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

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SUMMARY

Efforts on each of the five objectives addressed under the Cooperative are continuing.

Under Objective I, we continue to evaluate a variety of field trials of volatile and water diffusible internal treatments. Evaluations of poles internally treated with gelatin encapsulated methylisothiocyanate (MITC) prior to installation indicate that residual MITC remains in the poles 8 years after treatment. Similar evaluations of poles treated above ground with either encapsulated chloropicrin or MITC showed that relatively low levels of residual protection remained in the poles.

Evaluation of poles treated 1 year ago with metham sodium in California showed that MITC was well distributed around the treatment zone. These poles will continue to be monitored to assess performance of metham sodium in warmer climates.

Field trials using solid basamid with or without copper as an additive in Douglas fir poles are now in their third year. The results show that addition of copper initially enhanced MITC release, but this effect has diminished with time. All treatments experienced a marked increase in MITC levels this past year, probably due to the high rainfall levels at the test site.

Evaluations of boron and fluoride based internal treatments are also continuing. Evaluations of a boron/fluoride rod formulation indicate that boron and fluoride levels in poles treated with this formulation remain relatively low 3 years after treatment. The reasons for the low levels are unclear, although they may reflect leaching losses due to the high moisture levels present at the test site during the winter months. Further evaluations are planned. Poles treated with sodium fluoride rods were also evaluated one year after installation. After some initial analytical difficulties due to interference from oils in the wood, analysis showed that fluoride was beginning to move into the poles at rates that would eventually control decay fungi.

Laboratory trials were also established to evaluate the ability of glycol to enhance diffusion of boron from fused borate rods. In these trials, the ability of ethylene glycol alone, Boracol 20, Boracol 40, Boracare, or Timbor to increase boron diffusion was evaluated on Douglas-fir heartwood blocks conditioned to 15, 30 or 60% moisture content. As expected, boron diffusion in blocks conditioned to 60% MC was virtually complete in all treatments. The addition of glycol based formulations produced more variable results. In some instances, the addition of a glycol based material produced slight enhancement of diffusion in blocks conditioned to 15% MC, but the results were inconsistent. The results suggest that glycol based materials may have a minimal impact on diffusion of boron based rods.

The effect of various additives on decomposition of basamid to MITC was also investigated. Copper naphthenate was found to produce dramatic increases in MITC release from powdered basamid in the presence of moisture, while several clay materials had little effect on release.

Field trials to evaluate the efficacy of various topical treatments for protecting field-drilled bolt holes were not sampled this year, but will be evaluated in 1997 and reported upon in the 1998 annual report.

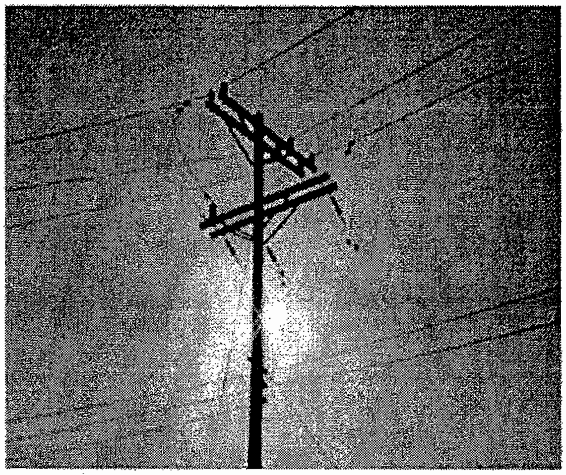
Efforts to improve the process of through-boring of Douglas-fir poles to enhance initial preservative treatment are continuing. This past year we completed analysis of tests performed in cooperation with Bonneville Power Administration, Pacific Power and Portland General Electric. The results indicated that poles through-bored using a modified pattern with a reduced number of holes experienced no significant loss in bending strength. In addition, we have

performed trials to assess the penetration around individual through bored holes in order to more accurately determine an optimum spacing pattern that ensures uniform treatment with a minimum of holes. The results show that penetration laterally from the holes was minimal, while longitudinal penetration varied widely. In most cases, however, longitudinal penetration exceeded 100 mm from the through bored hole. The results will be used to construct a standard through-boring pattern.

The evaluation of durability of western redcedar heartwood from various locations in the Pacific Northwest and Inland Empire has been completed. While cedar durability varied widely, no consistent patterns emerged. A comparison of the data with that of a similar study performed in the 1950's showed that durability had changed little in the intervening 40 years. These results reflect, in part, the fact that utility poles still come from relatively old trees.

The groundline preservative field trials were not sampled this past year, but will be sampled in 1998. A laboratory trial of a preservative paste containing propiconazole showed that this formulation was capable of migrating for short distances into Douglas-fir heartwood blocks at levels well above those required for protection against fungal attack.

Evaluation of copper naphthenate-treated western redcedar continues to show that this species/chemical combination is performing well under accelerated fungal exposure conditions. Field evaluations of copper naphthenate-treated Douglas-fir are planned for the coming year.



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 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 poles 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 decay-arresting fumigants in the late 1960s provided one of the first widely effective methods for economically prolonging the service life of 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-dithiocarbamate) is caustic. The third fumigant registered for wood use (methylisothiocyanate) 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 effectiveness of the various treatments. In this section, we describe results from those trials involving volatile chemicals.

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	20%	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/ sodium fluoride	58.2/24.3		Preschem Ltd.
PATOX Rods	sodium fluoride			Osmose Wood Preserving

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

Test Site	Chemicals Evaluated	Date Installed	1996-97 Activity
Peavy Arboretum	Field drilled bolt hole treatments	1981	None
Peavy Arboretum	Cedar pole sprays	1981	None
Dorena Tap (BPA)	Encapsulated MITC and Chloropicrin	1982	Inspected
Hamburg Line (NYSEG)	Encapsulated MITC	1981	None
Coos Bay, Oregon	Encapsulated MITC	1985	Inspected
Alderwood Tap (BPA)	Pelletized and encapsulated MITC	1984	Inspected
Peavy Arboretum	Encapsulated MITC (MITC-Fume)	1988	Inspected
Peavy Arboretum	Basamid	1988	Inspected
Peavy Arboretum	Copper naphthenate/boron	1989	None
Peavy Arboretum	Impel Rods	1993	Inspected
Hilo, Hawaii (CSI)	Impel Rods	1990	None
Central Lincoln (CLPUD)	Encapsulated MITC	1986	None
Peavy Arboretum	Gelled NaMDC	1992	None
Pacific Power, Corvallis	Basamid	1993	Inspected
Peavy Arboretum	Boron/Fluoride Rods	1993	Inspected
Peavy Arboretum	Sodium Fluoride Rods	1995	Inspected
San Jose, CA	Metham-sodium	1996	Inspected

Table I-3. Gelatin encapsulated treatments applied to Douglas-fir poles located in Cottage Grove, Oregon.

Pole No.	% Infested Cores	Chemical Treatment	Dosage (ml)	Treatment Sites (m above groundline)
3/2-/A	25	MITC	310	0.9,1.5,2.1,2.7,3.3
3/2-B	29	MITC	372	1.2,1.8,2.4,3.0,3.6,4.2
4/6-A	44	MITC	372	1.2,1.8,2.4,3.0,3.6,4.2
4/6-B	75	Chloropicrin	310	0.6,1.2,1.8,2.4,3.0
5/4-B	67	Chloropicrin	177.5	0.6,1.2,1.8
5/5-A	57	Chloropicrin	248	0.6,1.2,1.8,2.4

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. This test was abandoned due to treatment with Wood Fume in 1994.

2. **Treatment of through-bored Douglas-fir poles with gelatin encapsulated MITC or chloropicrin:** In 1982, a field study was initiated to determine the effectiveness of gelatin encapsulated MITC and chloropicrin in Bonneville Power Administration poles located near Cottage Grove, Oregon. Increment cores were removed from the above ground portion of sixteen poles. The cores were cultured for the presence of decay fungi. Six poles that contained active decay fungi well above ground line were selected for treatment. Three to six downward sloping holes (19 mm in diameter by 400 mm long) were drilled at sites located 0.6 to 4.2 m above the groundline of each pole (Table I-3). Generally, each pole received 177 to 372 ml of fumigant along with a small quantity of water. The holes were then plugged with treated wooden dowels. The poles are somewhat difficult to access and were only sampled 2, 7, and 15 years following treatment.

At each inspection point, increment cores were removed from sites 0.6 to 5.1 m above the groundline. The outer and inner 25 mm of each core were used to evaluate residual volatile toxicity using a closed tube bioassay. A test fungus, *Postia placenta*, was placed at the edge of a slanted film of 1.5 % malt extract agar in a test tube and incubated until the fungus had grown several mm. The edge of the growth was marked and the increment core segment is placed into the tube which is capped and incubated in an inverted position. This prevented the increment core from contacting the agar. Any fumigant present in the wood volatilized and moved upward where it contacted the growing fungus. The radial growth of the fungus in comparison with the same fungus in similar tubes containing either non-fumigant treated wood or no wood provided a measure of the degree of inhibition. The closed tube bioassay has previously been shown to be nearly as sensitive to residual fumigant as gas chromatographic analysis (Zahora and Morrell, 1989).

Culturing of increment cores removed from selected heights revealed that fungi were virtually absent from the cores 16 years after treatment with MITC or chloropicrin. The absence of nondecay fungi was puzzling, given their presence in cores cultured 9 years after treatment; however, earlier sampling 2 or 4 years after treatment had shown relatively low levels of nondecay fungi suggesting that the 9 year data represented an anomaly (Table I-4).

Closed tube bioassays of increment cores removed from selected locations along the poles revealed that most samples from the chloropicrin treated poles continued to retain a high degree of fungitoxicity, with all but 3 cores producing complete inhibition of the test fungus (Table I-5). These results are consistent with previous studies showing that chloropicrin has a long residual life in poles. Gelatin encapsulation did not appear to adversely affect this performance characteristic.

Samples from MITC-treated poles tended to produce far lower degrees of inhibition 16 years after treatment. Complete inhibition was only noted in 5 of 88 cores and most cores produced inhibition levels that suggested the treatment was nearing the end of its effective protective period. MITC has generally provided a shorter residual life in Douglas-fir than chloropicrin and these results closely follow that trend.

The results indicate that remedial treatment with gelatin encapsulated MITC or chloropicrin eliminated fungi from all of the test poles within 2 years after treatment. Closed tube bioassays suggest that chloropicrin remains in the poles at levels capable of inhibiting fungal attack, while MITC levels are declining to the point where fungal invasion can occur. It is important to remember, however, that fungal invasion above ground is far slower than that found at the groundline. As a result, the period between the loss of chemical protection and fungal invasion may be extended beyond that found with fumigant treatments in direct soil contact.

Table I-4. Colonization levels of decay and non-decay fungi in Douglas-fir poles 0 to 16 years after remedial treatment with gelatin encapsulated methylisothiocyanate (MITC) or chloropicrin (CP).[a]

			Percentage of Cores with Decay or Nondecay Fungi at Various Heights Above GL														
Pole No.	Treatment	Year	0	0.6	0.9	1.2	1.5	1.8m	2.1m	2.4m	2.7m	3.0m	3.3m	3.6m	3.9m	4.2m	5.1m
3/2A	MITC	0			0^{100}	50^{0}	0^{100}		–		–		–			–	–
		2			0^{50}		0^{0}		0^{50}		0^{0}		0^{0}			0^{0}	0^{0}
		4			0^{0}		0^{0}		0^{0}		0^{0}		0^{0}			0^{0}	0^{0}
		9	0^{100}		0^{0}		–		0^{50}		–		0^{100}			–	0^{100}
		16			0^{0}		0^{0}		0^{0}		0^{0}		0^{0}			0^{0}	0^{0}
3/2B	MITC	0		–		0^{67}		100^{100}		–		–		33^{67}		–	–
		2		0^{0}		0^{0}		0^{0}		0^{0}		0^{0}		0^{0}		0^{0}	0^{100}
		4		0^{0}		0^{0}		0^{0}		0^{0}		0^{0}		0^{0}		0^{0}	0^{0}
		9	0^{0}	—		0^{0}		0^{50}		—		0^{0}		0^{50}		33^{100}	–
		16		0^{0}		0^{0}		0^{0}		0^{0}		–		0^{0}		0^{0}	0^{0}
4/6A	MITC	0			50^{0}	0^{0}	0^{100}	–	100^{50}	–		–		–			
		2		0^{0}		0^{0}		0^{0}		0^{0}		0^{0}		–	0^{100}		
		4				0^{0}		0^{0}		0^{0}		0^{0}		0^{0}		0^{0}	0^{0}
		9				–		0^{50}		0^{50}		–		0^{75}			
		16				0^{0}		0^{0}		0^{0}		0^{0}		0^{0}		0^{0}	0^{0}
4/6B	CP	0		–		100^{0}		–									
		2		0^{0}		0^{0}		0^{50}									
		4															
		9		0^{50}		0^{25}		0^{0}									
		16		0^{0}		0^{0}		0^{0}		0^{0}		0^{0}			0^{0}		
5/4B	CP	0		–		33^{0}		–			–						
		2		0^{0}		0^{0}		0^{0}			0^{0}						
		4		0^{0}		0^{0}		0^{0}			0^{0}						
		9		–		0^{67}		0^{0}			–						
		16		0^{0}		0^{0}		0^{0}			0^{0}						
5/5A	CP	0		–		100^{0}		33^{0}		–			–				
		2		0^{0}		0^{0}		0^{0}		0^{0}			0^{0}				
		4		0^{0}		0^{0}		0^{0}		0^{50}			0^{50}				
		9	0^{100}	–		0^{25}		0^{100}		0^{100}			–				
		16		0^{0}		0^{0}		0^{0}		0^{0}			0^{0}				

a. Values represent percent decay fungi while superscripts represent percentage of nondecay fungi.

Table I-5. Degree of fungal inhibition of increment cores removed from Douglas-fir poles 2 to 16 years after treatment with gelatin encapsulated methylisothiocyanate (MITC) or chloropicrin (CP) as shown using a closed tube bioassay.

Pole No.	Treatment	Yr	Fungal growth in a closed tube bioassay as a percentage of controls at selected heights above GL (m)[a]																											
			0.6		0.9		1.2		1.5		1.8		2.1		2.4		2.7		3.0		3.3		3.6		3.9		4.2		5	
			I	O	I	O	I	O	I	O	I	O	I	O	I	O	I	O	I	O	I	O	I	O	I	O	I	O	I	O
3/2A	MITC	2			0	38			0	0			0	0			0	0			0	26					36	83	-	-
		4			0	0			0	0			0	0			0	0			0	0					0	20	36	27
		9			0	0			-	-			0	0			-	-			0	0					-	-	23	0
		16			0	63			20	43			24	59			20	63			0	27					0	59	39	59
3/2B	MITC	2	0	0			0	0			0	0			0	34			0	0			0	0			0	0	15	29
		4	0	0			0	0			0	0			0	0			0	0			0	0			0	0	0	64
		9	-	-			0	0			0	0			0	0			0	0			34	25			0	0	-	-
		16	78	63			63	67			61	71			8	16			98	98			82	59			71	55	0	47
4/6A	MITC	2	0	0			0	26			0	0			0	34			0	0			0	0			0	33	0	0
		5					0	0			0	0			0	0			0	0			0	0			0	3	0	5
		9					-	-			0	0			0	0			-	-			4	0			-	-	-	-
		16					67	63			47	31			8	16			39	67			59	0			0	0	24	67
4/6B	MITC	2	0	0			0	0			0	0			0	25			0	0					0	0				
		4	0	0			0	0			0	0			0	0			0	0					1	6				
		9	0	33			0	0			0	0			-	-			0	0					1	8				
		16	-	-			78	78			0	0			0	0			0	0					0 -	0 -				
5/4B	CP	2	0	0			0	0									79	62												
		4	0	0			0	0									0	59												
		9	-	-			0	0									-	-												
		16	0	0			0	0									0	0												
5/5A	CP	2	0	39			0	0			0	43			7	84														
		4	0	0			0	0			0	0			9	0														
		9	-	-			0	0			0	0			0	-														
		16	0	0			0	0			0	0			- 0	75														

a. Samples removed from the outer (O) or inner (I) 25 mm zones of each increment core sampler.

3. Above ground treatment with gelatin encapsulated or pelletized MITC: In 1986, 15 pentachlorophenol-treated Douglas-fir transmission poles were treated with 45 or 90 grams of gelatin encapsulated or pelletized MITC. The gelatin encapsulated formulation was similar to that described for the Dorena poles, while the pelletized MITC was reported to contain 65% MITC deposited on fumed silica pellets. The pellets were applied using a specially designed stainless steel closed application system. The MITC was presumed to be physically trapped in the silica and volatilized upon application into the wood. The gelatin capsules retained MITC until they were moistened, in this case by the normal moisture present in the wood. Previous tests have shown that the complete volatilization of MITC from gelatin capsules takes 1 to 2 years.

The formulations were applied 0.3 m below the field-drilled bolt holes used for cross arm attachments on a line located near Junction City, Oregon. The bolt holes had not received any supplemental treatment after being field- drilled and the fumigant was intended to protect any exposed untreated wood in the holes against possible fungal attack. A total of 45 or 90 ml of chemical was applied to 1 or 2 holes respectively and the holes were sealed with tight fitting wooden dowels. For the gelatin capsules, these dosages translated to 2 or 4 capsules per pole.

The poles were sampled annually for the first 3 years, then periodically thereafter. At each inspection, increment cores were removed from sites 0.6, 0.9, and 1.2 m below the lowest treatment hole. The outer and inner 25 mm of each core were separately evaluated for residual fumigant content using a closed tube bioassay, while the remainder of each core was placed on malt extract agar in a petri dish and observed for the presence of decay fungi. Because of concerns about removing too many cores from the zone around the treatment holes (which was near the bending moment for some poles), cores were not always removed from the same height at a given sampling point. As a result, the cultural and closed tube results may not be directly comparable between years, but they provide a relative guide to the degree of protection afforded by treatment.

No decay fungi were isolated from any cores removed from the poles 12 years after MITC application, regardless of treatment or dosage. These results are consistent with previous samples of these treatments (Table I-6).

Closed tube bioassays indicated that most cores retained some degree of residual protection (Table I-7). Interestingly, lower degrees of fungal inhibition were noted in cores from poles receiving the higher chemical loadings. Even these levels of inhibition, however, should be capable of preventing fungal colonization and this premise was borne out in the cultural results.

The results indicate that both MITC treatments continue to provide some degree of protection to the above ground zone of the field-drilled bolt holes. The pelletized treatment was subsequently found to contain much lower levels of MITC than originally reported, but these lower levels apparently have not yet affected the degree of protection afforded by the treatment.

These poles will be sampled periodically to estimate the protective period afforded to the field-drilled wood by internal fumigant treatment. While neither gelatin encapsulated or pelletized MITC are commercially used, the results should provide comparative data for evaluation of the glass or aluminum encapsulated formulations that can also be applied to wood above the groundline.

4. Preinstallation fumigation of Douglas-fir poles: Fumigants tend to be most effective when they are applied to sound wood. Decayed wood retains less fumigant and, since it has already lost some of its strength, represents a less valuable investment in terms of chemical application. The best time to apply fumigants may therefore be when poles are new. Application of fumigants immediately prior to installation may represent a relatively simple method for preventing the development of internal decay and maintaining poles at their highest strength value. The concept was evaluated on 23 pentachlorophenol-treated Douglas-fir poles using gelatin encapsulated methylisothiocyanate (MITC).

Table I-6. Colonization of Douglas-fir poles by decay fungi and nondecay fungi 0 to 12 years after treatment with 45 or 90 ml of gelatin encapsulated or pelletized MITC.

Pole #	Dosage	Form	Time Since Treatment (years)	Fungal Colonization at Sampling Locations			
				0m	0.6m	0.9m	1.2m
1/8	45 ml	capsule	0	0^{0}			
OSU12			1		0^{100}		
			2				33^{100}
			3			0^{0}	
			5				–
			12		–		
1/9	45 ml	capsule	0	0^{0}			
OSU11			1		0^{67}		
			2				0^{100}
			3			0^{100}	
			5				–
			12		–		
2/12	45 ml	capsule	0	0^{100}			
OSU9			1		0^{100}		
			2				0^{100}
			3			0^{100}	
			5		–		–
			12				
6/8	45 ml	capsule	0	100^{0}			
OSU5			1		0^{67}		
			2				33^{100}
			3			0^{100}	
			5				0^{0}
			12		0^{0}		
9/7	45 ml	capsule	0	0^{0}			
OSU15			1		0^{33}		
			2				0^{100}
			3			0^{0}	
			5				0^{0}
			12		0^{0}		
9/14	45 ml	capsule	0	0^{100}			
OSU4			1		0^{67}		
			2				0^{100}
			3			0^{0}	
			5				0^{0}
			12		0^{0}		
2/11	60 ml	pellets	0	0^{0}			
OSU10			1		0^{67}		
			2				0^{100}
			3			0^{0}	
			5				–
			12		–		

Table I-6. Colonization of Douglas-fir poles by decay fungi and nondecay fungi 0 to 12 years after treatment with 45 or 90 ml of gelatin encapsulated or pelletized MITC.

Pole #	Dosage	Form	Time Since Treatment (years)	Fungal Colonization at Sampling Locations			
				0m	0.6m	0.9m	1.2m
2/15	60 ml	pellets	0	0^{100}			
OSU8			1		0^{67}		
			2				0^{100}
			3			0^{0}	
			5		–		0^{0}
			12				
5/12	60 ml	pellets	0	0^{0}			
OSU7			1		0^{0}		
			2				0^{100}
			3			0^{100}	
			5				0^{0}
			12		0^{0}		
9/10	60 ml	pellets	0	0^{0}			
OSU1			1		0^{67}		
			2				0^{100}
			3			0^{100}	
			5				0^{0}
			12		0^{0}		
9/11	60 ml	pellets	0	0^{0}			
OSU2			1		0^{33}		
			2				0^{100}
			3			0^{0}	
			5				0^{0}
			12		0^{0}		
5/14	90 ml	2 capsules	0	0^{50}			
OSU6			1		0^{33}		
			2				33^{100}
			3			0^{0}	
			5				0^{0}
			12		0^{33}		
9/9	90 ml	2 capsules	0	0^{0}			
OSU13			1		0^{100}		
			2				0^{100}
			3			0^{0}	
			5				0^{0}
			12		0^{0}		
9/8	120 ml	pellets	0	100^{50}			
OSU14			1		0^{100}		
			2				33^{100}
			3			0^{100}	
			5				0^{0}
			12		0^{0}		

Table I-6. Colonization of Douglas-fir poles by decay fungi and nondecay fungi 0 to 12 years after treatment with 45 or 90 ml of gelatin encapsulated or pelletized MITC.

Pole #	Dosage	Form	Time Since Treatment (years)	Fungal Colonization at Sampling Locations			
				0m	0.6m	0.9m	1.2m
9/12	120 ml	pellets	0	0^{50}			
OSU3			1		0^{0}		
			2				0^{100}
			3			0^{0}	
			5				0^{33}
			12		0^{0}		

Table I-7. Residual fungitoxicity in Douglas-fir poles 1 to 12 years after treatment with selected levels of gelatin encapsulated or pelletized MITC as determined using a closed tube bioassay.

Pole No.	Dosage	Form	Time Since Treatment. (Yrs.)	Fungal growth as a percentage of controls with distance below lowest treatment hole.					
				0.6 m		0.9 m		1.2 m	
				I	O	I	O	I	O
1/8 OSU 12	45 ml	capsule	1	0	40				
			2					100	100
			3			0	0		
			5						
			12						
1/9 OSU 11	45 ml	capsule	1	0	52				
			2					58	100
			3			0	39		
			5						
			12						
2/12 OSU 9	45 ml	capsule	1	38	64				
			2					100	100
			3			0	0		
			5						
			12						

Table I-7. Residual fungitoxicity in Douglas-fir poles 1 to 12 years after treatment with selected levels of gelatin encapsulated or pelletized MITC as determined using a closed tube bioassay.

Pole No.	Dosage	Form	Time Since Treatment. (Yrs.)	Fungal growth as a percentage of controls with distance below lowest treatment hole.					
				0.6 m		0.9 m		1.2 m	
				I	O	I	O	I	O
6/8 OSU 5	45 ml	capsule	1	55	86				
			2					0	61
			3			0	36		
			5					0	0
			12	8	14				
9/7 OSU 15	45 ml	capsule	1	46	66				
			2					42	19
			3			0	0		
			5					0	3
			12	0	0				
9/14 OSU 4	45 ml	capsule	1	77	93				
			2					44	97
			3			27	0		
			5					0	16
			12	19	9				
2/11 OSU 10	60 ml	pellets	1	0	20				
			2					4	50
			3			0	0		
			5						
			12						
2/15 OSU 8	60 ml	pellets	1	0	0				
			2					0	40
			3			0	33		
			5					93	73
			12						
5/12 OSU 7	60 ml	pellets	1	74	12				
			2					0	45
			3			7	5		
			5					0	0
			12	11	22				

Table I-7. Residual fungitoxicity in Douglas-fir poles 1 to 12 years after treatment with selected levels of gelatin encapsulated or pelletized MITC as determined using a closed tube bioassay.

Pole No.	Dosage	Form	Time Since Treatment. (Yrs.)	Fungal growth as a percentage of controls with distance below lowest treatment hole.					
				0.6 m		0.9 m		1.2 m	
				I	O	I	O	I	O
9/10 OSU 1	60 ml	pellets	1	61	92				
			2					65	39
			3			25	19		
			5					0	0
			12	0	0				
9/11 OSU 2	60 ml	pellets	1	34	45				
			2					62	21
			3			0	32		
			5					0	0
			12	18	14				
5/14 OSU 6	90 ml	2 capsules	1	0	18				
			2					0	0
			3			0	0		
			5					0	0
			12	44	25				
9/9 OSU 13	90 ml	2 capsules	1	59	62				
			2					0	75
			3			0	10		
			5					0	0
			12	0	0				
9/8 OSU 14	120 ml	pellets	1	16	28				
			2					0	0
			3			35	34		
			5					0	0
			12	0	0				
9/12 OSU 3	120 ml	pellets	1	34	65				
			2					0	33
			3			0	0		
			5					0	0
			12	39	32				

This fumigant was chosen because it is a solid at room temperature and can be encapsulated in various materials including glass, aluminum or gelatin. Gelatin was employed in this test because of its ability to release MITC when wet. Gelatin capsules were purchased from a pharmaceutical supply company. The capsule components were sealed with molten gelatin and a small hole was drilled in the top of each capsule. Molten MITC was pumped to fill each capsule and a small square of gelatin film was placed over the hole. The gelatin square was sealed to the capsule using molten gelatin and the assemblies were allowed to cure for a minimum of 24 hours under a fume hood. Additional sealing was performed as required. Capsules with evidence of chemical loss were not used.

