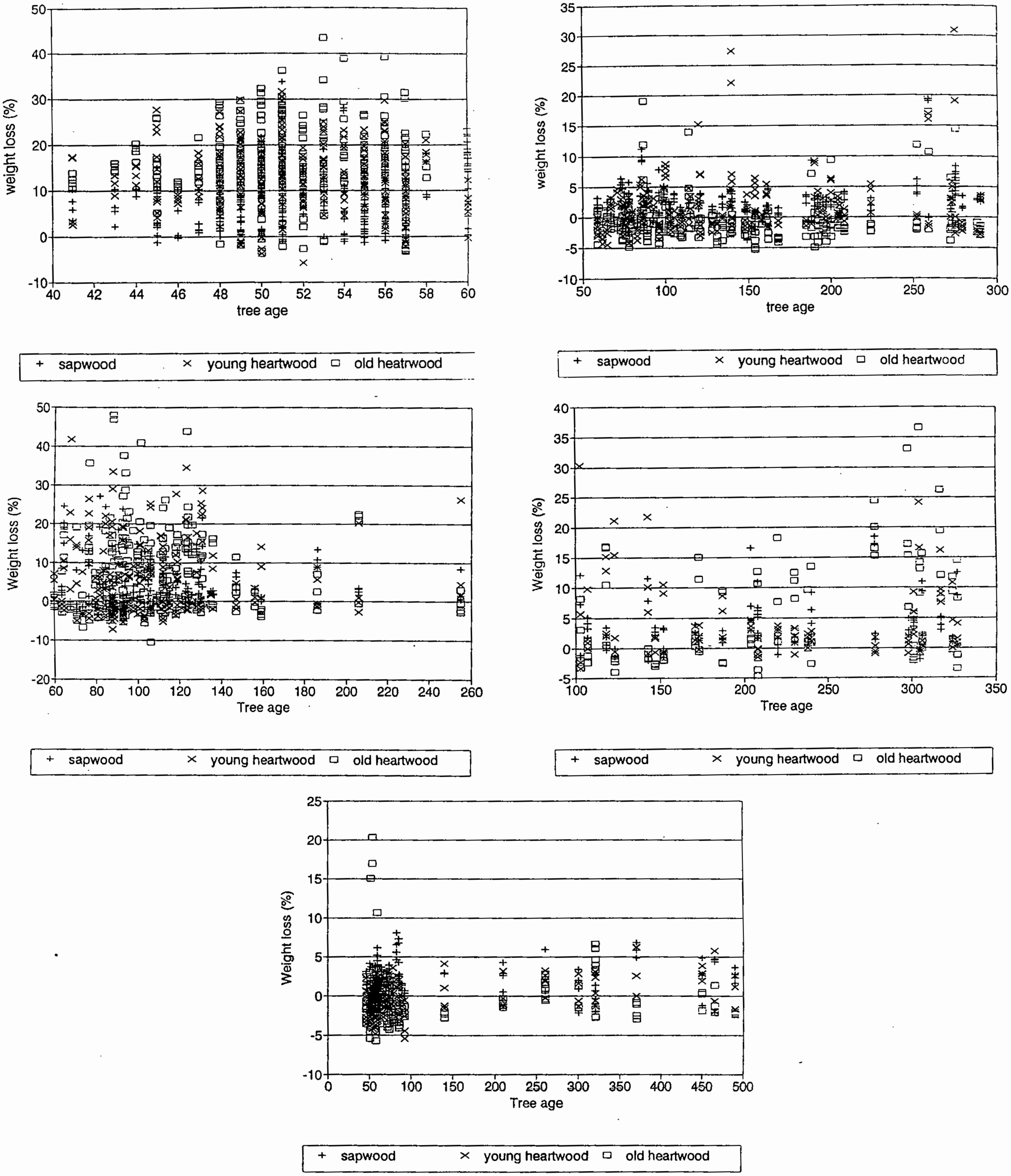


Figure III-4. Tree age vs weight losses of western redcedar heartwood cubes removed from selected zones of the cross-section of trees taken from five sites in the Pacific Northwest.

MacDonald 1971; Rennerfelt 1948; Rudman 1962,1963). Five tropolones have been identified in western redcedar. Of these, β-thujaplicin, γ-thujaplicin, and β-thujaplicinol are the most important in terms of quantity, together making up 98% of the total tropolone content (Barton and MacDonald 1971; Frazier 1987).

If tropolones are primarily responsible for the decay resistance of western redcedar, then it should be possible to use tropolone content of the wood as an indicator of decay resistance. Tropolone content can be assessed in days; the standard method of assessing decay resistance is the soil block test, which takes 12-16 weeks. Nault (1988) noted that measurement of tropolones using gas chromatography can be accomplished with very small samples, making it possible to use increment cores to assess tropolone content of standing trees. This procedure would be particularly useful for studying tropolone content in situations where destructive sampling of trees is undesirable.

Techniques have been developed for measuring thujaplicin content using gas chromatography (Johnson and Cserjesi 1975,1980; Nault 1987,1988). These techniques require extraction in a soxhlet apparatus; this restricts the number of samples that can be processed at one time to the number of soxhlet setups available. For some studies, it would be desirable to use a method that allows efficient handling of large numbers of samples.

Our objective was to modify the techniques for measuring thujaplicins to allow efficient handling of large numbers of increment cores or similar sized samples. We then examined the relationship between measurements of tropolone content using the modified extraction procedure and decay resistance in soil block tests.

Wood Samples: Material for this study came from western redcedar trees growing near Clatskanie, Oregon, on the Oregon State University College of Forestry's Blodgett Tract. Disks were cut every 2m from breast height (1.37m) to the top of 11 trees. The disks were air dried in the lab. A drill equipped with a 9.5mm plug cutter was used to remove two plugs, parallel to the stem axis and oriented side by side tangentially, from the outermost heartwood of each disk (Figure III-5). A second pair of plugs was removed approximately 1.5 cm from the pith. One of the plugs from each pair was used for tropolone analysis, while the other was used in the decay tests.

Tropolone Measurements: We modified the extraction technique of Johnson and Cserjesi (1980) by replacing soxhlet extraction with cold extraction in centrifuge tubes. The benefit of this modification was the ability to process larger numbers of samples. The disadvantage was that complete extraction was not possible. Thus, the method is suitable for studying relative differences in tropolone content between wood samples rather than absolute tropolone content.

Pure samples of γ-thujaplicin and β-thujaplicinol were provided by Forintek Canada Corporation. β-thujaplicin was purchased under the name Hinokitiol from a commercial supplier (TCI America). Tropolone contents were determined by comparison with prepared solutions of these known compounds. Tropolone content was expressed as a percentage of air-dried wood weight.

Each redcedar plug was cut into pieces and ground in a small Wiley mill to pass through a 30-mesh screen. Approximately 0.5 g of wood meal from each sample was weighed and placed in 50 ml plastic centrifuge tube, along with 9 ml of acetone and 1 ml of an internal standard solution (3,4,5-trimethoxyphenol in acetone, about 0.35 mg/ml). The tube was capped and allowed to sit overnight (16 hours) at room temperature (23-25°C). The sample was then centrifuged for 5 minutes, and the supernatant was transferred by Pasteur pipet to a clean 50ml plastic centrifuge tube.

The samples were evaporated to about 1 ml by blowing air through a small hoses into the tube. When the volume of the sample was reduced to about 1 ml, the solution was transferred it to a small glass vial, and evaporated to dryness using air as described above. When the sample was dry, 0.2 ml of B.S.A. (N,O-bis (trimethylsilyl) acetamide) was added, and the sample was placed in a

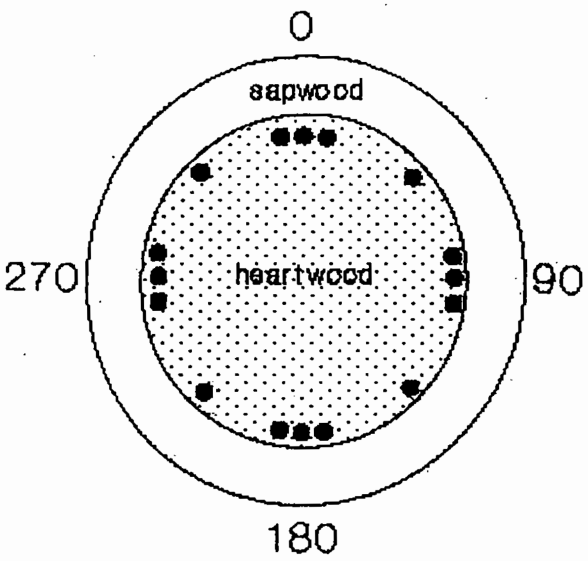


Figure III-5. Locations of plugs removed from western redcedar disks to evaluate cross-section variation in tropolone content.

