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McFarland-Cascade Company

CHEMICAL COMPANIES

*CSI, Inc.

*ISK Biotech

*Osmose Wood Preserving, Inc.

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

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

A. Field performance of fumigants

The control of decay inside poles remains an important aspect of most utility inspection and maintenance programs. Ever increasing sensitivities to the use of toxic materials for decay control also continue to encourage the development of less toxic materials that are easier and safer to apply for arresting internal decay. The objective of this section is to identify and evaluate safer materials for controlling internal decay. While the primary focus has been on Douglas-fir, the results are also generally applicable to other species. The research focuses on two broad approaches - the use of either volatile fumigants or water diffusible fungicides.

Performance of MITC-Fume in Douglas-fir and southern pine poles: Methylisothiocyanate (MITC) is the presumed primary breakdown product of metham sodium and has long been of interest because of its excellent activity against decay fungi and its affinity for wood. In addition, pure MITC is a solid at room temperature, creating the potential for reduced risk of spills during application. Unfortunately, MITC is also very caustic and must be contained to avoid skin burns to the applicator. In our initial trials, we encapsulated MITC in gelatin. While highly effective, the formulation was viewed as too costly and difficult to manufacture. In 1988, Degussa Corp developed a glass encapsulated formulation of MITC (MITC-Fume) which contained approximately 30 g of MITC in a borosilicate glass vial capped with a Teflon cap. The cap was removed prior to application, allowing the chemical to diffuse from the top and into the wood surrounding the treatment hole. Since this formulation differed from the gelatin encapsulated MITC formulations, we established the following field trials.

Douglas-fir and southern pine pole sections (25 to 30 cm in diameter by 3.6 m long) were pressure-treated with chromated copper arsenate Type C, then painted with an elastomeric paint from the intended groundline to approximately 1.8 m above ground. The poles were set to a depth of 0.9 m at the Corvallis test site. A series of two, four, six, or eight steeply sloping holes (19 mm in diameter by 205 mm long) were drilled beginning at groundline and moving upward at 150 mm intervals and around the pole 120 degrees. Each hole received a single ampule of MITC-Fume containing 30 g of MITC. The holes were plugged with tight fitting wooden dowels to retain fumigant. The zone between the lowest and highest treatment holes was considered to be the treatment zone. Each treatment was replicated on six to ten poles per species.

The poles were sampled 1, 2, 3, 5, 7, and 10 years after treatment by removing two increment cores from each of two sites 180 degrees apart and 150 mm below the groundline as well as at three sites 120 degrees apart 0.3, 0.9, and 1.5 m above the highest treatment hole (which varied depending on whether the pole had received two, four, six or eight ampules). The inner and outer 25 mm of the first core were placed separately into 5 ml of ethyl acetate and extracted for 48 hours. The extract was analyzed by gas chromatography. The extracted core was then oven dried and weighed. MITC content was expressed as ug of MITC per oven dried gram of wood.

The inner and outer 25 mm of the second increment core were placed in glass test tubes containing an actively growing culture of *Postia placenta* on malt extract agar in a closed tube bioassay. The tubes were capped and incubated in an inverted position so that any residual fumigant vapors in the wood could diffuse upward where they would contact and inhibit growth of the test fungus. Radial growth of the test fungus in the presence of the wood was compared with that of similar tubes without wood or with wood from poles not receiving fumigant.

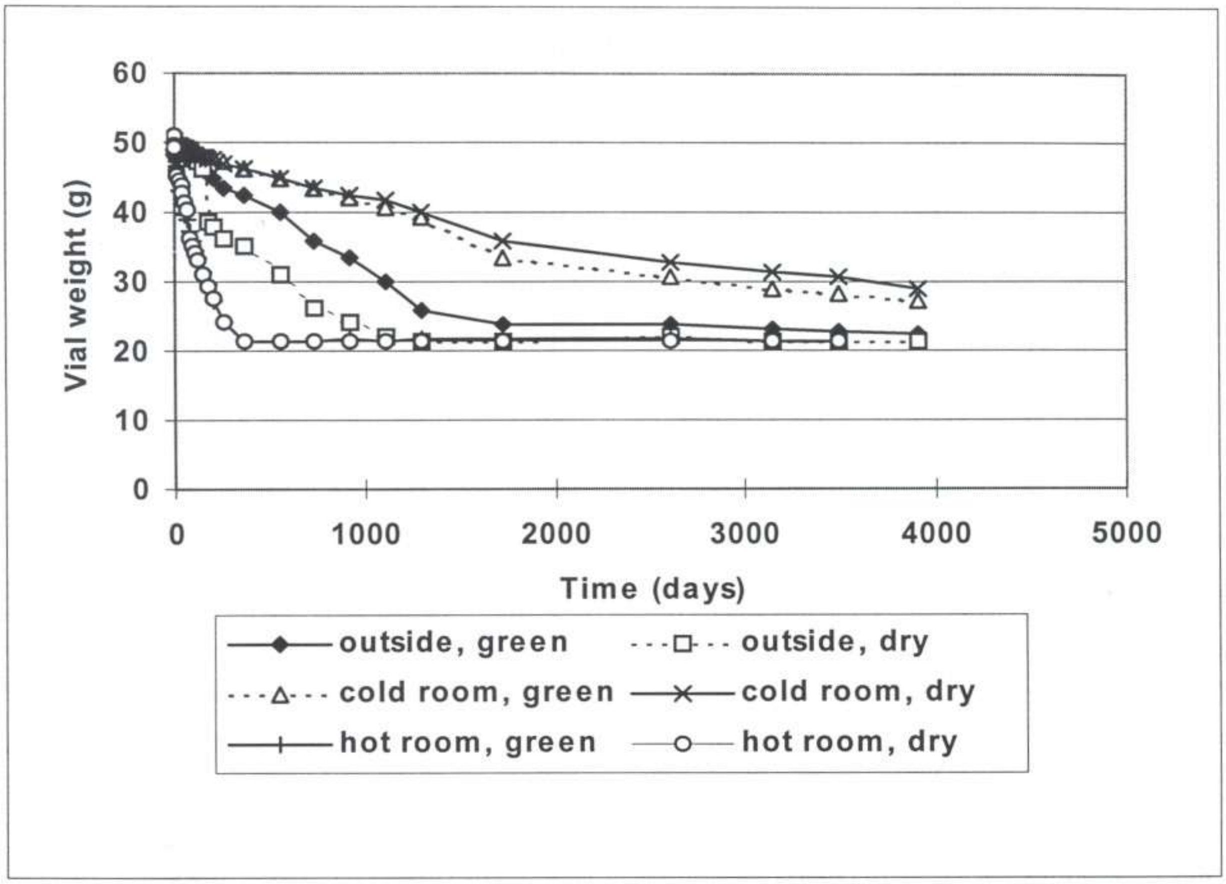
The remainder of one core was placed on malt extract agar in petri dishes and observed for evidence of fungal growth over a 30-day period. Any fungi growing from the wood were examined using a light microscope for characteristics typical of basidiomycetes, a class of fungi containing many important wood decayers. Fungi were then classified as decay or non-decay fungi.

Additional laboratory trials were also performed to assess the rate of MITC release from the ampules. MITC-Fume ampules were placed in 18 Douglas-fir sections (25 to 30 cm in diameter by 75 cm long) that were stored at 5 C, 32 C or outdoors, in the shade, adjacent to the laboratory. The ampules were periodically removed from the pole sections and weighed to follow release rates under the different conditions. Each condition was replicated on six sections, three that had been dry at the start of the test and three whose initial moisture contents were above the fiber saturation point.

The rates of ampule release varied widely with temperature, reflecting the influence of temperature on sublimation of MITC from solid to gas in the tubes (Figure I-1). Ampules exposed at 32 C lost their chemical in approximately 1 year, while those exposed outdoors required 3 to 5 years to lose the bulk of their chemical. Ampules exposed at 5 C still contain approximately one-third of the original chemical ten years after treatment. These results illustrate the release rates that are possible under varying temperature regimes. One factor that we did not investigate in our tests was the influence of solar heating on release. Darker utility poles can become extremely hot on bright sunny days. These poles can continue to heat internally as the sun sets, creating the potential for much higher temperatures in poles than in the surrounding air at certain times of the year. This heating may account for field reports of faster release rates in cooler climates.

MITC levels in the field pole sections were elevated 0.3 m above and below the treatment zone (Table I-1(a, b), Figure I-2(a, b)). Chemical levels at these heights were lowest in poles receiving either two ampules or 500 ml of liquid metham sodium. MITC levels were far higher in poles receiving four or more ampules. Chemical levels were generally higher in the inner zones of increment cores reflecting the tendency of the chemical to migrate out of the inward-pointing ampules and further into the poles. Chemical levels also tended to

Figure I-1. Residual MITC in MITC-FUME ampules 1 to 10 years after application to Douglas-fir pole sections incubated at 5 C, 32 C, or in an outdoor exposure



remain higher in southern pine poles, a finding that continues to remain puzzling, given the higher permeability of this species.

Chemical levels gradually declined in all treatments beginning 1 to 2 years after treatment. MITC levels are extremely low in all but the six and eight ampule dosages 10 years after treatment. Chemical levels in all treatments were extremely variable at the 7 and 10 year samplings, suggesting that the results must be viewed with some caution. The results imply that the protective zones in all of the MITC-based treatments (including metham sodium) declined rapidly between 5 and 7 years. Decay fungi may re-colonize these poles at varying rates which depend on new wood being exposed through checks and the level of fungal inoculum present. Thus, some poles may be colonized rapidly while others remain free of fungal attack.

Closed tube bioassays closely reflected the results of chemical analyses (Table I-2 (a, b)). Most cores produced little or no inhibition of the test fungus except at the highest dosages in cores removed near the groundline or slightly above the treatment zone. The closed

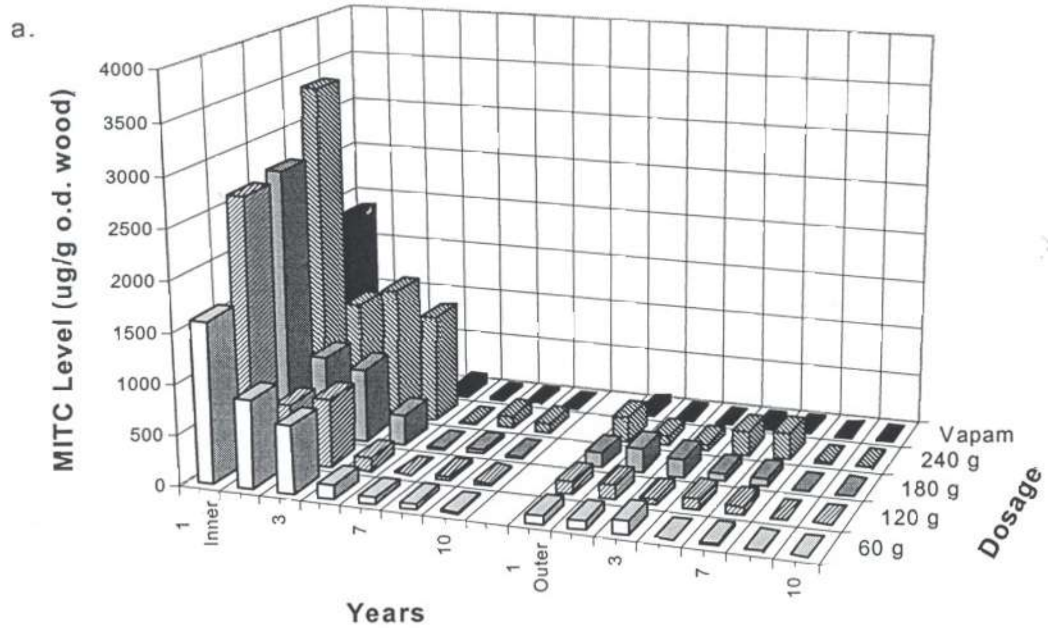
Table I-1. Residual MITC levels in Southern pine and Douglas-fir poles one to ten years after treatment with MITC-Fume.