The capsules were used to evaluate two treatment patterns, both with holes equally spaced in a spiral pattern up the pole to provide a zone of protection from just below the groundline to 7.2 m above that zone. Nineteen poles ranging from 12 to 18 m long were treated using pattern A, while 4 poles were treated using pattern B. A series of 11.5 mm diameter by 550 mm long holes were drilled at approximately a 60 degree angle to the vertical axis of the pole. Treatment holes in Pattern A were spaced between 0 and 7.2 m of the intended groundline at 1 m intervals with each hole spiraling around the pole 90 degrees. Treatment holes for Pattern B were drilled between -1.2 and 6 m of the intended groundline at the same spacing that was used for Pattern A. Each hole was capable of holding 6 capsules or 192 ml of methylisothiocyanate (MITC). Each pole received approximately 1.3 l of chemical along with 50 ml of water to facilitate gelatin breakdown and chemical release. The treatment holes were then plugged with 13 mm diameter pentachlorophenol-treated dowels. The capsules were installed during a driving rainstorm, and the ease of application under these inclement conditions illustrated the benefits of using an encapsulated formulation.

The poles were installed in a line located near North Bend, Oregon. This region, located along the Oregon coast, is characterized by excessive wind-driven rain during the winter months. Unlike many regions of the country where decay occurs principally at groundline, the wet conditions at this site result in decay sometimes extending well upward to the crossarms. As a result, expensive climbing inspections for the presence of internal decay are often necessary for poles in the region. Preinstallation fumigation was viewed as one potential approach for preventing this problem.

The poles were originally scheduled to be inspected 1, 2, and 5 years after treatment. Because of changes in industry personnel, however, the poles were never sampled. As part of our efforts to develop a better long-term base on MITC performance, we sampled these poles this past year, 11.5 years after installation. The poles were sampled by removing increment cores from sites 0.3, 1.3 and 3.0 m above the groundline at two sites 120 degrees apart. The inner and outer 25 mm of each increment core were placed into 5 ml of ethyl acetate while the remainder of the core was placed in a plastic drinking straw. The core segment in the straw was later flamed and placed on the surface of malt extract agar in petri dishes. The cores were observed for evidence of fungal growth and any growth was examined to determine if the organisms were possible decay fungi.

The ethyl acetate extracts were analyzed for residual MITC content as previously described (Zahora and Morrell, 1989) and levels were quantified by comparison with prepared standards and expressed on a ug MITC/g wood basis.

As a part of their normal maintenance program, a contractor for the cooperator inadvertently treated the poles with chloropicrin 9 years after installation. While this renders the culturing data less useful, the presence of chloropicrin did not interfere with MITC analysis nor is it likely that the chloropicrin reached the highest sampling point at appreciable levels. As a result, the chemical assays from these poles can still provide useful information on the feasibility of installing fumigants prior to installation. Of the 18 poles sampled, only one contained a

Table I-8. Fungal colonization levels in Douglas-fir poles 11.5 years after treatment with gelatin encapsulated methylisothiocyanate.

	Fungal Colonization (%)[a]		
Pole No.	0.3 m above GL	1.3 m above GL	3.0 m above GL
25861	0^{0}	0^{0}	0^{0}
25863	0^{0}	0^{0}	0^{0}
25864	0^{0}	0^{0}	0^{0}
25866	0^{0}	0^{0}	0^{0}
25870	0^{0}	0^{0}	0^{0}
25873	0^{0}	0^{0}	0^{0}
25874	0^{0}	0^{0}	0^{0}
25875	0^{0}	0^{0}	0^{0}
25877	0^{0}	0^{0}	0^{0}
25878	0^{0}	0^{0}	0^{67}
25879	0^{0}	0^{0}	0^{0}
25882	0^{0}	0^{0}	0^{0}
25884	0^{0}	0^{0}	0^{0}
25888	0^{0}	0^{0}	0^{0}
25889	0^{0}	0^{0}	0^{0}
25890	0^{0}	0^{0}	0^{0}
25891	0^{0}	0^{0}	0^{0}
25892	0^{0}	0^{0}	0^{0}
Average S.D.	0^{0}	0^{0}	$0^{3.5}$
	0^{0}	0^{0}	$0^{15.4}$

a. Values reflect percentage of 3 cores per height that contain decay fungi. The superscript number reflect the percentage of the same cores that contain non-decay fungi.

fungus in a single core and no decay fungi were isolated from any of the poles (Table I-8). These results illustrate the effectiveness of both fumigants for eliminating established fungi and limiting the reinvasion rate.

Chemical assays showed that MITC was well-distributed throughout the poles, even 11.5 years after initial treatment, although the levels were relatively low (Table I-9). MITC levels in the outer zone were generally lower than those in the inner zone, but the differences were slight near the groundline. Differences between inner and outer concentrations were much greater 1.3 and 3 m above the groundline, perhaps reflecting the likelihood that the surface of the pole might be exposed to more sun, and therefore increased heating that might encourage fumigant diffusion from the wood.

The MITC levels found in these poles remain slightly higher than those found in MITC-Fume-treated Douglas-fir poles at the Corvallis test site 7 years after treatment (Table I-10). A portion of this difference may reflect the initial preservative treatment. The poles at the North Bend site were treated with penta in heavy oil, while those in the Corvallis test were treated with chromated copper arsenate (CCA). Previous studies (Zahora and Morrell, 1990) indicate that MITC diffuses more readily through CCA than penta. As a result, any chemical present might move out of the CCA- treated poles more rapidly than it might in poles treated with an oil-based preservative. The CCA-treated poles also received a much lower dosage of MITC than the penta-treated poles (240 g vs 1300 g), but the treatment zone was more concentrated (1.2 m vs. 7 m), respectively. As a result, the relative amount of chemical applied within the treatment zones does not differ markedly. The results suggest that the poles in North Bend are retaining MITC to a greater extent than those at the Corvallis test site. These poles will continue to be monitored for residual MITC levels to determine the total residual treatment time for this system. The current results clearly demonstrate that MITC applied prior to installation has a long residual life in the above ground portion of the pole. This can be particularly useful in environments such as those typical of the coastal regions of the Pacific Northwest where internal decay above ground poses a significant maintenance problem.

5. Evaluation of MITC-Fume in southern pine and Douglas-fir poles: The poles treated with 60 to 240 g of MITC-Fume were not sampled in 1996. Their next regular sampling will be in 1998; however, this summer we are planning to assess MITC levels in the treated zone. Our 1995 results indicated that MITC levels were low above and below the zone where vials were applied. Questions were raised concerning chemical levels in the zone that originally received ampules. We have removed increment cores from this zone and will report the results of these assays in the next annual report.

6. Distribution of MITC in Douglas-fir and Ponderosa pine poles 1 year after metham sodium treatment: While we have developed a reasonable understanding of the performance of metham sodium in Douglas-fir poles in the Pacific Northwest, the effects of climate and other variables on the performance of this chemical remain less well documented. Yet, metham sodium remains the most commonly used fumigant for controlling internal decay and this trend is likely to continue. In order to develop a better understanding of metham sodium performance under conditions other than those in Oregon, we established a field test in the Pacific Gas & Electric system near San Jose, California. Pentachlorophenol-treated Douglas-fir and ponderosa pine distribution poles were inspected by a commercial inspection crew for the presence of decay and other defects. The poles were installed between 1952 and 1963, with the majority of poles being set between 1961 and 1963. Pole circumferences ranged from 725 to 975 mm (Class 4 to 6, 10.5 to 12 m long). Three steep angled holes were then drilled beginning slightly below groundline and moving upward at approximately 300 mm intervals and around the pole 120 degrees. Shavings from the drill were collected and placed in bags.

Table I-9. Residual methylisothiocyanate (MITC) in Douglas-fir poles 11.5 years after treatment with gelatin encapsulated MITC.

	ug MITC/g O.D. Wood					
Pole No.	0.3 m		1.3 m		3.0 m	
	inner	outer	inner	outer	inner	outer
25861	15.7	7.7	35.9	35.0	51.2	40.7
25863	27.1	31.5	17.7	19.9	26.3	23.6
25864	17.4	17.0	35.0	12.3	25.1	19.3
25866	17.5	10.6	29.3	21.8	44.0	27.5
25870	33.2	18.9	42.0	20.6	69.2	30.4
25873	13.1	21.1	24.1	12.6	57.0	24.4
25874	18.9	12.3	57.9	16.5	43.8	45.0
25875	55.4	16.6	51.6	32.7	52.9	32.5
25877	14.3	21.9	17.2	11.4	10.5	12.4
25878	32.6	26.9	26.2	18.5	47.4	16.6
25879	13.9	8.2	13.6	7.4	46.1	10.6
25882	44.3	30.1	24.4	19.2	24.2	15.8
25884	7.9	12.0	32.2	29.7	63.7	51.3
25888	10.6	21.6	10.6	9.1	20.7	12.8
25889	45.8	46.0	54.6	23.8	55.8	24.5
25890	32.7	38.5	39.8	12.4	44.5	12.0
25891	30.4	20.6	68.1	22.9	80.9	45.6
25892	34.8	31.2	32.8	16.5	52.2	21.2
Avg. S.D.	25.9 13.2	21.8 10.3	34.1 15.6	19.0 7.6	45.3 17.6	25.9 12.3

a. Values reflect the means of 3 replicates per height per pole. Inner and outer zones refer to the 25 mm segments on each end of increment cores removed from a given height.

Table 1-10. Residual MITC content, as measured by gas chromatographic analysis of increment cores in 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 (ug/g oven dried wood)				
			MITC-Fume®				Metham-sodium
			60 g	120 g	180 g	240 g	500 ml
-0.3 m	Outer	12	164	346	401	439	–
		24	140	168	404	273	15
		36	18	81	28	55	2
		60	58	65	24	18	26
		84	4	0	14	4	5
	Inner	12	292	270	1327	441	–
		24	1322	154	2161	1240	143
		36	186	219	182	127	44
		60	68	58	95	36	26
		84	41	26	19	9	17
0.0 m	Outer	12	119	485	280	1500	41
		24	219	200	192	322	31
		36	61	59	51	78	3
		60	99	36	44	37	18
		84	12	6	4	12	2
	Inner	12	2525	2879	3745	3985	978
		24	1191	1928	1600	1242	34
		36	418	223	260	251	68
		60	267	70	135	46	64
		84	30	14	14	8	12
0.3 m	Outer	6	5	84	132	132	4
		12	26	12	149	206	11
		24	46	94	177	311	22
		36	37	48	63	99	8
		60	51	31	26	56	30
		84	7	4	5	6	5
	Inner	6	132	296	534	624	352
		12	128	349	1052	262	105
		24	256	459	363	554	306
		36	92	142	108	107	24
		60	29	30	18	28	10
		84	10	7	2	9	4
0.9 m	Outer	6	0	2	0	0	0
		12	34	94	25	34	10
		24	84	60	40	72	T
		36	26	40	17	20	4
		60	21	30	18	28	10
		84	3	1	2	4	3

Table 1-10. Residual MITC content, as measured by gas chromatographic analysis of increment cores in 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 (ug/g oven dried wood)				
			MITC-Fume®				Metham-sodium
			60 g	120 g	180 g	240 g	500 ml
	Inner	6	2	115	4	2	2
		12	24	198	26	31	102
		24	149	117	92	165	49
		36	34	26	28	48	8
		60	12	22	12	16	15
		84	2	3	1	3	2
1.5 m	Outer	6	0	0	0	0	0
		12	5	T	T	T	T
		24	T	T	T	49	0
		36	3	3	T	4	T
		60	9	15	7	16	16
		84	3	2	2	3	6
	Inner	6	0	0	0	0	0
		12	T	T	T	21	0
		24	T	T	T	120	0
		36	3	6	3	2	T
		60	9	9	7	12	14
		84	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.

They were returned to the laboratory where they were briefly flamed and placed on malt extract agar in petri dishes. These segments were observed for evidence of fungal growth as described earlier.

The poles were then treated by adding 500 ml of metham sodium, equally distributed among the three drill holes which were plugged with tight fitting dowels. Five ponderosa pine and 11 Douglas-fir poles were treated in this manner.

One year after treatment, a series of increment cores were removed from sites located 0.3, 0.6, and 1.3 m above the groundline. Two cores were removed 0.3 m above groundline 120 degrees around from the highest treatment. Three cores were removed from sites 120 degrees apart at the 2 other sampling heights, with one core at each height being removed from directly above the highest treatment hole. Three poles located in backyards were inaccessible for sampling. The outer and inner 25 mm of each core was placed into tightly capped vials and shipped to Corvallis, Oregon for later analysis. Five ml of ethyl acetate was then added to the vials and the samples were extracted for 48 hr prior to analysis. The remainder of the core was placed in a plastic drinking straw and stored on ice for later processing. The latter core segments were briefly flamed to kill any fungi on the wood.

The ethyl acetate extracts were analyzed for residual methylisothiocyanate content using a Varian 3700 Gas Chromatograph equipped with a flame photometric detector specific for sulfur residues as previously described (Zahora and Morrell, 1989). MITC levels were quantified by comparisons with prepared standards. The cores were then oven dried overnight and weighed (nearest 0.01 g). MITC content was then expressed on a ug/wood weight basis.

No decay fungi were isolated from samples removed prior to treatment, however, numerous nondecay fungi were present in the wood (Table I-11). The presence of nondecay fungi is typical of both wood species. No decay fungi were isolated from cores removed one year after treatment; while the levels of nondecay fungi were markedly lower, particularly at the samples closest to the groundline. Fungal populations above this zone were also fairly low, suggesting that the metham sodium had rapidly altered the fungal flora present in the pole. If these poles follow the trends noted in previous studies, fungal populations will rebound within 2 to 3 years after treatment but basidiomycete levels will be relatively low over the treatment life cycle.

Chemical analysis of cores removed one year after treatment indicated that MITC was present at high levels 0.3 m and 0.6 m above the groundline, but levels above this zone were relatively low (Table I-12). The 0.3 m sampling zone is at the highest treatment hole, and chemical levels might be expected to be elevated in these samples. MITC levels were generally higher in Douglas-fir than ponderosa pine, perhaps reflecting the more permeable nature of the latter species. Increased permeability might translate into more rapid loss from the wood. This would be particularly important for metham sodium which tends to rapidly decompose shortly after treatment, but does so at a relatively inefficient rate per unit volume of chemical applied. Interestingly, while chemical levels were lower in pine than Douglas-fir, MITC levels in pine were higher farther away from the treatment site. The reasons for this anomaly are unclear.

The results indicate that MITC from the decomposition of metham sodium is moving well through both Douglas-fir and ponderosa pine poles in California. These poles will be studied over the next 2 to 4 years to develop data on the distribution of MITC over time so that reliable estimates of the efficacy of this treatment can be developed for the drier California conditions.

7. Treatment of Douglas-fir transmission poles with basamid and copper: The field trial of solid basamid with and without copper sulfate is now in its third year. Details of this trial have been described previously (1996 Annual Report, pages 14-19). Briefly, 3 steeply sloped 19 mm diameter by 375 mm long holes were drilled into pentachlorophenol-treated Douglas-fir poles beginning at groundline and moving upward at 150 mm intervals and 120 degrees around the pole. The poles received 200 or 400 g of Basamid with or without 1% copper sulfate. An additional set of poles received 500 g of metham sodium (32.7% sodium n-methyldithiocarbamate). Each treatment was replicated on 5 poles.

The poles have been sampled annually by removing increment cores from 3 sites around the pole 1, 2, and 3 m above the highest treatment hole (1.6, 2.6, and 3.6 m above groundline). The outer, treated shell was discarded, then the outer and inner 25 mm of the remaining core were placed into tubes containing 5 ml of ethyl acetate. The tubes were stored for 24 hours at room temperature before the ethyl acetate was analyzed for MITC by gas chromatography. The remainder of each core was placed on malt extract agar in petri dishes and observed for fungi growth from the wood. Any fungi growing from the wood were examined microscopically for characteristics typical of basidiomycetes, a group of fungi containing many important wood decayers. Culturing indicated that none of the test poles contained viable decay fungi (Table I-13).

Table I-11. Fungal colonization levels in Douglas-fir and Ponderosa pine poles in San Jose, California, 1 year after treatment with 500 ml of metham sodium.

Pole No.	Species	Year installed	Class	Circumference (mm)	Length (m)	Fungal Colonization (%)[a]			
						Year 0	Year 1		
						0 m	0.3 m	0.6 m	1.3 m
3	Douglas-fir	1961	6	750	12.0	0^{100}	0^{0}	0^{0}	0^{0}
5	Douglas-fir	1961	6	775	10.5	0^{100}	0^{0}	0^{0}	0^{0}
6	Douglas-fir	1961	5	800	10.5	0^{100}	0^{0}	0^{0}	0^{0}
7	Douglas-fir	1961	5	775	10.5	0^{100}	0^{0}	0^{0}	0^{0}
8	Douglas-fir	1959	5	800	10.5	0^{100}	0^{0}	0^{67}	0^{33}
9	Douglas-fir	1960	5	825	12.0	0^{67}	0^{0}	0^{0}	0^{0}
10	Douglas-fir	1961	5	925	12.0	0^{67}	0^{0}	0^{0}	0^{0}
11	Douglas-fir	1961	4	900	12.0	0^{100}	0^{0}	0^{0}	0^{0}
14	Douglas-fir	1962	5	875	12.0	0^{67}	–	–	–
15	Douglas-fir	1963	5	725	10.5	0^{67}	–	–	–
16	Douglas-fir	1963	5	750	10.5	0^{100}	–	–	–
Average S.D.						$0^{91.8}$ ($0^{15.3}$)	0^{0} (0^{0})	$0^{8.4}$ ($0^{23.7}$)	$0^{4.1}$ ($0^{11.7}$)
1	Ponderosa pine	1952	4	975	13.5	0^{100}	0^{0}	0^{0}	0^{0}
2	Ponderosa pine	1961	4	900	12.0	0^{100}	0^{0}	0^{0}	0^{0}
4	Ponderosa pine	1961	4	850	12.0	0^{100}	0^{0}	0^{0}	0^{0}
12	Ponderosa pine	1961	4	975	12.0	0^{100}	0^{0}	0^{0}	0^{0}
13	Ponderosa pine	–	4	975	12.0	0^{0}	0^{0}	0^{0}	0^{0}
Average S.D.						0^{80} ($0^{44.7}$)	0^{0} (0^{0})	0^{0} (0^{0})	0^{0} (0^{0})

a. Values reflect the means of 2 to 3 samples per pole per height. Values represent decay fungi while superscripts represent nondecay fungi.

Table I-12. Residual methylisothiocyanate in Douglas-fir and Ponderosa pine poles in San Jose, California, 1 year after groundline treatment with 500 ml of metham sodium.

Pole No.	Species	MITC Levels (ug/g wood)					
		0.3 m		0.6 m		1.3 m	
		inner	outer	inner	outer	inner	outer
3	DF	513.9	485.0	293.4	271.6	0.0	0.0
5	DF	640.3	68.4	165.1	27.7	0.0	0.0
6	DF	316.2	386.9	42.4	39.6	0.0	0.0
7	DF	191.9	0.0	123.4	34.4	0.0	0.0
8	DF	72.9	25.7	8.5	13.8	12.6	1.4
9	DF	223.4	105.5	121.7	48.8	0.0	0.0
10	DF	78.3	113.2	5.8	17.9	0.0	0.0
11	DF	203.6	49.6	30.4	19.9	0.0	0.0
Avg.		280.1	154.3	98.8	59.2	1.6	0.2
S.D.		189.1	168.2	92.2	81.0	4.2	0.5
1	WP	183.5	35.5	41.1	29.5	0.0	1.0
2	WP	22.6	86.9	1.9	41.1	0.0	1.8
4	WP	16.1	50.6	0.0	7.2	2.1	0.0
12	WP	17.1	11.6	23.7	14.4	2.5	9.3
13	WP	110.5	49.6	56.8	20.4	9.0	10.1
Avg.		70.0	46.8	22.7	22.5	2.7	4.4
Std. Dev.		67.0	24.5	19.3	11.8	3.3	4.3

[a] Values represent means of 2 or 3 analysis per height per pole. Inner and outer zones refer to the 25 mm on each of the increment cores removed from that height.

Table I-13. Fungal colonization in Douglas-fir poles 3 years after treatment with metham sodium or basamid with and without copper sulfate.

Treatment	Dosage (g)	Cu	Cores with Decay and Nondecay Fungi %[a]								
			Distance from Treatment Hole (m)								
			0.3 m			1.3 m		2.3 m		3.3 m	
			0 yr	2 yr	3 yr	2 yr	3 yr	2 yr	3 yr	2 yr	3 yr
Metham sodium	500 ml	–	3^{23}	0^{10}	0^{10}	0^{23}	0^{7}	0^{17}	0^{3}	0^{10}	0^{3}
Basamid	400 g	–	0^{33}	0^{14}	0^{10}	0^{14}	0^{8}	0^{13}	0^{0}	0^{7}	0^{7}
Basamid + Cu	400 g	+	0^{25}	0^{14}	0^{0}	0^{7}	0^{0}	0^{21}	0^{7}	0^{17}	0^{8}
Basamid	200 g	–	0^{0}	0^{7}	0^{0}	13^{13}	0^{13}	0^{13}	0^{13}	0^{13}	0^{13}
Basamid + Cu	200 g	+	0^{21}	0^{7}	0^{0}	0^{27}	0^{8}	0^{13}	0^{25}	0^{13}	0^{18}

a. Initial samples were shavings from the treatment hole. Values represent 15 samples/treatment. Superscripts represent percentage of nondecay fungi.

In previous studies, the incidence of nondecay fungi has slowly risen with time following treatment and we would expect this trend to also occur in these poles.

MITC levels in Metham sodium-treated poles were initially extremely low and continued to remain low in the second year following treatment (Table I-14). This past year, however, MITC levels have risen nearly 10 fold in these poles (Figure I-1). The reasons for this sharp increase in MITC levels are unclear, however, the past year was characterized by record rainfall and it is possible that this increased precipitation resulted in higher internal wood moisture content causing decomposition of additional sodium n-methyldithiocarbamate. In previous trials, we have noted a considerable amount of crystalline material deposited along the edges of holes treated with metham sodium. While some of this crystalline material is likely to be residual sulfur, some may also be undecomposed fumigant. The addition of water may result in renewed decomposition, helping to explain the unexpected increase in MITC levels 3 years after treatment.

MITC levels in the inner zone near groundline in poles treated with 400 g of basamid plus copper sulfate increased markedly between 1 and 2 years after treatment, then declined slightly after an additional year of exposure. Chemical levels in the outer zone at this same height have steadily increased over the 3 year period. Chemical levels 1.3 m above the groundline declined between 1 and 2 years, then rose sharply in the third year. These variations reflect, in part, natural variations in chemical levels in different areas of the pole. While more intensive sampling would reduce this variation, these poles were in-service and there were concerns about removing too many cores from a given structure.

MITC levels in the remaining three basamid treatments followed trends similar to those found with metham sodium with slight increases between years one and two, followed by a sharp rise in MITC levels 3 years after treatment. Once again, the increased precipitation may have influenced these results. The addition of copper apparently had little or no effect on levels of MITC subsequently found in poles treated with basamid. MITC levels 3 years after treatment were generally lower in poles receiving basamid plus copper sulfate. Previous studies have suggested that copper enhances the decomposition rate of basamid under a variety of conditions and have shown that this effect remains for some time after chemical application. The absence of a copper effect in the current study suggests that other factors, such as wood moisture content, may affect basamid decomposition to an equal or greater extent. While it would be difficult to alter internal wood moisture content in poles in service, it might be possible to alter the application pattern to ensure that the treatment holes were closer to the groundline where moisture contents would be expected to be elevated for at least a part of the season.