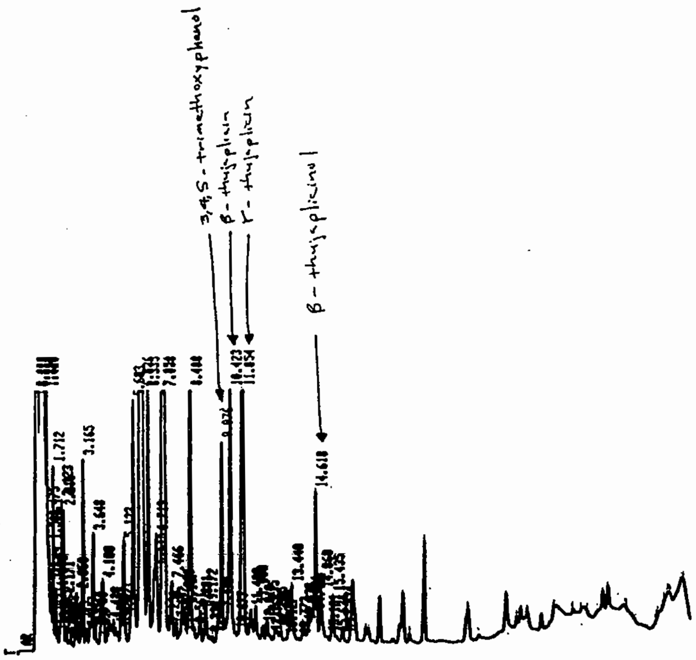


Figure III-6. Sample chromatogram of western redcedar heartwood extract.

warming tray at 70°C for 10 minutes. A needle and syringe were then used to transfer the solution to an autosampler vial, which was capped and placed in the autosampler tray to await injection into the gas chromatograph. One microliter injections were made.

A Hewlett Packard HP-5890 gas chromatograph equipped with a flame ionization detector and an autosampler was used for analysis. The column was a Supelco SPB-5 (30m x 0.75mm). Hydrogen was the carrier gas, with a flow rate of 15 ml/min. The initial oven temperature of 125°C was held for 4 minutes, then raised at 5°C/minute to 200°C. Injector temperature was 250°C and the detector temperature was 250°C. Retention times for the internal standard and tropolone were as follows 3,4,5-trimethoxyphenol: 9.9 min; β-thujaplicin: 10.4 min; γ-thujaplicin: 11.0 min; β-thujaplicinol: 14.6 min (Figure III-6).

Additional Samples Run: The precision of the analytical method was assessed by extracting 5 subsamples of a single cedar heartwood sample and by examining 5 injections from a single extract. Also, the variations in tropolone content in an individual stem were assessed by analyzing 16 plugs from a single cross-section.

Soil Block Tests: Soil block tests were performed using procedures described by Scheffer et al. (1987). Briefly, 113 ml glass bottles were half-filled with moist forest loam and a single 15x15x3 mm thick alder (*Alnus rubra*) feeder strip was placed on the soil surface. Water was added to raise the moisture content to 100% (wet basis), then the jars were loosely capped prior to autoclaving for 45 minutes at 121°C. After cooling, the feeder strips were inoculated with 3mm diameter disks of agar cut from the actively growing edge of cultures of *Poria placenta,* a fungus which causes brown rot of many coniferous species. The bottles were incubated at 28°C until the feeder strips were throughly colonized by the test fungus. The cedar heartwood plugs were oven dried (54°C), weighed, and sealed in plastic bags and subjected to 2.5 mrads of ionizing radiation from a cobalt 60 source. The plugs were placed on the feeder strips (1/bottle) and the jars were then incubated at 28°C for 16 weeks. The plugs were removed, scraped clean of adhering mycelium prior to oven drying (54°C), and weighed. Weight loss was used as the measure of decay resistance.

A. Small-scale analysis:

Consistency of Method: Multiple injections from a single sample of cedar extract and extractions of 5 subsamples from a single batch of cedar meal produced uniform results with coefficients of variation of 1.9% and 4.5%, respectively. These low levels of variation attest to the consistency of the method.

Variation in Tropolone Content Around the Stem: Tropolone content around the circumference of a disk was fairly uniform, averaging between 0.2 and 0.3% (Figure III-7). However, samples from the 180 degree position contained nearly double the tropolone content of samples from the rest of the disk. There were no apparent reasons for these variations.

For the most part, a single increment core should be a reliable indicator of tropolone content at a given height in a tree. The similarity between tropolone contents at positions where clusters of three samples were taken increased our confidence that the method gave consistent results. It also suggested that where increment cores are used, the cores should be removed from points at least 90 degrees apart, since taking two cores near the same point may do little to improve the estimate of the average tropolone content at that height in the tree.

B. Relationship of Tropolone Measurements to Soil Block Tests: Tropolone content of the wood samples ranged from 0 to 1.2% (weight basis). Weight losses ranged from 0 to 70% (Figure III-8). Weight losses were variable for samples with tropolone content of <0.10%, but averaged 21%. Weight losses were less variable for samples with tropolone contents between 0.10% and 0.24%, averaging 9%. Samples with tropolone content of 0.25% and greater had consistently high decay resistance. Average weight loss was 4%; only 3 out of the

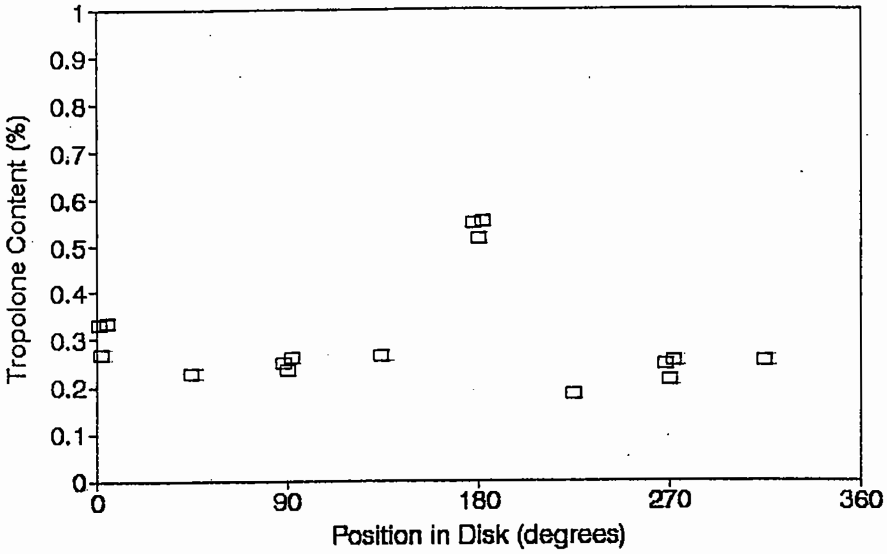


Figure III-7. Effect of sampling position on tropolone content in a single western redcedar disk (see Figure III-5 for sampling pattern).

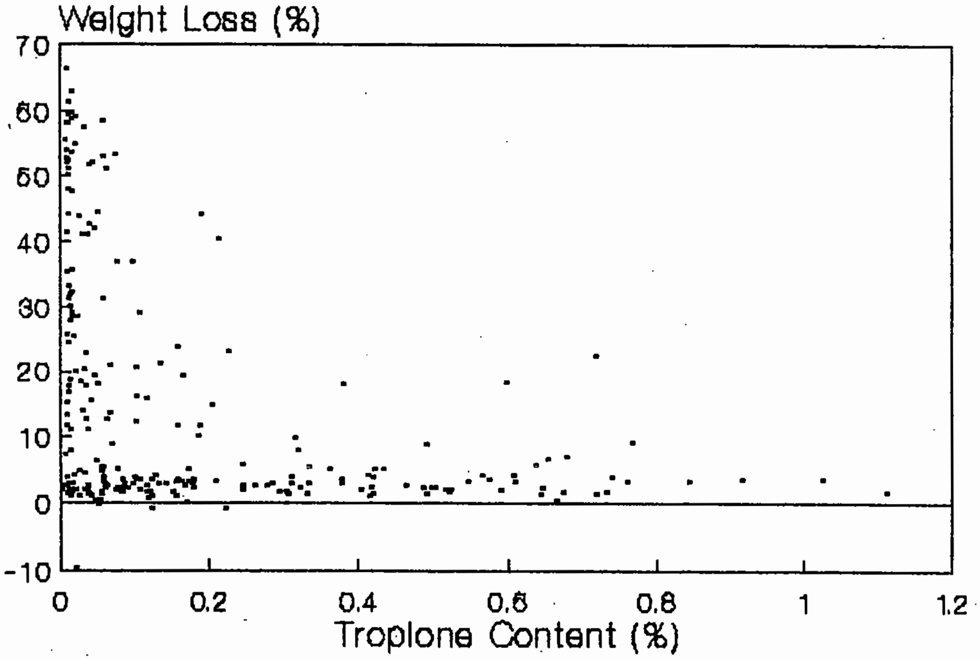


Figure III-8. Relationship between tropolone content and decay resistance (measured by weight loss in soil block tests) for plugs cut from western redcedar heartwood.

59 samples with high tropolone content had more than 10% weight loss.