Sampling Height	Core Segment Tested	Years after Treatment	Residual MITC (ug/g of oven dried wood)									
			Southern Yellow Pine					Douglas-fir				
			MITC-fume				Vapam	MITC-fume				Vapam
			60 g	120 g	180 g	240 g	500 ml	60 g	120 g	180 g	240 g	500 ml
-0.3 m below ground line	Inner	0.75										
		1	94	1259	917	1600	118	269	256	1047	522	94
		2	880	744	829	666	425	580	582	935	553	49
		3	536	368	284	277	257	186	219	202	127	44
		5	186	119	163	854	212	68	58	87	36	27
		7	27	20	5	14	13	4	1	9	4	5
		9										
		10	64	7	30	59	8	19	6	5	5	7
-0.3 m below ground line	Outer	0.75										
		1	325	201	156	269	7	146	242	309	334	12
		2	78	148	158	125	83	89	99	192	167	23
		3	30	31	56	163	2	18	81	65	55	2
		5	14	70	75	61	56	58	65	24	18	26
		7	73	72	113	372	43	37	25	24	9	17
		9										
		10	12	11	0	4	2	3	2	2	0	0
Ground Line	Inner	0.75										
		1	1603	2625	2697	3377	1870	2269	2314	3285	3960	712
		2	883	582	817	1135	215	518	714	731	526	21
		3	675	673	736	1323	227	273	223	389	251	68
		5	137	131	303	1085	93	235	70	118	46	64
		7	64	13	8	8	12	12	6	6	12	2
		9	53	37	33	130	15	33	9	12	11	8
		10	20	22	16	98	3	17	4	7	8	8
Ground Line	Outer	0.75										
		1	80	131	146	246	64	84	400	290	1386	38
		2	80	146	229	101	13	96	125	143	253	18
		3	138	62	176	62	1	61	59	66	78	3
		5	10	107	80	235	15	107	36	51	38	19
		7	23	81	83	256	26	30	12	19	9	12
		9	4	4	1	7	1	4	3	7	4	3
		10	4	10	0	9	3	5	1	1	2	1
Center of Treated Zone	Inner	0.75										
		1										
		2										
		3										
		5										
		7										
		9	17	172	80	283	27	12	8	12	19	8
		10										
Center of Treated Zone	Outer	0.75										
		1										
		2										
		3										
		5										
		7										
		9	1	3	2	9	1	4	3	4	4	3
		10										

			Residual MITC (ug/g of oven dried wood)									
Sampling Height	Core Segment Tested	Years after Treatmen	Southern Yellow Pine					Douglas-fir				
			MITC-fume				Vapam	MITC-fume				Vapam
			60 g	120 g	180 g	240 g	500 ml	60 g	120 g	180 g	240 g	500 ml
		0.75	0	24	285	7	7	41	73	92	165	60
0.3 m above Treated Zone	Inner	1	194	206	281	170	83	86	320	679	237	73
		2	219	265	209	192	36	167	254	318	367	183
		3	77	139	91	135	19	92	142	122	107	24
		5	51	47	40	112	10	28	29	49	30	21
		7	3	6	4	6	5	7	4	5	6	5
		9										
		10	2	2	0	8	1	1	1	2	4	2
		0.75	3	12	121	8	10	53	58	89	116	41
0.3 m above Treated Zone	Outer	1	18	39	24	30	6	9	11	61	172	10
		2	5	20	20	10	2	28	43	111	224	11
		3	21	42	61	36	2	37	48	59	99	8
		5	9	17	24	37	14	51	30	29	56	30
		7	7	19	12	31	8	10	6	3	9	4
		9										
		10	0	1	0	1	0	1	0	0	3	1
		0.75	0	0	0	0	0	9	40	21	42	11
0.9 m above Treated Zone	Inner	1	0	7	5	2	0	19	154	64	26	53
		2	5	5	27	22	1	67	63	87	156	21
		3	2	12	12	8	0	34	26	32	48	8
		5	8	7	14	15	8	11	22	14	16	15
		7	2	4	2	5	4	3	1	2	4	3
		9										
		10	0	0	0	0	0	0	1	0	0	2
		0.75										
0.9 m above Treated Zone	Outer	1	2	8	8	7	0	21	33	28	24	8
		2	1	4	3	1	2	60	27	13	48	2
		3	1	4	6	5	0	26	40	27	20	4
		5	6	6	5	14	7	21	30	19	28	10
		7	1	5	3	5	2	2	4	1	3	2
		9										
		10	0	0	0	0	0	0	0	0	1	0
		0.75										
1.5 m above Treated Zone	Inner	1	0	0	0	0	0	1	4	1	12	2
		2	0	1	0	0	0	4	0	1	71	0
		3	0	0	1	2	0	3	6	5	0	2
		5	5	4	4	12	10	9	9	7	12	14
		7	1	4	4	1	3	3	1	2	3	6
		9										
		10	0	0	0	0	0	0	0	0	0	0
		0.75										
1.5 m above Treated Zone	Outer	1	0	0	0	0	0	3	2	1	2	2
		2	0	0	1	0	0	25	2	0	27	0
		3	0	1	1	2	0	3	3	5	0	4
		5	7	24	3	11	7	9	16	9	16	17
		7	1	6	3	2	2	2	4	2	1	2
		9										
		10	0	0	0	0	0	0	0	1	0	0

Figure I-2 (a, b). Residual MITC near the groundline in Douglas-fir and southern pine 1 to 10 years after treatment with MITC-Fume or metham sodium.

a.



b.

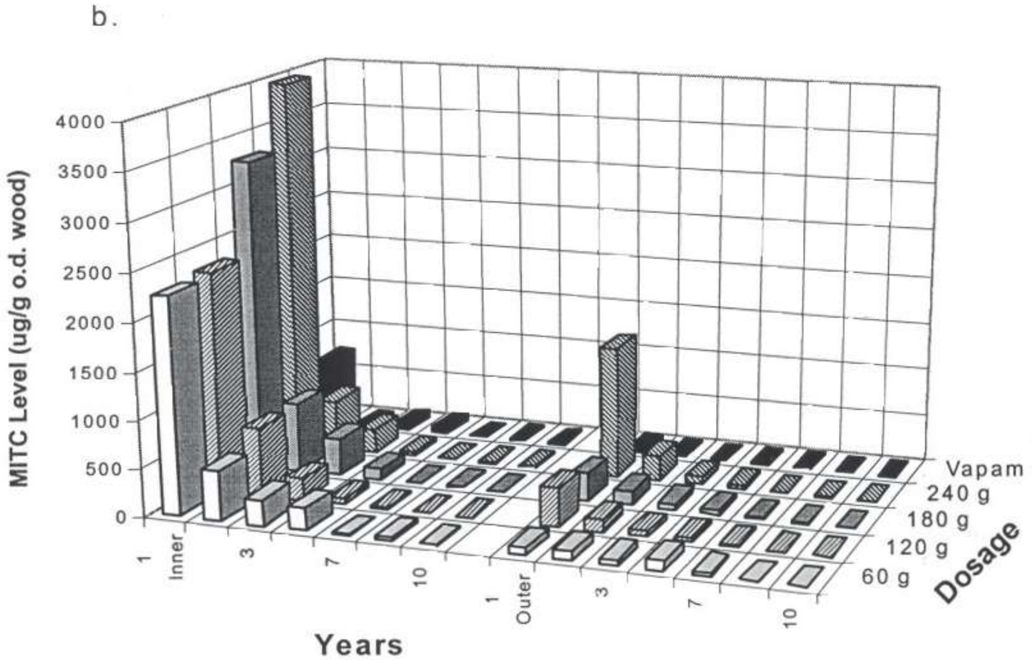


Table I-2a. Fungal inhibition as measureed by closed tube bioassay of increment cores taken at or below groundline from southern pine or Douglas-fir poles 1-10 years after treatment with MITC-Fume.

			Fungal Growth (as % of control)											
	Height	inner	Southern Yellow Pine						Douglas-fir					
Treatment	cms.	outer	Yr 1	Yr 2	Yr 3	Yr 5	Yr 7	Yr 10	Yr 1	Yr 2	Yr 3	Yr 5	Yr 7	Yr 10
0 g MITC-fume	-30	inner	140	28	99	75	98	65		33	98	84	94	76
60 g MITC-fume	-30	inner	0	0	11	40	62	48	0	0	1	43	74	62
120 g MITC-fume	-30	inner	0	0	1	28	58	42	20	0	14	50	88	78
180 g MITC-fume	-30	inner	12	0	3	27	69	72	8	10	7	59	97	66
240 g MITC-fume	-30	inner	0	0	0	3	110	29	0	0	16	58	102	90
500 ml methamNa	-30	inner	16	0	9	26	90	60	82	15	69	75	75	82
0 g MITC-fume	-30	outer	133	41	102	95	77	80		51	89	91	78	109
60 g MITC-fume	-30	outer	13	18	58	92	37	62	54	16	25	69	44	76
120 g MITC-fume	-30	outer	0	0	37	94	45	63	45	6	20	83	60	93
180 g MITC-fume	-30	outer	18	21	33	77	27	92	15	12	25	73	79	67
240 g MITC-fume	-30	outer	0	0	33	86	10	91	0	0	20	72	94	89
500 ml methamNa	-30	outer	30	112	78	74	51	88	129	20	82	93	62	92
0 g MITC-fume	0	inner		2	86	77	75	75		52	89	87	94	76
60 g MITC-fume	0	inner	16	0	9	33	73	42	0	0	8	49	75	64
120 g MITC-fume	0	inner	0	0	3	50	68	61	0	10	17	57	79	76
180 g MITC-fume	0	inner	0	0	7	24	72	74	0	0	1	42	89	66
240 g MITC-fume	0	inner	0	0	3	1	71	17	0	0	0	48	93	90
500 ml methamNa	0	inner	0	0	5	25	93	59	0	2	82	77	81	69
0 g MITC-fume	0	outer		13	106	89	79	85		54	104	95	92	83
60 g MITC-fume	0	outer	0	0	40	92	60	66	0	18	19	58	44	90
120 g MITC-fume	0	outer	3	7	13	82	40	63	0	0	21	81	82	76
180 g MITC-fume	0	outer	11	30	24	81	53	100	0	0	13	78	74	73
240 g MITC-fume	0	outer	0	0	10	80	31	82	0	0	18	67	81	87
500 ml methamNa	0	outer	34	113	69	91	64	87	11	13	77	89	56	89

bioassay provides a relative measure of the ability of actively growing fungi to re-colonize the wood. These results suggest that any fungi present would be capable of growing through outer zones of the wood or through the groundline zone in poles receiving lower dosages of MITC-Fume or the liquid metham sodium treatment.

Culturing of increment cores from MITC-Fume and metham sodium treated poles revealed that fungal colonization of the poles was relatively sparse over the 10 year test (Table I-3). Decay fungi have been isolated from all but the 240 g MITC- Fume treatment as well as the metham sodium treatment and the non-treated control. In general, isolations have been scattered among the treatments, suggesting that the colonization is sparse. In addition, no evidence of advanced decay has been detected in the fumigant-treated poles. Levels of non-decay fungi have steadily increased over the 10 year period to the point where at least one non-decay fungus was isolated from nearly 50 % of the cores. These fungi do not damage the wood, but their presence implies that the levels of chemical protection have

Table I-2b. Fungal inhibition as measured by closed tube bioassay of increment cores taken above the treated zone from southern pine or Douglas-fir poles 1-10 years after treatment with MITC-Fume.