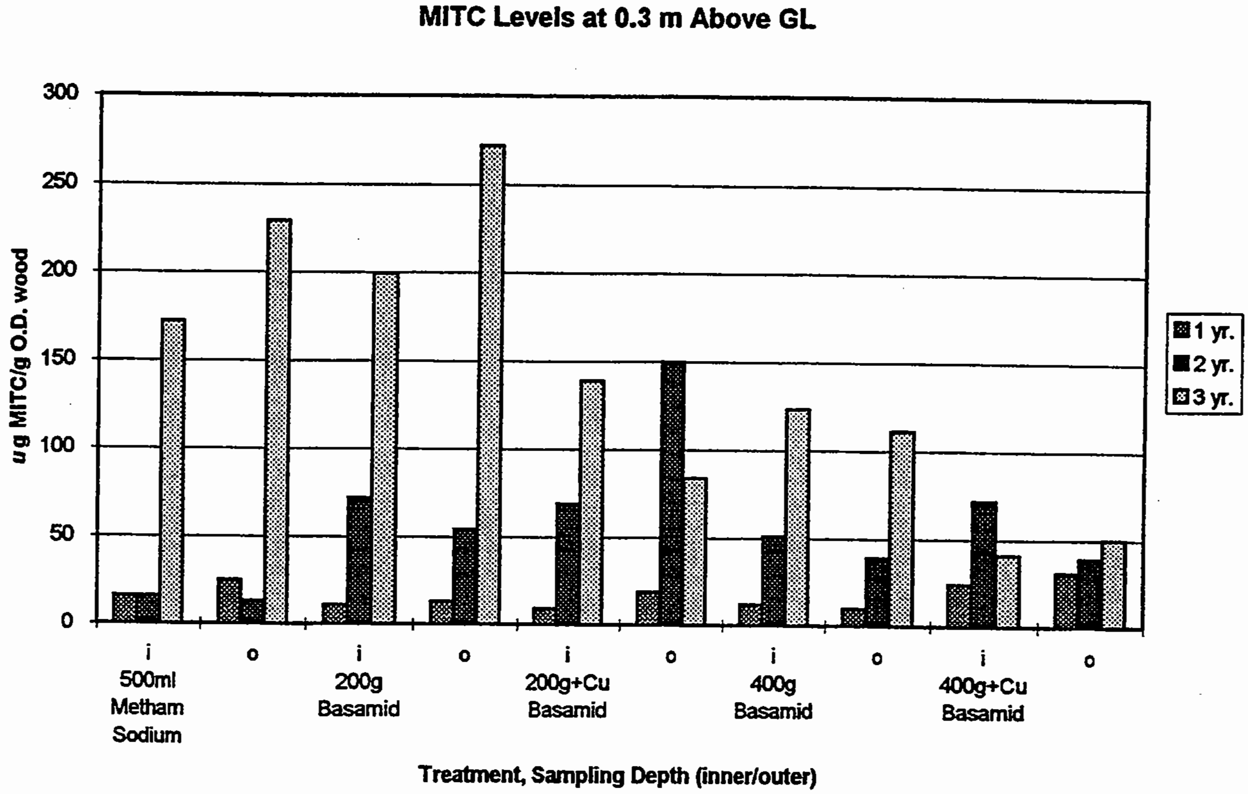
8. Evaluation of metham sodium for remedial treatment of large Douglas-fir timbers: While a majority of our studies have evaluated the efficacy of fumigants on poles and piling, these chemicals are also used on sawn members and may find some use for high value, larger dimension cross arms or braces. The characteristics of sawn members and poles vary slightly in that sawn members expose slightly more surface area than a pole per unit volume. In addition, the process of sawing exposes and ruptures large numbers of cells on the wood surface. These cells can act as pathways for more rapid fumigant loss from the interior of the wood.

In order to better understand the behavior of fumigants in sawn timbers, a study was initiated in 1990 in which a Douglas-fir highway bridge located near Salem, Oregon was treated with metham sodium. Metham sodium was applied through 19 mm diameter holes drilled at 1.2 m intervals along the length of the timbers. Residual chemical levels in the timbers have been assessed 1, 3, and 6 years after treatment by removing increment cores from sites near the top and bottom edge, 0.6 m from the original

Table I-14. Residual MITC in pentachlorophenol-treated Douglas-fir transmission poles 1 to 3 years after internal treatment with 200 or 400 g of basamid alone or amended with 1% (wt.) copper sulfate as compared with similar poles receiving 500 ml of metham sodium.

Chemical	Years	$CuSO_4$	Dose (g)	Residual MITC (ug/g oven dried wood)[2] Distance above treatment zone (m) 0 m		1 m		2 m		3 m	
				Inner	outer	inner	outer	inner	outer	inner	outer
Metham sodium	1	-	500	16	25	33	31	0	1	1	0
	2	-		16	13	6	8	9	3	4	4
	3	-		172	229	77	47	10	6	2	1
Basamid	1	-	400	11	13	27	55	0	0	0	1
	2	-		72	54	11	6	2	1	4	8
	3	-		199	272	65	59	12	10	2	1
	1	+	400	9	19	29	85	1	0	0	0
	2	+		69	150	8	2	2	2	3	6
	3	+		139	84	137	107	17	7	2	2
Basamid	1	-	200	12	10	6	18	0	0	1	0
	2	-		51	39	7	4	4	3	5	3
	3	-		123	111	54	54	6	5	0	0
	1	+	200	24	31	61	33	1	0	0	0
	2	+		72	39	10	2	5	2	2	3
	3	+		41	50	29	24	15	6	13	5

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.



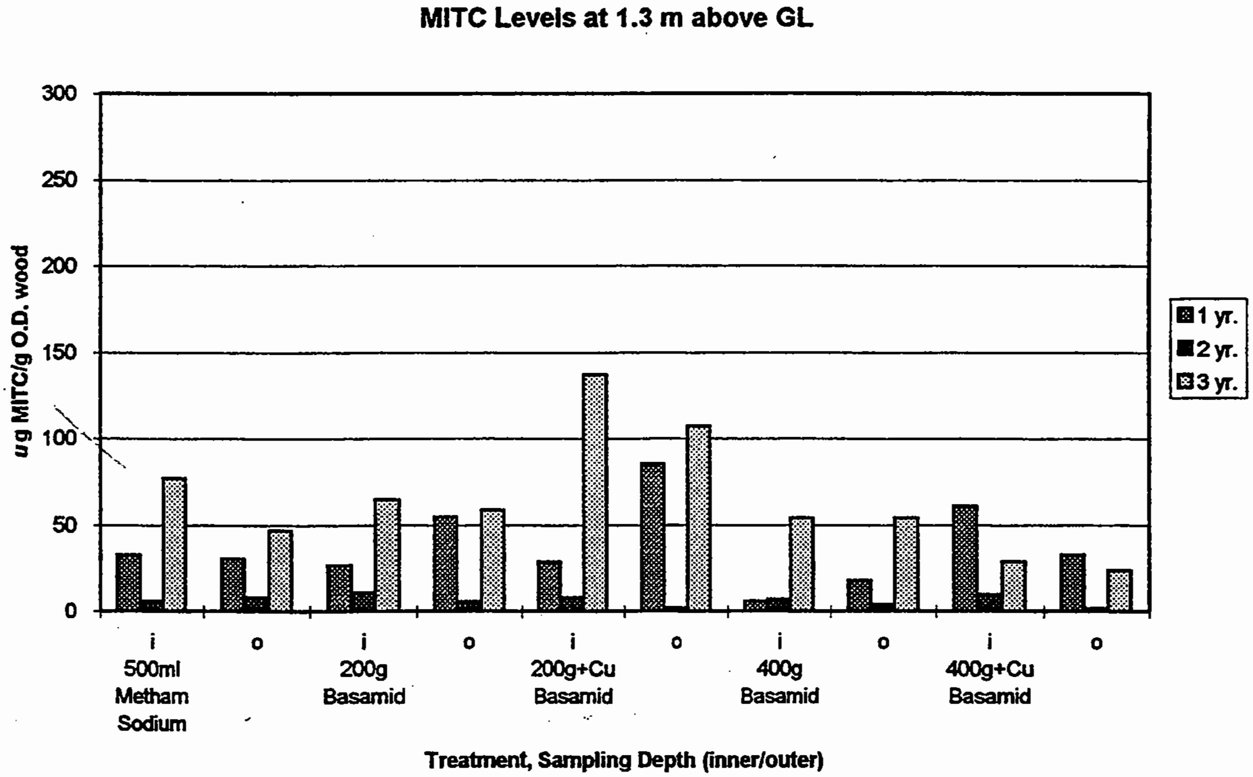


Figure I-1. MITC levels in Douglas-fir poles 1 to 3 years after treatment with 500 ml of metham sodium or 200 or 400 g of Basamid with or without copper sulfate.

original treatment holes on each of 8 stringers. The outer, treated segment of each increment core was discarded and the inner and outer 25 mm of the remaining core were individually placed into test tubes containing 5 ml of ethyl acetate. The cores were extracted in ethyl acetate for a minimum of 48 hours at room temperature, then the extract was analyzed for residual MITC by gas chromatography. The remainder of each core segment was placed on malt extract agar in petri dishes and observed for growth of decay fungi which served as a measure of chemical effectiveness.

Culturing of increment cores revealed that none of the samples removed from the timbers 6 years after treatment contained a viable decay fungus (Table I-15). Examination of earlier data, however, revealed that decay fungi were present in some timbers 4 years after treatment. These results suggest that propagules (spores or hyphae) of decay fungi may be present in isolated locations of the timbers, but they do not appear to be causing appreciable damage at this time. The presence of viable decay fungi in these timbers would, however, become a concern once the chemical levels declined below the levels that inhibited fungal growth since these fungi would be positioned for rapid reinvasion of the substrate ahead of other fungi.

Levels of nondecay fungi in samples removed 6 years after treatment were extremely low in comparison with the 3 and 4 year samples. It is unclear whether these lower levels of nondecay fungi reflect changes in chemical level or an anomaly of the isolation procedures.

MITC levels in the seven structures were initially low, but rose following the first year after treatment and have remained relatively steady over the additional 5 years of sampling (Table I-16). In some instances, distinct increases in MITC levels were noted between 3 and 6 years following treatment, suggesting that some additional decomposition of metham sodium occurred.

Chemical levels appeared to differ little between samples removed from near the top or bottom of a given member nor were there consistent differences in MITC levels between samples from the inner and outer ends of the core samples. These results suggest that MITC has become relatively well distributed throughout the members over the 6 year period.

Previous studies suggest that metham sodium treatments provide only 3 to 5 years of residual chemical protection; however, these results indicate that the potential protective period is somewhat longer. Further evaluations are planned to develop more concise recommendations for retreatment schedules for this metham sodium treatment of timbers.

9. Effectiveness of MITC-Fume in Ponderosa pine and Douglas-fir poles in California: In 1989, Douglas-fir and Ponderosa pine poles in the Pacific Gas and Electric system located near San Francisco, California, were remedially treated with MITC-Fume. The poles had originally been treated with pentachlorophenol in liquified petroleum gas (Cellon®). One set of poles was located in sandy soil at a drier site near Half Moon Bay, while the others were set in concrete in a wetter site near Belmont.

The poles were treated by drilling a series of 20 mm diameter holes beginning at groundline and spiraling around the pole 90 degrees and upward 150 mm. A single glass MITC-Fume vial containing 30 g of MITC was inserted into each hole. The holes were plugged with tight-fitting wood dowels to retard fumigant loss. Poles received either 3 or 4 vials.

MITC levels in the poles were assessed 2,4,5, and 7 years after treatment by removing increment cores from 3 equidistant sites 300 and 900 mm above the highest treatment hole. The outer treated zone from each core was discarded, and the inner and outer 25 mm of each core segment was analyzed for residual MITC by gas chromatography. The remainder

Table I-15. Isolation frequency of decay fungi and non-decay fungi from Douglas-fir bridge timbers 0 to 6 years after treatment with metham sodium.

	Fungal Colonization (%)				
Structure	1 year	2 years	3 years	4 years	6 years
5	–	0^{42}	0^{90}	0^{22}	0^{0}
10	0^{17}	0^{42}	0^{58}	0^{50}	0^{0}
15	0^{17}	0^{0}	0^{100}	8^{67}	0^{0}
20	–	0^{0}	0^{100}	0^{83}	0^{8}
25	0^{29}	0^{0}	0^{100}	8^{58}	0^{0}
30	29^{43}	0^{8}	0^{100}	0^{0}	0^{8}
35	13^{87}	0^{0}	0^{17}	8^{33}	0^{27}
40	0^{17}	–	8^{42}	–	–
Average	8^{35}	0^{13}	1^{70}	4^{60}	0^{7}

[a]Values represent percent of cores containing decay fungi. Superscripts represent percent of non-decay fungi present in the same cores.

Table I-16. Residual MITC in Douglas-fir bridge timbers 1 to 6 years after treatment with metham sodium.

		MITC Content (ug/g wood)							
		Inner				Outer			
Structure No.	Stringer Position	1 year	2 years	3 years	6 years	1 year	2 years	3 years	6 years
5	Top	4.3	52.3	9.7	40.2	0.0	27.6	3.3	50.4
	Bottom	59.7	34.7	31.1	39.9	24.5	112.4	84.1	108.3
10	Top	40.2	136.1	71.3	46.9	53.2	60.3	76.4	42.6
	Bottom	75.8	114.9	43.0	60.0	39.9	59.4	116.3	58.4
15	Top	27.3	66.1	46.4	64.1	37.4	59.5	145.4	65.6
	Bottom	16.0	99.7	17.8	37.7	24.3	112.9	43.4	54.8
20	Top	26.2	115.5	58.2	32.0	65.4	130.6	44.6	6.1
	Bottom	82.7	42.6	67.7	57.1	23.2	19.9	163.1	51.9
25	Top	26.5	80.2	40.7	16.0	13.1	44.4	52.5	28.7
	Bottom	33.4	83.3	86.0	59.3	65.5	95.4	32.1	51.9
30	Top	73.2	126.8	77.5	40.5	100.3	63.7	49.3	40.0
	Bottom	83.6	40.8	83.3	28.2	75.8	120.8	56.5	60.0
35	Top	44.1	74.1	108.7	30.5	60.6	120.8	56.5	60.0
	Bottom	14.0	75.1	19.2	35.6	9.2	42.4	8.8	36.6
40	Top	–	50.1	–	–	–	140.4	–	–
	Bottom	–	92.1	–	–	–	56.7	–	–
Average	Top	34.5	87.7	58.9	38.6	47.1	85.3	64.1	50.1
	Bottom	52.3	72.9	49.7	45.4	37.5	70.4	71.0	57.4

a. Values represent means of 3 replicates. Inner and outer zones represent the 25 mm on each end of the increment core sample.

of each core was cultured for the presence of decay fungi as previously described. A total of 7 pine and 13 Douglas-fir poles were treated in Belmont and 3 pine and 7 Douglas-fir were treated in Half Moon Bay.

Sometime in 1996, the poles were inadvertently retreated with metham sodium by a contractor. Despite this problem, the poles were sampled as described in 1997 to assess final MITC levels. MITC levels away from the groundline were similar to those found in 1995 (Table I-17). Fumigant levels were higher in the inner zone, but the differences were generally slight. MITC levels were elevated at the lower sampling point, however, this increase most likely reflects the retreatment rather than any resurgence in MITC from the original ampules.

The results of the above-ground sampling suggests that the MITC was still detectable 7 years after application. These results are similar to those found at the Corvallis test site. Culture results showed that no decay fungi were present in any cores removed from the poles 7 years after treatment (Table I-18). Decay fungi were generally infrequent over the course of the test. Nondecay fungi were abundant in samples removed immediately prior to treatment, but declined precipitously 2 years after treatment and remain at relatively low levels 8 years after treatment. These overall low levels of fungal colonization imply that residual MITC remains at levels that are inhibitory to recolonization. The treatment earlier in the year may have enhanced this effect. This test site will no longer be sampled since it has become a metham sodium test and duplicates a similar trial already established within the PG&E system.

B. EVALUATE THE PROPERTIES OF WATER-SOLUBLE DIFFUSIBLE REMEDIAL TREATMENTS

While volatile fumigants remain the most commonly used chemicals for controlling intemal decay of wood poles, a number of non-volatile systems have also been developed for this purpose (Table I-1). These systems lack the ability to move rapidly through the wood and appear to take longer to eliminate any fungi present, but the chemicals used have much lower toxicity and may therefore be applied with fewer restrictions.

As a part of our efforts to develop comparative information on internal treatments, we have undertaken a number of field trials of these water diffusible systems as reported below.

1. Chemical movement of a fluoride/boron rod through Douglas-fir poles: Douglas-fir poles (3.6 m long by 250 to 300 mm in diameter) were set to a depth of 0.3 m at the Peavy Arboretum test site. A series of 3 holes (19 mm in diameter by 250 mm long) were drilled at steep sloping angles beginning at the groundline and moving upwards 150 mm and around the pole at 90 or 120 degrees. A total of 70.5 or 141 g of a boron/fluoride rod was equally distributed among the three holes which were plugged with tight-fitting wood dowels. The boron/fluoride rods contained 24.3% sodium fluoride and 58.2% sodium octaborate tetrahydrate in a chalk-like form (Preschem Ltd., Australia).

Boron and fluoride levels in the wood have been assessed annually since installation by removing increment cores from three equidistant sites around each pole 300 mm below, 300 mm above, and 800 mm above the groundline. The outer, treated shell of each core was discarded, then the inner and outer 25 mm of the remaining core were segregated. Core segments from a given zone for the same sampling height were combined for the 5 poles in each treatment group. The cores were then ground to pass a 20 mesh screen and the resulting sawdust was analyzed for fluoride and boron. The samples were hot water extracted, then boron levels were determined using the Azomethine-H method, while the fluoride levels were determined using a specific ion-electrode. Boron levels in the poles not receiving the rods remain negligible (Figure 1-2). The boron level believed to confer protection against fungal attack is 0.25% boric acid equivalent. Boron levels in poles treated with 3 rods remained below the target loading over the test period at about one half of the

Table I-17. Residual methylisothiocyanate in Douglas-fir and Ponderosa pine utility poles 2, 4, 5, and 8 years after treatment with 3 or 4 vials of MITC-fume.

Wood species	Dosage (g)	Months in Test	Residual MITC ($\mu g/g$ wood)[a]							
			Half-Moon Bay				Belmont			
			0.6 m		1.2 m		0.6 m		1.2 m	
			inner	outer	inner	outer	inner	outer	inner	outer
Douglas-fir	90	24	81	30	10	0	138	56	2	9
		48	309	71	184	123	174	7	70	9
		60	306	22	99	19	146	24	12	0
		96	138	104	34	23	23	26	10	6
	120	24	938	60	165	5	174	6	15	1
		48	568	270	267	204	245	49	108	20
		60	706	30	321	27	202	36	62	4
		96	130	80	80	61	80	22	36	8
Ponderosa pine	120	24	210	63	25	19	184	89	8	2
		48	69	8	20	14	51	10	64	9
		60	92	4	30	2	84	22	13	6
		96	200	139	8	1	10	13	3	6

[a] Values represent means of 30 analyses per sampling site.

Table I-18. Residual levels of decay fungi and non-decay fungi increment cores removed from Douglas-fir and Ponderosa pine poles treated 8 years earlier with MITC fume.

Site	Wood Species	Reps	MITC Dosage (g)	Sampling Heights (m)	Fungal Colonization (%)				
					0 yr	3 yr	4 yr	5 yr	8 yr
Belmont	Douglas-fir	4	90	0	0^{50}	–	–	–	–
				0.3	0^{50}	–	–	–	–
				0.6	–	0^{8}	0^{8}		
				1.2	–	8^{8}	0^{0}	0^{0}	0^{8}
		7	120	0	0^{71}	–	–	–	–
				0.3	17^{33}	–	–	–	–
				0.6	–	0^{0}	0^{0}	0^{5}	0^{0}
				1.2	0^{0}	–	–	–	–
	Ponderosa pine	5	120	0	0^{0}	–	–	–	–
				0.3	0^{0}	–	–	–	–
				0.6	–	0^{0}	0^{0}	0^{0}	0^{25}
				1.2	–	0^{0}	0^{7}	0^{8}	0^{0}
Half Moon Bay	Douglas-fir	3	90	0	50^{50}	–	–	–	–
				0.3	0^{0}	–	–	–	–
				0.6	–	–	0^{22}	0^{0}	0^{0}
				1.2	–	–	–	–	–
		2	120	0	50^{10}	–	–	–	–
				0.3	0^{0}	–	–	–	–
				0.6	–	–	0^{0}	0^{22}	0^{0}
				1.2	–	–	0^{0}	0^{0}	0^{17}
Half Moon Bay	Ponderosa pine	3	120	0	0^{0}	—	—	—	—
				0.3	0^{0}	—	—	—	–
				0.6	—	—	0^{0}	0^{22}	0^{0}
				1.2	—	–	0^{0}	0^{0}	0^{17}

a. Values represent percent of cores containing decay fungi. Values in parentheses represent levels of nondecay fungi.

sampling locations. Chemical loadings in the 3 rod treatments were consistently higher in samples removed from 300 mm below and above the groundline, reflecting the higher availability of moisture for diffusion in this zone. Boron levels at 600 mm were generally low, but were above those found in the control poles. These results suggest that some upward boron diffusion has occurred. Boron levels below the groundline were generally higher in the inner zone. This effect may reflect a tendency for any boron nearer the wood surface to leach from the pole. These test poles are subjected to extremely high moisture levels during the winter months, creating ideal conditions for boron loss.

The application of six boron/fluoride rods did not result in a doubling of resulting boron concentrations (Figure 1-2). In a number of instances, boron levels differed little between the two dosages. In addition, altering the treatment pattern had little or no effect on the resulting boron levels. The absence of such effects is perplexing and will require additional monitoring to determine if treatment pattern has any long term effect on chemical performance.

Fluoride levels in all poles were generally well below the levels required for fungal control (>0.3% sodium fluoride) although they were somewhat higher than those found 2 years after treatment (Figure 1-3). As with boron, fluoride levels were elevated in the samples removed from locations 300 mm above or below the groundline. Levels 600 mm above groundline were once again lower than those nearer the groundline, but were above those found in the untreated control poles. Fluoride levels as a composite by position (regardless of dosage) indicated that there was little difference in chemical levels in the inner and outer zones. The absence of marked differences implies that fluoride has become relatively uniformly distributed across the pole at a given height albeit at a relatively low level.

While both boron and fluoride levels remain below the levels that are generally accepted as thresholds for suppressing fungal attack of wood, the effects of sublethal levels of both boron and fluoride on fungal growth are unknown. We will continue to seek methods for more accurately assessing the potential for synergism with these two chemicals.

2. Performance of fused boron rods in above ground exposures in Douglas-fir pole stubs: Fused borate rods were originally developed in Europe for remedial decay control in utility poles, railway ties and window frames. Boron rods (produced by melting and pouring boron into molds where it cools into a glass-like material) provide a relatively high concentration of boron per unit area. In theory, the boron is released from the rod in the presence of water and diffuses throughout the wood in the same manner as other boron based systems.

A number of field trials of boron rods have been established under the Cooperative including one above ground trial from which data was provided in 1996, and two tests that are reported on here.

In the first 30 pentachlorophenol-treated Douglas-fir pole sections (250 to 300 mm in diameter by 2 m long) were set to a depth of 0.3 m at the Peavy Arboretum test site. Three 19 mm diameter by 450 mm long holes were drilled perpendicular to the grain direction beginning at groundline and moving upward at 150 mm intervals and spiraling around the pole 120 degrees. Each hole received 1 or 2 rods, and each treatment was replicated on 10 poles.

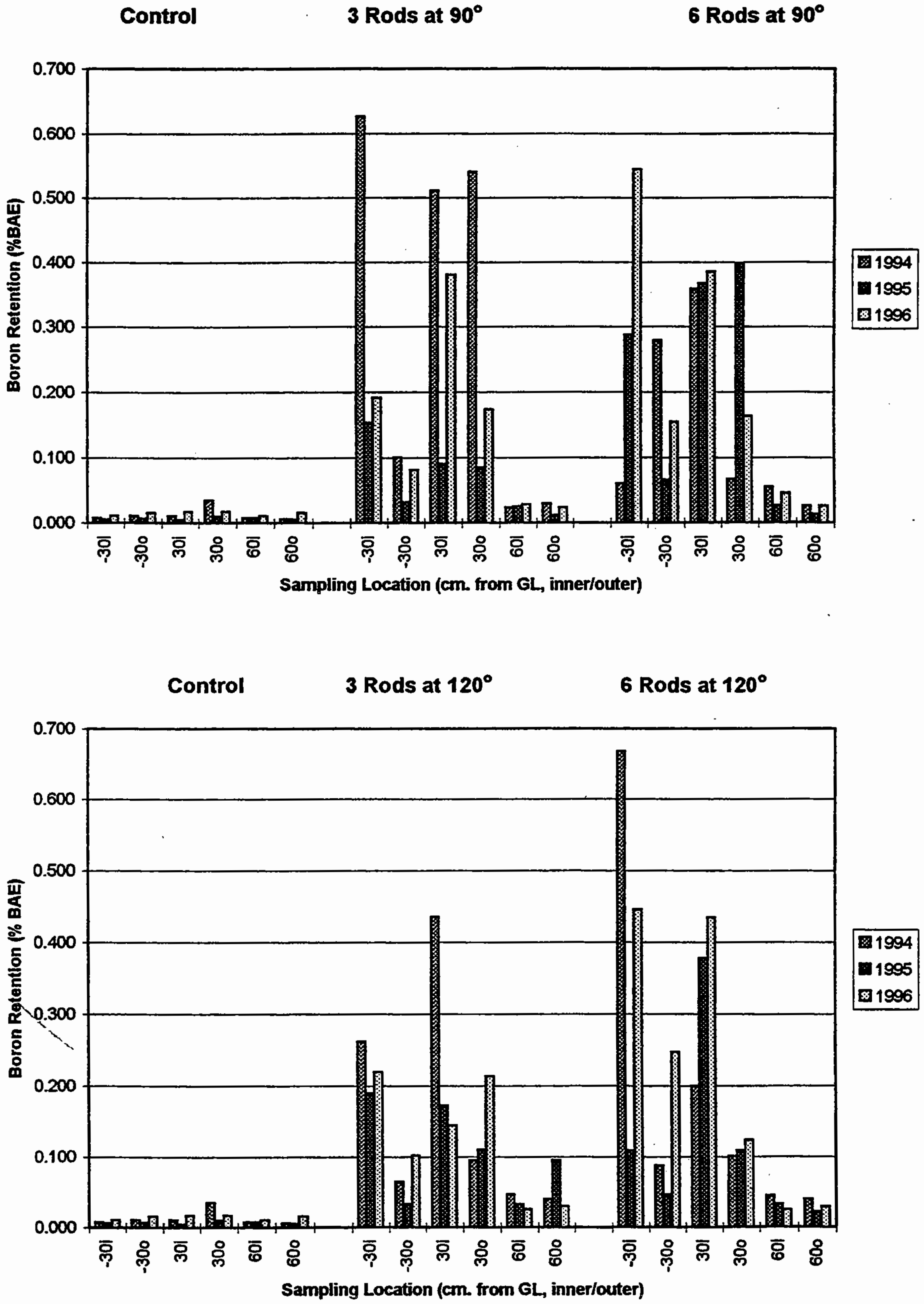


Figure 1-2. Residual boron levels at selected distances from the groundline of Douglas-fir poles 1 to 3 years after treatment with 3 or 6 boron/fluoride rods in three holes spaced 90 or 120 degrees around the pole.