We are unsure of the reasons for the variability in weight loss in samples with low tropolone levels. One possibility is that other substances in the heartwood prevented significant decay in some samples. However, there were no obvious patterns in the chromatograms to suggest any major differences between low tropolone samples. Differences in tropolone distribution might influence the results, since the extract and decay samples were removed from adjacent locations; however, the initial multiple sample of a single disk (Figure III-8) suggests that these differences should be minimal. The variability of the soil block test may also influence the results since individual decay tests can sometimes vary widely.

The modified tropolone analysis method gave consistent results, and could handle large numbers of samples fairly efficiently. A single increment core should provide a reasonable estimate of tropolone content for a given height in the tree. The method we used provides relative tropolone content rather than absolute content, and is useful for comparing differences between wood samples rather than establishing absolute tropolone content for a given sample. High decay resistance can be expected when tropolone content reaches 0.25% as measured by this modified method.

LITERATURE CITED

Barton, G.M. and B.F. MacDonald. 1971. The chemistry and utilization of western red cedar. Canadian For. Serv. Publ. No. 1023. 31 pp.

Frazier, C.E. 1987. The essential oil of western red cedar, (*Thuja plicata*). M.S. Thesis. Univ. of Washington. Seattle, WA. 112 pp.

Johnson, E.L. and A.J. Cserjesi. 1975. Gas-liquid chromatography of some tropolone-TMS ethers. J. Chromatog. 107(2):388.

Johnson, E.L. and A.J. Cserjesi. 1980. Weathering effect on thujaplicin concentration in western redcedar shakes. For. Prod. J. 30(6):52-53.

Nault, J. 1987. A capillary gas chromatographic method for thujaplicins in western redcedar extractives. Wood Sci. Technol. 21(4):311-316.

Nault, J. 1988. Radial distribution of thujaplicins in old growth and second growth western red cedar (*Thuja plicata* Donn). Wood Sci. Tech. 22(1):73-80.

Rennerfelt, E. 1948. Investigations of thujaplicin, a fungicidal substance in the heartwood of *Thuja plicata* D. Don. Physiologia Plantarum 1(3):245-254.

Rudman, P. 1962. The causes of natural durability in timber. IX. The antifungal activity of heartwood extractives in a wood substrate. Holzforschung 16(3):74-77.

Rudman, P. 1963. The causes of natural durability in timber. Part XI. Some tests on the fungi toxicity of wood extractives and related compounds. Holzforschung 17(2):54-57.

Scheffer, T.C., J.J. Morrell and M.A. Newbill. 1987. Shellrot control in western redcedar: potential replacements for pentachlorophenol spray. For. Prod. J. 37(7/8):51-54.

OBJECTIVE IV
PERFORMANCE OF EXTERNAL GROUNDLINE BANDAGES

Initial preservative treatment using pressure processes produces well-treated barriers that resist fungal and insect attack in terrestrial exposures. In some species, or in some exposures, this protective effect declines with time permitting degradation of the outer surface of the pole, typically by the action of soft rot fungi (Zabel et al., 1985). This damage can have a dramatic negative impact on pole strength, thereby shortening service life and decreasing system reliability. Surface decay is generally controlled by application of preservative pastes to the wood surface. The effectiveness of this approach to pole maintenance has long been known (Panek et al., 1961; Leutritz and Lumsden, 1962; Harkom et al., 1948; DeGroot, 1981; Henningsson et al., 1988; Chudnoff et al., 1977; Ziobro et al., 1987; Smith and Cockroft, 1967). For many years, the biocides used in these systems included oilborne chemicals such as creosote or pentachlorophenol and water-based fungicides such as sodium dichromate, dinitrophenol, and sodium fluoride. The oil-based biocide was presumed to provide supplemental protection against renewed fungal attack from the surrounding soil, while the water-based materials diffused for short distances into the wood to arrest growth of fungi which had already become established in the pole. The final resolution of the rebuttable presumption against registration (RPAR) process by the U.S. Environmental Protection Agency led to the designation of creosote, pentachlorophenol (penta) and the inorganic arsenicals as restricted use pesticides which could only be used by certified applicators. These activities, coupled with desires by many utilities to move to less toxic biocides encouraged a widespread effort to reformulate external groundline preservative systems using combinations of copper naphthenate, sodium fluoride, or boron. While each of these biocides is a proven wood preservative, their performance as external groundline preservatives was untested. In order to develop comparative information, the following test was performed.

A. *EVALUATION OF FORMULATIONS IN DOUGLAS-FIR TEST POLES AT CORVALLIS, OREGON*

Freshly peeled sections of Douglas-fir (*Pseudotsuga menziesii* (Mirb.) Franco) (1.8 m long and 25 to 30 cm in diameter) were air-seasoned for 6 months before use. Five sections each were treated with one of six external preservative systems:

CUNAP WRAP® (CSI, Inc., Charlotte, NC), containing 2.0 percent copper naphthenate (as Cu) on an absorbent pad.

CuRap20® (ISK Biotech, Memphis, TN), a paste containing 18.16 percent amine-based copper naphthenate and 40 percent sodium tetraborate decahydrate.

COP-R-NAP® (Osmose Wood Preserving, Inc., Buffalo, NY), a paste containing 19.25 percent copper naphthenate.

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

POLNU 15-15® (ISK Biotech), a grease containing 12.9 percent pentachlorophenol, 15 percent creosote, and 1.5 percent chlorinated phenols.

POLNU® (ISK Biotech), a grease containing 10.2 percent pentachlorophenol.

The POLNU systems were included to provide comparisons between new formulations and those used previously.

The pastes were applied according to the manufacturer's directions. All but the self-contained CUNAP WRAP were covered with polyethylene wrap before being set 45 cm deep in the ground at the Peavy Arboretum test site, near Corvallis, Oregon. 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 precipitation per year, 81 percent of which falls between October and March. Average monthly temperatures range from 3.9° to 11.7°C during that period and rarely exceed 30°C or fall below 0°C at other times. The soil is an Olympic silty clay and is slightly acidic (pH 5.4). During the winter months, the water table rises to within 15 cm of the soil surface. Over the first 3 years of the study, however, rainfall was below average.

Preservative distribution was assessed 18, 30, 42, 54, and 66 months after treatment. Either 2 cm diameter plugs or increment cores were removed from three equidistant sites around each pole section, 15 cm below the groundline. Cores were removed initially, but as the poles became wetter and internally decayed, it was difficult to obtain solid cores, so plugs were substituted. Multiple increment cores were required from each site to produce an equivalent volume of wood. 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 with an Asoma 8620 x-ray fluorescence analyzer (XRF) (Asoma Instruments, Austin, TX). Borate was analyzed by the azomethine-H method described in AWPA Standard A2, Method 16 (AWPA, 1995a). Fluoride analyses were performed on blind samples by R. Ziobro (Osmose Wood Preserving, Inc.) according to AWPA Standard A2 Method 7 (AWPA, 1995b).

The condition of the untreated posts has declined considerably over the 5.5-year test, but the wrapped sections retained sufficient integrity for sampling purposes. Levels of all wrap components were initially well above the thresholds for fungal attack and declined markedly with distance from the wood surface (Table IV-1). For example, penta levels at 18 months in the outer 4 mm in both POLNU and POLNU 15-15 treated posts ranged from 3.36 to 6.24 kg/m^3, well above the reported threshold of 2.4 kg/m^3 (Figure IV-1). Penta levels farther from the surface declined precipitously, with little or no penta being detected beyond 16 mm from the surface. Penta levels in the outer zone also declined with time, with levels in the POLNU declining below the threshold 66 months after chemical application.

Copper levels in formulations containing copper naphthenate initially followed trends similar to those found for the penta based systems with declining levels with distance from the surface and time after treatment, but these levels in the outer zone had not yet declined below the purported threshold against non-copper tolerant fungi (0.64 kg/m^3 Cu) 66 months after treatment (Figure IV-2). In addition to these trends, there appeared to be slight differences in copper levels with the four copper based systems. Copper levels in the outer 4 mm of posts 66 months after treatment, have declined most substantially in CUNAP WRAP®, COP-R-NAP® and CuRap20® treatments, although these levels all remained above the threshold for protection against fungal attack. Copper levels in COP-R-PLASTIC® treated poles continue to remain over ten times higher than those in the remaining three copper naphthenate treatments, and show no signs of declining.

One other interesting aspect of the copper naphthenate systems was the inability of the water soluble, amine-based copper naphthenate in CuRap20® to move more readily into the wood. In previous trials using green southern pine posts, this chemical moved for substantial distances from the wood surface (West et al., 1992). In the current trial, however, the posts were partially seasoned prior to chemical application. Perhaps inability of the copper naphthenate to migrate reflects this lower initial moisture level.