			Fungal Growth (as % of control)											
	Height	inner	Southern Yellow Pine						Douglas-fir					
Treatment	cms.	outer	Yr 1	Yr 2	Yr 3	Yr 5	Yr 7	Yr 10	Yr 1	Yr 2	Yr 3	Yr 5	Yr 7	Yr 10
0 g MITC-fume	30	inner	67	90	87	97	77	74	97	51	104	96	92	100
60 g MITC-fume	30	inner	99	0	5	74	86	70	46	16	8	74	64	86
120 g MITC-fume	30	inner	86	0	6	63	77	64	17	12	19	75	77	86
180 g MITC-fume	30	inner	20	15	20	69	91	94	10	0	4	53	95	69
240 g MITC-fume	30	inner	19	0	1	37	88	44	0	0	3	66	94	77
500 ml methamNa	30	inner	85	13	24	67	103	83	18	31	85	89	78	87
0 g MITC-fume	30	outer	97	113	99	99	87	77	96	53	97	89	85	91
60 g MITC-fume	30	outer	133	84	50	92	79	87	96	39	25	78	62	89
120 g MITC-fume	30	outer	77	36	23	97	61	61	43	23	18	75	71	89
180 g MITC-fume	30	outer	62	32	28	84	86	101	17	0	7	62	85	75
240 g MITC-fume	30	outer	48	34	17	75	59	79	0	0	7	61	92	94
500 ml methamNa	30	outer	76	65	46	78	93	79	61	0	91	90	82	90
0 g MITC-fume	90	inner	68	75	89	82	83	70	91	74	94	96	96	86
60 g MITC-fume	90	inner	114	58	67	89	100	68	38	18	38	95	64	96
120 g MITC-fume	90	inner	112	62	46	99	84	71	35	0	58	91	57	86
180 g MITC-fume	90	inner	103	38	43	93	79	89	27	9	22	73	99	79
240 g MITC-fume	90	inner	118	46	38	87	104	55	37	0	15	87	97	91
500 ml methamNa	90	inner	104	59	52	88	102	80	47	32	91	93	84	96
0 g MITC-fume	90	outer	81	117	105	98	86	89	88	56	101	94	102	88
60 g MITC-fume	90	outer	131	88	87	99	95	85	86	43	38	80	66	86
120 g MITC-fume	90	outer	125	85	69	97	81	71	73	42	30	79	64	84
180 g MITC-fume	90	outer	105	95	66	94	82	106	35	36	16	71	95	90
240 g MITC-fume	90	outer	113	99	86	94	88	80	43	34	13	81	101	91
500 ml methamNa	90	outer	108	105	84	92	100	86	83	62	84	95	87	94
0 g MITC-fume	150	inner	93	73	84	84	90	80	88	67	100	96	101	112
60 g MITC-fume	150	inner	136	101	82	108	99	77	97	76	77	92	66	94
120 g MITC-fume	150	inner	151	94	79	93	86	74	88	43	73	87	63	90
180 g MITC-fume	150	inner	108	79	75	91	81	102	88	13	72	93	98	86
240 g MITC-fume	150	inner	96	56	60	84	99	66	114	69	73	84	102	90
500 ml methamNa	150	inner	111	71	57	87	110	73	76	66	103	96	85	96
0 g MITC-fume	150	outer	98	101	97	95	82	85	93	72	111	96	106	108
60 g MITC-fume	150	outer	155	98	72	99	92	82	80	52	74	88	63	80
120 g MITC-fume	150	outer	150	108	86	101	95	76	112	45	67	91	68	104
180 g MITC-fume	150	outer	117	102	90	105	70	99	79	78	65	88	99	89
240 g MITC-fume	150	outer	115	113	86	100	83	85	86	103	83	90	95	97
500 ml methamNa	150	outer	119	88	95	100	79	76	79	103	93	102	90	101

Figure I-3. Incidence of decay (regular script) and non-decay (superscript) fungi in southern pine and Douglas-fir pole sections 1-10 years after treatment with MITC-Fume or metham sodium with reference to height above groundline

Height			Southern Yellow Pine							Douglas-fir						
cms.	RP	treatment	1 yr	2 yr	3 yr	5 yr	7 yr	9 yr	10 yr	1 yr	2 yr	3 yr	5 yr	7 yr	9 yr	10 yr
-30	GL	60		0^{50}	0$^{66.7}$	0^{50}	0$^{83.3}$		8.33^{100}		0^{0}	0$^{41.7}$	0$^{8.33}$	0$^{91.7}$		8.33^{75}
0	GL	60	0^{67}	0^{0}	0^{17}	0^{17}	0^{83}	0^{58}	0^{75}	0^{40}	0^{33}	0^{0}	0^{8}	0^{75}	8^{17}	0^{25}
0	TZ	60						0^{75}							8.33$^{33.3}$	
30	TZ	60	0^{100}	0^{100}	0^{39}	6^{22}	0^{78}		0^{78}	0^{33}	0^{67}	0^{0}	0^{11}	0^{72}		0^{33}
90	TZ	60	0^{100}	0^{100}	6^{83}	0^{39}	0^{100}		0^{89}	0^{50}	0^{83}	0^{17}	0^{17}	6^{83}		11^{67}
150	TZ	60	0^{100}	0^{100}	0^{76}	0^{56}	0^{100}		6^{78}	10^{40}	0^{100}	6^{39}	0^{17}	0^{89}		6^{44}
-30	GL	120		0$^{33.3}$	0$^{41.7}$	0$^{33.3}$	0^{75}		0$^{83.3}$		0$^{57.1}$	0$^{7.14}$	0$^{21.4}$	0$^{85.7}$		7.14$^{64.3}$
0	GL	120	0^{83}	0^{33}	0^{8}	8^{8}	0^{92}	0^{42}	0^{75}	0^{29}	14^{29}	0^{0}	0^{14}	0^{86}	0^{14}	0^{50}
0	TZ	120						0$^{41.7}$							0$^{14.3}$	
30	TZ	120	0^{100}	0^{83}	0^{17}	6^{28}	0^{83}		0^{67}	0^{64}	0^{86}	0^{5}	0^{5}	5^{76}		0^{48}
90	TZ	120	0^{100}	0^{100}	0^{56}	0^{61}	0^{100}		0^{78}	0^{55}	29^{100}	0^{10}	0^{29}	0^{95}		0^{57}
150	TZ	120	0^{100}	0^{100}	0^{56}	0^{33}	0^{94}		0^{100}	0^{73}	14^{86}	10^{29}	0^{38}	0^{95}		10^{48}
-30	GL	180		0^{50}	0^{50}	0$^{21.4}$	0^{100}		14.3$^{78.6}$		0^{40}	0^{15}	0^{15}	0^{95}		0^{60}
0	GL	180	0^{40}	0^{33}	0^{14}	0^{29}	7^{93}	0^{36}	0^{71}	0^{36}	0^{10}	0^{5}	0^{10}	0^{75}	0^{20}	0^{25}
0	TZ	180						0$^{57.1}$							0^{20}	
30	TZ	180	0^{100}	0^{100}	0^{67}	0^{29}	5^{81}		5^{81}	5^{53}	0^{70}	0^{3}	0^{10}	3^{87}		0^{43}
90	TZ	180	0^{100}	0^{100}	0^{67}	0^{48}	0^{90}		0^{76}	5^{63}	0^{60}	0^{13}	0^{17}	0^{87}		3^{43}
150	TZ	180	0^{100}	0^{100}	0^{52}	0^{48}	0^{100}		0^{100}	28^{72}	0^{70}	3^{17}	0^{33}	0^{97}		3^{43}
-30	GL	240		0^{0}	0$^{58.3}$	0$^{41.7}$	8.33$^{91.7}$		0$^{91.7}$		0$^{33.3}$	0$^{33.3}$	0$^{16.7}$	0^{100}		0$^{66.7}$
0	GL	240	0^{40}	0^{0}	0^{25}	0^{17}	8^{83}	0^{42}	0^{58}	0^{40}	0^{17}	0^{0}	0^{17}	0^{92}	0^{33}	0^{25}
0	TZ	240						0$^{41.7}$							0$^{8.33}$	
30	TZ	240	0^{78}	0^{100}	0^{38}	6^{35}	6^{89}		0^{78}	0^{25}	17^{67}	6^{6}	0^{11}	0^{72}		0^{33}
90	TZ	240	0^{100}	0^{100}	6^{72}	6^{33}	0^{100}		0^{78}	0^{8}	17^{100}	0^{0}	0^{22}	0^{83}		0^{28}
150	TZ	240	0^{100}	0^{100}	0^{94}	6^{94}	0^{100}		0^{94}	10^{90}	0^{100}	0^{13}	0^{20}	0^{100}		0^{27}
-30	GL	none		0^{100}	0$^{91.7}$	0^{75}	0^{100}		0$^{91.7}$		33.3^{100}	33.3^{75}	0^{25}	0^{100}		0$^{58.3}$
0	GL	none	0^{0}	0^{100}	0^{83}	0^{50}	0^{100}	0^{92}	0^{92}		33^{100}	58^{67}	0^{17}	8^{100}	8^{50}	0^{50}
0	TZ	none						0^{100}							16.7$^{41.7}$	
30	TZ	none	0^{100}	0^{100}	0^{83}	0^{56}	0^{100}		6^{61}	0^{50}	50^{100}	33^{39}	17^{50}	44^{100}		11^{50}
90	TZ	none	0^{100}	0^{100}	0^{89}	0^{72}	0^{100}		0^{94}	8^{33}	17^{100}	28^{50}	0^{39}	22^{100}		11^{61}
150	TZ	none	0^{100}	0^{100}	0^{83}	6^{61}	0^{100}		0^{72}	0^{40}	0^{100}	0^{6}	0^{33}	22^{100}		0^{44}
-30	GL	methamNa		0^{60}	0^{70}	0^{30}	0^{90}		20^{90}		0^{60}	0^{40}	0^{50}	0^{90}		0^{50}
0	GL	methamNa	0^{40}	0^{40}	0^{40}	0^{20}	0^{100}	0^{100}	0^{80}	0^{60}	0^{40}	10^{30}	0^{40}	0^{80}	0^{60}	0^{30}
0	TZ	methamNa						0^{50}							10^{20}	
30	TZ	methamNa	0^{100}	0^{80}	0^{73}	0^{33}	0^{100}		0^{87}	0^{40}	20^{60}	20^{47}	7^{27}	0^{86}		7^{40}
90	TZ	methamNa	0^{100}	0^{100}	0^{93}	7^{53}	0^{100}		0^{87}	10^{50}	20^{100}	13^{13}	0^{33}	0^{93}		0^{27}
150	TZ	methamNa	0^{100}	0^{100}	0^{87}	0^{53}	0^{100}		0^{80}	0^{40}	20^{80}	0^{0}	0^{33}	7^{100}		0^{73}

declined. In practical terms, the results indicate that MITC-Fume treatments should not be extended beyond the normal 10 year inspection and maintenance cycles currently specified by most utilities unless the utility has compelling information showing that the risk of fungal attack in their poles is such that the re-invasion rate is slower than that found in other regions.

Distribution of MITC in Douglas-fir and ponderosa pine poles 3 years after metham sodium treatment: Metham sodium remains the most frequently used fumigant for arresting internal decay in utility poles; however, information on the longevity of this treatment under varying climate regimes is lacking.

We established a field test in the Pacific Gas and Electric system near San Jose, California. Pentachlorophenol treated Douglas-fir and ponderosa pine poles (Classes 4 to 6) that had been installed between 1952 and 1963 were selected. Three steeply angled holes were drilled beginning slightly below the groundline and moving upward at approximately 300 mm intervals and around the pole 120 degrees.

Drill shavings were collected and cultured on malt extract agar to detect the presence of decay fungi. These isolations served as a measure of the degree of colonization at the time of treatment.

The poles were then treated with 500 ml of metham sodium equally distributed among the three holes. Treatments were applied to five ponderosa pine and 11 Douglas-fir poles. All treatments were performed by the PG&E contractor.

Each year after the initial treatment, increment cores have been removed from sites located 0.3, 0.6, and 1.3 m above the groundline. Two cores were removed 0.3 m above groundline and 120 degrees around from the highest treatment hole. Three cores were removed at equidistant locations around the pole at the two other sampling heights, with one core at each height being removed directly above the highest treatment hole. One pole originally included in the test was later deemed inaccessible for sampling.

The outer and inner 25 mm of each core were cut and placed into glass vials which were tightly capped and shipped to Corvallis, Oregon for analysis. Five ml of ethyl acetate was added to each of the vials, which were recapped and incubated for 48 hours. A sub-sample from each extract was removed after 48 hrs, and analyzed for residual MITC using a Varian 3700 Gas Chromatograph (GC) equipped with a flame photometric detector with filters specific for sulfur compounds (Zahora and Morrell, 1989). MITC levels were quantified by comparing the GC peaks with those produced by prepared standards. The cores were oven-dried at 54 C and weighed. MITC content was expressed on a gram of MITC per gram of oven dried wood basis.

The remainder of each core was placed in a plastic drinking straw which was also returned to Corvallis. These cores were then flamed to eliminate contaminating surface fungi and placed on plates of malt extract agar. The plates containing the cores were observed for evidence of decay fungi over a 30-day period.