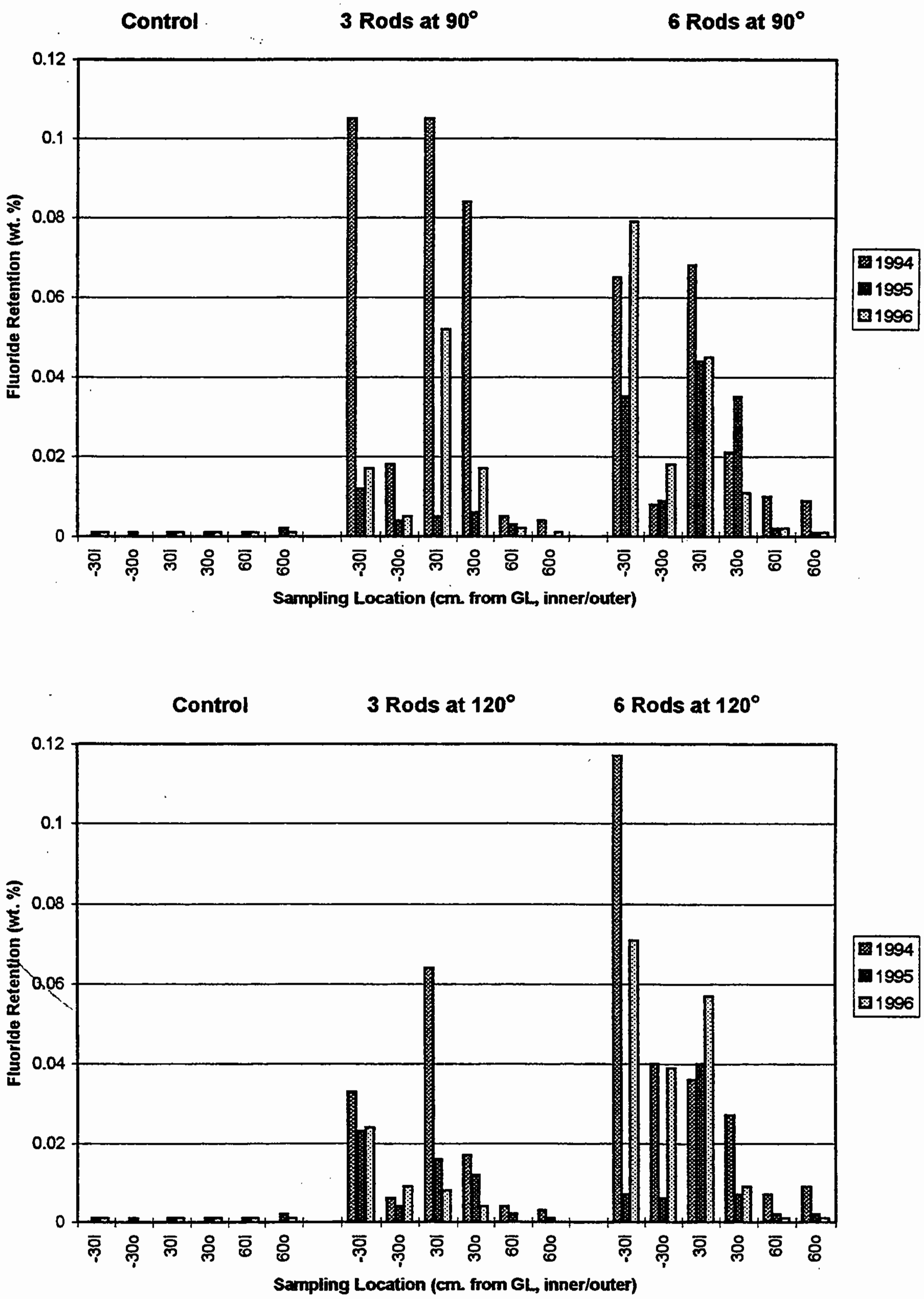


Figure I-3. Residual fluoride levels at selected distances from the groundline of Douglas-fir poles 1 to 3 years after treatment with 3 or 6 boron/fluoride rods in 3 holes spaced 90 or 120 degrees around the pole.

The poles were sampled 1 and 3 years after treatment by removing increment cores from sites located 150 mm below the groundline as well as 75, 225, 450, and 600 mm above the groundline. Three cores were removed at each height. The outer, treated shell was discarded, then the remaining core was divided into inner and outer halves that were retained for analysis. Core segments from the same height and depth for a given treatment were combined and ground to pass a 20 mesh screen. The boron samples were hot water extracted and analyzed on a blind basis by CSI (Charlotte, NC) using an Ion Coupled Plasma Spectrograph (ICP). The results were expressed on a percent boric acid equivalent basis (wt./wt.).

Boron levels in increment cores removed from near the groundline increased markedly between 1 and 3 years after treatment (Table I-19). Chemical levels in the inner zone of samples from below ground increased over 4 fold in that time interval, while those 75 mm above the groundline increased by one-third and those 225 mm above the groundline increase over three-fold. Boron levels in the outer zone were more variable and some decreases were noted between the first and third year samples. Boron levels in the higher dosage treatment also increased in the inner zones between one and three years. In one instance (225 mm above the groundline), boron levels were extremely high (10.88% BAE). We believe this reflects analysis of a sample removed from immediately adjacent to a treatment site rather than a representative example of the types of boron loadings that might develop near the rods.

As noted in an earlier section, the threshold for prevention of fungal attack with boron is reported to be 0.25% BAE. Using this value as a guideline, it is clear that protective levels of boron are present in the inner zones at four of five sampling points for both dosages. Loadings in the outer zone tended to be lower and were at or near the threshold for only three of the sites for the lower dosage and two of five sites for the higher dosage. The reasons for the lower boron levels in the outer zones in the above ground portions of the poles is unclear. The original preservative treatment should largely limit the potential for boron loss to the surrounding environment above the groundline and the perpendicular treatment holes should produce a relatively uniform boron distribution with time. Boron distribution has not developed in a uniform manner, and further sampling will be required to determine if such distributions are possible in these poles. The results do indicate that protective levels of boron are present near the groundline three years after treatment.

3. Performance of sodium fluoride rods in Douglas-fir poles: Fluoride has long been used as a remedial treatment for controlling internal decay in railroad ties. This material has recently been labeled for application to wood poles, but there is relatively little data on the ability of sodium fluoride to diffuse from the rod into the surrounding pole. Twenty pentachlorophenol-treated Douglas-fir pole sections (250 to 300 mm in diameter by 2.4 m long) were set to a depth of 0.6 m at the Peavy Arboretum test site. Three 19 mm diameter by 200 mm long holes were drilled into the poles beginning at groundline and moving upward at 150 mm intervals and 120 degrees around the pole. Each hole received 1 or 2 sodium fluoride rods, then the holes were plugged with tight fitting wooden dowels. Each treatment was assessed on 10 poles.

Fluoride movement was assessed 1 year after treatment by removing increment cores from 3 sites around each pole 150 mm below the groundline, 225 mm above the groundline, and 150 mm above the highest treatment hole (450 mm above groundline).

The outer, treated shell was discarded, then the remaining core was divided into inner and outer halves. Cores from a given height and treatment were combined prior to grinding to pass a 20 mesh screen. A hot water extract of sawdust was analyzed using a specific ion electrode for fluoride. In examining the results, we became concerned that the fluoride levels were lower than expected. To evaluate the possibility that our analysis was faulty, we sent 7 coded samples to be analyzed by Osmose Wood Preserving (Buffalo, New York). The results were markedly higher than those produced by hot water extraction. Previous trials at our laboratory have shown that hot water extraction works well with samples that do not contain oil (from the original preservative treatment). The poles used for the fluoride rod test were particularly well treated and we believe that oil inadvertently contaminated the samples prior to analysis. To overcome this problem, we sent the residual sawdust from each sample to Osmose for analysis using AWPA Standard A2 Method 7 which involves ashing the wood to remove contaminants that might interfere with fluoride extraction. The analyses were performed on a blind sample basis.

As expected for samples removed one year after treatment with a water diffusible compound, fluoride levels varied widely by position and dosage (Table I-20). For example, fluoride levels in the outer zone 150 mm below ground approached 1.00%; however, this high level of reflects the presence of one sample that had nearly 5% sodium fluoride (Figure I-4). The remainder of samples had fluoride levels that were far lower. The large variations in fluoride levels imply that this chemical is still actively diffusing across the pole sections. We would expect that continued sampling over the next 2 years will produce results indicating an increasingly uniform fluoride distribution. At present, fluoride levels near the groundline remain below the threshold for limiting fungal attack while levels above and below this zone remain more variable.

C. EVALUATE FUNDAMENTAL PROPERTIES OF INTERNAL REMEDIAL TREATMENTS

While many of the treatments evaluated under Objective I have been used in other wood products, it is important to understand the many variables that might affect their performance on wood poles. For this reason, we routinely evaluate new remedial internal treatments under more controlled laboratory conditions. These trials provide guidance concerning the environmental factors that might affect performance and help to identify methods for improving performance.

1. Effect of glycol and moisture content on diffusion of boron from fused borate rods: The field trials of fused borate rods have produced somewhat variable results. In several instances, boron levels remained below those reported to be necessary for controlling decay fungi for periods extending up to 3 years following treatment. These delays reflect, in part, the variable moisture regimes that are present inside wood poles, While the slow rate of diffusion poses little concern if the poles are not actively decaying, poles with active infestations will continue to experience losses in properties over this diffusion period. Elevated moisture contents can enhance boron diffusion, but it is not feasible to alter the moisture content in the entire groundline of the pole to improve treatment. Adding water to the treatment holes at the time of rod application can enhance immediate boron diffusion, but only affects moisture levels in a relatively small area surrounding the hole.

One alternative to the use of water is glycol. A number of studies indicate that glycol can markedly enhance the diffusion of boron through drier wood, thereby producing a more even distribution over time. A number of boron/glycol formulations are available commercially, but the potential benefits of using combinations of boron/glycol and fused borate rods are not known (Table I-21). In order to evaluate the potential for using glycol to enhance boron diffusion from borate rods, the following laboratory study was undertaken.

Douglas-fir heartwood blocks (38 by 88 by 150 mm long) were oven-dried and weighed prior to being pressure soaked with water. The blocks were then conditioned to 30 or 60% moisture content. An additional set of blocks was conditioned to 15% MC without an initial

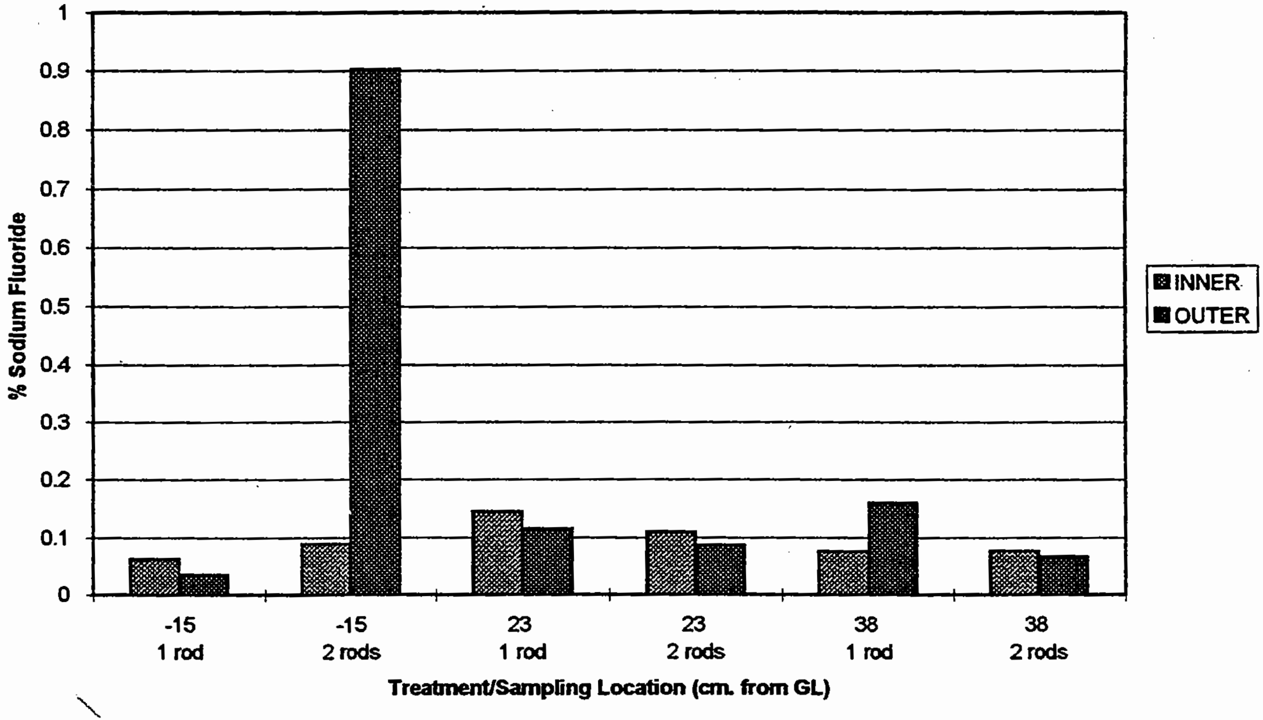


Figure I-4. Residual fluoride levels in the inner or outer 25 mm of increment cores removed from above or below the groundline of Douglas-fir poles 1 year after treatment with sodium fluoride rods.

Table I-19. Residual boron (as % boric acid equivalent) in Douglas-fir poles 1 and 3 years after treatment with 180 or 360 g of fused borate rod.

Borate Dosage (g)	Distance from Treated Zone (mm)	Boric Acid Equivalent (%)			
		Inner Zone		Outer Zone	
		1 year	3 years	1 year	3 years
180	-150	0.38	1.81	0.24	0.25
	+75	2.82	3.75	0.65	1.10
	+225	0.89	3.16	0.98	0.58
	+450	0.54	0.22	0.22	0.20
	600	0.18	0.24	0.14	0.09
360	-150	0.09	0.76	0.07	0.23
	+75	0.96	10.88	0.59	0.61
	+225	0.48	3.21	0.13	0.14
	+450	0.04	0.11	0.02	0.09
	+600	0.05	0.39	0.02	0.09

Table I-20. Residual sodium fluoride in Douglas-fir poles 1 year after treatment with 3 or 6 fluoride rods.

Dosage	Residual Sodium Fluoride (%)[a]					
	-150 mm[b]		225 mm		450 mm	
	outer	inner	outer	inner	outer	inner
3 rods	0.035 (0.012)	0.062 (0.079)	0.115 (0.217)	0.145 (0.236)	0.160 (0.198)	0.076 (0.079)
6 rods	0.903 (2.011)	0.089 (0.069)	0.087 (0.119)	0.110 (0.127)	0.067 (0.071)	0.077 (0.108)

a. Values represent means of 7 analyses per treatment. Figures in parentheses represent one standard deviation.

b. Sampling heights above or below groundline. Cores were divided into inner and outer halves prior to analysis.

soaking. Once a block reached a given moisture content, it was dipped in molten paraffin to retard further moisture loss. The blocks were stored at 5°C for at least 4 weeks to allow for further moisture equilibration within the wood.

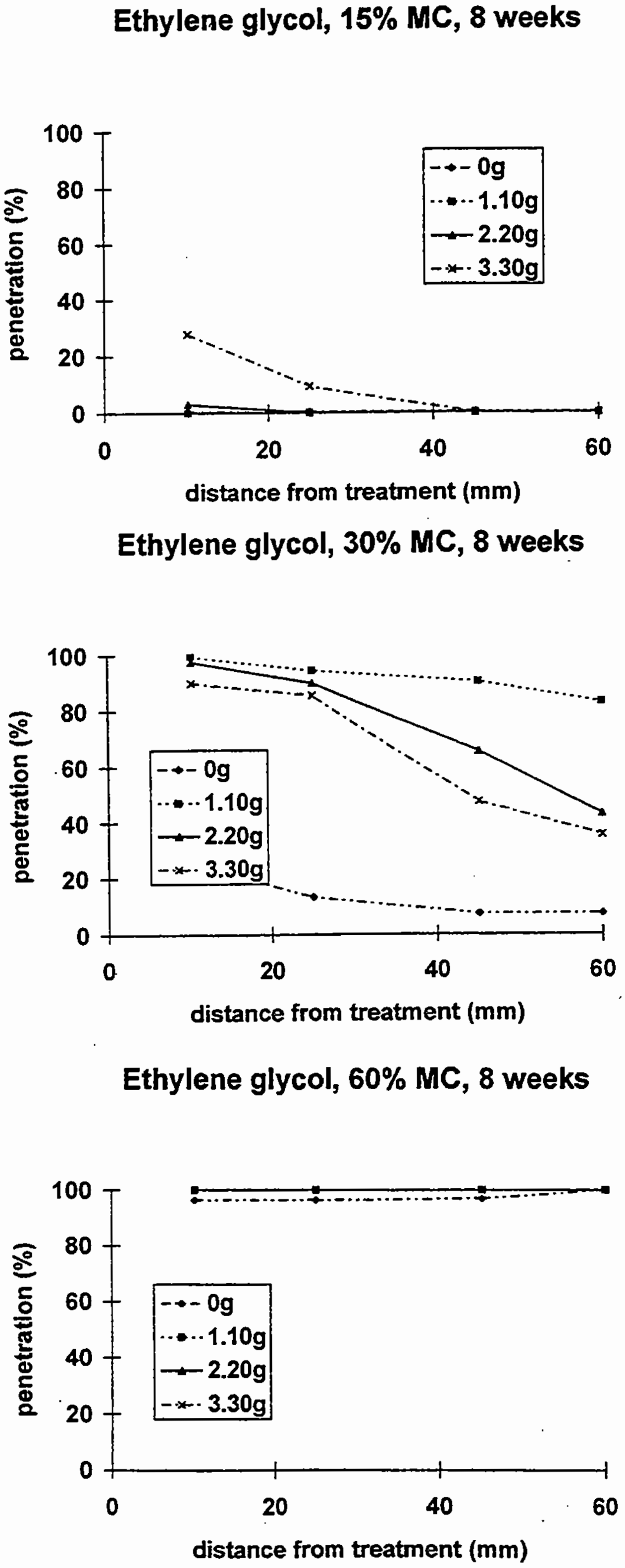
A single 9.5 or 11.1 mm by 60 mm long hole was drilled at the midpoint of the 39 mm wide face of each block and a measured amount of fused borate rod alone or with Boracol 20, Boracol 40, Boracare (diluted 1:1 with water), 10% Timbor (disodium octaborate tetrahydrate) or glycol was added to each hole. The holes were plugged with rubber serum caps and the blocks were incubated at room temperature (23-25°C) for 8 to 12 weeks.

At each time point, four blocks per treatment combination were destructively sampled by cutting a series of 5 mm thick sections 10, 25, 45, and 60 mm from the original treatment hole. The sections were oven-dried overnight (54°C) then sanded lightly to minimize the potential for boron carry over during sawing. The sanded surfaces were then sprayed with a curcumin/salicylic acid indicator specific for boron. The percent boron penetration on each section was visually estimated. Once penetration was measured, a 25 mm wide sample was removed from each section in line with the original treatment hole. This material was ground to pass a 20 mesh screen and hot water extracted prior to analysis for residual boron content by Ion Coupled Plasma Spectroscopy.

As expected, the degree of boron penetration increased markedly with increasing moisture content (Figure I-5 to I-9). Penetration was virtually complete (>95%) 8 weeks after treatment 60 mm from the treatment hole in blocks conditioned to 60% moisture content prior to treatment, except for the highest dosage of Boracol 40. It is unclear why this formulation did not enhance boron diffusion to the same extent as the other treatments or even to the same extent as the lower levels of the same formulation.

Boron diffusion in blocks equilibrated to 15% moisture content prior to treatment was generally limited to the first 25 mm around the treatment hole. Boron penetration in the absence of added glycol or water was nil, reflecting the inability of boron to diffuse through wood in the absence of free water. A boron rod alone or with glycol added resulted in limited penetration within 25 mm of the original treatment site. Even within the zone where penetration was noted, the percent of boron penetration was generally below 40% of the cross sectional area. While some boron penetration was noted further away from the treatment site at the highest Boracol 40 treatment level, the degree of penetration noted on these samples was still less than 20% of the cross section. These results suggest that the addition of glycol either alone or in a formulation with boron does not markedly enhance the diffusion of boron from the fused borate rods through wood below the fiber saturation point. These results compare favorably with previous studies of boron diffusion at various wood moisture contents.

Boron diffusion increased substantially in blocks conditioned to 30% moisture content, in some instances approaching 100% penetration within 25 mm of the treatment hole. Once again, boron penetration was lowest in blocks that did not receive any supplement, although penetration in boron rod treatments approached that found with 15% MC blocks receiving added glycol. In addition, some boron penetration was noted along the total length of blocks conditioned to 30% MC but not receiving glycol or water. The sporadic nature of this extended boron penetration may reflect the presence of moisture differences within the blocks. While every attempt was made to ensure that the blocks were uniformly conditioned prior to treatment, it is likely that moisture gradients remained in the wood and that these gradients influenced subsequent boron diffusion. Substantial moisture gradients are also likely to occur in poles and may have


Ethylene glycol, 15% MC, 8 weeks

Ethylene glycol, 30% MC, 8 weeks

Ethylene glycol, 60% MC, 8 weeks

Figure I-5. Penetration of boron in cross sections cut from various distances from holes drilled in Douglas-fir heartwood blocks conditioned to 15, 30 or 60% moisture content and treated 8 weeks earlier with fused boron rod plus selected levels of polyethylene glycol to produce a dosage of 3.1 g boric acid equivalent per block.

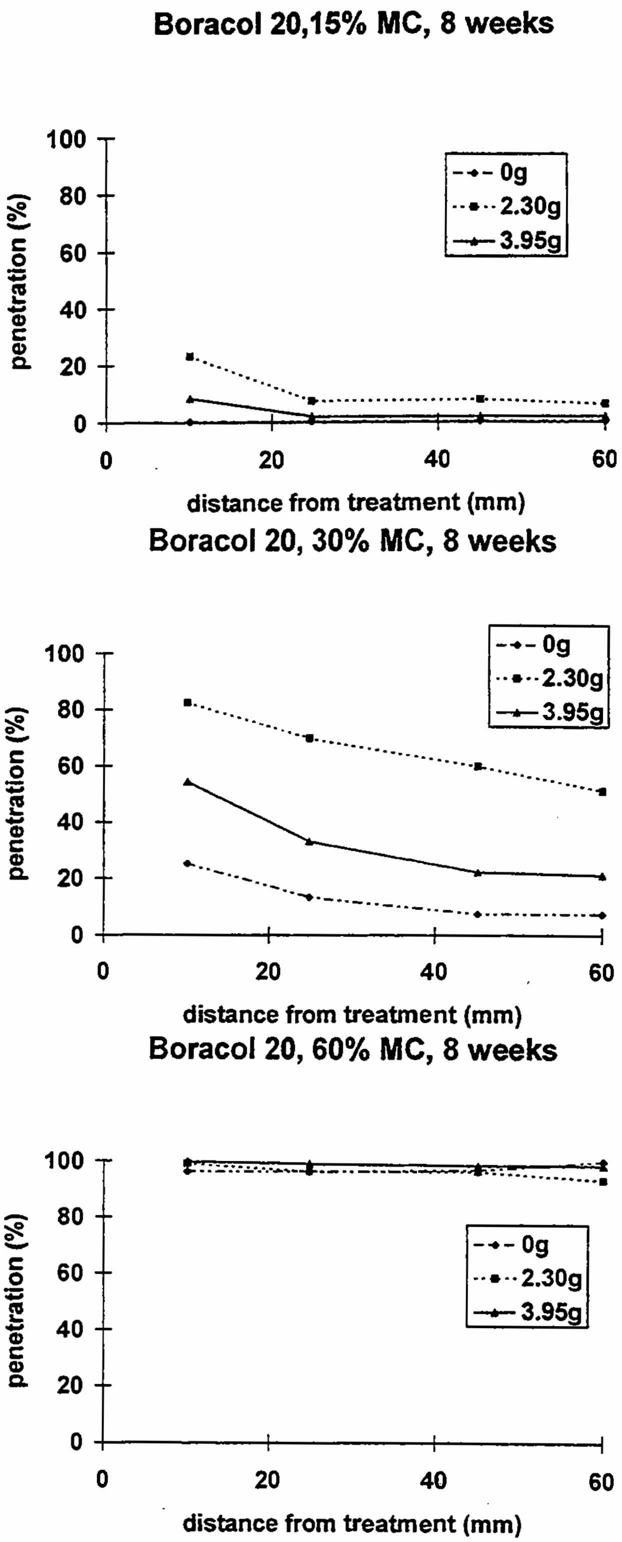


Figure I-6. Penetration of boron in cross sections cut from various distances from holes drilled in Douglas-fir heartwood blocks conditioned to 15, 30 or 60% moisture content and treated 8 weeks earlier with fused boron rod plus selected levels of Boracol 20 to produce a dosage of 3.1 g boric acid equivalent per block.