Levels of boron in posts receiving CuRap20® were initially well above the

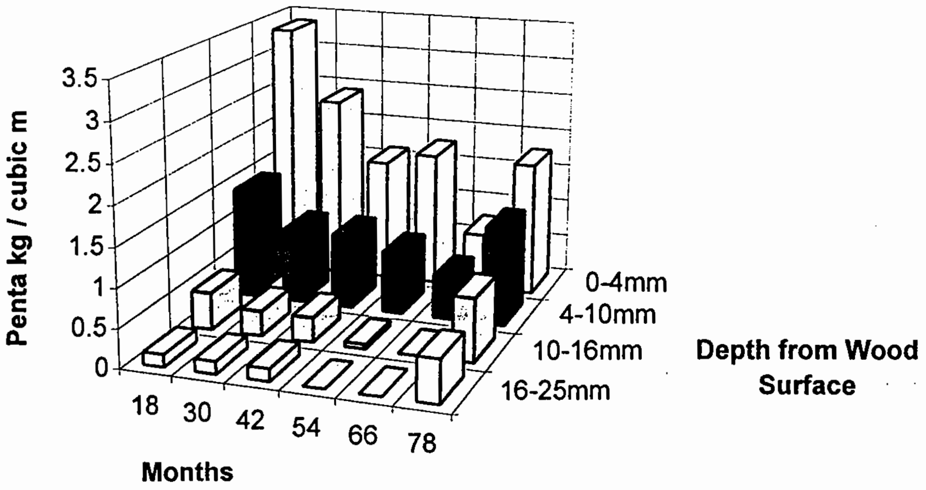
Table IV-1. Chemical content at selected depths from the wood surface of Douglas-fir posts 18, 30, 42, 54, 66, and 78 months after treatment with selected groundline bandage systems.

Chemical Treatment	Exposure Period (months)	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/m^3)				(kg/m^3)				(%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	–	–	–	–	–	–	–	–	–	–	–	–
	54	1.61	1.01	0.61	0.31	–	–	–	–	–	–	–	–	–	–	–	–
	66	1.54	1.23	1.71	0.51	–	–	–	–	–	–	–	–	–	–	–	–
	78 (n = 5)	1.17	1.00	0.59	0.43	–	–	–	–	–	–	–	–	–	–	–	–
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	–	–	–	–	–	–	–	–	–	–	–	–
	54	1.45	0.52	0.30	0.15	–	–	–	–	–	–	–	–	–	–	–	–
	66	1.14	0.67	0.52	0.28	–	–	–	–	–	–	–	–	–	–	–	–
	78 (n = 1)	0.99	0.78	0.61	0.37	–	–	–	–	–	–	–	–	–	–	–	–
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	–	–	–	–
	54	2.10	0.34	0.60	0	–	–	–	–	0.12	0.10	0.11	0.08	–	–	–	–
	66	1.43	0.32	0	0	–	–	–	–	0.07	0.05	0.04	0.05	–	–	–	–
	78 (n = 4)	2.09	0.52	0.15	0.09	–	–	–	–	0.04	0.03	0.03	0.03	–	–	–	–
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
	54	2.65	0.70	0.24	0.11	–	–	–	–	–	–	–	–	0.73	0.37	0.28	0.27
	66	3.63	1.13	0.47	0.15	–	–	–	–	–	–	–	–	1.45	0.55	0.39	0.19
	78 (n = 5)	2.51	0.71	0.28	0.12	–	–	–	–	–	–	–	–	0.75	0.30	0.21	0.19
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	–	–	–	–	–	–	–	–
	54	–	–	–	–	1.76	0.80	0.06	0	–	–	–	–	–	–	–	–
	66	–	–	–	–	0.73	0.56	0	0	–	–	–	–	–	–	–	–
	78 (n = 4)	–	–	–	–	1.75	1.27	0.81	0.55	–	–	–	–	–	–	–	–

		Average Chemical Level															
Chemical Treatment	Exposure Period (months)	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)			
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	–	–	–	–	–	–	–	–
	54	–	–	–	–	3.04	1.28	0.32	0	–	–	–	–	–	–	–	–
	66	–	–	–	–	1.98	1.03	0.20	0	–	–	–	–	–	–	–	–
	78 (n=4)	–	–	–	–	2.70	2.08	1.23	0.68	–	–	–	–	–	–	–	–

[a] By distance (mm) from wood surface.

n = Number of poles sampled with plugs. Pole number reduced at 78 months due to advanced decay. Number of poles sampled equals five unless otherwise noted.


Pol-Nu 15-15 Penta Levels from Groundline Bandages

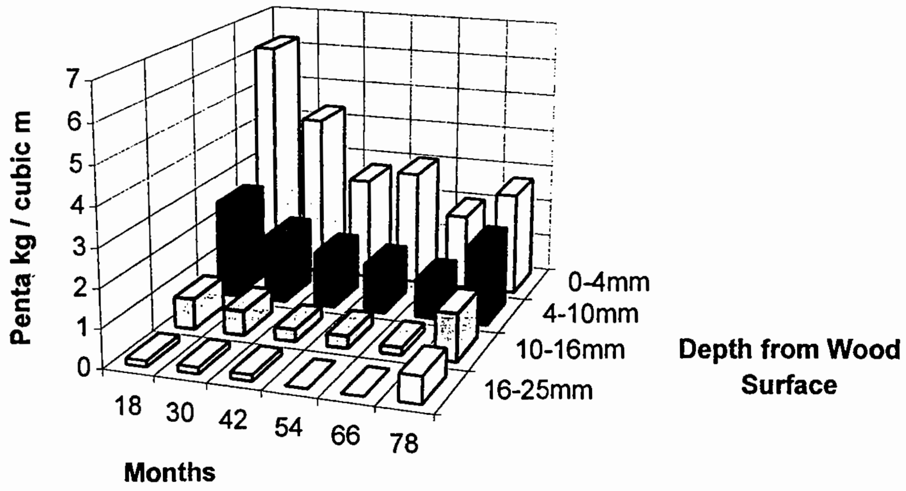

Pol-Nu Penta Levels from Groundline Bandages

Figure IV-1. Residual levels of pentachlorophenol in Douglas-fir poles treated with POLNU® and POLNU 15-15® groundline bandage systems.

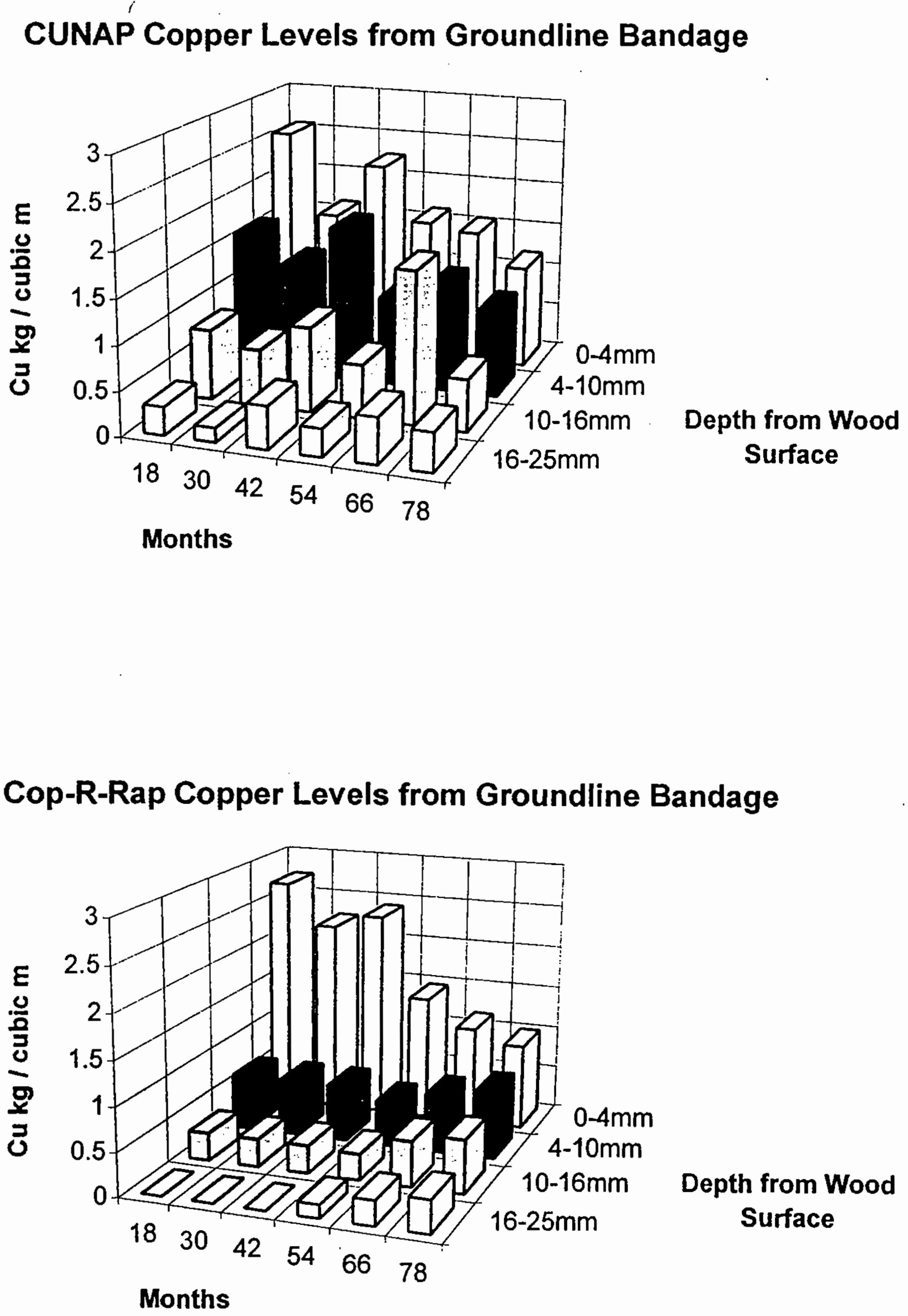


Figure IV-2. Residual levels of copper naphthenate (as Cu) in Douglas-fir poles treated with (a) CUNAP WRAP®, (b) COP-R-Rap groundline bandage systems.