MITC was detectable in all of the poles 3 years after treatment, but the levels continued to decline between the second and third years of the test (Table I-4). Chemical levels were generally higher in the inner zone 0.3 m above groundline and were present at extremely low levels 1.2 m above groundline. MITC levels also differed markedly between the two wood species. Douglas-fir poles consistently retained higher levels of fumigant near the groundline. These findings are somewhat at odds with those found in the original MITC-Fume test, where southern pine poles tended to have slightly higher residual chemical loadings than Douglas-fir over time.

The differences in chemical retention with species over time may be less important in these poles because of the deeper preservative penetration in ponderosa pine. While internal decay can occur in ponderosa pine, the initial MITC release should eliminate these established fungi and the deeper preservative shell should minimize the risk of re-invasion. Further sampling will determine when fungi begin to re-invade these poles.

Although the primary purpose of fumigation is to eliminate decay fungi from poles, none of the poles in the current test contained active basidiomycetes prior to treatment (Table I-5). This finding must be accompanied by the caution that the sampling was limited to drill shavings from the original treatment holes, which minimized the potential sampling area. Subsequent samples, however, have failed to result in any other isolations of decay fungi. Non-decay fungi were abundant at the beginning of the test but were largely absent one year after treatment, particularly in the area closest to the original treatment site. These non-decay fungi have slowly begun to re-invade the poles, but have not yet reached their former frequencies. These findings are consistent with previous field trials. While these fungi do not degrade the wood, their presence can serve as an indicator of residual protection afforded by chemical treatment. A number of these fungi are also antagonistic and may help prevent colonization by decay fungi,

Table I-4. Residual levels of MITC various distances above the groundline in Douglas-fir and ponderosa pine poles 1 to 3 years after treatment with 500 ml of metham sodium.

Wood Species	Year	MITC Content (ug/g of wood)[a]					
		0.3 m		0.6 m		1.2 m	
		inner	outer	inner	outer	inner	outer
Douglas-fir	1	280 (189)	154 (168)	99 (92)	59 (81)	2 (4)	0 (0)
	2	178 (188)	87 (94)	118 (96)	59 (37)	10 (18)	9 (23)
	3	79 (63)	59 (50)	79 (64)	48 (31)	7 (5)	3 (5)
Ponderosa pine	1	70 (67)	47 (25)	23 (19)	23 (12)	3 (3)	4 (4)
	2	86 (70)	9 (11)	20 (16)	9 (11)	2 (2)	0 (0)
	3	34 (23)	15 (11)	21 (12)	11 (8)	3 (4)	2 (2)

[a]Numbers in parentheses represent one standard deviation.

Table I-5. Fungal colonization of Douglas-fir and ponderosa pine utility poles 1 to 3 years after treatment with 500 ml of metham sodium.

Species	Year	Fungal Colonization (%)[a]		
		0.3 m	0.6 m	1.2 m
Douglas-fir	0	0^{92}	-	-
	1	0^{0}	0^{8}	0^{4}
	2	0^{19}	0^{4}	0^{4}
	3	0^{19}	0^{8}	0^{8}
Ponderosa pine	0	0^{80}	-	-
	1	0^{0}	0^{0}	0^{10}
	2	0^{0}	0^{17}	0^{33}
	3	0^{26}	0^{5}	0^{4}

[a] Values represent means of 33 samples for Douglas-fir and 15 samples for ponderosa pine. Main values represent percentage of cores containing basidiomycetes, while the superscripts denote non-decay fungi.

Field performance of Basamid in combination with copper sulfate in Douglas-fir transmission poles: Basamid is a solid fumigant that decomposes to produce MITC as one of its primary breakdown products. The decomposition of Basamid is fairly slow, but previous studies have shown that Basamid will produce more MITC over a longer time period than metham sodium. In addition, laboratory and limited field studies showed that MITC production could be enhanced by simultaneous application of copper compounds. In 1993, we established a field test in Douglas-fir transmission poles located near Corvallis, Oregon to evaluate the effects of copper compounds on Basamid release.

The poles were treated by drilling a series of three steeply sloping holes beginning at groundline and moving upward at 150 mm intervals and around the pole 120 degrees. Each pole received 200 or 400 g of Basamid with or without 1 % copper sulfate equally distributed among the treatment holes. An additional set of poles was treated with 500 ml of metham sodium. Each treatment was replicated on five poles, except for metham sodium which was replicated on ten poles.

The poles have been sampled on an annual basis by removing increment cores from three equidistant sites around the poles 0.3 m, 1.3 m, 2.3 m and 3.3 m above groundline. The outer and inner 25 mm from the untreated zone of each core was placed into 5 ml of ethyl acetate and extracted for 48 hours. The wood was removed, oven dried and weighed. A sub-sample of the extract was analyzed by gas chromatography as previously described and the results were expressed as ug MITC per oven dried gram of wood. The remainder of each increment core was cultured on malt extract agar and examined for evidence of fungal growth over a 30-day period. Fungi growing from the wood were examined for characteristics typical of basidiomycetes, a class of fungi containing many important wood decomposers.

MITC levels in all of the poles have generally remained confined to the zone 1.3 m or closer to the groundline (Table I-6, Figure I-3 (a, b, c, d)). As expected concentrations remain typically higher closer to the groundline although there are some inconsistencies in these trends that might reflect the effects of wood variation on chemical distribution. Examples of these might be checks or knots that alter fumigant flow, producing less uniform chemical distribution. MITC levels were relatively low even 0.3 m above groundline 1 year after treatment. Levels were highest at this time in poles treated with metham sodium. MITC levels in poles receiving Basamid alone or amended with copper were initially low, but increased steadily over the first three years of the test and exceeded those found in metham sodium treated poles. The addition of copper to the basamid produced slight increases in MITC levels at both dosages, suggesting that copper may be useful as an accelerant for Basamid decomposition. This effect has resulted in consistently higher levels of MITC in copper amended treatments.

Overall, the levels of MITC in all of the samples are declining, although this effect is most important for the metham sodium treatment since the levels are so low.

Isolation of fungi from increment cores removed from the Basamid and metham sodium treated poles has produced more variable results (Table I-7). Decay fungi have been isolated from a number of structures, but the results have been inconsistent from one year to another. As a result, it is difficult to determine if the results represent sporadic isolations or a trend toward increased fungal isolations. The only concern in the present data was the marked increase in fungal isolations from poles treated with 200 grams of Basamid plus copper, where the incidence of decay fungi rose from none to 13% of the cores at the lowest sampling level. We will watch these poles carefully to ensure that the treatment is still performing adequately. Isolations of non-decay fungi have also increased, particularly between 4 and 5 years after treatment. These fungi do not affect wood properties, but their presence can be an indicator that chemical levels may be declining.

Table I-6. Residual MITC in Douglas-fir poles 1 to 5 years after treatment with metham sodium or Basamid with or without copper sulfate.

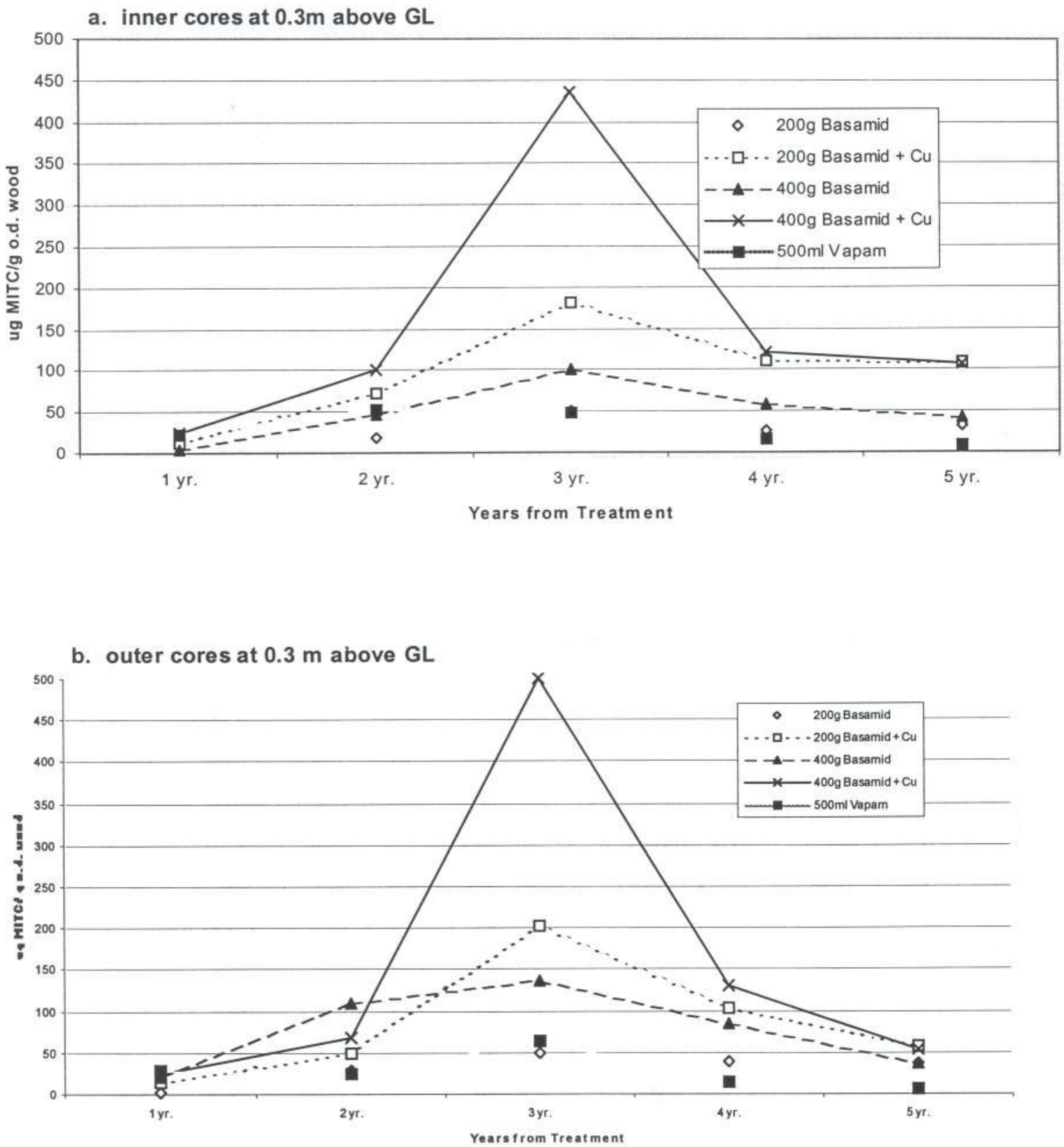
Chemical Treatment	Dosage	Yr	MITC Content (ug/g of wood)[a]							
			0.3 m		1.3 m		2.3 m		3.3 m	
			inner	outer	inner	outer	inner	outer	inner	outer
Basamid	200 g	1	8 (21)	2 (7)	5 (9)	13 (23)	0 (0)	0 (1)	1 (4)	1 (2)
		2	18 (20)	29 (37)	8 (11)	7 (16)	4 (6)	1 (4)	4 (8)	4 (7)
		3	51 (44)	50 (63)	19 (21)	38 (36)	8 (5)	9 (7)	2 (4)	2 (3)
		4	25 (15)	39 (31)	8 (4)	9 (11)	0 (1)	0 (0)	0 (0)	0 (0)
		5	31 (31)	37 (26)	10 (5)	7 (6)	0 (1)	0 (1)	0 (0)	0 (0)
Basamid plus copper	200 g	1	12 (27)	14 (31)	26 (38)	42 (65)	0 (0)	1 (5)	2 (5)	0 (0)
		2	72 (100)	50 (74)	13 (18)	8 (13)	7 (19)	4 (9)	6 (13)	10 (21)
		3	182 (215)	203 (272)	63 (70)	47 (52)	10 (13)	9 (17)	1 (4)	0 (0)
		4	110 (86)	103 (86)	25 (20)	11 (16)	1 (2)	0 (2)	0 (0)	0 (0)
		5	110 (92)	59 (101)	28 (21)	10 (10)	3 (4)	1 (2)	0 (0)	0 (0)
Basamid	400 g	1	5 (9)	22 (49)	16 (31)	56 (86)	1 (4)	0 (0)	0 (0)	1 (4)
		2	45 (47)	110 (108)	5 (5)	1 (3)	1 (2)	1(3)	1 (2)	4 (10)
		3	102 (97)	137 (207)	107 (106)	69 (105)	15 (15)	6 (8)	3 (6)	3 (6)
		4	59 (35)	84 (54)	11 (8)	7 (6)	0 (0)	0 (0)	0 (0)	0 (0)
		5	42 (23)	38 (31)	12 (8)	7 (6)	1 (2)	0 (0)	0 (0)	0 (0)