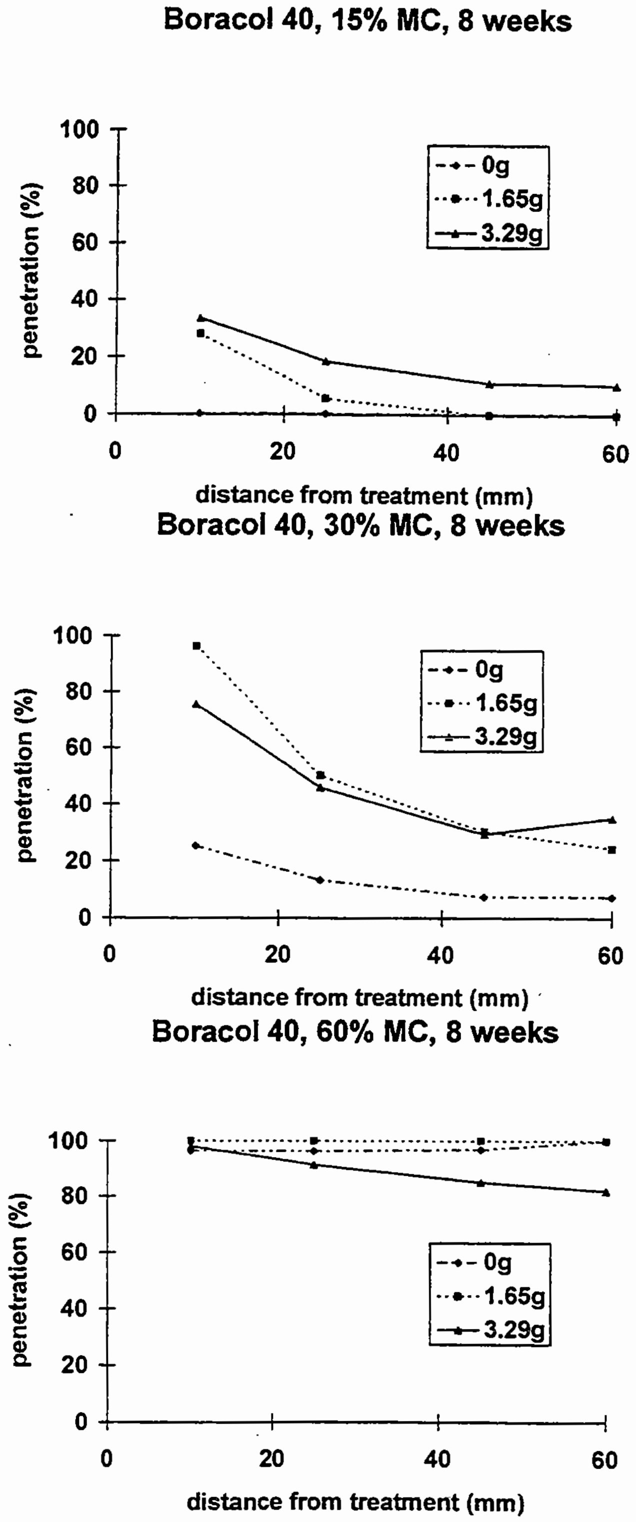
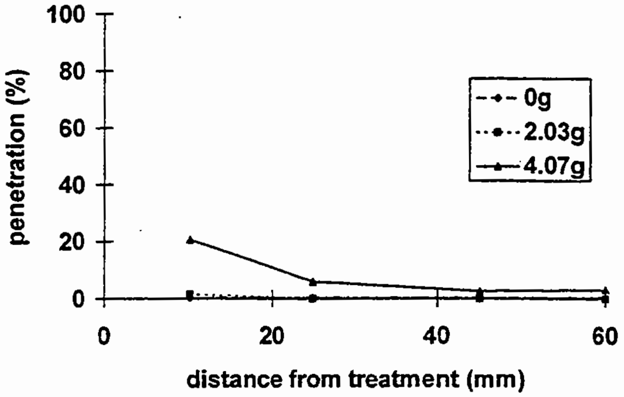
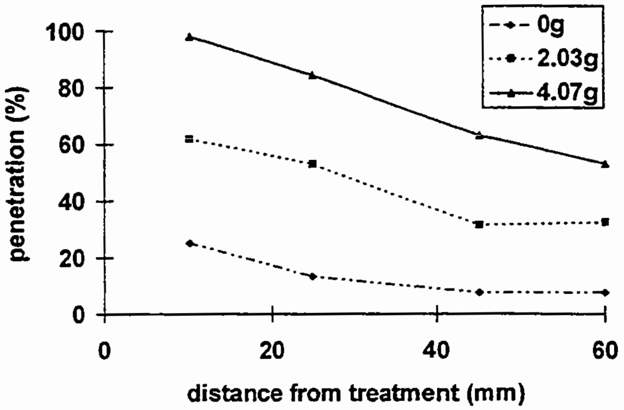


Figure I-7. Penetration of boron in cross sections cut from various distances from holes drilled in Douglas-fir heartwood blocks conditioned to 15, 30 or 60% moisture content and treated 8 weeks earlier with fused boron rod plus selected levels of Boracol 40 to produce a dosage of 3.1 g boric acid equivalent per block.

Boracare (1:1), 15% MC, 8 weeks



Boracare (1:1), 30% MC, 8 weeks



Boracare (1:1), 60% MC, 8 weeks

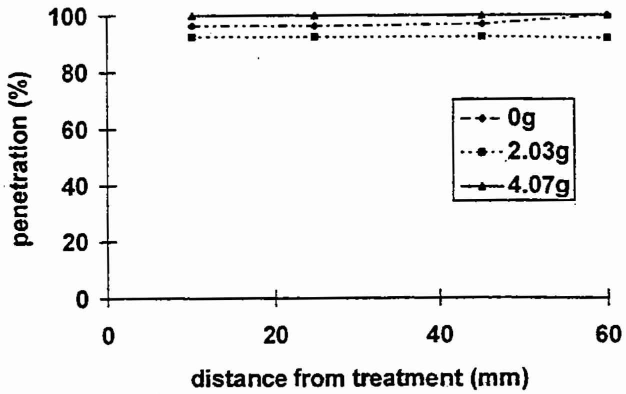
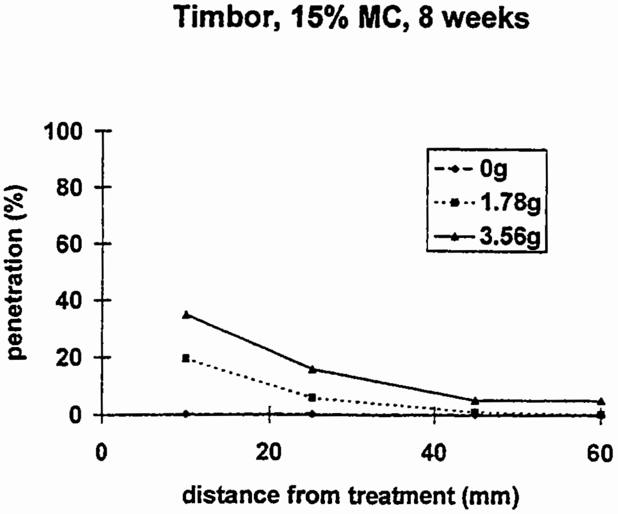
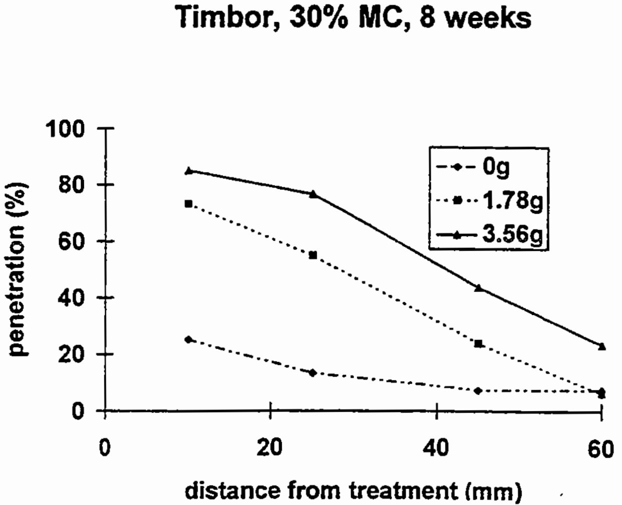


Figure I-8. Penetration of boron in cross sections cut from various distances from holes drilled in Douglas-fir heartwood blocks conditioned to 15, 30 or 60% moisture content and treated 8 weeks earlier with fused boron rod plus selected levels of Boracare to produce a dosage of 3.1 g boric acid equivalent per block.





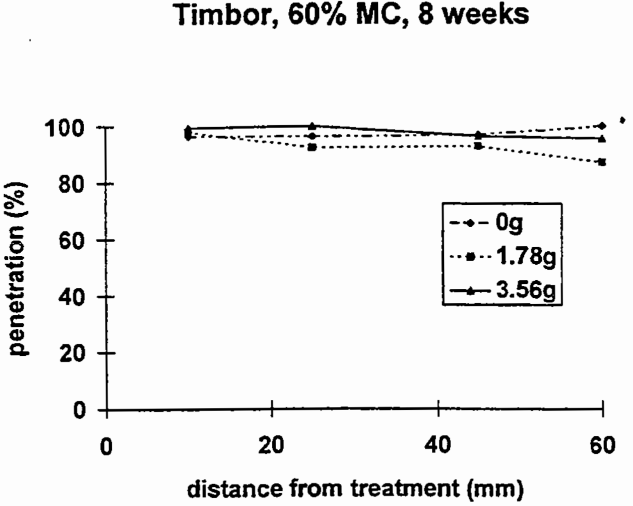


Figure I-9. Penetration of boron in cross sections cut from various distances from holes drilled in Douglas-fir heartwood blocks conditioned to 15, 30 or 60% moisture content and treated 8 weeks earlier with fused boron rod plus selected levels of 10% Timbor to produce a dosage of 3.1 g boric acid equivalent per block.

similar effects on penetration. The degree of penetration away from the treatment hole at this moisture content however, was extremely limited (<10%). The addition of small amounts of ethylene glycol alone had the most dramatic effect on boron penetration in blocks at 30% MC although all 5 treatments enhanced boron penetration to some extent. Boracare and Boracol 20 appeared to enhance penetration to the greatest extent of the four boron supplements followed by Timbor and Boracol 40.

All three glycol levels produced much greater boron penetration than the control (boron rod alone). Penetration in the glycol treatments ranged from 60 to 80 % of the cross section 60 mm from the original treatment hole. Boron penetration at the 60 mm sampling point in the remaining treatments were generally lower than the glycol treatment, regardless of dosage except for the higher loading of Boracol 40. These results again suggest that boron in the glycol somehow interfered with subsequent boron release from the rods. The enhancement in penetration by glycol alone in comparison with the boron based additives is interesting. One might expect the boron based additives to have higher degrees of penetration given that the boron was applied in a soluble form capable of immediate diffusion. This apparently did not result in increased diffusion, suggesting that the ability to solubilize the boron rod may have been more important.

It is also interesting to note the sometimes negative effect of increasing amounts of the glycol systems (with or without boron) on subsequent boron distribution. Boron penetration was slightly lower at the higher levels of Boracol 20 or ethylene glycol. This effect was reversed with Boracare and Timbor, while amount of supplement had no effect on percent penetration with Boracol 40. It is unclear why increasing levels of either glycol or water would adversely affect boron movement in the 30% MC blocks. Increasing moisture levels should improve release of boron from the rods as well as enhance diffusion away from the treatment hole. It is important, however, to remember that penetration measurements with boron can be deceiving since the indicator has a sensitivity that is lower than the presumed threshold for preventing fungal attack. Chemical analyses should provide a better measure of the effects of glycol or water on boron movement from the rods.

Boron distributions tended to improve with increasing incubation time (12 weeks), although the differences were sometimes slight (Figures I-10 to 14). Penetration was virtually complete in blocks conditioned to 60% MC prior to treatment, reflecting the ability of boron to diffuse through wood where free moisture was present.

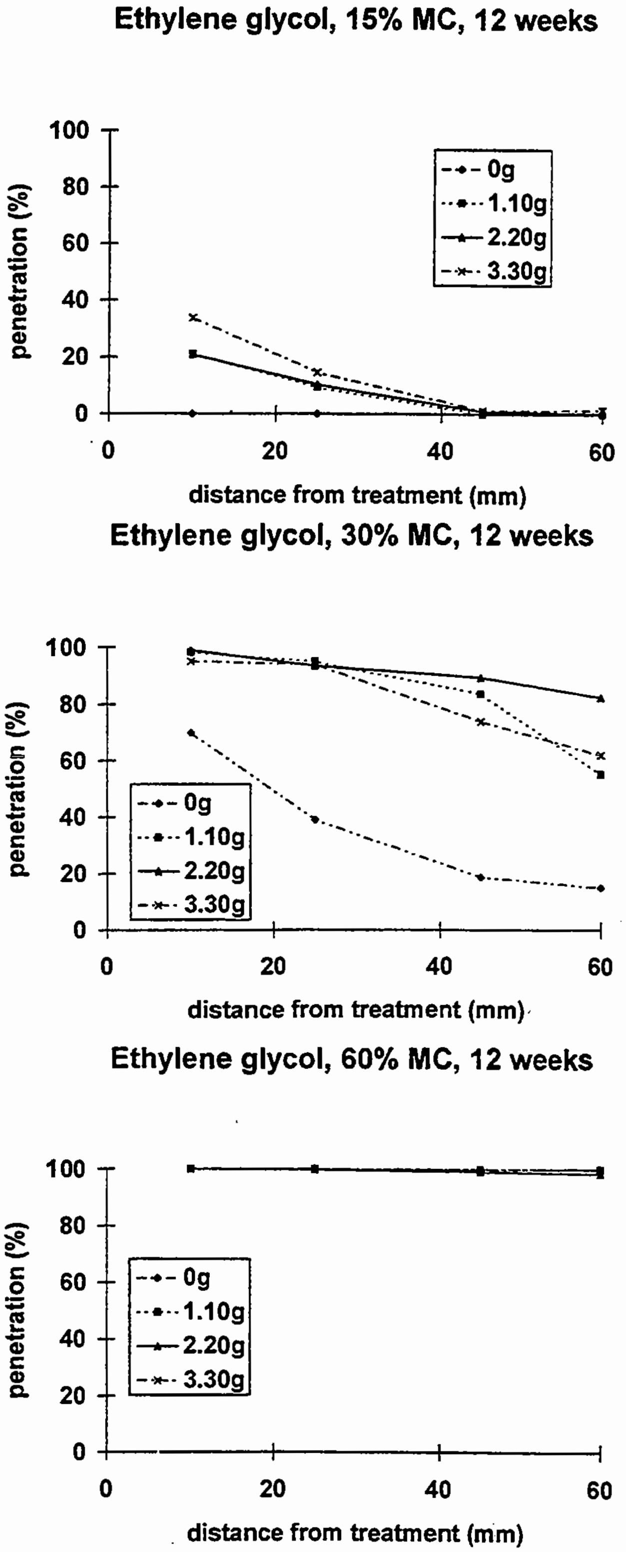
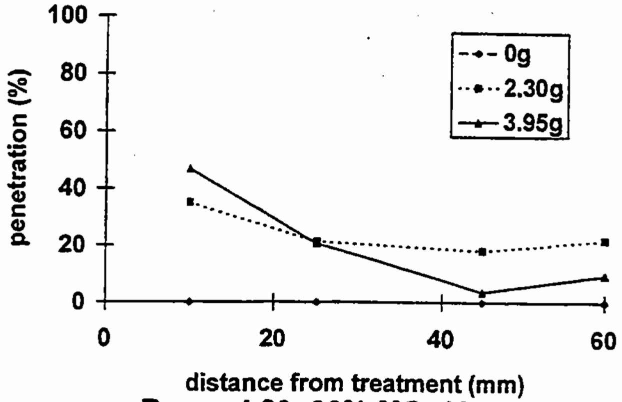
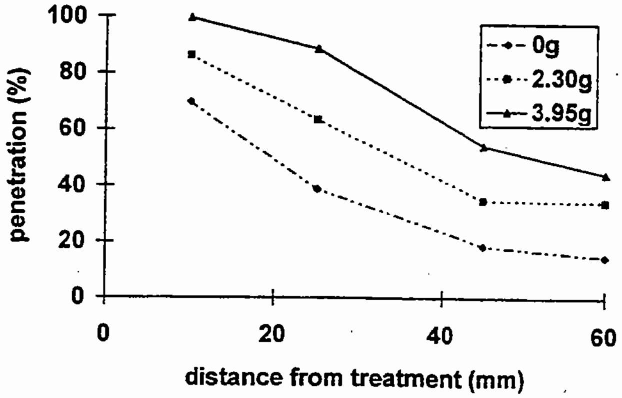


Figure I-10. Penetration of boron in cross sections cut from various distances from holes drilled in Douglas-fir heartwood blocks conditioned to 15, 30 or 60% moisture content and treated 12 weeks earlier with fused boron rod plus selected levels of polyethylene glycol to produce a dosage of 3.1 g boric acid equivalent per block.

Boracol 20,15% MC, 12 weeks



Boracol 20, 30% MC, 12 weeks



Boracol 20, 60% MC, 12 weeks

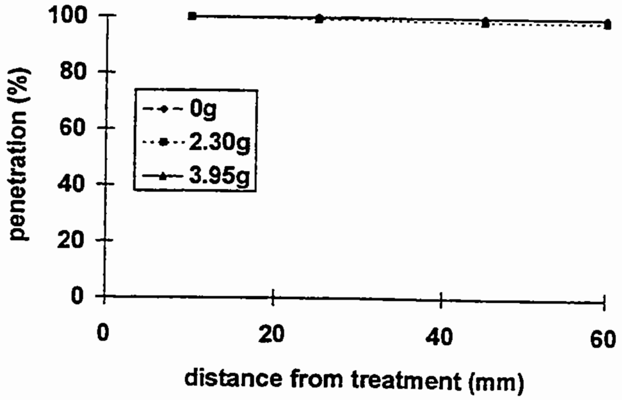
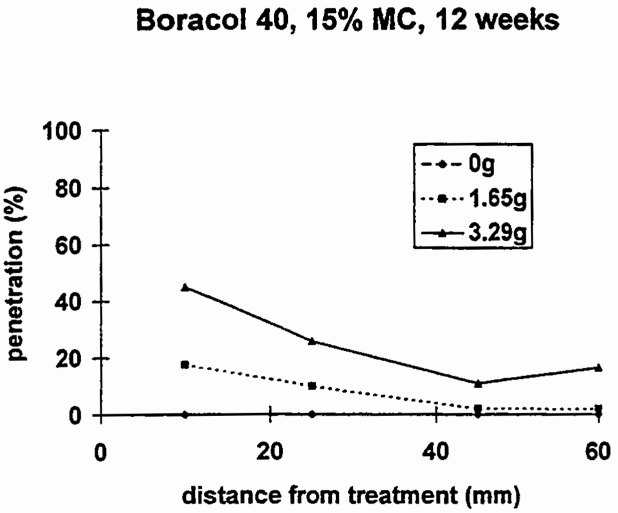
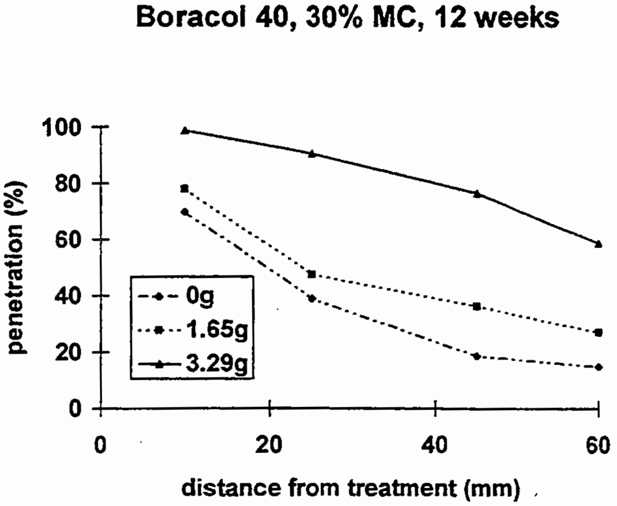


Figure I-11. Penetration of boron in cross sections cut from various distances from holes drilled in Douglas-fir heartwood blocks conditioned to 15, 30 or 60% moisture content and treated 12 weeks earlier with fused boron rod plus selected levels of Boracol 20 to produce a dosage of 3.1 g boric acid equivalent per block.





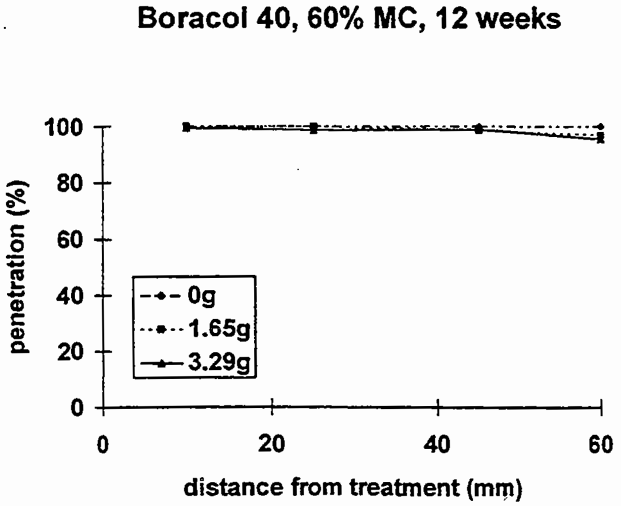
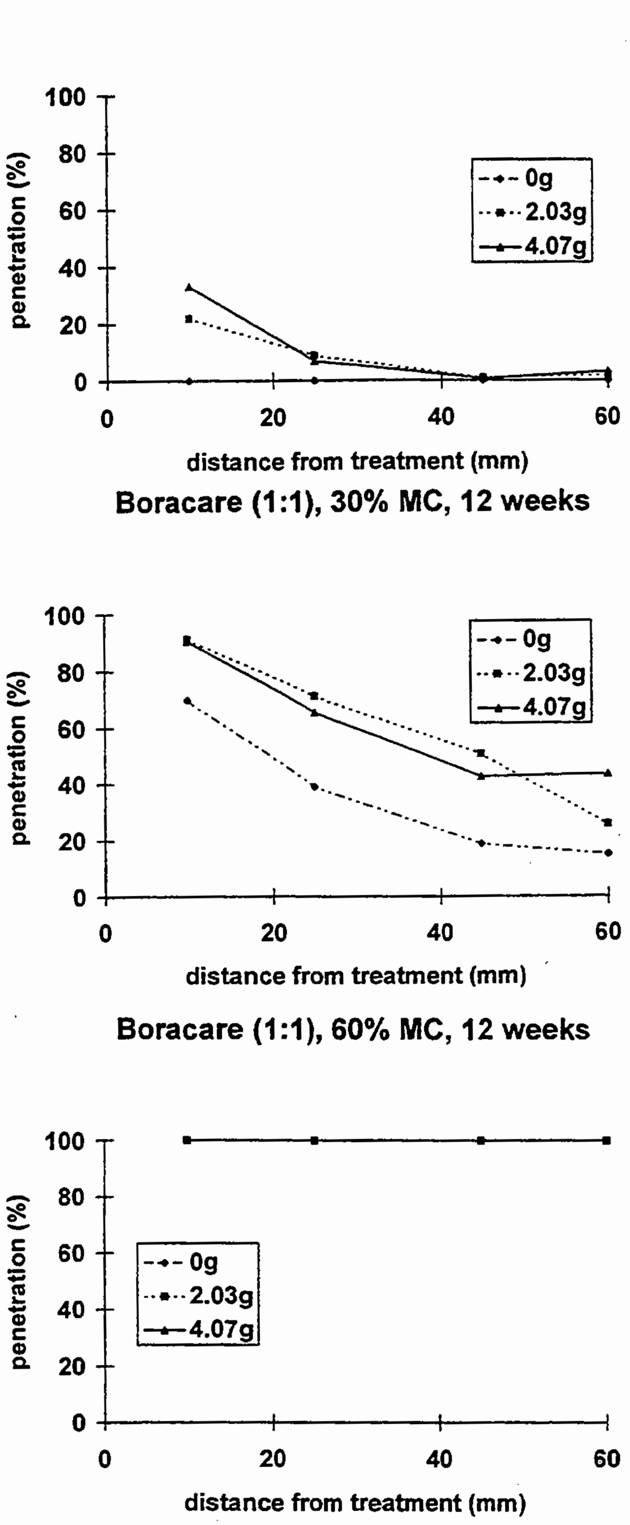


Figure I-12. Penetration of boron in cross sections cut from various distances from holes drilled in Douglas-fir heartwood blocks conditioned to 15, 30 or 60% moisture content and treated 12 weeks earlier with fused boron rod plus selected levels of Boracol 40 to produce a dosage of 3.1 g boric acid equivalent per block.



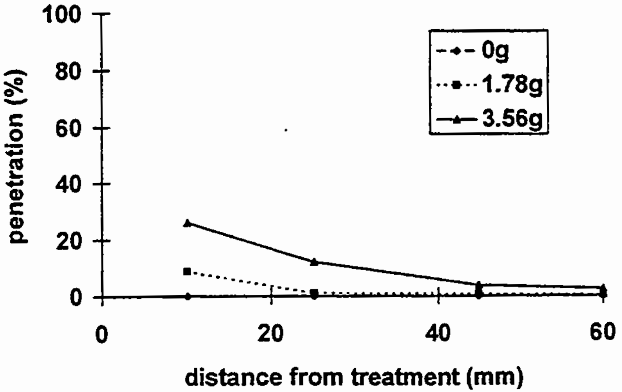
Boracare (1:1), 15% MC, 12 weeks

Boracare (1:1), 30% MC, 12 weeks

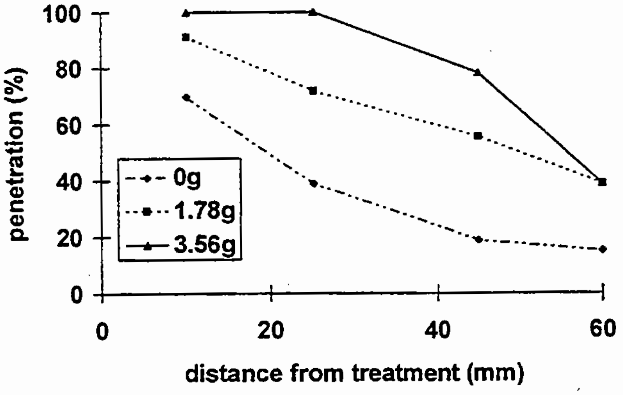
Boracare (1:1), 60% MC, 12 weeks

Figure I-13. Penetration of boron in cross sections cut from various distances from holes drilled in Douglas-fir heartwood blocks conditioned to 15, 30 or 60% moisture content and treated 12 weeks earlier with fused boron rod plus selected levels of Boracare to produce a dosage of 3.1 g boric acid equivalent per block.