reported threshold for fungal attack (0.25% BAE) 18 months after treatment to a depth of 25 mm, but these levels rapidly declined over the remaining test period (Figure IV-3). At present, boron levels in the posts are similar to those found naturally in Douglas-fir. Boron has been widely used as a fungicide and insecticide because of its well known ability to migrate through normally impermeable woods with moisture. This characteristic, must be considered a negative, particularly under the test conditions employed. Suggestions have been made that boron might diffuse from the surface far into the wood to provide supplemental internal protection, however, amortizing the levels assayed at 1 year across a pole 350 mm in diameter would result in boron levels far below those required for fungal protection. Thus, the boron in CuRap20® should be viewed as a temporary supplement to copper naphthenate in this formulation.

Fluoride in COP-R-PLASTIC® treated pole sections behaved markedly different from boron in CuRap20® tested pole sections (Figure IV-3). Fluoride levels were similar to those for boron 18 months after treatment, but declined much more slowly over the remaining 48 months of the test. Fluoride is generally more toxic to decay fungi than boron and its ability to remain in the posts under a high leaching exposure suggests that the combination of fluoride and copper naphthenate in this formulation should provide excellent long-term surface protection (Becker, 1976).

One factor which complicates the assessment of external bandages is the role of the preservative present from the original treatment. In the present tests, untreated posts were used to provide a direct comparison of efficacy of the various formulations without a complicating initial treatment. In practice, these treatments are applied over the existing biocide to supplement protection. For example, it is likely that residual chemical loadings from the initial pressure treatment coupled with the declining levels of the two POLNU formulations would continue to protect the wood surface. Further studies to better understand the performance of these formulations are underway on in-service Douglas-fir, western redcedar, Ponderosa and southern pine poles in New York and California, as are laboratory trials to determine the thresholds for boron/fluoride/copper naphthenate mixtures. This information will help utilities make more informed decisions concerning the frequency of retreatment with these systems.

All of the alternative external preservative systems continue to provide protection to Douglas-fir posts which is equivalent or greater than that provided by penta based formulations. Further studies are underway to more fully delineate the protective role of these systems.

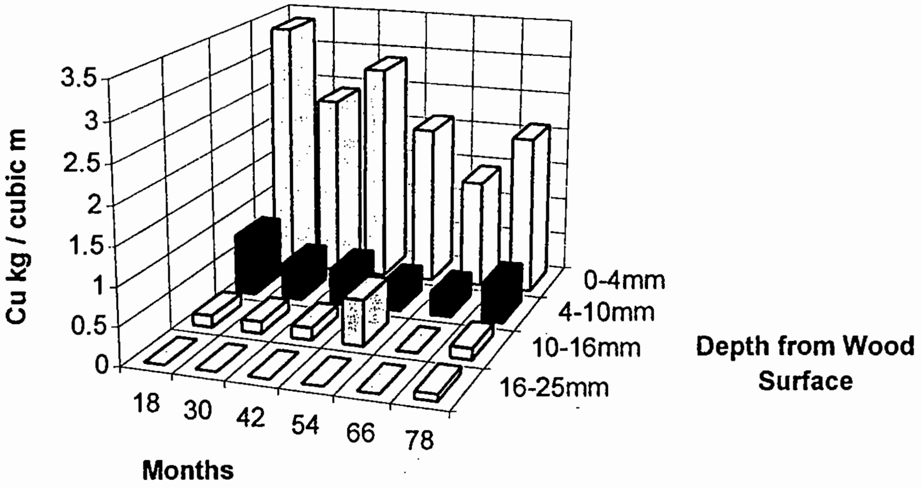
B. EVALUATION OF SELECTED GROUNDLINE BANDAGE SYSTEMS IN DOUGLAS-FIR, WESTERN REDCEDAR, AND PONDEROSA PINE POLES IN MERCED, CALIFORNIA

While controlled field trials using otherwise untreated Douglas-fir have provided excellent data for the various chemicals and have demonstrated the comparable performance of these newer systems, it is also desirable to generate data on groundline bandages on in-service poles of other species exposed at alternative sites.

The Merced area in Northern California was selected for this purpose because it tends to be slightly drier than Corvallis, experiences higher temperatures, and, most importantly, the cooperation utility in this area had three wood species available for evaluation.

A total of 27 Douglas fir, 27 western redcedar, and 15 Ponderosa pine poles was presampled by removing plugs from three equidistant locations around the groundline. The outer 25 mm of each plug was removed and plugs from a single pole were combined prior to being ground to pass a 20 mesh screen. The resulting powder was analyzed for pentachlorophenol using an Asoma 8620 x-ray fluorescence analyzer. These results were then used to partition the poles into three equal groups so that each group contained poles with similar ranges of preservative retentions (Table IV-2).

CuRAP 20 Copper Levels from Groundline Bandage



COP-R-PLASTIC Copper Levels from Groundline Bandages

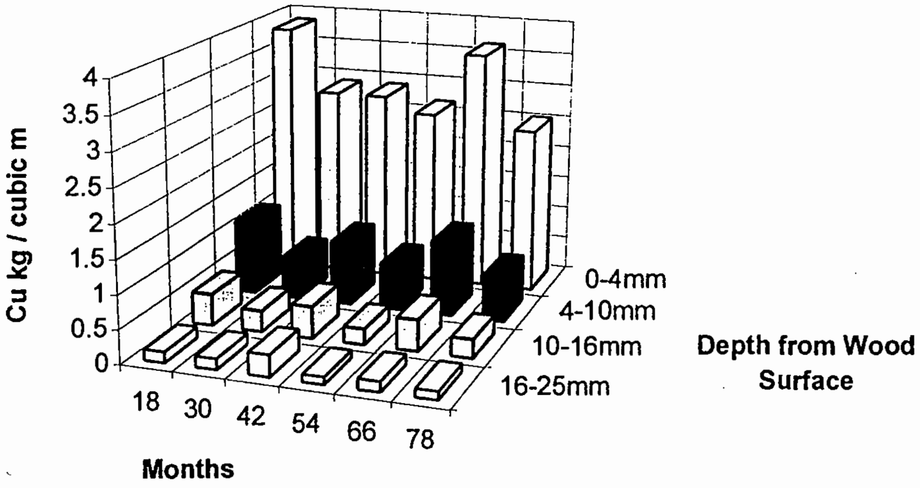


Figure IV-3. Residual levels of copper naphthenate (as Cu) in Douglas-fir poles treated with CuRap20 or Cop-R-Plastic groundline bandage systems.

Table IV-2. Retentions of pentachlorophenol in the outer 2.5 cm of Douglas-fir, western redcedar, and ponderosa pine poles prior to groundline preservative treatment.

Pole #	Species	Retention (kg/m^3)	Treatment	Pole#	Species	Retention (kg/m^3)	Treatment
2/6	DF	.563	PATOX II	4/14	WRC	.370	CUNAP
2/7	DP	.386	DUNAP	4/15	WRC	.285	CUNAP
2/8	DF	.331	CURAP	4/16	WRC	.221	PATOX II
2/9	DP	.427	PATOX II	5/0	WRC	.618	PATOX II
2/10	DF	.505	CUNAP	5/1	WRC	.592	PATOX II
2/11	DF	.402	CUNAP	5/2	WRC	.372	CURAP 20
2/13	DF	.472	CURAP 20	5/3	WRC	1.639	CUNAP
2/14	DF	1.027	CURAP 20	5/4	WRC	.397	PATOX II
2/16	DF	.398	CURAP 20	5/5	WRC	.400	CUNAP
2/17	DF	.278	CUNAP	5/6	WRC	.198	PATOX II
2/18	DF	1.548	PATOX II	5/7	WRC	.244	CUNAP
2/19	DF	1.413	CUNAP	5/8	WRC	1/111	CUNAP
3/0	DF	.224	PATOX II	5/11	WRC	.153	CUNAP
3/1	DF	.791	CURAP 20	5/12	WRC	.837	CUNAP
3/2	DF	.657	PATOX II	5/13	WRC	.203	CUNAP
3/3	DF	.696	CURAP 20	5/14	WRC	.738	CURAP 20
3/4	DF	.487	CURAP 20	5/15	WRC	1.395	PATOX II
3/5	DF	.828	CUNAP	5/16	WRC	.419	CUNAP
3/11	DF	.394	PATOX II	L9/0	WRC	.104	CUNAP
3/12	DF	.794	PATOX II	L9/2	WRC	.025	CURAP 20
4/3	DF	.290	CURAP 20	L9/3	WRC	.110	CURAP 20
4/4	DF	.653	CUNAP	L9/4	WRC	.168	CURAP 20
4/5	DF	.481	PATOX II	L9/6	WRC	.076	PATOX II
4/8	DF	.779	CUNAP	L9/8	WRC	.110	CUNAP
4/9	DF	.914	PATOX II	L10/1	WRC	.154	PATOX II
4/12	DF	.557	CURAP 20	L10/2	WRC	.234	CUNAP
4/13	DF	.479	CUNAP	L10/3	WRC	.139	PATOX II
1	PP	.552	CURAP 20	9	PP	.569	CUNAP
2	PP	.478	PATOX II	10	PP	.357	CUNAP
3	PP	.774	PATOX II	11	PP	.304	PATOX II
4	PP	.535	CUNAP	12	PP	.523	CURAP 20
5	PP	.582	CURAP 20	13	PP	.333	CUNAP
6	PP	.819	CUNAP	14	PP	1.009	PATOX II
7	PP	.722	PATOX II	15	PP	.458	CURAP 20
8	PP	.762	CURAP 20				