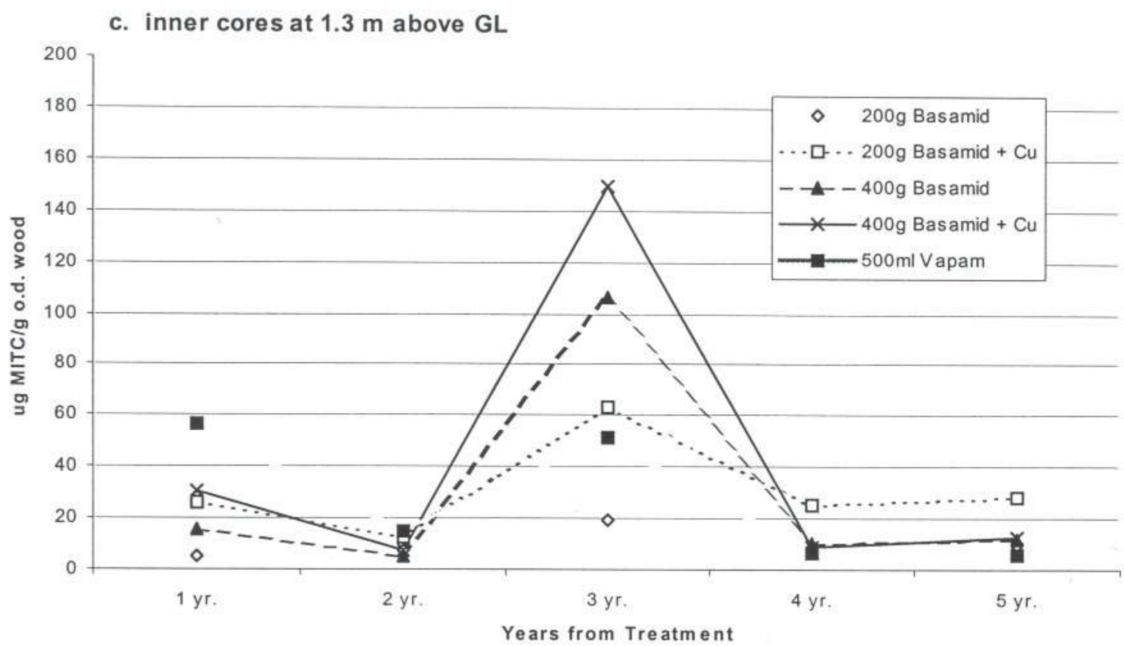
Table I-6 continued.

Chemical Treatment	Dosage	Yr	MITC Content (ug/g of wood)[a]							
			0.3 m		1.3 m		2.3 m		3.3 m	
			inner	outer	inner	outer	inner	outer	inner	outer
Basamid plus copper	400 g	1	25 (41)	25 (76)	31 (46)	64 (139)	0 (0)	0 (0)	0 (0)	0 (0)
		2	100 (93)	69 (126)	7 (8)	3 (5)	2 (5)	3 (5)	3 (5)	4 (6)
		3	435 (613)	501 (787)	149 (162)	132 (185)	11 (11)	6 (8)	1 (2)	1 (2)
		4	121 (82)	130 (116)	9 (100	7 (10)	1 (2)	0(0)	0 (0)	0 (0)
		5	108 (89)	54 (70)	13 (14)	9 (10)	14 (49)	6 (21)	0 (0)	0 (0)
Metham sodium	500 ml	1	21 (43)	30 (61)	57 (82)	38 (46)	1 (3)	0 (0)	1 (3)	0 (0)
		2	53 (47)	26 (28)	15 (17)	8 (16)	4 (7)	3 (5)	3 (6)	3 (5)
		3	48 (34)	64 (106)	51 (122)	25 (31)	12 (9)	5 (5)	7 (15)	2 (6)
		4	15 (16)	14 (11)	7 (8)	4 (7)	1 (3)	1 (2)	0 (0)	0 (0)
		5	8 (8)	7 (6)	6 (6)	2 (4)	0 (0)	0 (0)	0 (0)	0 (0)

[a] Numbers in parentheses represent one standard deviation.

Figure I-3 (a, b, c, d). MITC levels in the inner and outer zones of increment cores removed from Douglas-fir poles 1 to 5 years after treatment with Basamid alone or amended with copper sulfate or treated with metham sodium to serve as a control.




c. inner cores at 1.3 m above GL
200
180
160
140
120
100
80
60
40
20
0
ug MITC/g o.d. wood
200g Basamid
200g Basamid + Cu
400g Basamid
400g Basamid + Cu
500ml Vapam
1 yr.
2 yr.
3 yr.
4 yr.
5 yr.
Years from Treatment

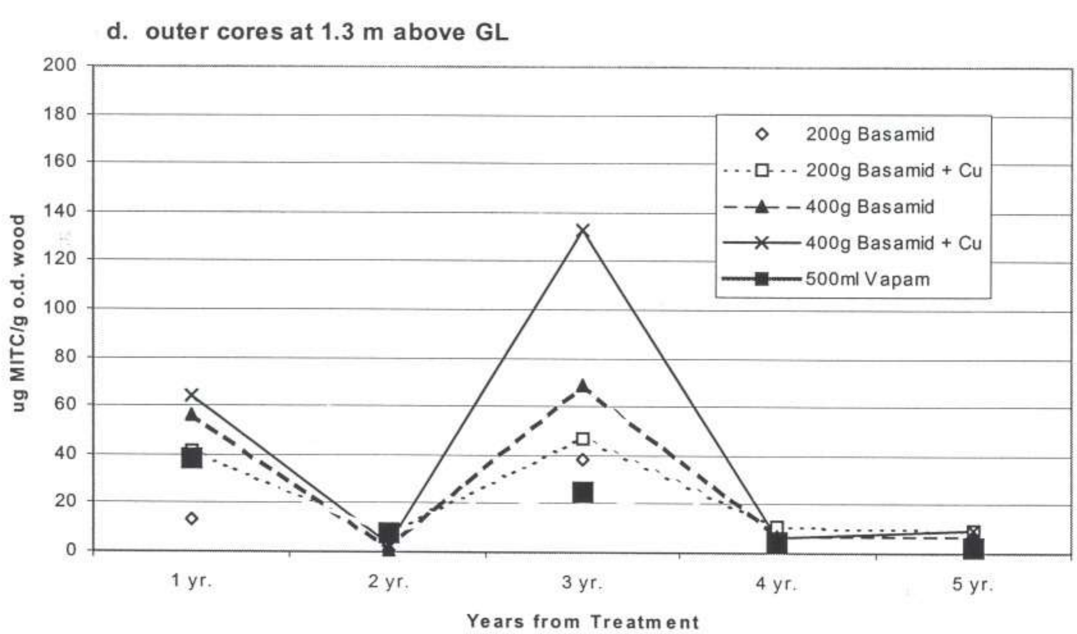

d. outer cores at 1.3 m above GL
200
180
160
140
120
100
80
60
40
20
0
ug MITC/g o.d. wood
200g Basamid
200g Basamid + Cu
400g Basamid
400g Basamid + Cu
500ml Vapam
1 yr.
2 yr.
3 yr.
4 yr.
5 yr.
Years from Treatment

Table I-7. Frequency of fungal isolations from basamid and methan sodium treated poles.

		Copper Sulfate	Isolation Frequency %[a] Distance above GL																
			0.3 m					1.3 m				2.3 m				3.3 m			
Treatment	Dose	Added	0 yr	2 yr	3 yr	4 yr	5 yr	2 yr	3 yr	4 yr	5 yr	2 yr	3 yr	4 yr	5 yr	2 yr	3 yr	4 yr	5 yr
Vapam	500 ml		0^{47}	0^{10}	0^{5}	0^{13}	0^{27}	0^{13}	0^{3}	0^{10}	0^{30}	0^{10}	0^{7}	0^{10}	3^{40}	0^{10}	0^{3}	0^{13}	0^{50}
Basamid	400 g		0^{14}	0^{7}	0^{0}	0^{0}	0^{27}	0^{23}	0^{0}	0^{0}	0^{13}	0^{7}	0^{25}	0^{20}	0^{27}	0^{14}	0^{25}	7^{7}	7^{33}
Basamid	400 g	+	0^{27}	0^{7}	0^{20}	0^{0}	0^{27}	0^{13}	0^{7}	0^{0}	0^{27}	0^{13}	0^{7}	0^{7}	0^{33}	0^{7}	0^{13}	0^{0}	0^{33}
Basamid	200 g		7^{20}	0^{27}	0^{0}	0^{0}	0^{33}	0^{33}	0^{0}	0^{7}	0^{40}	0^{27}	0^{14}	7^{33}	0^{33}	0^{40}	0^{0}	7^{27}	0^{33}
Basamid	200 g	+	0^{0}	0^{0}	0^{0}	0^{7}	13^{13}	13^{0}	0^{20}	0^{0}	7^{40}	0^{27}	0^{0}	0^{7}	0^{27}	0^{0}	0^{13}	0^{7}	0^{27}

a) Initial samples were shavings from the treatment hole. Values from other years represent 15 samples/treatment for Basamid and 30 for Vapam. Superscripts represent pecentage of nondecay fungi.

Effect of copper naphthenate and copper sulfate on release of MITC from Basamid in Douglas-fir poles: While Basamid will eventually release a sufficient quantity of MITC to control any decay fungi present, there is some concern about the length of time required for decomposition to produce this chemical. This is of greatest concern in poles with active decay since the decay fungus can continue to degrade the wood until the chemical decomposes and moves through the wood at levels sufficient to provide inhibition. One approach to accelerating the rate of Basamid decomposition is to add copper compounds. A number of previous tests have shown that copper sulfate markedly enhances the initial rate of Basamid decomposition. While the rate eventually declines to the same level found in treatments with Basamid alone, the initial rise may be sufficient to rapidly eliminate fungi. One problem with using copper sulfate would be the need to register this material for application to wood as a remedial treatment. Ideally, the accelerant would be either a chemical that is not considered to be a fungicide or one that already has a label for wood application. Cooperators at Chemical Specialties Incorporated suggested that we look at the potential for using copper naphthenate as the Basamid decomposition accelerant. This compound is widely used as a topical preservative and is labeled for wood use.

Preliminary experiments indicated that copper naphthenate markedly increased MITC release from Basamid and we installed a field test to confirm the test results. Douglas-fir poles (250 to 300 mm in diameter by 1.8 m long) were set to a depth of 0.6 m at the Corvallis test site. Three steeply angled holes were drilled beginning at groundline and moving upward 150 mm and around the pole 120 degrees. Two hundred grams of Basamid was equally distributed among the three holes. One set of three poles received no additional treatment while three received 20 grams of copper sulfate and another three received 20 grams of copper naphthenate. The holes were plugged with tight fitting wooden dowels.

The poles were sampled 1 year after treatment by removing increment cores from three equidistant points around each pole at sites 0.3, 1.3 and 2.3 m above the groundline. The outer and inner 25 mm of each increment core was placed into 5 ml of ethyl acetate. After 48 hours the wood was removed, oven-dried and weighed (nearest 0.01 g). A sub-sample of the extract was then analyzed for MITC by gas chromatography as described previously in this report.

Table I-8. Residual levels of MITC in Douglas-fir poles 1 year after treatment with Basamid alone or amended with copper sulfate or copper naphthenate.

Chemical Additive	MITC Content (ug/g of wood)[a]					
	0.3 m		1.3 m		2.3 m	
	inner	outer	inner	outer	inner	outer
None	18 (13)	16 (33)	0 (0)	0 (0)	0 (0)	3 (8)
copper sulfate	103 (79)	55 (86)	4 (6)	0 (0)	0 (0)	0 (0)
Cu naphthenate	33 (19)	41 (54)	0 (0)	0(0)	2 (5)	6 (19)

[a] Values represent means of 9 analyses. Numbers in parentheses represent one standard deviation.