Timbor, 15% MC, 12 weeks



Timbor, 30% MC, 12 weeks



Timbor, 60% MC, 12 weeks

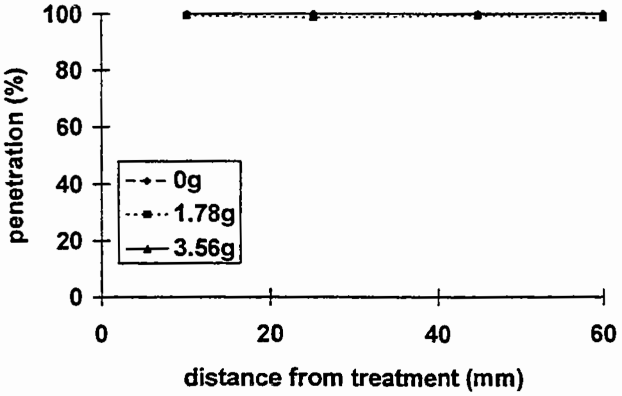


Figure I-14. Penetration of boron in cross sections cut from various distances from holes drilled in Douglas-fir heartwood blocks conditioned to 15, 30 or 60% moisture content and treated 12 weeks earlier with fused boron rod plus selected levels of 10% Timbor to produce a dosage of 3.1 g boric acid equivalent per block.

Table I-21. Combinations of boron rods and boron/glycol or boron/water additives applied to Douglas-fir heartwood blocks conditioned to 15, 30, or 60°C MC.

Boron Rod Dosage (g)	Supplement	Supplement Dosage (g)	BAE (%)	Supplement Source	Boron Component
2.1	—	—	2.1	–	
1.58	Boracol 40	1.65	3.1	CSI, Charlotte, NC 28210	disodium octaborate tetrahydrate plus polyethylene glycol (40% DOT)
1.05	Boracol 40	3.29	3.1		
–	Boracol 40	3.29	1.5		
–	Boracol 40	1.65	0.8		
1.73	Boracol 20	2.30	3.1		disodium octaborate tetrahydrate plus polyethylene glycol (20% DOT)
1.47	Boracol 20	3.95	3.1		
–	Boracol 20	3.95	0.9		
–	Boracol 20	2.30	0.5		
1.76	Boracare (1:1)	2.03	3.1	Nisus Corp. 215 Dunavent Drive, Rockford, TN 37853	disodium octaborate tetrahydrate plus poly and monoethylene glycol (47.08%, DOT)
1.43	Boracare (1:1)	4.07	3.1		
–	Boracare (1:1)	4.07	1.0		
–	Boracare (1:1)	2.03	0.5		
1.95	Timbor (10%)	1.78	3.1	U.S. Borax Inc. 26877 Tourney Road, Valencia, CA 91355	disodium octaborate tetrahydrate
1.81	Timbor (10%)	3.56	3.1		
–	Timbor (10%)	3.56	0.4		
–	Timbor (10%)	1.78	0.2		
2.1	Ethylene glycol	1.10	3.1	VanWaters and Rogers, Seattle, WA	
2.1	Ethylene glycol	2.20	3.1		
2.1	Ethylene glycol	3.30	3.1		

Table I-22. Boron retention in samples cut 10-60 mm away from treatment holes in Douglas-fir heartwood blocks conditioned 15 to 60% MC and treated 8 or 12 weeks earlier with combinations of boron rod and boron with glycol or water.

Boron Rod Dosage (g)	Supplement	Dosage (g)	Distance from treatment site (mm)	Boron Retention (kg/m^3 BAE)					
				8 weeks			12 weeks		
				15% MC	30% MC	60% MC	15% MC	30% MC	60% MC
2.1	–	–	10	–	–	–	0.13	7.03	6.22
			25	–	–	–	–	–	–
			45	–	–	–	–	0.74	–
			60	–	–	–	–	–	5.51
1.58	Boracol 40	1.65	10	0.55	11.73	7.30	–	–	–
			25	0.07	–	–	–	–	–
			45	–	–	–	–	–	–
			60	–	0.78	5.18	–	–	–
1.05	Boracol 40	3.29	10	0.73	4.45	7.88	–	–	–
			25	–	–	–	–	–	–
			45	–	–	–	–	–	–
			60	0.27	1.92	3.81	–	–	–
–	Boracol 40	1.65	10	0.54	3.42	1.62	–	–	–
			25	–	–	–	–	–	–
			45	0.08	—	—	–	–	—
			60	—	0.17	—	—	–	–
1.47	Boracol 20	3.95	10	0.67	6.44	8.77	–	–	–
			25	–	–	–	–	–	–
			45	0.36	0.86	–	–	–	—
			60	—	—	5.47	–	–	–

Table I-22. Boron retention in samples cut 10-60 mm away from treatment holes in Douglas-fir heartwood blocks conditioned 15 to 60% MC and treated 8 or 12 weeks earlier with combinations of boron rod and boron with glycol or water.

Boron Rod Dosage (g)	Supplement	Dosage (g)	Distance from treatment site (mm)	Boron Retention (kg/m³ BAE)					
				8 weeks			12 weeks		
				15% MC	30% MC	60% MC	15% MC	30% MC	60% MC
–	Boracol 20	3.95	10	1.25	5.89	2.24	3.11	5.36	1.90
			25	0.15	1.33	1.44	–	–	–
			45	0.12	0.51	1.24	–	–	–
			60	0.15	0.77	1.65	0.37	1.15	2.10
–	Boracol 20	2.30	10	0.23	2.43	1.29	–	–	–
			25	0.03	–	–	–	–	–
			45	–	–	–	–	–	–
			60	–	0.56	1.16	–	–	–
1.76	Boracare	2.03	10	0.28	5.57	7.86	–	–	–
			25	0.26	–	–	–	–	–
			45	—	—	—	–	–	–
			60	–	1.15	4.91	–	–	–
1.43	Boracare	4.07	10	0.35	6.52	7.22	0.65	14.50	–
			25	–	–	–	–	–	–
			45	0.12	–	–	–	–	—
			60	—	1.23	4.72	0.08	1.03	5.57
–	Boracare	4.07	10	0.88	4.39	2.35	–	–	–
			25	–	–	–	–	–	–
			45	–	0.97	–	–	–	—
			60	0.19	0.73	1.73	–	–	–

Table I-22. Boron retention in samples cut 10-60 mm away from treatment holes in Douglas-fir heartwood blocks conditioned 15 to 60% MC and treated 8 or 12 weeks earlier with combinations of boron rod and boron with glycol or water.

Boron Rod Dosage (g)	Supplement	Dosage (g)	Distance from treatment site (mm)	Boron Retention (kg/m³ BAE)					
				8 weeks			12 weeks		
				15% MC	30% MC	60% MC	15% MC	30% MC	60% MC
–	Boracare	2.03	10	0.39	–	–	–	–	–
			25	–	0.46	0.97	–	–	–
			45	–	–	–	–	–	–
			60	0.07	0.19	1.31	–	–	–
2.1	Ethylene glycol	1.10	10	0.08	8.88	7.84	0.30	13.04	6.63
			25	–	–	–	0.09	–	–
			45	–	–	–	0.08	–	–
			60	–	0.22	5.74	–	1.84	6.38
2.1	Ethylene glycol	2.20	10	0.18	9.15	8.81	0.64	11.03	7.59
			25	–	–	–	–	–	–
			45	–	–	–	0.09	–	–
			60	–	0.60	7.11	–	1.24	6.60
2.1	Ehtylene glycol	3.30	10	1.13	7.41	7.56	1.29	3.59	8.69
			25	–	–	–	–	–	–
			45	–	–	–	0.11	–	–
			60	0.42	5.67	6.20	—	11.96	6.22

An additional 4 weeks incubation of blocks conditioned to 15% MC resulted in improved boron penetration with both Boracol treatments, but appeared to have little effect on boron distribution in the remaining treatments. The lack of effect in these treatments likely reflects the presence of excess moisture for only a short period of time after treatment. Boron diffusion would cease once this moisture dissipated into the wood. The slight enhancement in boron distribution in the Boracol treatments suggests that boron associated with the glycol in this formulation continued to move into the wood for a longer period following treatment.

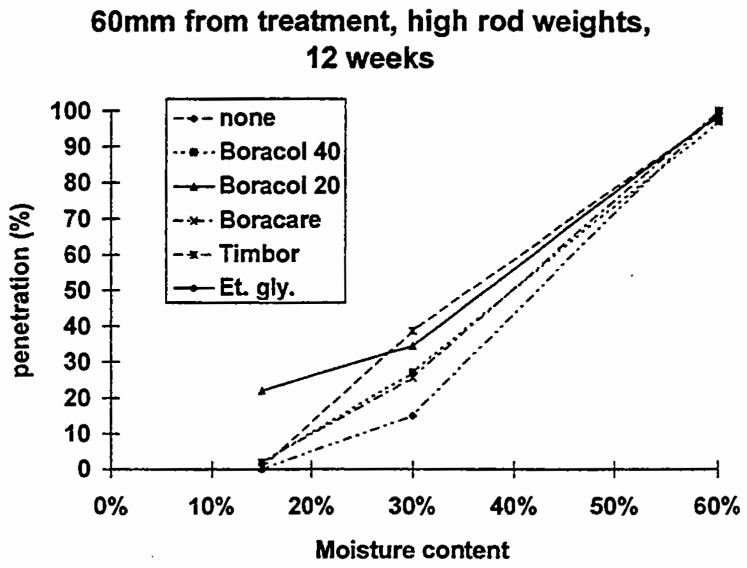
The results indicate that increasing moisture content has a much greater influence on boron distribution than addition of glycol or water with or without boron (Figure I-15). While the glycol additives enhanced boron movement, the effects were limited with the greatest benefit occurring in wood at 30% moisture content. In these instances, it is likely that the wood was near the fiber saturation point and the added glycol or water provided an environment that was far more conducive to diffusion. At the lower moisture level, glycol or water addition did not increase the wood moisture content near the point where free water was present and the resulting influence on boron diffusion was, thus, limited.

Analyses of the ground wood samples for residual boron content are continuing (Table I-22). Where complete treatment sets have been analyzed, the results indicate that boron levels adjacent to the treatment hole were elevated for all treatments where glycol or water based boron were added. Boron levels in blocks at 30 or 60% moisture content appeared to vary somewhat, with some 30% MC blocks containing higher levels of boron near the original treatment hole than comparable 60% MC blocks. The reasons for these anomalies are unclear. As expected, boron levels were more uniform in blocks conditioned to 60% MC prior to treatment. The results also show that boron levels tended to increase with increasing incubation period in blocks conditioned to 30 or 60% MC, confirming the improvements noted with the penetration measurements.

In general, boron levels near the treatment hole were above those required for fungal control at all moisture levels. Chemical levels away from the treatment hole declined markedly, particularly in the 15% MC blocks, generally to the point where the protective effect of boron would be marginal. The results suggest that any enhancement in boron diffusion provided to blocks at 15% did not result in an adequate level of diffusion to confer protection against fungal attack, however, these results are not complete and caution should be exercised regarding these data.

2. Effect of copper naphthenate on release of methylisothiocyanate from basamid: While our field studies of basamid have produced promising results, we continue to explore improved methods for enhancing basamid decomposition to methylisothiocyanate (MITC). Previous studies have shown that the addition of copper sulfate markedly enhanced MITC release from basamid. This effect appears to decline slightly over time, but the ability to increase MITC production shortly after treatment has major advantages for utilities, particularly if active decay fungi are present. While copper sulfate is useful for this purpose, its use would require the development of a label for external wood use, a costly effort for what is essentially an additive. This past year, we performed a preliminary evaluation of alternative copper materials that might also enhance MITC release.

In these tests, 500 mg of Douglas-fir heartwood that has been ground to pass a 20 mesh screen was placed into a test tube along with 10 mg of basamid. Selected tubes received 10 mg of water and/or 10 mg of 6 % copper naphthenate (as Cu). The tubes were incubated for 48 hours at room temperature. At the end of the test, the tubes were removed and air samples were withdrawn. The air samples were injected into a Varian 3700 Gas



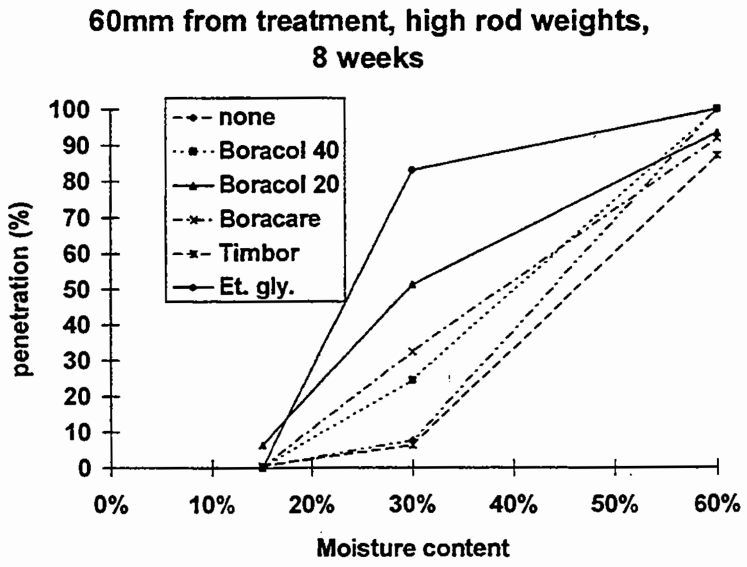


Figure I-15. Boron penetration 60 mm from the ends of Douglas-fir heartwood blocks 8 or 12 weeks after application of fused borate rod plus ethylene glycol or glycol plus boron.

Chromatograph equipped with a flame photometric detector with filters specific for sulfur (a component of MITC). The results were compared with similar analyses of prepared MITC standards.

MITC production from dry basamid was below the detectable limit, reflecting the stability of this compound in the absence of moisture (Table I-23). The addition of 10 mg of water resulted in MITC air concentrations averaging 0.22 mg/L, while the addition of copper naphthenate alone resulted in air concentrations averaging 0.91 mg/L. The addition of 10 mg each of water and copper naphthenate produced an MITC air concentration of 1.30 mg/L. Clearly, the presence of copper naphthenate had a dramatic influence on the resulting decomposition of basamid. These results suggest that addition of a small amount of liquid copper naphthenate at the time of basamid application may represent a simple method for increasing the MITC release rate. This approach may be especially useful for application to poles where decay fungi are already active. Field trials of this combination system will be established shortly.

3. Effect of selected clay materials on release of MITC from basamid: As noted earlier, basamid decomposition is especially slow in wood and appears to be enhanced by the addition of copper compounds. Basamid is also commonly used to treat soils, where it readily decomposes on soil contact to produce MITC. The increased decomposition in the presence of soil led us to explore the use of small amounts of various soils as accelerants for basamid breakdown. Douglas-fir sawdust (500 mg) was placed into a screw cap tube along with 100 mg of basamid. Selected tubes received combinations of 500 mg of water as well as 10 mg of copper sulfate, EPA-12, KgA-1 or Swy-1. The latter three materials are clays that are used as inert supports for chromatography. The tubes were incubated for 8, 30 or 48 hours at room temperature, then air samples were removed and analyzed for MITC as described in the previous section.

As expected, MITC levels in treatments with wood and basamid were low 8 hours after treatment, but increased to 0.38 and 0.36 mg/L after 30 and 48 hours, respectively (Table I-24). The higher MITC levels at 30 and 48 hours in comparison with those found in the earlier trial with copper naphthenate and most likely reflect the 50 fold higher level of basamid applied to the sawdust in this experiment.

The addition of copper sulfate markedly enhanced MITC production at all three time points, illustrating the benefits of copper addition to basamid decomposition. Addition of any of the three clay materials had little or no effect on MITC production at any of the three time points. These results suggest that adding small amounts of clay to basamid at the time of application will not enhance decomposition to MITC while the addition of copper compounds provides the most substantial increase in MITC production.

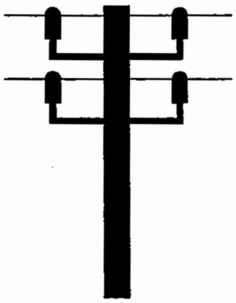


Table I-23. Effect of moisture and copper naphthenate on decomposition of basamid to MITC in Douglas-fir heartwood sawdust.[a]

Water Added	MITC LEVEL (mg/L)	
	No Copper	Copper Added
0 mg	0.00 (0.00)	0.91 (0.35)
10 mg	0.22 (0.01)	1.30 (0.03)

[a] Values reflect means of 3 replicates, while those in parenthesis represent one standard deviation.

Table I-24. Effect of copper sulfate or selected clay materials on decomposition of basamid to MITC in the presence of Douglas-fir heartwood.[a]

Additive	MITC Level (mg/L)		
	8 hours	30 hours	48 hours
-	0.03 (0.00)	0.38 (0.15)	0.36 (0.09)
$CuSO_4$	1.11 (0.28)	1.53 (0.10)	1.37 (0.06)
EPA-12	0.04 (0.01)	0.42 (0.03)	0.58 (0.09)
KGa-1	0.04 (0.00)	0.31 (0.06)	0.38 (0.04)
Swy-1	0.07 (0.01)	0.43 (0.03)	0.41 (0.06)

[a] Values represent means of 3 replicates while numbers in parenthesis represent one standard deviation. All additives were incorporated at 10 mg per tube.

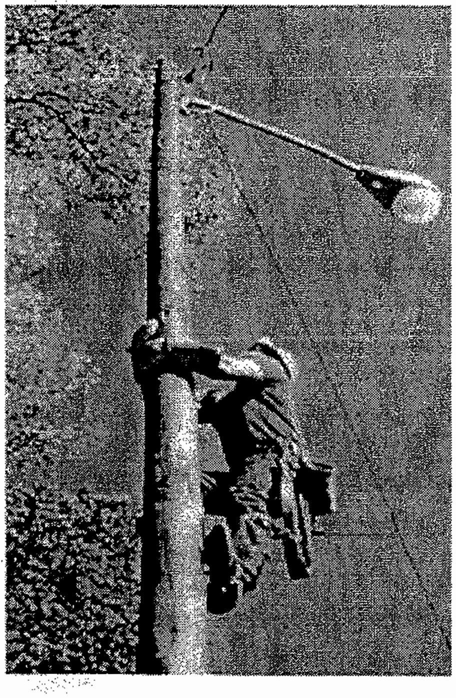
OBJECTIVE II
IDENTIFY CHEMICALS FOR PROTECTING EXPOSED WOOD SURFACES IN POLES

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 pole damage should remain a critical objective.

A. EVALUATION OF TREATMENTS FOR PROTECTING FIELD-DRILLED BOLT HOLES

Trials to evaluate the effectiveness of various protective treatments of exposed heartwood in Douglas-fir poles were not sampled in 1996. They were sampled in 1997 and the results from these tests will be included in this 1998 Annual Report.



OBJECTIVE III
EVALUATE PROPERTIES AND DEVELOP IMPROVED SPECIFICATIONS FOR WOOD POLES

A. DEVELOP IMPROVED PATTERNS FOR THROUGH-BORING OF POLES PRIOR TO TREATMENT

Through-boring is increasingly used by utilities to improve preservative treatment around the groundline zone, thereby reducing the risk of internal decay in service. While through-boring is a highly effective method for limiting decay in the groundline, the process has developed empirically over the course of many years. Many utilities have resisted the incorporation of through-boring into their specifications in the belief that the process adversely affects wood strength. While a limited number of studies have shown that through-boring has little or no negative impact on pole strength, we have undertaken a series of studies to develop less intensive boring patterns that still produce adequate treatment. The objective of these trials is to identify improved patterns for through-boring that will be acceptable to more utilities. At the same time, we are seeking to standardize through-boring patterns so that automated equipment can be developed for this process. This will reduce the costs of through-boring to utilities.

1. Evaluate the distribution of preservative around through-bored holes in Douglas-fir poles: The current through-boring specification originated from patterns developed by Bonneville Power Administration and Portland General Electric in the early 1960's. These patterns have proven highly effective, but there are increasing requests for patterns with fewer, more widely spaced holes to reduce drilling costs, reduce preservative consumption, and decrease potential impacts on wood strength.

Last year (1996 Annual Report, Pages 50-55), we reported on preservative penetration around single holes drilled in Douglas-fir pole sections that were subsequently pressure treated with pentachlorophenol in a commercial pole charge. Increment cores were then drilled at selected distances from the original hole and penta penetration was assessed visually, or where necessary, using indicators. One drawback of this approach is the relatively narrow area for measuring penetration. An increment core sample might contain a resin pocket or other defect that limited preservative penetration. Preservative penetration measurements according to American Wood Preservers' Association Standard C4 and most utility specifications that incorporate through-boring, however, would note that penetration stopped at this point, even if annual rings deeper in the wood were treated. This works well for pole quality control, but provides an incomplete image of penetration for assessing overall treatment distribution.

In order to develop more complete information on the distribution of preservative around through-bored holes in Douglas-fir poles, we repeated the treatment trials described last year but used creosote as the preservative. In the earlier trial, we found that the light oil used with the pentachlorophenol treatment was difficult to detect in some zones of the wood.

Six air-seasoned Douglas-fir poles (250 to 300 mm by 2.4 m long) were end-coated with an elastomeric sealant. Three 14 mm diameter holes were drilled through the poles on one surface beginning 0.6 m from one end and moving toward the other end at 0.6 m intervals.

The poles were included in a commercial charge of poles being treated to 144 kg/m^3 of creosote. Following treatment, the poles were allowed to stand for 2 months to allow any immediate volatile materials to dissipate. The poles were then cut into sections beginning 0.9m from one end, then at 0.6 m intervals so that each through-bored hole was at the center of a 0.6 m long section. The 0.6 m long pole sections were then cut into a series of approximately 25 mm thick slabs perpendicular to the orientation of the through- bored hole (so that the hole was at the center of a slab). Preservative penetration around each through-bored hole was marked on each slab using a wax crayon and then photographed to provide a permanent record of preservative distribution. Preservative penetration was then measured radially from the through-bored hole as well as above and below the hole. The values from a given pole section were averaged to provide a relative measure of preservative distribution around holes from the same pole.

Average radial preservative penetration around a given through-bored hole for each pole varied from 16.4 mm to 20.1 mm (Table III-1). These values include the original 14 mm diameter through-bored hole, illustrating the relatively narrow zone affected by these holes in the radial direction. Previous studies of preservative distribution around incisions in lumber produced similar results. Both processes function primarily to increase the amount of transverse face exposed to the preservative, but have little effect on radial or tangential flow.

As expected, longitudinal preservative penetration was nearly an order of magnitude greater than radial penetration. Longitudinal preservative penetration varied from as low as 104 mm to 300 mm (essentially complete treatment). A plot of frequency of longitudinal preservative penetration indicates that penetration was most often between 300 and 349 mm, followed by 100 to 149 and 150 to 199 mm (Figure III-1). Even within these plots, it is important to note that the variations in penetration among individual slabs was relatively high. Thus, some caution should be exercised in applying these data to the development of specific through-boring patterns. For example, plotting longitudinal preservative penetration around through-bored holes on three different pole sections illustrates the wide variation possible along an individual hole. Clearly, these variations will affect the ability to effectively treat the entire cross section. At present, most utility specifications incorporating through-boring require 100% penetration of the through-bored zone although there is some debate about the need for this degree of treatment. The presence of a small untreated skip or gap in an area surrounded by well treated wood is highly unlikely to become infested by a decay fungus since that fungus would have to first grow through the heavily treated wood. If this premise is accepted, it may be possible to design through-boring patterns that use fewer holes to produce a treatment pattern that still prevents decay around the groundline.

2. Effect of modified through-boring patterns on residual strength and treatment quality of Douglas-fir poles: The heartwood of Douglas-fir is notoriously difficult to treat and utility poles of this species are susceptible to internal decay as a result of the invasion of decay fungi through seasoning checks that open beyond the depth of the treated sapwood following initial preservative treatment. While this decay can be controlled remedially by application of fumigants (Morrell and Corden, 1986), a far more practical approach is to improve the initial treatment and therefore prevent fungi from entering the wood. A number of methods have been developed for this purpose including kerfing, radial drilling, and through-boring (Graham, 1983). Through-boring is the most widely used of these practices.

First proposed by Merz (1959), through-boring involves drilling a series of holes at a 5 degree angle into the transverse face of the pole beginning approximately 0.9 m below the intended groundline and extending 0.6 m above this point. Flow of preservatives in wood is markedly greater in the longitudinal direction (Siau, 1995). Through-boring exposes additional transverse wood surface to preservative, increasing the potential for longitudinal penetration. When done properly, the process should result in complete or nearly

Table III-1. Radial and longitudinal preservative penetration around through-bore holes in creosoted Douglas-fir poles as show by cutting 25 mm thick slabs perpendicular to the hole.

Pole No.	Hole No.	Preservative Penetration (mm)			
		Board	Radial	Longitudinal	
				Up	Down
1	1	1	28	300	300
1	1	2	19	300	300
1	1	3	17	172	225
1	1	4	17	383	220
1	1	5	18	567	300
1	1	6	17	407	300
1	1	7	17	277	205
1	1	8	18	272	163
1	1	9	19	329	300
1	1	10	22	300	292
1	2	11	22	300	300
1	2	12	22	116	582
1	2	13	19	76	129
1	2	14	18	56	101
1	2	15	14	300	85
1	2	16	17	98	136
1	2	17	19	134	246
1	2	18	17	174	119
1	2	19	22	115	171
1	2	20	19	197	248
1	3	21	19	300	300
1	3	22	40	136	455
1	3	23	20	275	200
1	3	24	18	300	233
1	3	25	16	378	300
1	3	26	14	211	460
1	3	27	17	249	326

Table III-1. Radial and longitudinal preservative penetration around through-bore holes in creosoted Douglas-fir poles as show by cutting 25 mm thick slabs perpendicular to the hole.