1. Where DF= Douglas-fir, WRC= Western redcedar, and PP= Ponderosa pine.

Poles in a selected group were excavated to a depth of 45 cm and one of three groundline bandage systems was applied according to manufacturer's specifications.

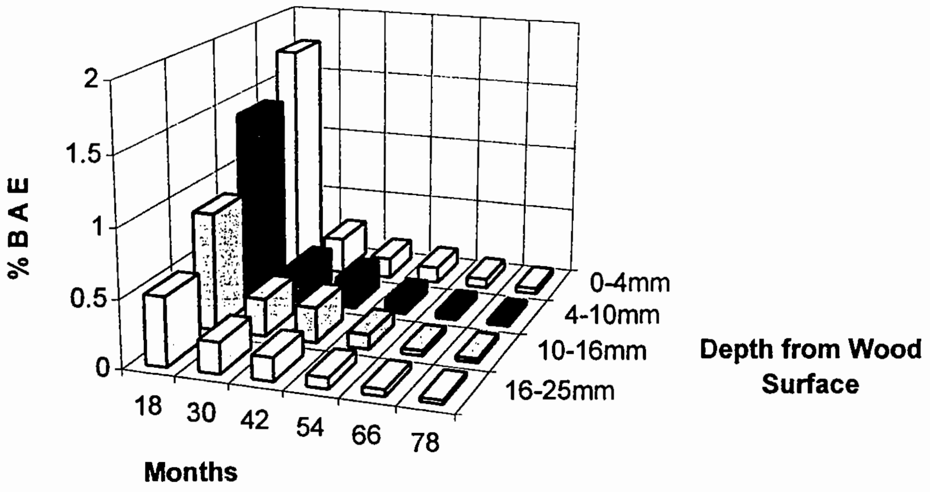
CUNAP® and CuRap20® were the same formulations evaluated on untreated Douglas-fir poles at the Corvallis test site, while PATOX II (Osmose Wood Preserving Inc., Buffalo, NY), was a newer formulation containing 70.3% sodium fluoride as the only active ingredient.

The ability of the three formulations to move into the selected wood species was assessed 1-, 2-, 3-, and 5 years after application by removing three increment cores from equidistant points around each pole approximately 15 cm below groundline. These cores were divided into zones corresponding to 0 to 4, 4 to 10, 10 to 16 and 16 to 24 mm from the wood surface. Samples from the same zone from a respective treatment group were combined prior to grinding to pass a 20 mesh screen. Samples from poles treated with CuRap20® or CUNAP WRAP® were analyzed for residual copper content by x-ray fluorescence. Samples treated with boron were analyzed by hot water extraction followed by the Azomethine H method (AWPA, 1995). Samples treated with PATOX II were analyzed on a blind sample basis by Osmose Wood Preserving, Inc. using the method described in AWPA Standard A2-94, Method 7 (AWPA, 1995).

The copper levels in the two formulations containing copper naphthenate varied widely (Figure IV-5,6). Copper in CuRap20® treated poles was initially higher than that found in poles treated with CUNAP WRAP® and these trends have continued over the 5-year test period. Copper levels in both treatments were highest 1 to 2 years after treatment, then steadily declined. The threshold for protection of wood against fungal attack using copper naphthenate where copper tolerant fungi are not prevalent varies from 0.3 to 0.7 kg/m^3 (as Cu). Based upon this range, copper levels in the outer zone remain at or above the threshold for both systems, although the levels in CuRap20® treated poles are far in excess of this range implying that this treatment may provide a longer residual protective period under the test conditions. Copper levels in CUNAP WRAP® treatments were slightly higher in Douglas-fir poles 5 years after treatment. Penetration of copper naphthenate into the various pole species varied, reflecting the permeability of each wood. This was particularly true for CUNAP WRAP®. The gradient of copper from outer to inner assaying zones was relatively shallow in Ponderosa pine, and dropped off more sharply in the other two species. Ponderosa pine is considerably more permeable that either Douglas-fir or western redcedar. This effect was not present in CuRap20®. The copper naphthenate in CuRap is amine based and initially water soluble, while CUNAP WRAP® is oil soluble. Differences in interactions with the wood or the moisture present in the wood may account for the differential movement.

Boron levels in CuRap20® treated poles were well above the threshold for decay prevention 1 and 2 years after treatment, then declined to near the threshold at 3 years (Figure IV-5). Boron levels [5 years after treatment] have rebounded in Douglas-fir and western redcedar but continue to decline in Ponderosa pine. In the earlier field tests on Douglas-fir pole sections, boron levels steadily declined over the test period, reflecting the sensitivity of the fungicide to water. The Corvallis test site has a high water table which encourages leaching and presents a formidable challenge to the use of boron in the groundline. The Merced site is much drier, lacks the high water table, and potentially represents a less severe leaching exposure. The reasons for the sudden increase in boron levels is unclear, although it may represent differences in seasonal rainfall. Boron levels in the four sampling zones were uniform for Ponderosa pine and western redcedar and exhibited a slight outer to inner gradient in Douglas-fir. Boron distribution should become reasonably uniform in these poles as the chemical diffuses across the pole with moisture.

Fluoride levels in PATOX II treated poles indicate that levels remain well above the threshold in the two outer assay zones (Figure IV-6). Fluoride levels remain highest in western


CuRAP 20 Boron Levels from Groundline Bandages

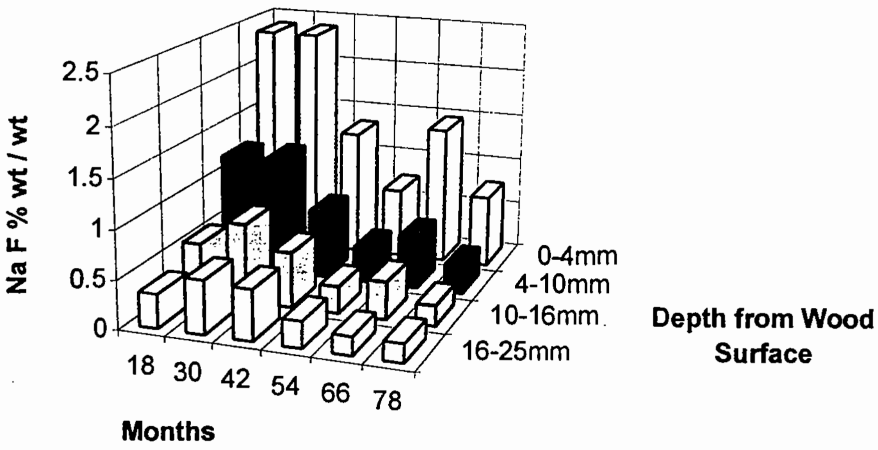

COP-R-PLASTIC Sodium Fluoride Levels from Groundline Bandages

Figure IV-4. Residual levels of boron or fluoride in Douglas-fir poles treated with CuRap20® or COP-R-PLASTIC®, respectively.