MITC levels in the poles were generally highest in the poles treated with Basamid amended with copper sulfate, followed by those receiving Basamid plus copper naphthenate (Table I-8). MITC levels were generally elevated 0.3 m above ground, but little or no chemical was detected above this zone. In general, the variation in chemical distribution as shown by the standard deviations, was quite high in all treatments. The results from treatments with Basamid alone and Basamid plus copper sulfate are consistent with those found in previous field trials. Although the MITC levels found in the copper naphthenate supplemented treatments were only half those found with copper sulfate, they were still twice those found with Basamid alone, suggesting that copper naphthenate enhanced MITC release rates.

Culturing from increment core segments that remained after removing the inner and outer 25 mm revealed that 5 of 81 cores contained decay fungi (Table I-9). Three of these cores were removed from 0.3 m above the groundline in poles treated with basamid plus copper naphthenate, while the remainder were cultured from cores removed 1.3 m above ground in poles treated with copper sulfate. All of the poles contained non-decay fungi, although the distribution was somewhat variable. The presence of viable decay fungi in poles receiving the copper supplements is perplexing, particularly given the higher levels of MITC detected in adjacent zones of these same cores.

Table I-9. Fungal colonization in increment cores removed from Douglas-fir poles 1 year after treatment with Basamid alone or amended with copper sulfate or naphthenate.

Chemical Treatment	Fungal Colonization (%)[a]		
	0.3 m	1.3 m	2.3 m
None	0^{11}	0^{11}	0^{11}
Copper sulfate	0^{11}	22^{33}	0^{44}
Copper naphthenate	33^{33}	0^{22}	0^{44}

a. Values represent means of 9 cores per treatment per height above groundline. Values in superscripts represent percentage of cores containing non-decay fungi.

B. Field Performance of Diffusible Internal Treatments

Volatile chemicals have provided excellent protection against internal decay, but there are applications where the odor and volatility of these chemicals makes them unsuitable. In addition, many utilities object to the toxicity of these chemicals. One alternative to fumigants is the use of diffusible fungicides, primarily boron or fluoride. These chemicals move through the wood with moisture and have a long history of successful use as fungicides. At the time of their registration in the U.S. however, there was relatively little data on the field performance of these systems in wood poles. As a result, we have initiated a series of field and laboratory trials to assess various aspects of the performance. Three formulations have been evaluated: fused borate rods, sodium fluoride rods, and sodium fluoride/sodium octaborate tetrahydrate rods. The results of these trials are reported below.

Effect of glycol on movement of boron from fused borate rods applied to Douglas-fir poles: Boron has many excellent attributes as a fungicide and insecticide. The low toxicity of this chemical also makes boron especially attractive for wood applications. The need for moisture for boron diffusion to occur is a major drawback to the use of this chemical where relatively rapid decay control is required. One suggested solution to this problem is the addition of glycol to accelerate boron release. This approach is already commercially employed with glycol based boron formulations that are sold for remedial treatments of decay in buildings, but there is little data available on the effects of these treatments in larger wood structures such as poles. To evaluate the potential for supplementing boron rods with glycol we established the following laboratory and field trials.

Laboratory trials: Douglas-fir heartwood blocks (38 by 88 by 150 mm long) were oven-dried, weighed and then pressure soaked with water. The blocks were then dried to produce target moisture contents of 30 or 60 %. The blocks were then dipped in molten paraffin to retard further moisture loss. An additional set of blocks was conditioned to 15 % moisture content without an initial soaking period, then similarly coated with paraffin. The blocks were stored at 5 C for a minimum of 4 weeks to allow for more uniform moisture distribution following waxing.

A single 9.5 or 11.1 mm by 60 mm long hole was drilled at the mid-point 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, or glycol was added to each hole. The holes were plugged with rubber serum caps and incubated at room temperature (23 to 25 C) for 8 or 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 on either side of and away from the original treatment hole. These sections were oven dried overnight (54 C), then sanded to minimize the potential for boron carry-over during sawing. The sanded surfaces were 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 mess screen and hot water extracted. The resulting extract was analyzed by either ion-coupled plasma spectroscopy (ICP) or the azomethine H method.

Boron penetration improved markedly with increasing moisture content (Figures I-4 - I-14) . Penetration was virtually complete (>95 %) eight weeks after treatment 60 mm from the treatment hole in blocks conditioned to 60 % MC except at the highest Boracol 40 dosage. It is unclear why this formulation did not enhance boron diffusion to the same extent as lower levels of the same formulation.

Boron diffusion in blocks conditioned to 15 % MC was generally limited to the first 25 mm around the treatment hole. Boron penetration in the absence of glycol or water was nil, reflecting the inability of boron to diffuse through wood in the absence of free water. Even when boron penetration was noted, the percentage 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 level, the degree of penetration was still less than 20 % of the cross section. The results suggest that glycol, either alone or in combination with boron, does not enhance the diffusion of boron from fused borate rods in drier wood. The results compare favorably with previous studies of boron diffusion at various wood moisture contents.

Boron diffusion was substantially greater in blocks conditioned to 30 % MC , in some instances approaching 100 % penetration 25 mm from the original treatment hole. Once again, boron penetration was poorest in blocks that did not receive any supplemental moisture or glycol. In some cases, however, boron penetration was noted along the length of blocks that did not receive water or glycol. We believe this abnormal penetration was due either to moisture variations in some blocks or because the treatment moved out of the treatment hole along the outside of the wood beneath the wax and penetrated the ends of the blocks. Even in these blocks, the amount of penetration away from the treatment hole was minimal. The addition of ethylene glycol alone had the most substantial effect on boron movement at 30 % MC, although all five of the boron/glycol treatments produced some increase in boron movement. Boracare and Boracol 20 appeared to enhance penetration to the greatest extent followed by Timbor and Boracol 40.

All three glycol levels produced much greater penetration than the boron rods alone. Penetration in glycol treatments ranged from 60 to 80 % of the cross section 60 mm away from the original treatment hole. Boron penetration at 60 mm in the remaining treatments was generally lower than the glycol treatment except for the higher loading of Boracol 40. These results suggest that the boron in the glycol somehow interfered with boron release from the rods. The enhancement of boron release with glycol alone was interesting. One might expect boron to move further when applied in an existing solubilized form, but this apparently did not occur, suggesting that the ability to

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 mess screen and hot water extracted. The resulting extract was analyzed by either ion-coupled plasma spectroscopy (ICP) or the azomethine H method.

Boron penetration improved markedly with increasing moisture content (Figures I-4 - I-14) . Penetration was virtually complete (>95 %) eight weeks after treatment 60 mm from the treatment hole in blocks conditioned to 60 % MC except at the highest Boracol 40 dosage. It is unclear why this formulation did not enhance boron diffusion to the same extent as lower levels of the same formulation.

Boron diffusion in blocks conditioned to 15 % MC was generally limited to the first 25 mm around the treatment hole. Boron penetration in the absence of glycol or water was nil, reflecting the inability of boron to diffuse through wood in the absence of free water. Even when boron penetration was noted, the percentage 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 level, the degree of penetration was still less than 20 % of the cross section. The results suggest that glycol, either alone or in combination with boron, does not enhance the diffusion of boron from fused borate rods in drier wood. The results compare favorably with previous studies of boron diffusion at various wood moisture contents.

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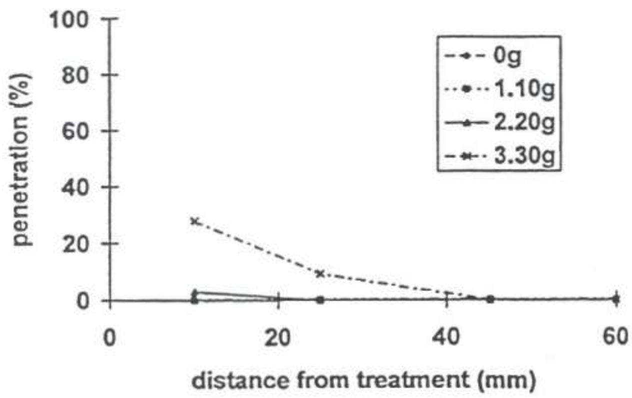
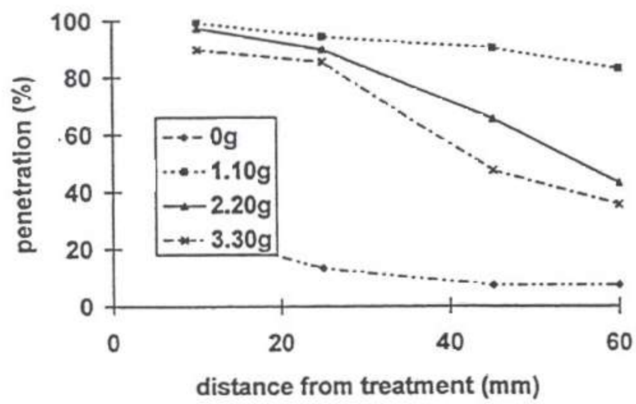


Ethylene glycol, 30% MC, 8 weeks



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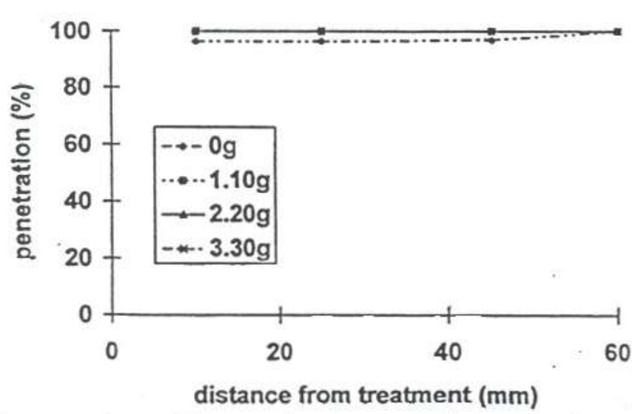


Figure I-4. Penetration of boron in cross sections cut from various distances from holes drilled in Douglas-fir heartwood blocks conditioned to 15. 30 or 60% moisture content and treated 8 weeks earlier with fused boron rod plus selected levels of polyethylene glycol to produce a dosage of 3.1 g boric acid equivalent per block.

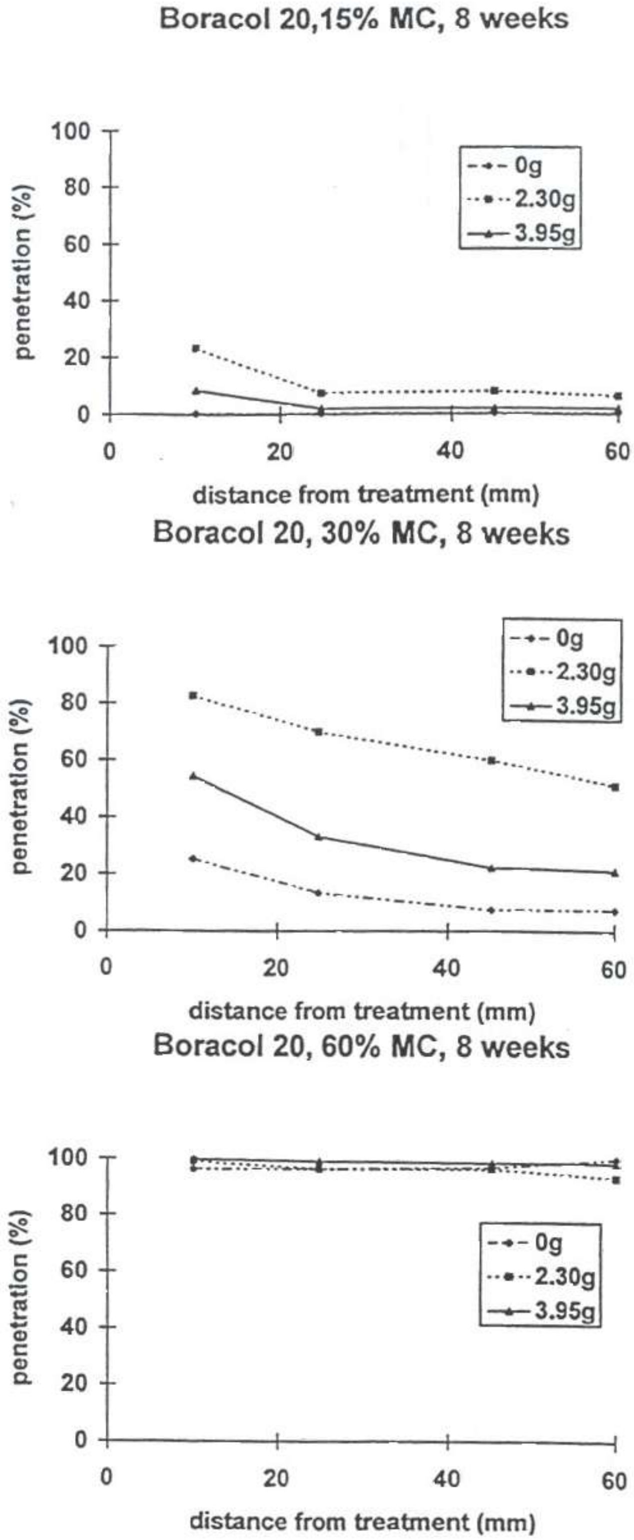


Figure I-5. Penetration of boron in cross sections cut from various distances from holes drilled in Douglas-fir heartwood blocks conditioned to 15. 30 or 60% moisture content and treated 8 weeks earlier with fused boron rod plus selected levels of Boracol 20 to produce a dosage of 3.1 g boric acid equivalent per block.