		Preservative Penetration (mm)			
				Longitudinal	
Pole No.	Hole No.	Board	Radial	Up	Down
1	3	28	19	240	248
1	3	29	18	119	290
1	3	30	20	367	252
2	1	31	17	187	134
2	1	32	18	172	150
2	1	33	15	201	124
2	1	34	16	117	162
2	1	35	19	219	249
2	1	36	17	166	126
2	1	37	13	165	106
2	1	38	16	116	95
2	1	39	17	118	262
2	1	40	17	152	172
2	2	41	16	144	196
2	2	42	16	132	158
2	2	43	15	161	180
2	2	44	19	193	167
2	2	45	18	335	138
2	2	46	15	204	337
2	2	47	17	238	285
2	2	48	19	235	276
2	2	49	16	96	112
2	2	50	34	300	300
2	3	51	26	142	161
2	3	52	16	92	80
2	3	53	15	132	248
2	3	54	16	190	140
2	3	55	18	320	217

Table III-1. Radial and longitudinal preservative penetration around through-bore holes in creosoted Douglas-fir poles as show by cutting 25 mm thick slabs perpendicular to the hole.

Pole No.	Hole No.	Preservative Penetration (mm)			
		Board	Radial	Longitudinal	
				Up	Down
2	3	56	16	156	195
2	3	57	16	102	150
2	3	58	19	300	241
2	3	59	14	113	128
2	3	60	31	300	300
3	1	61	19	300	111
3	1	62	18	128	117
3	1	63	16	142	110
3	1	64	17	138	141
3	1	65	19	248	326
3	1	66	18	258	314
3	1	67	16	117	220
3	1	68	16	148	172
3	1	69	26	300	120
3	1	70	19	102	157
3	2	71	26	300	300
3	2	72	22	123	242
3	2	73	17	71	257
3	2	74	22	430	135
3	2	75	21	329	282
3	2	76	19	351	296
3	2	77	14	76	180
3	2	78	15	91	155
3	2	79	18	316	155
3	2	80	18	84	86
3	3	81	16	300	300
3	3	82	21	208	87
3	3	83	17	143	148

Table III-1. Radial and longitudinal preservative penetration around through-bore holes in creosoted Douglas-fir poles as show by cutting 25 mm thick slabs perpendicular to the hole.

		Preservative Penetration (mm)			
				Longitudinal	
Pole No.	Hole No.	Board	Radial	Up	Down
3	3	84	22	300	135
3	3	85	19	225	511
3	3	86	18	219	236
3	3	87	20	121	90
3	3	88	15	88	92
3	3	89	19	140	157
3	3	90	21	147	219
4	1	91	17	151	133
4	1	92	16.6	272	169
4	1	93	15	141	174
4	1	94	17	125	163
4	1	95	15	154	295
4	1	96	14	222	285
4	1	97	14	249	120
4	1	98	18	133	165
4	1	99	21	274	138
4	1	100	18	482	300
4	2	101	21	117	327
4	2	102	16	189	190
4	2	103	18	210	184
4	2	104	16	372	165
4	2	105	17	367	233
4	2	106	16	472	297
4	2	107	16	129	246
4	2	108	15	325	143
4	2	109	22	540	364
4	2	110	23	300	362
4	3	111	14	229	341

Table III-1. Radial and longitudinal preservative penetration around through-bore holes in creosoted Douglas-fir poles as show by cutting 25 mm thick slabs perpendicular to the hole.

		Preservative Penetration (mm)			
				Longitudinal	
Pole No.	Hole No.	Board	Radial	Up	Down
4	3	112	14	142	124
4	3	113	15	420	116
4	3	114	17	321	167
4	3	115	17	300	78
4	3	116	15	300	90
4	3	117	15	182	117
4	3	118	17	303	66
4	3	119	16	300	138
4	3	120	23	300	300
5	1	121	28	58	201
5	1	122	26	300	106
5	1	123	18	123	116
5	1	124	20	488	121
5	1	125	16	300	300
5	1	126	15	300	300
5	1	127	19	183	222
5	1	128	18	116	188
5	1	129	20	126	152
5	1	130	19	85	142
5	2	131	32	300	193
5	2	134	21	300	300
5	2	135	17	300	197
5	2	136	26	300	138
5	2	137	15	477	300
5	2	138	15	269	300
5	2	139	20	258	300
5	2	140	15	234	121
5	2	141	15	300	127

Table III-1. Radial and longitudinal preservative penetration around through-bore holes in creosoted Douglas-fir poles as show by cutting 25 mm thick slabs perpendicular to the hole.

		Preservative Penetration (mm)			
				Longitudinal	
Pole No.	Hole No.	Board	Radial	Up	Down
5	2	142	14	98	300
5	3	143	16	327	162
5	3	144	23	462	300
5	3	145	17	300	300
5	3	146	18	300	300
5	3	147	18	416	436
5	3	148	18	136	226
5	3	149	29	284	192
5	3	150	18	170	165
5	3	151	15	225	300
5	3	152	21	345	300
6	1	153	20	147	140
6	1	154	21	158	143
6	1	155	20	91	155
6	1	156	`9	132	93
6	1	157	15	49	28
6	1	158	16	127	46
6	1	159	20	92	131
6	1	160	14	152	65
6	1	161	14	111	169
6	1	162	15	57	76
6	2	163	37	300	300
6	2	164	29	300	300
6	2	165	18	80	183
6	2	166	17	300	189
6	2	167	12	92	113
6	2	168	17	143	155
6	2	169	17	300	84

Table III-1. Radial and longitudinal preservative penetration around through-bore holes in creosoted Douglas-fir poles as show by cutting 25 mm thick slabs perpendicular to the hole.

		Preservative Penetration (mm)			
				Longitudinal	
Pole No.	Hole No.	Board	Radial	Up	Down
6	2	170	18	90	127
6	2	171	17	144	83
6	2	172	16	118	120
6	3	173	17	300	300
6	3	174	14	71	161
6	3	175	15	154	228
6	3	176	18	263	165
6	3	177	19	259	300
6	3	178	19	300	300
6	3	179	14	263	300
6	3	180	16	256	300
6	3	181	17	300	230
6	3	182	15	91	68
		Avg.	18.4	222.3	206.0
		SD	4.2	107.6	93.4

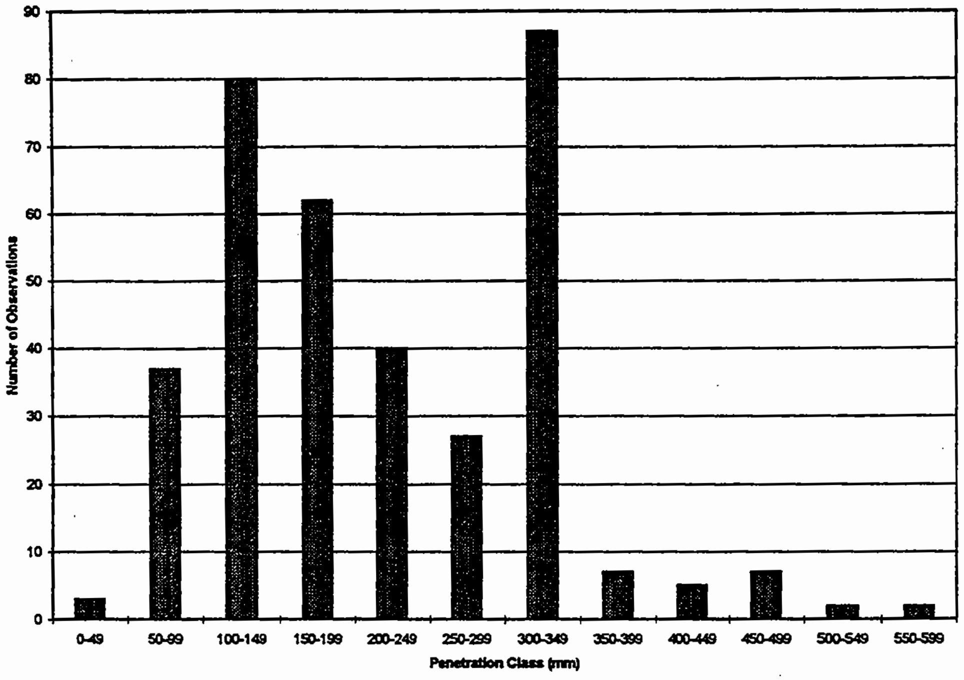


Figure III-1. Relative degree of longitudinal preservative penetration around holes drilled in Douglas-fir pole sections.

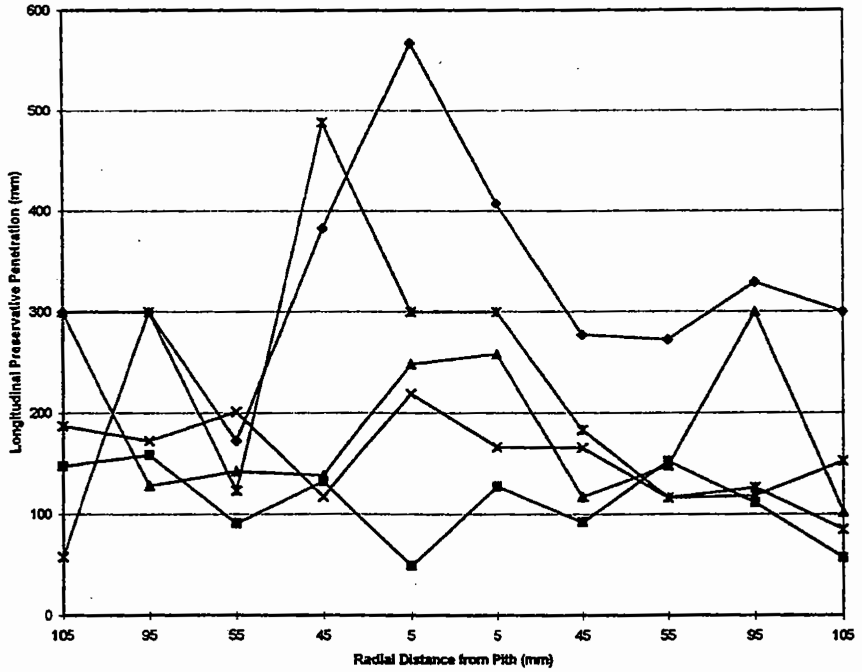


Figure III-2. Longitudinal of penetration of preservative from through-bored holes employed to improve preservative treatment of Douglas-fir poles.

complete treatment in the through-bored zone, virtually eliminating the risk of decay in this zone. While through-boring is highly effective, it has only been slowly adopted by North American utilities. One concern of these utilities is the potential for strength losses as a result of the drill holes. In addition, through-boring does not completely eliminate the risk of decay away from the through-bored zone (Morrell and Schneider, 1995). More recently, concerns have arisen that the higher preservative retentions in the through-bored zone might make pole disposal more difficult. While a number of studies have addressed these concerns, these sentiments indicate that there is potential for improving the through-boring specification to reduce the number of holes per linear meter of pole. In this report, we describe the results of tests to develop modified through-boring patterns for protecting the entire length of a pole.

Twelve Class 2 - 18 meter long Douglas-fir poles were selected from existing pole stock in a treatment facility located near Eugene, Oregon. The poles had an average pretreatment moisture content of 22% (21-23%) 50 mm beneath the surface at the pole mid-point as determined using a resistance type moisture meter. The poles had been air-seasoned for 15 to 16 months prior to treatment.

The poles were drilled along their length (Figure III-2) and then treated with pentachlorophenol in P9 type A solvent according to Standard C4 of the American Wood Preservers' Association (AWPA, 1996) in a single charge consisting of nearly 28 hours of Boultonizing at 205°F, initial air pressure for 45 minutes at 30 psi, a 1.75 hour pressure period at 125 psi and 175°F, a 3 hour expansion bath at 205°F, 48 hours of steaming at 230°F and finally, a 2 hour vacuum at 25 inches Hg. Wood moisture content averaged 12% following treatment.

Preservative treatment was assessed on each pole by removing three 40 mm long increment cores from sites between through-boring holes within 300 mm of the theoretical groundline. The cores were visually assessed for preservative penetration. In one pole, an additional 2 cores were removed 250 to 300 mm from the first increment core hole as well as 6 m from the pole top to confirm treatment patterns.

The cores removed from the groundline zone were split into two groups of 18 cores each. These cores were further divided into three groups of six cores each. The cores in a given group were divided into 25 mm zones and zones from a given location were combined prior to being ground to pass a 20 mesh screen. The ground wood was analyzed for pentachlorophenol (penta) using an ASOMA x-ray fluorescence analyzer (ASOMA Instruments Inc., Austin, Texas) with elements and filters specific for chlorine. The results were presented on a kg of penta/cubic meter of wood basis.

Following treatment and preservative evaluation, ten of the twelve poles were shipped to the Bonneville Power Administration Ross Complex, located near Hazel Dell, Washington, where they were tested to failure in cantilever loading according to the American Society for Testing Materials Standard D-1036 (ASTM, 1996). The butt of each pole was confined in a metal bracket and a steel cable was attached 0.61 m below the top. The load was applied using the cable and deflection data was collected at approximately 2.22 KN loading intervals (Figure III-3). At the conclusion of each test, the distance between the point of failure and the intended groundline was measured and the load deflection data were used to calculate breaking point stress. The results were compared with those for non-through-bored poles of the same ANSI class and length (ANSI, 1993).

Penta penetration was complete in 34 of 36 cores examined. The two cores with incomplete penetration came from one pole and had skips greater than 2.5 mm starting 50 to 75 mm from the pole surface. Additional cores removed from other sites on this pole were

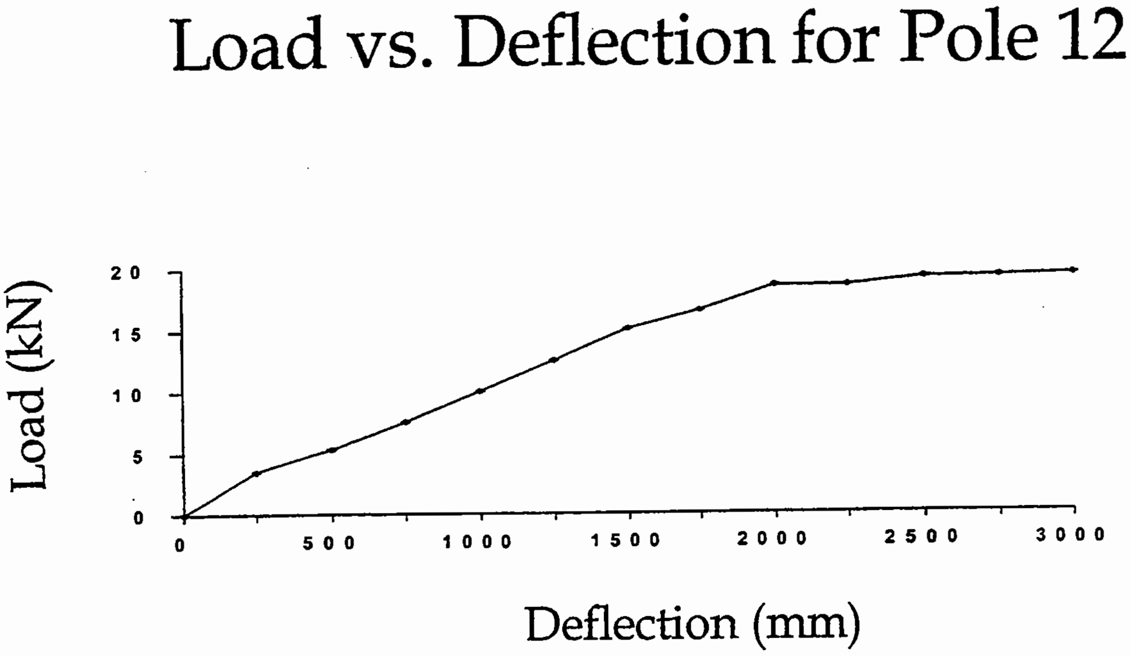


Figure III-3. Typical load deflection curves plotted from data collected during cantilever loading of a Class 2, 18 m long Douglas-fir poles.

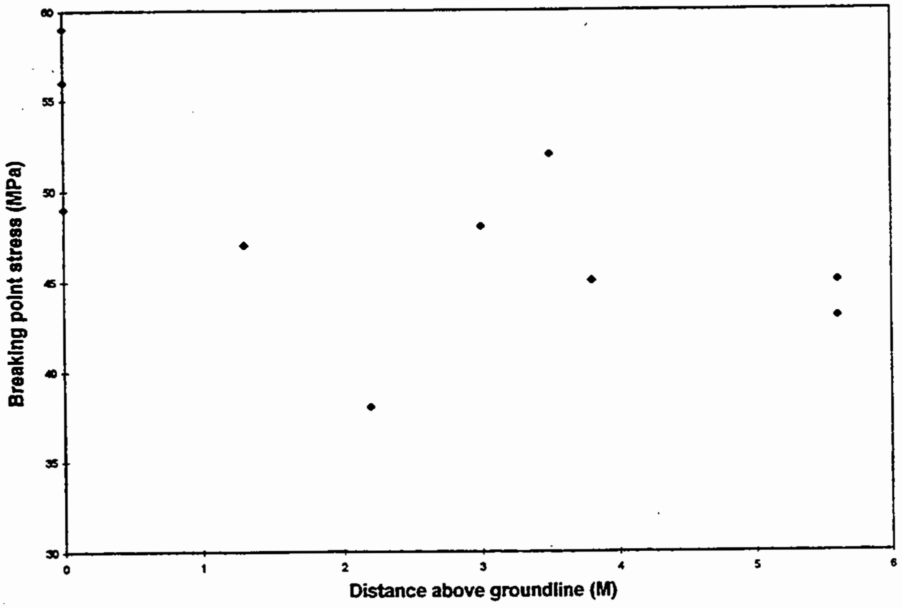


Figure III-4. Relationship between failure location above the groundline and breaking point stress for full length through-bored Douglas-fir poles.

completely penetrated, suggesting that the untreated pocket was relatively confined. The effect of such skips on the performance of through-bored poles has been the subject of considerable debate; however, field surveys have failed to detect either visible decay or the presence of decay fungi in untreated zones of through-bored poles in the field (Morrell and Schneider, 1994).

These results suggest that small, untreated zones may be so thoroughly surrounded by well-treated wood that fungi are unable to gain access. Even if decay could become established in these zones, the presence of small gaps or skips 50 to 75 mm inside the pole will have little effect on wood strength since 80-90% of a pole's strength lies outside this zone. Thus, the presence of small skips deeper in the wood may be tolerable if the spacing of the through-bored holes is increased, thereby reducing uptake of preservative, decreasing treatment time and ultimately lowering pole cost. The results indicate that through-boring patterns can be widened to reduce the number of holes required with little effect on treatment outcome.

The American Wood Preserver's Association Standard C4 currently requires penta treatment of Douglas-fir poles to retentions of 0.96 kg/m^3 in the zone corresponding to 6 to 25 mm from the surface and 0.48 kg/m^3 in a zone 50 to 62.5 mm from the surface (AWPA, 1996). Unfortunately, our assays were performed on a 0 to 25 mm outer zone. The inclusion of the outer 6 mm may artificially inflate retention analysis since the preservative retention tends to follow a downward sloping curve with distance from the surface. However, even if we completely discount the contribution of the outer 6 mm by multiplying retention by 0.75, it is clear that the target retention was achieved in all three core subsets (Table III-2).

Table III-2. Retentions of pentachlorophenol at 25 mm intervals in cores removed from full length through-bored Douglas-fir poles.

Distance from surface (mm)	Pentachlorophenol Retention (kg/m^3)						
	Set 1	Set 2	Set 3	Set 4	Set 5	Set 6	Average
0 to 25	23.2	13.4	15.4	20.8	15.5	13.1	16.9 (4.1)
25 to 50	13.8	5.0	12.0	14.1	5.8	9.6	10.1 (4.0)
50 to 75	10.1	5.4	13.4	9.6	5.8	10.6	9.2 (3.1)
75 to 100	8.2	6.1	15.5	7.5	5.8	12.0	9.2 (3.8)
100 to 125	7.2	7.2	17.4	7.2	8.5	8.5	9.3 (4.0)
125 to 150	8.6	7.7	18.7	6.2	8.2	9.4	9.8 (4.5)
							10.8 (3.9)

Retentions were generally highest in the outer 25 mm, with the exception of core set 3, where retentions in the innermost assay zone were higher than on the wood surface (Table III-2). Douglas-fir is a species with a well documented variation in treatability (Miller and Graham, 1963). It is likely the poles sampled in this group contained more treatable heartwood. Conversely, poles in treatment sets two and five were somewhat refractory in the zone 25 to 100 mm from the surface. Retentions increased deeper in these sets, illustrating the variable nature of Douglas-fir heartwood permeability. On average, the retention analysis showed a slight gradient between the outer 25 mm and the next assay zone followed by little or no change in retention. These results demonstrate the benefits of increasing longitudinal flow in Douglas-fir heartwood. It is also useful to note that these retentions are at or near the retention specified in the outer assay zone. That retention is, itself, over two times the reported threshold for penta in P9 Type A oil. Clearly, these poles have little risk of decay development.

All ten poles tested were within the minimum ANSI dimensions for a Class 2, 18 m long pole (Table III-3). Strength values for the poles in 8 of 10 tests were below that specified by ANSI for coastal Douglas-fir (ANSI, 1995). Average bending point stress for the ten poles was 48.9 MPa, 88% of the recommended value for this species. Given the relatively small sample size and the natural variation in bending strength distributions of Douglas-fir poles, these results should be used as a relative guide to the effects of through-boring on Douglas-fir poles. Previous studies have shown that through-boring at groundline, has only a minimal effect on pole bending strength (Merz, 1959). The lack of effect on poles bored only about the groundline, in part, reflects the fact that the bending moment for larger poles lies some distance above the groundline and away from the through-bored zone. Full length through-boring places holes into the bending moment zone, creating the potential for some strength loss. The failure locations in the ten tests ranged from groundline to 5.5 m above this zone. There did not appear to be any relationship between failure location above the groundline and breaking point stress (Figure III-4).

Through-boring has a long history of improving the performance of Douglas-fir poles by reducing internal decay at the groundline, but decay above the groundline is likely to become an increasing problem as utilities extend pole service life far beyond the originally planned 40 to 50 years (Morrell and Schneider, 1995). Full length through-boring could markedly reduce the risk of above ground decay, producing more reliable poles with lower maintenance costs. Bending tests suggest that full length through-bored poles had slightly lower average bending strength but these results must be viewed with some caution since the test sample was relatively small. Despite these possible strength effects, through-bored poles are less likely to develop decay in service. Thus, through-bored poles are more likely to retain their original strength for their service life, while poles not receiving this treatment could experience internal decay and some loss in pole strength properties. As a result, full length through-bored poles should provide longer, more reliable performance than comparable poles through-bored only at the groundline. This approach is probably most effective for larger poles used for transmission lines since these poles are more likely to be treated when the moisture content is elevated and will, therefore, also tend to develop checks that extend beyond the normal preservative-treated shell.

Table III-3. Effect of full length through-boring on residual strength, failure zone, and deflection of pentachlorophenol-treated Douglas-fir poles

Pole #	Pole Circumference (mm)[a]			Deflection (mm)	Load at max deflection (KN)	Failure location above GL (m)	Breaking point stress (MPa)	Percent ANSI
	Load Point	Groundline	Tip					
1	885	1134	875	2788	4000	–	57.8	104.7
2	748	1164	732	2702	3400	3.7	44.9	81.3
3	777	1161	762	2362	3500	1.3	47.3	85.7
4	792	1161	777	3077	4000	5.5	43.0	77.9
5	809	1219	792	2753	4200	3.0	47.9	86.8
6	760	1180	744	3483	3000	2.2	38.9	70.5
7	670	1186	649	3333	3400	5.5	44.9	81.3
8	800	1152	786	2657	4000	3.0	52.7	95.5
9	891	1155	881	2506	4300	–	59.0	106.9
10	861	1192	847	3286	4000	–	49.4	89.5
Mean							48.9 (6.3)	88.6

[a] Minimum ANSI Tip and GL circumferences for Class 2, 18 m long poles are 635 and 1124, respectively.

B. EVALUATE POTENTIAL CHANGES IN WOOD SPECIES USED AS WOOD POLES WITH SPECIAL EMPHASIS ON WESTERN REDCEDAR

Western redcedar has long been used to support overhead electric lines. The reputation of this species for natural resistance to decay makes it the preferred wood for many utilities. Recently, however, concerns have arisen regarding the durability of poles currently being produced. In an attempt to answer these concerns, we undertook the following tests.

1. Decay resistance of western redcedar heartwood from various geographic sources: The heartwood of western redcedar (*Thuja plicata* D. Don.) has a well deserved reputation for resistance to fungal and insect attack (Scheffer, 1957) and utility poles of this species have provided excellent performance under a range of climatic conditions (Lindgren, 1989). As the ray parenchyma in the sapwood of this species senesce and eventually die, the stored carbohydrates are converted into a series of potent antimicrobial compounds (Bamber, 1976). Notable among these are thujone and thujaplicin. The relative amount of these compounds has been the subject of considerable study (Eades and Alexander, 1934; Rennerfelt, 1948; Southam and Ehrlich, 1943a,b; Anderson et al., 1962; Roff et al., 1962; Nault, 1988; Jin et al., 1988). These compounds are believed to be present at the highest levels at the sapwood/heartwood interface and decline with increasing heartwood age. In addition, durability varies between trees and, to some extent, with tree source. One area related to western redcedar heartwood that has received little attention is the potential for changes in durability as the resources change from old growth logs harvested from virgin forests to a heavier dependence on more intensively managed second growth forests. Trees from managed second growth forests often have faster growth rates that could conceivably translate to higher levels of carbohydrates in the ray parenchyma at the time of cell death, thereby creating the potential for the production of elevated extractive levels. However, limited studies have shown that the durability of coast redwood (*Sequoia sempervirens* (D. Don) Endl.) was lower in second growth lumber (Clark and Scheffer, 1983), while the durability of second and old-growth Douglas-fir differs little (Scheffer and Englerth, 1952). Such declines in durability have important implications for the use of these species without supplemental protection.