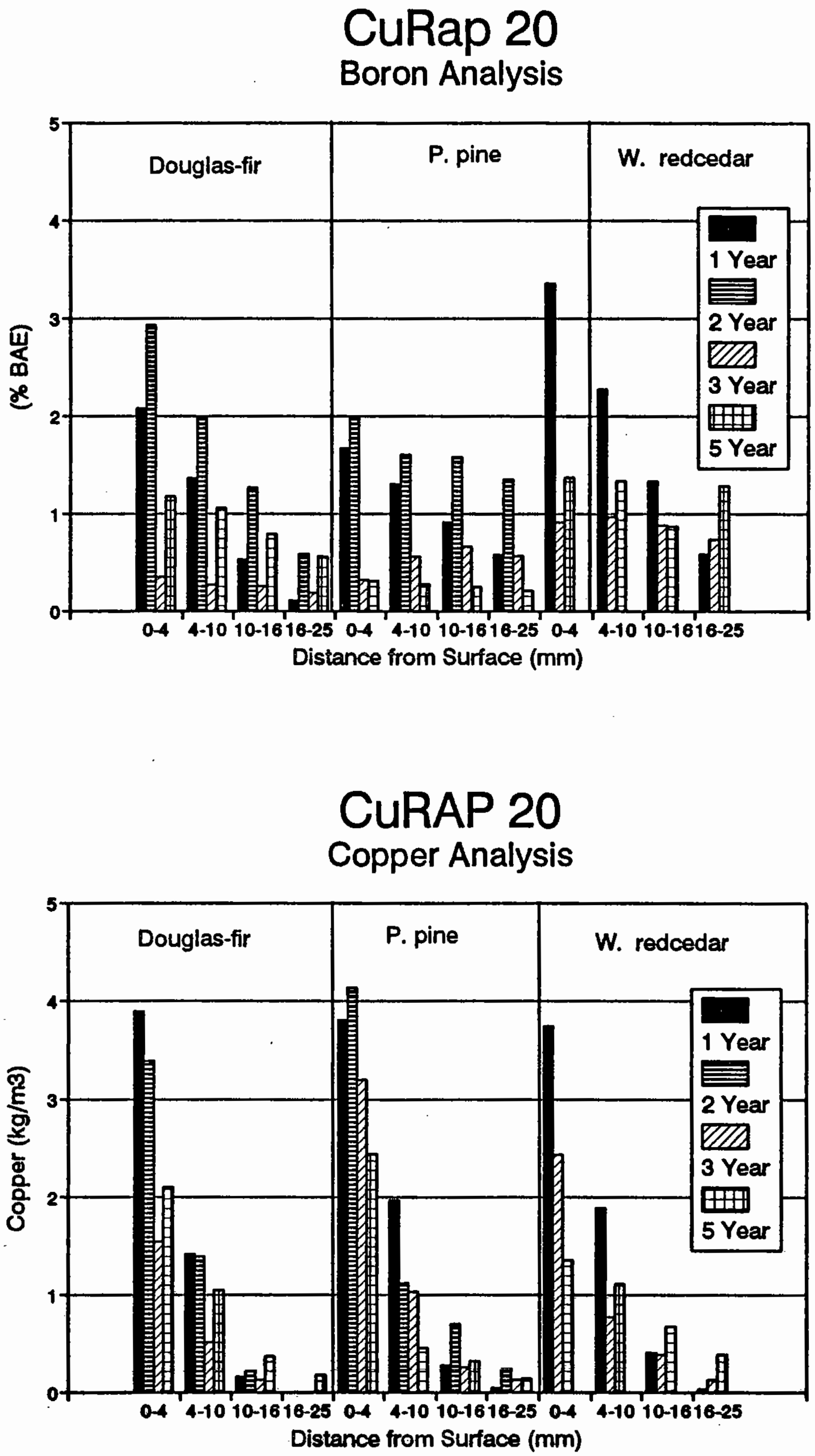


Figure IV-5. Residual levels of copper or boron in Ponderosa pine, western redcedar, or Douglas-fir poles 3 years after treatment with CuRap20®.

redcedar, while levels in Ponderosa pine and Douglas-fir appear similar. Unlike boron, fluoride levels continue to exhibit a concentration gradient from the surface inward, suggesting that the chemical distribution has not yet equilibrated.

While the results appear similar to those found with Douglas-fir poles at the Corvallis site, subtle differences have emerged. Boron appears to remain for longer periods in the California poles, while the fluoride levels are similar at both sites. Copper levels in CuRap20® are similar in both sites on the outer assay zone, but are higher in the next zone in the California poles. Copper levels in CUNAP WRAP®-treated poles in California have never approached the levels found in Corvallis. These results illustrate the need to assess systems on a multitude of sites with varying environmental characteristics to develop estimated service life data.

Despite these differences, chemical levels in poles receiving all three treatments remain adequate for protecting the surface against fungal attack five years after treatment.

C. EVALUATION OF GROUNDLINE BANDAGE SYSTEMS ON WESTERN RED-CEDAR AND SOUTHERN PINE POLES IN NEW YORK

In order to generate additional data on groundline bandage systems on the southern pine, the species most often receiving this treatment, a field test was established in Binghamton, New York. Western redcedar and southern pine distribution poles ranging in age from 5 to 60 years were treated with CUNAP WRAP®, CuRap20®, or PATOX II as described earlier. This test was only installed in October of last year and will be sampled shortly.

Outcomes of This Objective

- Reformulated groundline bandages performing similarly to earlier systems
- Boron is most susceptible to loss, although rate of loss varies with site conditions
- Copper levels vary widely with site and formulation

LITERATURE CITED

American Wood-Preservers' Association. 1995a. Book of Standards. Standard A2-94. Standard methods for analysis of waterborne preservatives and fire-retardant formulations. Method 7. Determination of the fluoride in wood and solutions. AWPA, Woodstock, MD.

American Wood-Preservers' Association. 1995b. Book of Standards. Standard A2-94. Standard methods for analysis of waterborne preservatives and fire-retardant formulations. Method 16. Determination of boron in treated wood using Azomethine H or Carminic acid. AWPA, Woodstock, MD.

Becker, G. 1976. Treatment of wood by diffusion of salts. Doc. No. IRG/WP/358. Inter. Res. Group on Wood Preservation, Stockholm, Sweden.

Chudnoff, M., W.E. Eslyn, and R. Wawriw. 1977. Effectiveness of groundline treatment of creosoted pine poles under tropical exposures. Forest Prod. J. 28(4):28-32.

DeGroot, R.C. 1981. Groundline treatments of southern pine posts. Res. Pap. FPL-409. USDA Forest Service, Forest Prod. Lab., Madison, WI.

Harkom, J.F., M.J. Colleary, and H.P. Sedziak. 1948. Results of the examination of seven ground-line treatments and one butt treatment of eastern white cedar pole stubs after six years' service. IN: Proc. Am. Wood-Preservers' Association, 44:158-171.

Henningsson, B., H. Friis-Hansen, A. Kaarik, and M.-L. Edlund. 1988. Remedial groundline treatment of CCA poles in service: A progress report after 28 months' testing. Doc. No. IRG/WP/3481. Inter. Res. Group on Wood Preservation. Stockholm, Sweden.

Leutritz, J., Jr., and G.Q. Lumsden. 1962. The groundline treatment of standing southern pine poles. IN: Proc. Am. Wood-Preservers' Assoc. 58:79-86.

Morrell, J.J., A.E. Connelly, P.F. Schneider, P.G. Forsyth, and J.J. Morrell. 1996. Performance of external groundline bandages in Douglas-fir poles. Proceedings International Conference on Wood Poles and Piles. Fort Collins, CO, pp.

Morrell, J., Forsyth, P.G., and Newbill, M.A. 1994. Distribution of biocides in Douglas-fir poles 42 months after application of groundline preservative systems. For. Prod. J. 44(6):24-26.

Panek, E., J.O. Blew, Jr., and R.H. Baechler. 1961. Study of groundline treatments applied to five pole species. Rept. No. 2227. USDA Forest Service, Forest Prod. Lab., Madison, WI.

Smith, D.N. and R. Cockroft. 1967. The remedial treatment of telephone and electric transmission poles. Part 1. Treatment for external decay. Wood 32(9):35-40.

West, M.H., M.H. Freeman, and R.S. Gross. 1992. Remedial treatments with a borate-copper naphthenate paste. Proceedings International Conference on Wood Poles and Piles, Fort Collins, CO, p. 95-99.

Zabel, R.A., F.F. Lombard, C.J.K. Wang, and F.C. Terracina. 1985. Fungi associated with decay in treated southern pine utility poles in the eastern United States. Wood and Fiber Sci. 17:75-91.

Ziobro, R.J., W.S., McNamara, and J.F. Triana. 1987. Tropical field evaluations of groundline remedial treatments on soft rot attacked CCA-treated eucalyptus poles. Forest Prod. J. 37(3):42-45.

OBJECTIVE V
PERFORMANCE OF COPPER NAPHTHENATE TREATED WESTERN WOOD SPECIES

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

The naturally durable heartwood of western redcedar makes it a preferred species for supporting overhead utility lines. For many years, utilities used cedar without treatment or only treated the butt portion of the pole to protect the high hazard ground contact zone. The cost of cedar, however, encouraged many utilities to full-length treat their cedar poles. While most utilities use either pentachlorophenol or creosote for this purpose, there is increasing interest in less toxic alternatives. Among these chemicals in copper naphthenate, a complex of copper and naphthenic acids derived from the oil refining process. Copper naphthenate has been used for many years, but its performance as an initial wood treatment for poles remains untested on western redcedar.