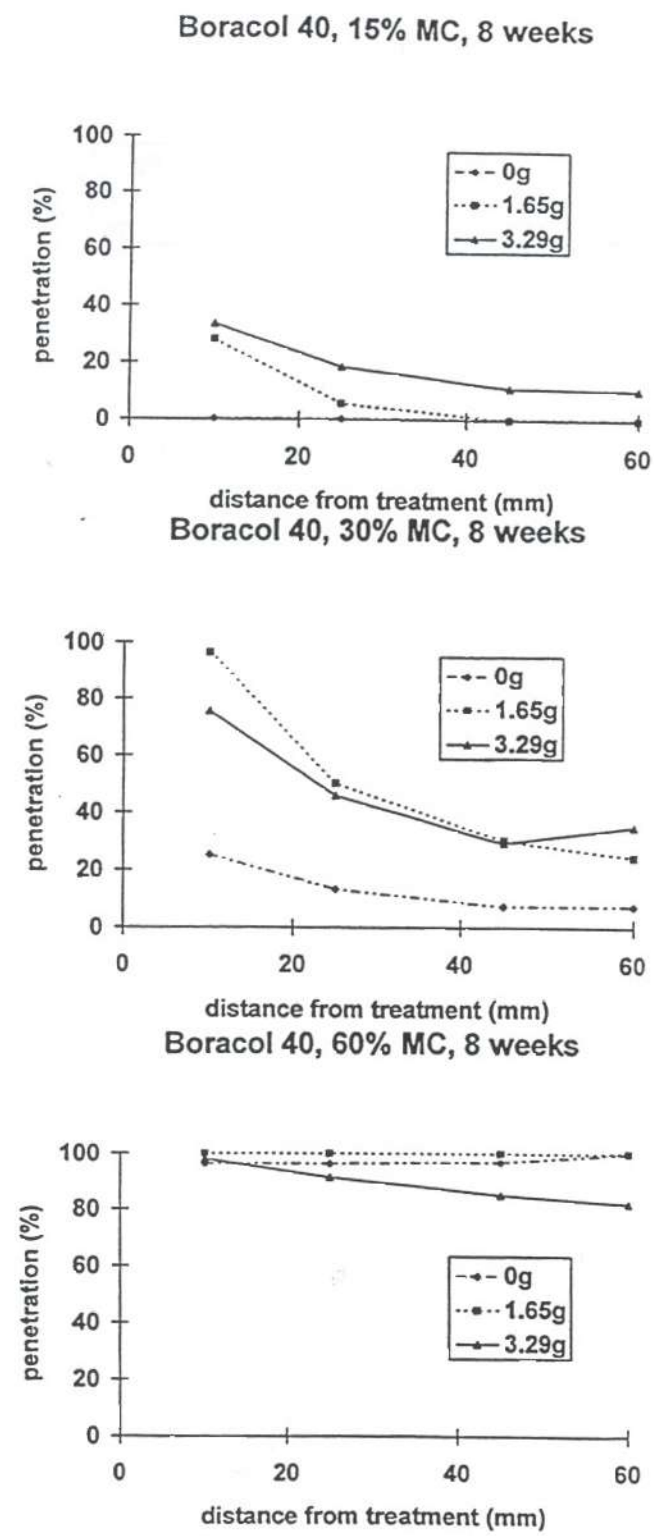


Figure I-6. Penetration of boron in cross sections cut from various distances from holes drilled in Douglas-fir heartwood blocks conditioned to 15. 30 or 60% moisture content and treated 8 weeks earlier with fused boron rod plus selected levels of Boracol 40 to produce a dosage of 3.1 g boric acid equivalent per block.

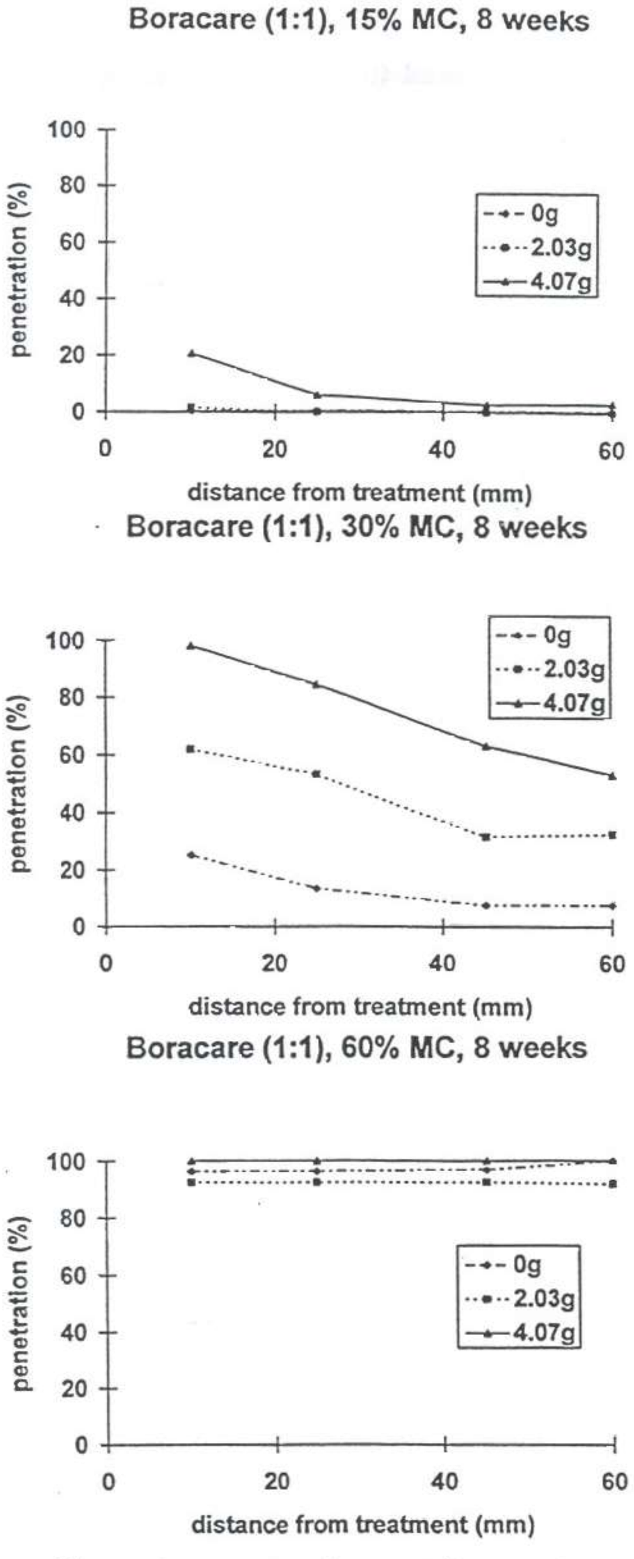


Figure I-7. Penetration of boron in cross sections cut from various distances from holes drilled in Douglas-fir heartwood blocks conditioned to 15. 30 or 60% moisture content and treated 8 weeks earlier with fused boron rod plus selected levels of 10% Timbor to produce a dosage of 3.1 g boric acid equivalent per block.

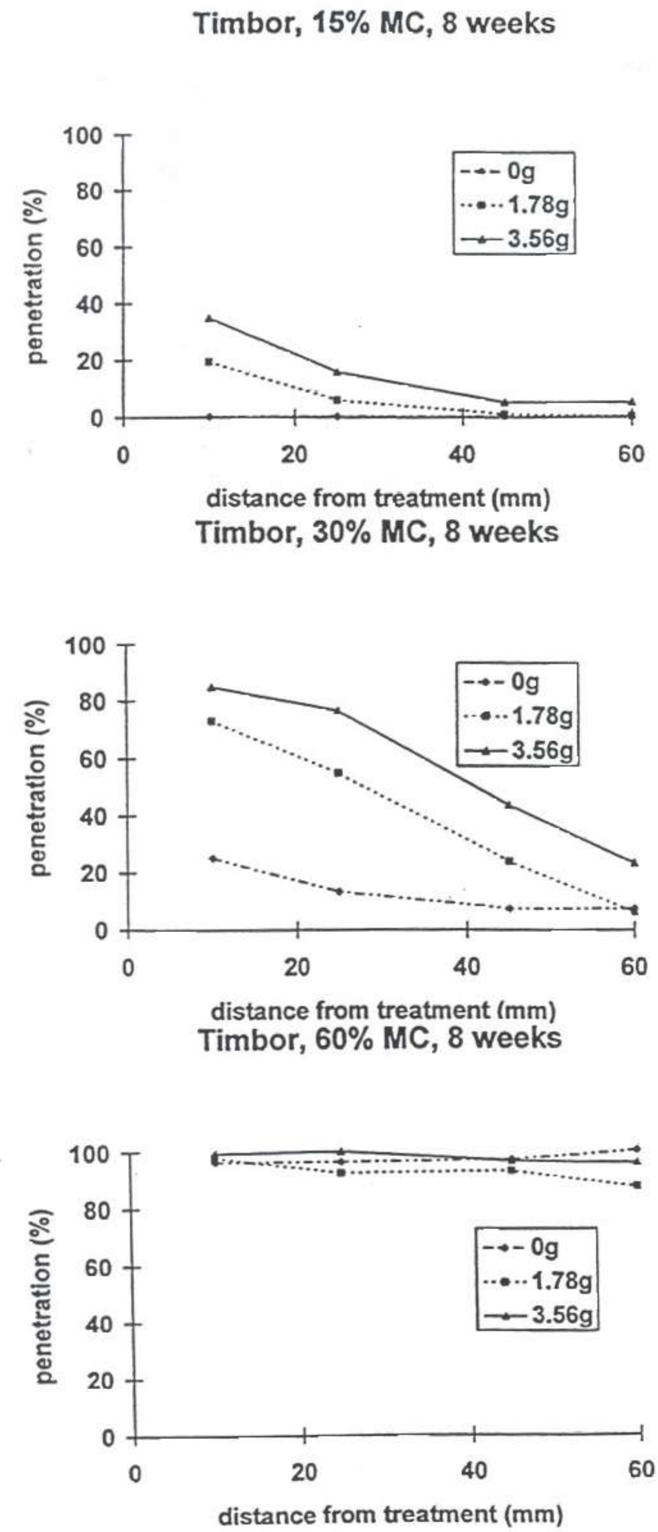


Figure I-8. Penetration of boron in cross sections cut from various distances from holes drilled in Douglas-fir heartwood blocks conditioned to 15. 30 or 60% moisture content and treated 8 weeks earlier with fused boron rod plus selected levels of Boracare to produce a dosage of 3.1 g boric acid equivalent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