In previous studies, Englerth and Scheffer (1954,1955) found that average soil block weight losses for western redcedar samples cut from the inner, middle, and outer heartwood of the lower, central, and upper trunk, to range from a low of 11% in the outer heartwood from the lower trunk to 27% in the central trunk. The weight losses at any given site, however, varied widely. In a subsequent study, Scheffer (1957) evaluated the durability of blocks cut from 74 western redcedar trees from sites throughout the Pacific Northwest. Weight losses caused by *Postia placenta* were again variable, although there were distinct trends in durability with tree source. Weight losses were greatest in samples from western Washington near Mr. Rainier and lowest in samples from the Olympic Peninsula. The number of trees from any given site in this study however, were limited, making it difficult to draw definitive conclusions on the relationship between geographic source and heartwood durability.

As forests become more intensively managed, changes in silvicultural practices may produce important effects on durability. Understanding the magnitude of these changes will help foresters to develop the most appropriate management techniques and alert wood users to an impending change in wood properties. In this report, we describe a preliminary survey of durability of western redcedar from various locations in the Pacific Northwest.

Discs (75 mm thick) were cut from the butt ends of western redcedar logs at 5 sites (Figure III-5). The logs were all destined for use as

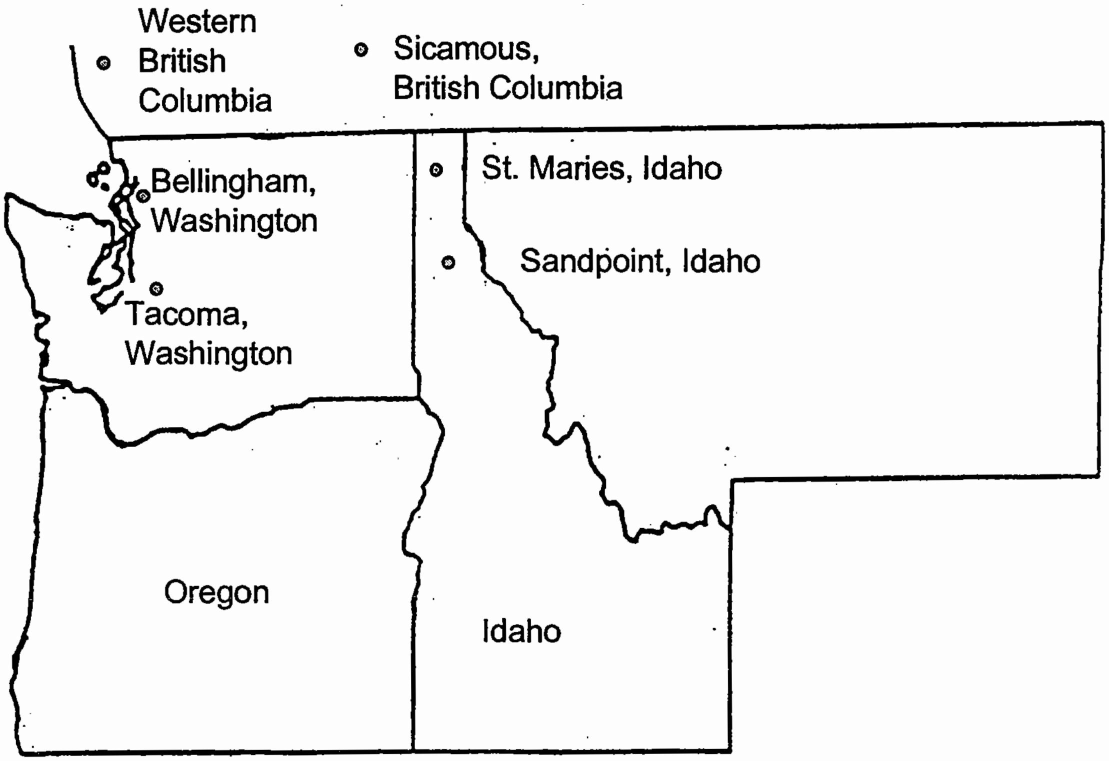


Figure III-5. Locations from which western redcedar pole cross-sections were obtained for assessing natural durability.

utility poles and their bark and some portion of the sapwood had been removed during the peeling process. Each disc was marked with regard to the stand from which it was cut. In some cases, the location was known in detail (e.g., the individual timber sale), while in others, only the region was known. Seventy-five disks were collected from each of four sites and samples from the fifth site were collected from three separate locations within the site (25 sections/site). Disks from 375 trees were examined.

The number of rings on each disk were counted and the depth of sapwood was noted. A series of 1 cm cubes were then cut from each cross-section along two radial lines. Blocks were cut from just inside the sapwood heartwood interface, the middle of the heartwood and the pith. A total of 18 cubes were cut from each section.

The cubes were soaked with water and sealed in plastic bags before being subjected to 2.5 mrads of ionizing radiation from a cobalt 60 source. The sterile cubes were then exposed to *P. placenta* using a modified soil block test. Briefly, 56 ml glass bottles were half filled with forest loam soil. Enough water was added to increase the soil moisture content to 60 percent (wt/wt). A 15 x 15 x 3 mm thick feeder strip of western hemlock (*Tsuga heterophylla* (Raf.) Sarg) was placed on top of the soil. The jars were then loosely capped and autoclaved for 45 minutes at 121°C. The jars were allowed to cool overnight, then reautoclaved for an additional 15 minutes at 121°C. After cooling, a small agar plug cut from the actively growing edge of a culture of the test fungus was placed on the surface of the feeder. The jars were then incubated at 28°C until the fungus had thoroughly covered the feeder, then a single western redcedar cube was placed, cross-section down, on the feeder strip. The jars were incubated for an additional 12 weeks at 28°C.

At the end of the test period, the cubes were scraped clean of adhering mycelium and weighed to determine wood moisture content. The cubes were then oven-dried at 54°C until their weights stabilized. The cubes were weighed and the difference between the initial and final oven dry weight was used to determine fungal-associated weight loss.

The data were analyzed on the basis of tree source, age of the tree, and position in the cross-section. Data were also compared to a previous report on durability of western redcedar in which trees were obtained from a wide geographic area (Scheffer 1957) to determine if durability had changed since the earlier survey.

2. Effect of cross-section position and durability: The most recently formed heartwood of many species is believed to be more durable than heartwood in other parts of the stem. As the heartwood ages, reaction between extractives and microbial inactivation are presumed to decrease the toxicity of these chemicals (Nault, 1988). In addition, there is some evidence that heartwood in the juvenile wood core is less resistant to decay than mature wood (DeBell et al., in prep). Weight losses in samples cut from outer, middle, and inner heartwood in our study differed little from one another. Although weight losses were slightly higher in inner heartwood samples from 5 of 7 sites, the differences were slight. The results suggest that overall durability does not change significantly with heartwood age, although there is a distinct increase in variability of decay resistance as evidenced by the elevated standard deviations associated with means of inner heartwood weight losses.

3. Effect of tree age on durability: Changes in management of forests containing western redcedar might be expected to accelerate growth. It has long been presumed that heartwood of older, thus slower growing trees, is more durable. Therefore, managed western redcedar forests could produce trees containing less durable heartwood. An examination of tree age versus durability suggests that there was little difference in durability with tree age (Table III-4). Although younger trees (less than 100 years old) from the Tacoma site experienced higher weight losses, there were no older trees available at this site for comparison. Weight losses in trees of varying ages at the other sites showed no distinct trend with age, suggesting that tree age did not affect heartwood durability. This conclusion must be viewed cautiously. In many regions, western redcedar has not been the subject of intensive management practices such as thinning, pruning, or fertilization. Such practices may influence the heartwood extractive, content, and this possibility merits further study. The results from our study indicate that there is no effect of tree age durability in currently harvested forests. The results, in fact, differ little from those reported 40 years earlier (Scheffer, 1957).

In part, the similarity of the results reflects the ages of the trees examined in both studies. Forty years is likely to have little effect on a pool of trees where the ages of many trees exceeded 150 years. Additional studies would be warranted as western redcedar forests move to shorter rotations and more intensive silvicultural practices.

4. Effect of geographic source on durability: Western redcedar has a tremendous range, extending from the coastal forests of Oregon, Washington, and British Columbia, in the Cascade Mountains, and reaching into the forests of the Inland Empire. As a result,

Table III-4. Weight losses of cubes cut from selected zones of the heartwood of western redcedar trees from 7 sites in the Pacific Northwest and Inland Empire.[a]

Location	No. of Trees	Average weight loss by position			Average weight loss of all samples	Average weight loss by tree age					
		outer	middle	inner		0-50	51-100	101-150	151-200	201-250	250+
Sicamous, BC	25	5.5 (5.46) 99	7.8 (7.31) 94	9.3 (10.09) 108	7.5 (8.01)	–	7.3 (7.80) (n=8)	8.2 (8.89) (n=8)	6.9 (6.7) (n=6)	8.7 (9.36) (n=1)	–
Nelson, BC	25	3.4 (6.08) 179	1.7 (6.27) 369	4.8 (8.79) 183	3.3 (7.27)	–	3.3 (7.27) (n=25)	–	–	–	–
St. Maries, ID	25	16 3.2 (4.01)	155 3.8 (5.90)	166 5.1 (8.46)	4.1 (6.44)	–	–	–	–	–	–
Western British Columbia	75	2.0 (2.59) 129	1.2 (4.40) 3.67	-1.0 (3.22) 322	0.7 (3.58)	–	0.5 (2.92) (n=30)	0.6 (3.58) (n=17)	0.4 (2.75) (n=15)	0.8 (1.96) (n=4)	2.5 (6.07) (n=9)
Tacoma, WA	75	8.0 (6.09) 76	12.7 (7.49) 59	16.2 (8.14) 50	12.3 (8.02)	11.6 (7.58) (n=30)	12.8 (8.27) (n=45)	–	–	–	–
Sandpoint, ID	76	3.18 (5.51) 173	3.7 (8.61) 2.33	5.2 (9.86) 190	4.0 (8.24)	–	3.5 (8.65) (n=38)	4.7 (7.9) (n=33)	2.2 (4.53) (n=3)	5.6 (9.14) (n=2)	–
Bellingham, WA	13	1.5 (1.85) 123	-0.4 (1.76) 440	-1.1 (2.53) 230	0.0 (2.33)	-0.3 (2.16) (n=3)	-0.1 2.24 61	0.2 2.23 1	–	0.6 (2.01) (n=1)	1.2 (2.64) (n=9)
		129	245	176		10.5	4.1	3.9	2.3	3.0	1.9

[a] Values represent means and standard deviation. N = number of trees examined.

environmental conditions under which individual trees have grown can vary tremendously. Previous studies have shown some variations in durability with geographic source (Scheffer, 1957), but the natural variation in decay resistance between trees in the same stand is often of a similar magnitude, masking any site differences.

Average weight losses at the seven sites ranged from 0 to 12.3%. The most durable heartwood was obtained from northwestern Washington and British Columbia. Samples taken near Tacoma, WA, experienced the highest weight losses, but even this level of decay would place the wood in the highly durable classification (Scheffer and Cowling, 1966; Scheffer, 1981). As expected, weight losses varied widely within a site (Figure III-6). Most weight losses were less than 10 percent, but weight losses nearing 50 percent were occasionally found. Once again, there was no consistent relationship between site and elevated weight losses.

5. Changes in durability: This study was initiated because of concerns that the western redcedar resource was changing. While changes may be underway, our results suggest that the current supply of this species differs little from that investigated 40 years ago. The sporadic early failures that initiated these tests most likely reflect the inherent variation in natural durability. The current emphasis on prolonged service life will likely magnify the importance of limiting the risk of early failures since reporting of early failures is more likely to occur. One method for limiting the risk of early failures would be the use of full length treatments to ensure complete protection of the wood. Small scale studies suggest that such supplemental treatments increase the uniformity of performance of naturally durable woods even though the amount of treatment employed is relatively small (Newbill and Morrell, 1993).

6. Conclusions: While natural resistance of western redcedar heartwood to fungal attack in laboratory tests differed widely, the variation did not reflect site, age, or heartwood position. Heartwood durability appears similar to that found in an earlier study. Further studies are advised as management practices change for this species.

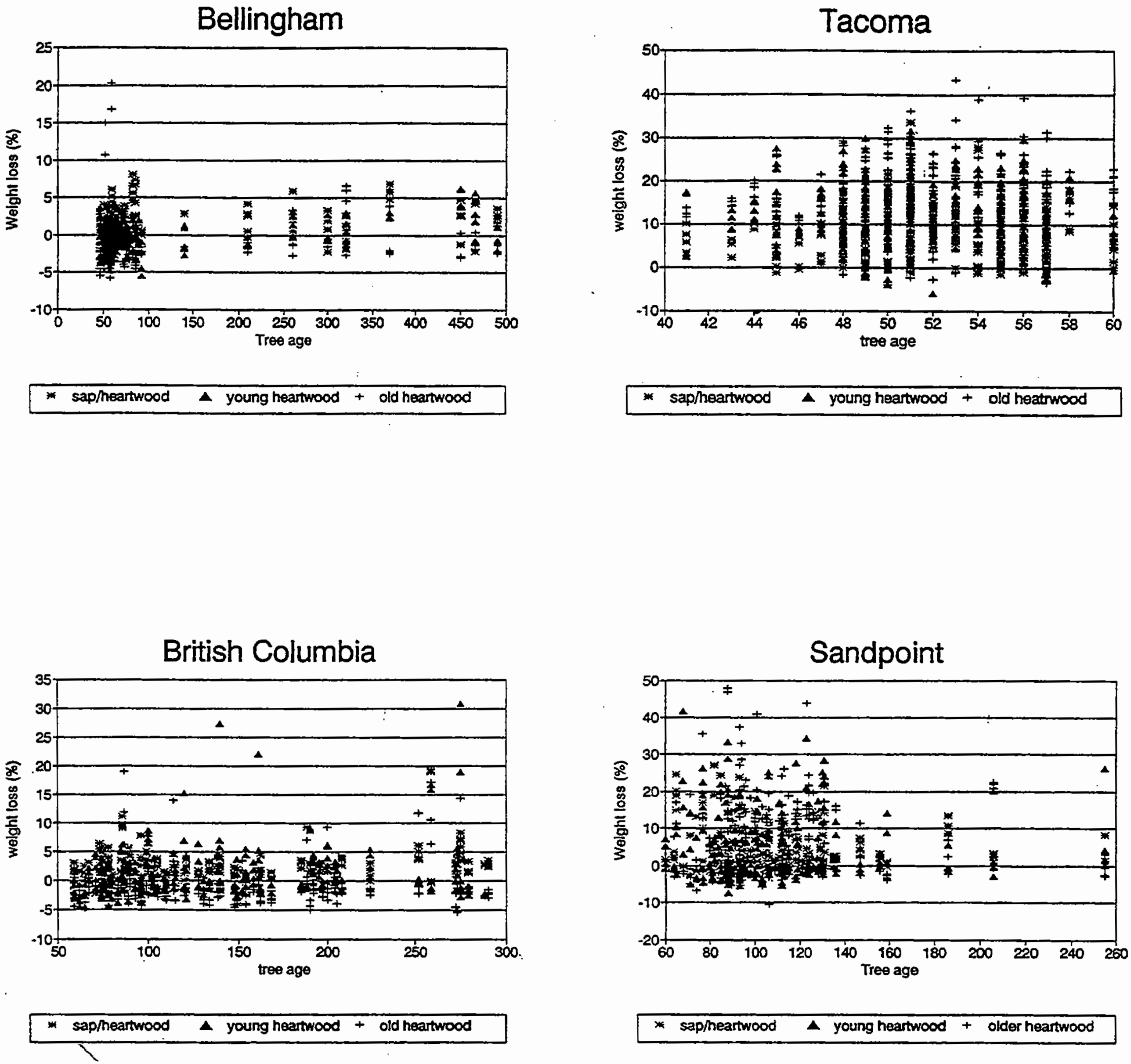


Figure III-6. Relationship between wood source, tree age and position with heartwood on weight losses of western redcedar heartwood cubes from (a) Tacoma, Washington; (b) Sandpoint, Idaho; (c) western Washington; (d) St. Maries, Idaho; (e) Sicamous, British Columbia; or (f) Nelson, British Columbia.

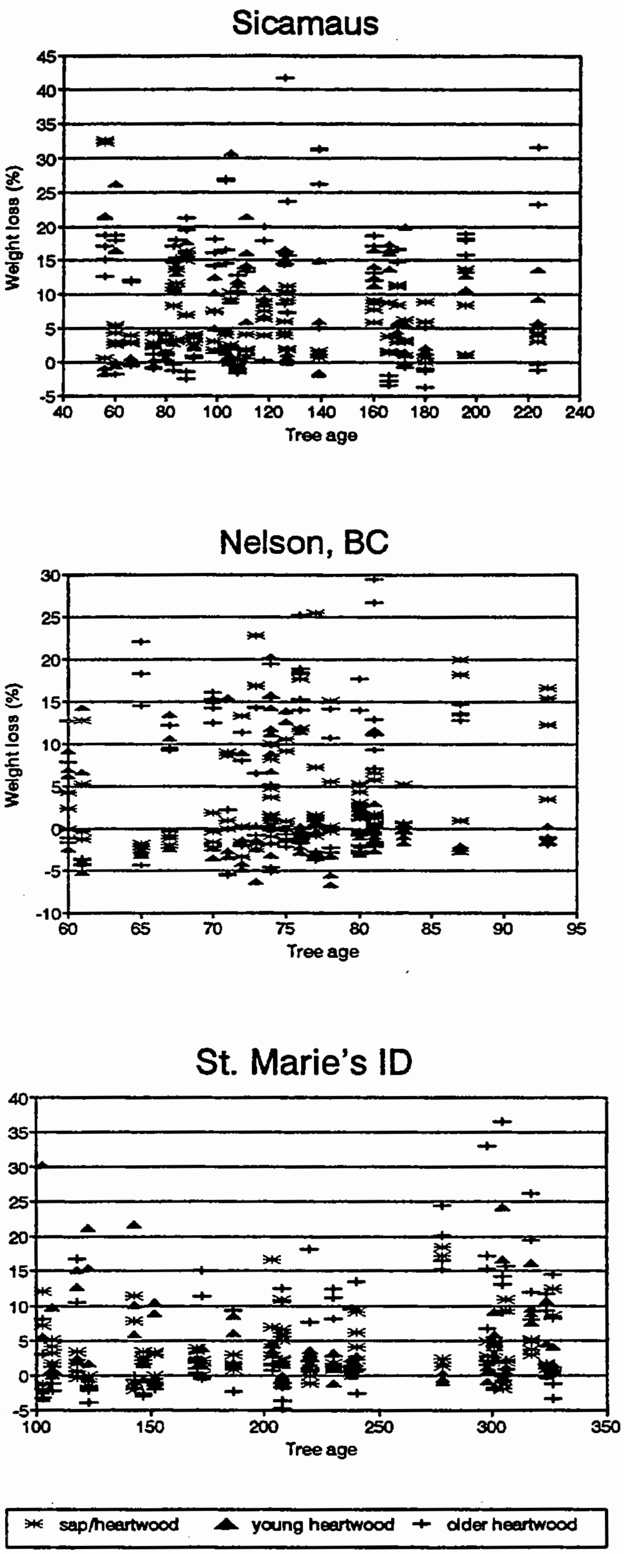


Figure III-6. Relationship between wood source, tree age and position with heartwood on weight losses of western redcedar heartwood cubes from (a) Tacoma, Washington; (b) Sandpoint, Idaho; (c) western Washington; (d) St. Maries, Idaho; (e) Sicamous, British Columbia; or (f) Nelson, British Columbia.

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 (Harkom et al., 1948; Panek et al., 1961; Leutritz and Lumsden, 1962; Smith and Cockroft, 1967; Chudnoff et al., 1977; DeGroot, 1981; Ziobro et al., 1987; Henningsson et al., 1988). 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 tests were performed.

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

Douglas-fir pole sections treated with various external preservatives in 1989 were not sampled this year. The internal condition of many of these posts makes it difficult to obtain sound cores for chemical analysis. These pole sections will no longer be sampled, although we plan to sample the soil around selected pole sections to assess the potential for loss of chemical into the surrounding soil at the later stages of remedial treatment.

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

The poles treated with various copper, boron, and fluoride based external preservative systems in 1991 were not sampled this past year (year 6). These poles will be sampled in 1998 to provide a 7 year sample.

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

The field trials established in 1995 were not sampled last year. These trials will be sampled in September 1997 to provide two year data of chemical distribution.

D. ABILITY OF A PROPICONAZOLE PRESERVATIVE PASTE TO DIFFUSE THROUGH DOUGLAS-FIR HEARTWOOD AT SELECTED MOISTURE CONTENTS

The performance of external groundline preservative systems is predicated on their ability to form a protective barrier on the wood surface that prevents renewed fungal attack from the surrounding soil and to diffuse for a short distance into the wood to kill any fungi already present near the surface. Most groundline preservative systems have multiple components including one chemical capable of diffusing with moisture and another that is oilborne and remains nearer the wood surface. Our three field tests clearly attest to the efficacy of these systems on a variety of species, but other external preservative systems are also under development in other parts of the world. This past year we evaluated the ability of one of these systems to migrate through Douglas-fir heartwood.

Air-dried Douglas-fir heartwood blocks (100 mm square) were pressure soaked with water and air-equilibrated to 30 or 60 percent moisture content. The equilibrated blocks were triple dipped in molten paraffin to retard further moisture loss. The blocks were then stored for an additional 4 weeks to allow for further equilibration of the moisture present in the wood. A flat bottomed treatment hole 25 mm in diameter by 3 mm deep was then drilled into the center of either the transverse or tangential face of each block and 5 g of a paste containing 0.5 g of propiconazole was placed in the hole which was covered with heavy duty tape and sealed with molten paraffin. The blocks incubated at room temperature with the grain oriented vertically to simulate a standing pole. Selected blocks were sampled 1, 2, 3, 6 and 12 months after treatment to determine the amounts of preservative that had moved into the wood.

After each exposure, a 25 mm^2 core was taken from the center of each of 5 blocks per treatment. The core was taken directly through the treated face. Each core was divided into 5 assay zones: 0 to 6 mm, 6 to 13 mm, 13 to 25 mm, 25 to 38 mm and 38 to 54 mm. The samples were oven dried overnight at 54°C, then ground to pass a 20 mesh screen.

The ground samples were then extracted and analyzed for propiconazole according to American Wood Preserver's Association Standard A23-94. Briefly, approximately 2.5 g of wood was added to 50 ml of methanol and the mixture was stirred for 2 hours at room temperature. The resulting extract was filtered through a 0.45 u filter, then the samples were diluted with tetrahydrofluran to a level between 1 and 50 ug/ml prior to analysis. The resulting extract was analyzed using a Shimadzu HPLC with a 10 cm long stainless steel column (I.D. 4.6 m) with Hypersil ODS (3 um). The eluent was a 50:50 mixture of 0.5 % ammonium carbonate and acetonitrile. Acetonitrile was used to purge the column between analyses. The results were quantified by comparison with analyses of solutions containing known amounts of propiconazole.

The estimated threshold for propiconazole against decay fungi is 0.12 kg/m^3. Propiconazole levels near the wood surface were far in excess of those required for preventing fungal attack (Table IV-1). Chemical levels declined sharply further inward from the block surface, but were still capable of providing protection from fungal attack. The results indicate that propiconazole is diffusing into the heartwood at levels that confer protection against most conventional decay fungi. Additional blocks will be monitored over the next 9 months to determine the long-term movement of this chemical.

Table IV-1. Effect of wood moisture content and incubation time on propiconazole retentions in Douglas-fir heartwood blocks treated with an external groundline preservative system.

		Propiconazole Retention (kg/m^3)[a]				
Wood Moisture Content (%)	Incubation Period (months)	0-6 mm	6-13 mm	13-25 mm	25-38 mm	38-33 mm
15	1	84.2 (46.2)	18.2 (16.3)	4.3 (7.0)	0.7 (0.4)	3.2 (2.9)
	2	30.5 (21.3)	7.7 (12.3)	2.2 (4.6)	2.0 (5.6)	1.7 (4.9)
	3	55.3 (14.3)	18.3 (14.9)	10.0 (12.6)	8.4 (13.0)	5.6 (9.1)
60	1	62.1 (30.3)	5.6 (5.6)	2.8 (4.9)	0.5 (0.3)	1.1 (1.0)
	2	25.7 (24.5)	4.0 (7.9)	0.5 (0.4)	1.1 (2.4)	2.8 (7.9)
	3	59.7 (20.2)	9.0 (10.6)	2.6 (2.9)	0.9 (0.8)	1.1 (1.3)

[a] Values represent means of 10 replicates/treatment. Values in parenthesis represent one standard deviation.

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 alternative chemicals. 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 re-treat cedar poles 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 from 0 (failure) to 10 (sound).

Results 84 months after 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 7.7 for the diesel control while similarly treated weathered stakes had ratings averaging 1.4.

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 continues to provide 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 a series of copper naphthenate treated Douglas-fir 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 88 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	88 mos		6 mos	14 mos	26 mos	40 mos	52 mos	64 mos	76 mos	88 mos
Control	–	4.7	0.9	0.4	0.1	0	0	0	0	—	6.6	3.2	1.3	1.1	1.1	1.0	0.9	0.5
diesel	–	8.5	6.8	5.3	3.8	3.4	3.4	2.0	1.4	-	9.9	8.4	8.0	8.6	8.4	8.0	8.0	7.7
0.8	1.6	9.0	8.0	7.5	6.9	5.7	5.6	5.3	5.1	0.8	10.0	9.6	9.4	9.5	9.6	9.3	9.3	9.3
1.6	1.4	9.5	8.9	8.8	9.0	8.0	7.8	7.4	7.3	1.5	10.0	9.4	9.3	9.2	9.4	9.1	9.2	9.2
2.4	2.1	9.6	9.2	9.1	8.6	8.2	8.2	7.9	7.7	1.9	10.0	9.4	9.4	9.2	9.3	9.2	9.1	9.1
3.2	2.7	9.6	9.1	9.0	8.8	8.1	8.1	8.1	8.1	2.6	10.0	9.2	9.2	9.0	8.9	8.9	9.1	9.1
4.0	4.0	9.9	9.2	9.1	9.1	8.7	8.3	8.2	8.2	3.4	10.0	9.5	9.4	9.4	9.3	9.2	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.

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