Copper naphthenate performance on western redcedar was evaluated by cutting sapwood stakes (12.5 by 25 by 150 mm long) from either freshly sawn boards or from the above ground, untreated portion of poles which had been in service for about 15 years. Weathered stakes were included because of a desire by the cooperator to retreat cedar poles in their for reuse. In prior trials, a large percentage of cedar poles removed from service due to line upgrades were found to be serviceable and the utility wanted to recycle these in their system. The stakes were conditioned to 13% moisture content prior to pressure treatment with copper naphthenate in diesel oil to produce retentions of 0.8, 1.6, 2.4, 3.2, and 4.0 kg/m^3. Each retention was replicated on 10 stakes.

The stakes were exposed in a fungus cellar maintained at 28°C and approximately 80% relative humidity. The soil was a garden loam with a high sand content. The original soil was amended with compost to increase the organic matter. The soil is watered regularly, but is allowed to dry between waterings to simulate a natural environment. The condition of the stakes has been assessed annually on a visual basis using a scale form 0 (failure) to 10 (sound).

Results after 76 months of treatment continue to show a difference in performance levels between stakes cut from freshly sawn sapwood and weathered wood (Table V-1). These differences most probably reflect the fact that the increased permeability of the weathered material makes it more susceptible to leaching losses. This effect is most noticeable with both the diesel control and the lower retentions. The freshly sawn stakes have ratings of 8.0 for the diesel control while similarly treated weathered stakes had ratings which averaged 3.4.

Treatment with copper naphthenate to the retention specified for western redcedar in the American Wood Preservers' Association for pressure process (1.92 kg/m^3) continues to provide excellent protection to both weathered and freshly sawn samples. At present, copper naphthenate appears to be providing excellent protection to western redcedar sapwood.

B. EVALUATION OF COPPER NAPHTHENATE TREATED DOUGLAS-FIR POLES IN SERVICE

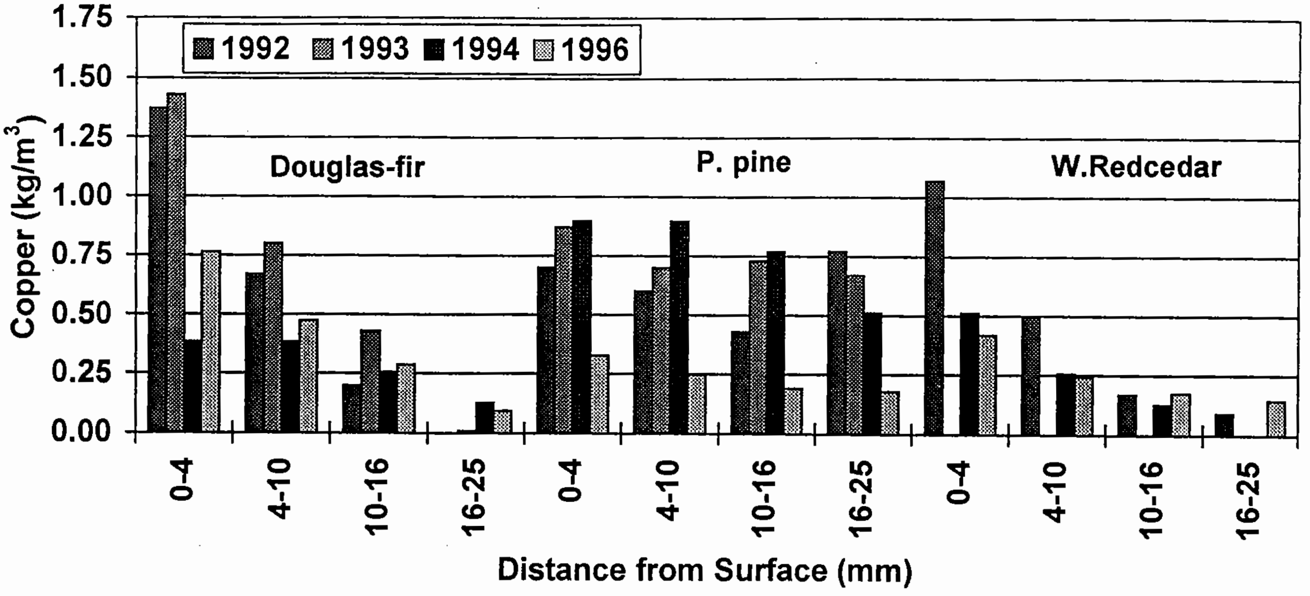
The trials to evaluate the performance of Douglas-fir poles treated with copper naphthenate were not evaluated this past year. We will inspect these poles in 1997.

Table V-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 76 months.

Target Retention [1] (kg/m³)	Weathered Samples								New Samples							
	Actual Retention (kg/m³)	Average Decay Rating [2]							Actual Retention (kg/m³)	Average Decay Rating [2]						
		6 mos	14 mos	26 mos	40 mos	52 mos	64 mos	76 mos		6 mos	14 mos	26 mos	40 mos	52 mos	64 mos	76 mos
Control	–	4.7	0.9	0.4	0.1	0	0	0	–	6.6	3.2	1.3	1.1	1.1	1.0	0.9
diesel	–	8.5	6.8	5.3	3.8	3.4	3.4	2.0	–	9.9	8.4	8.0	8.6	8.4	8.0	8.0
0.8	1.6	9.0	8.0	7.5	6.9	5.7	5.6	5.3	0.6	10.0	9.6	9.4	9.5	9.6	9.3	9.3
1.6	1.4	9.5	8.9	8.8	9.0	8.0	7.8	7.4	1.3	10.0	9.4	9.3	9.2	9.4	9.1	9.2
2.4	2.1	9.6	9.2	9.1	8.6	8.2	8.2	7.9	1.9	10.0	9.4	9.4	9.2	9.3	9.2	9.1
3.2	2.7	9.6	9.1	9.0	8.8	8.1	8.1	8.1	2.6	10.0	9.2	9.2	9.0	8.9	8.9	9.1
4.0	4.0	9.9	9.2	9.1	9.1	8.7	8.3	8.2	3.4	10.0	9.5	9.4	9.4	9.3	9.2	9.2

[1] Retention measured as (kg/m³) (as copper).

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



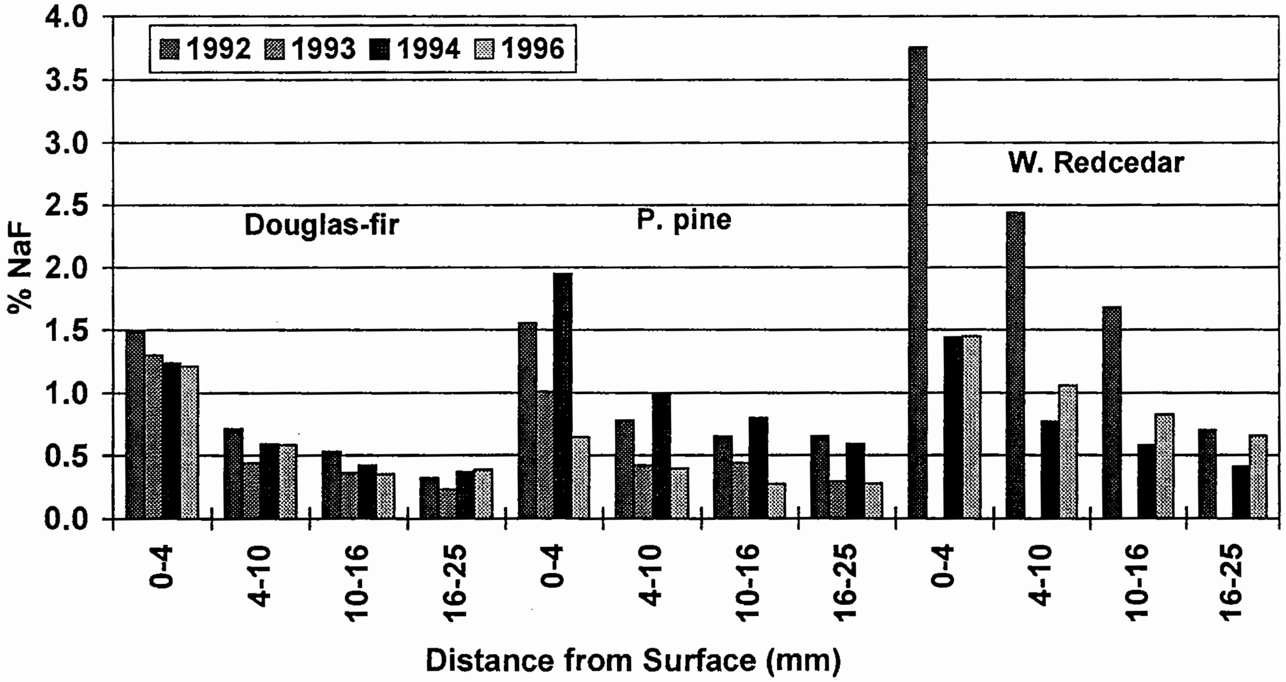


Figure IV-6. Residual copper or fluoride levels in Ponderosa pine, western redcedar, or Douglas-fir poles 5 years after treatment with (a) CUNAP WRAP® or (b) PATOX II.