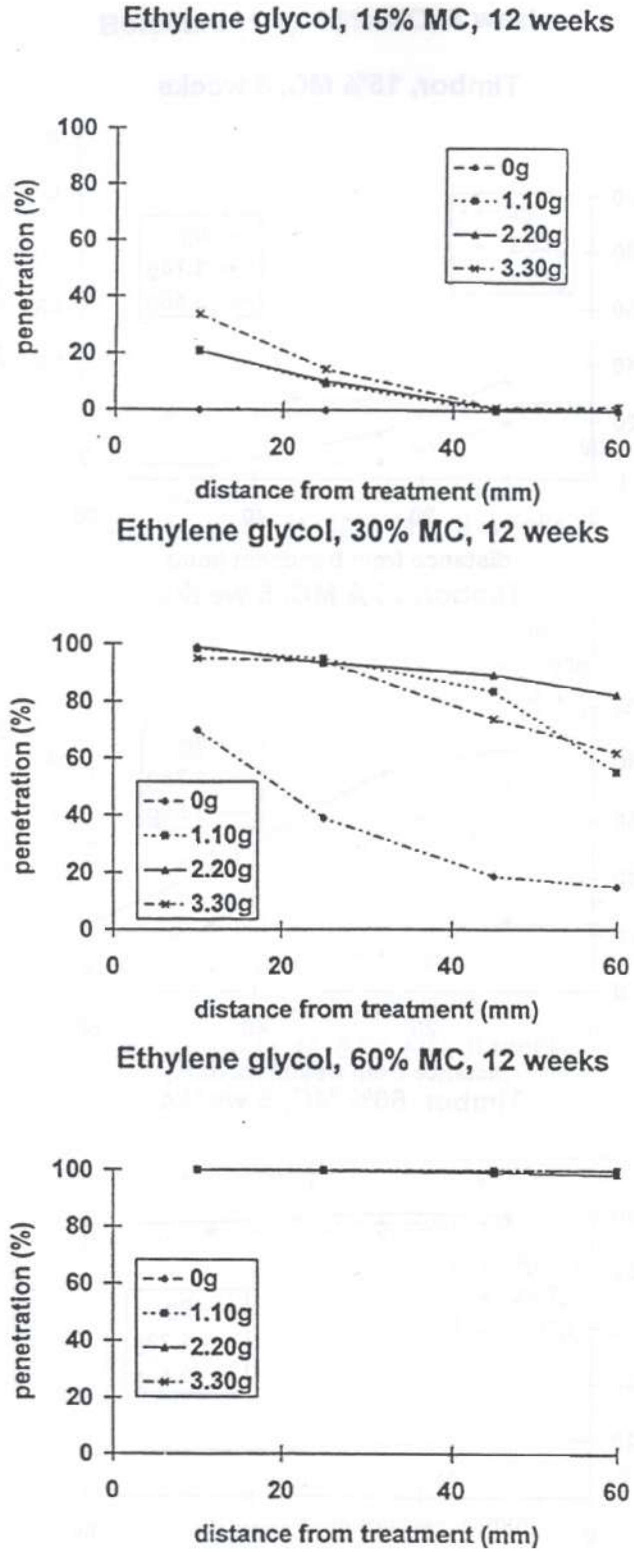
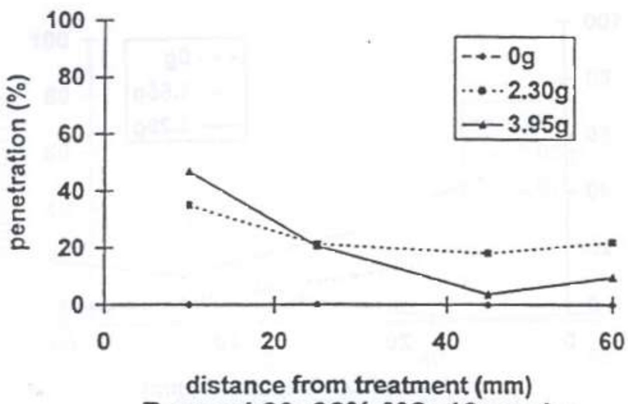
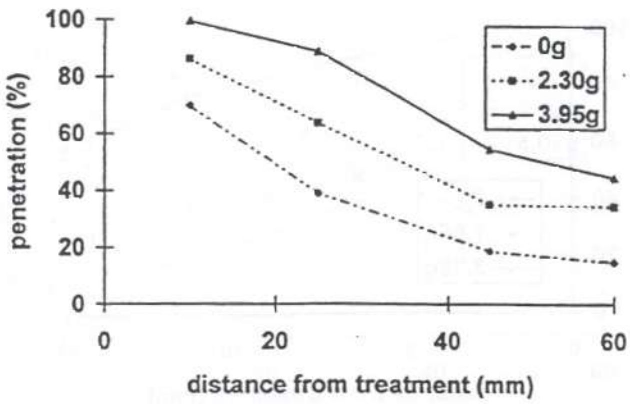


Figure I-9. Penetration of boron in cross sections cut from various distances from holes drilled in Douglas-fir heartwood blocks conditioned to 15. 30 or 60% moisture content and treated 12 weeks earlier with fused boron rod plus selected levels of polyethlyene glycol to produce a dosage of 3.1 g boric acid equivalent per block.

Boracol 20,15% MC, 12 weeks



Boracol 20, 30% MC, 12 weeks



Boracol 20, 60% MC, 12 weeks

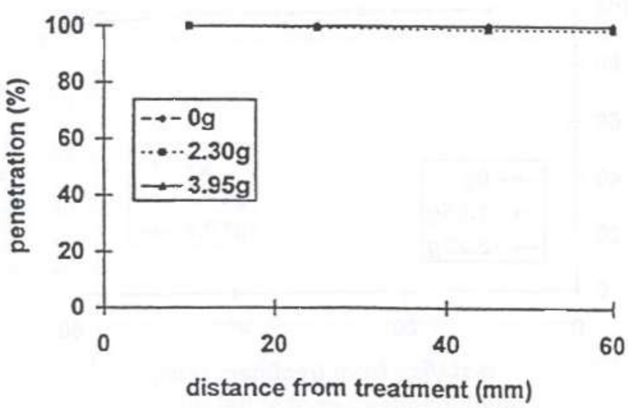
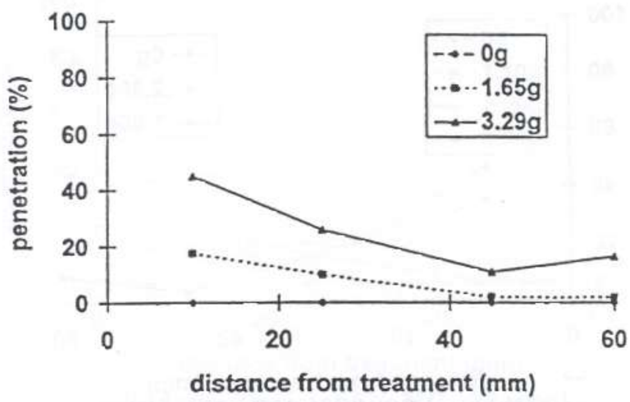
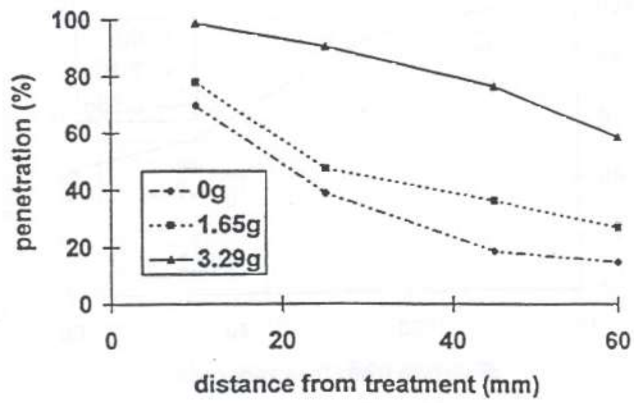


Figure I-10. Penetration of boron in cross sections cut from various distances from holes drilled in Douglas-fir heartwood blocks conditioned to 15. 30 or 60% moisture content and treated 12 weeks earlier with fused boron rod plus selected levels of Boracol 20 to produce a dosage of 3.1 g boric acid equivalent per block.

Boracol 40, 15% MC, 12 weeks



Boracol 40, 30% MC, 12 weeks



Boracol 40, 60% MC, 12 weeks

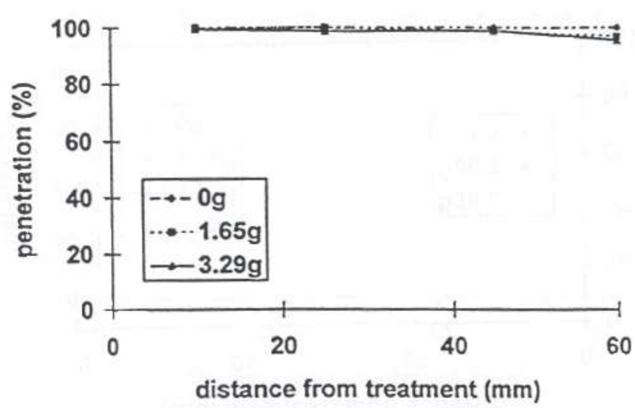
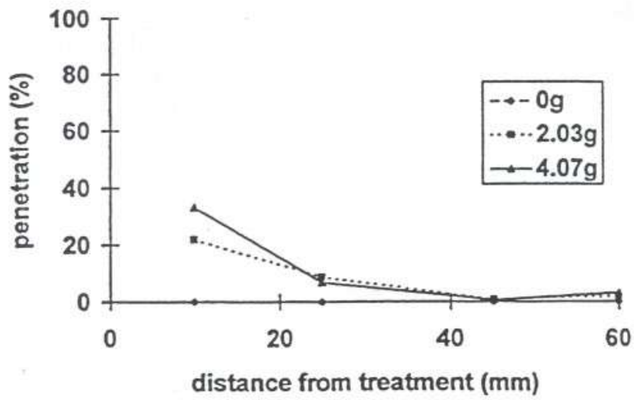
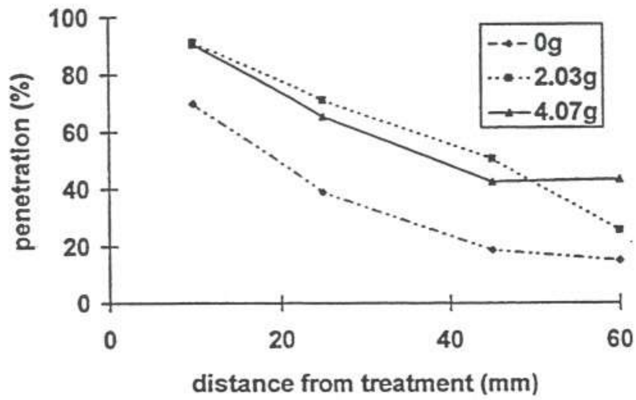


Figure I-11. Penetration of boron in cross sections cut from various distances from holes drilled in Douglas-fir heartwood blocks conditioned to 15. 30 or 60% moisture content and treated 12 weeks earlier with fused boron rod plus selected levels of Boracol 40 to produce a dosage of 3.1 g boric acid equivalent per block.

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



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



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

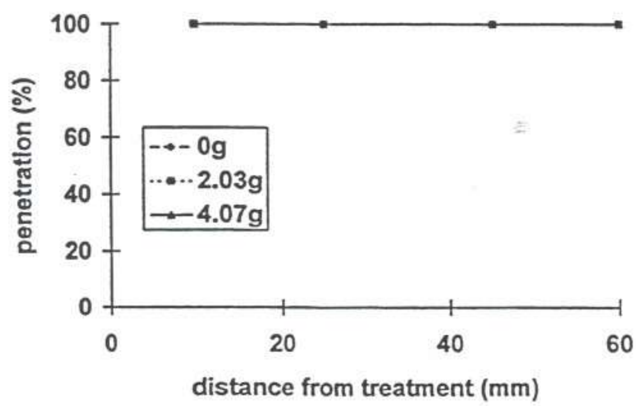


Figure I-12. Penetration of boron in cross sections cut from various distances from holes drilled in Douglas-fir heartwood blocks conditioned to 15. 30 or 60% moisture content and treated 12 weeks earlier with fused boron rod plus selected levels of Boracare to produce a dosage of 3.1 g boric acid equivalent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

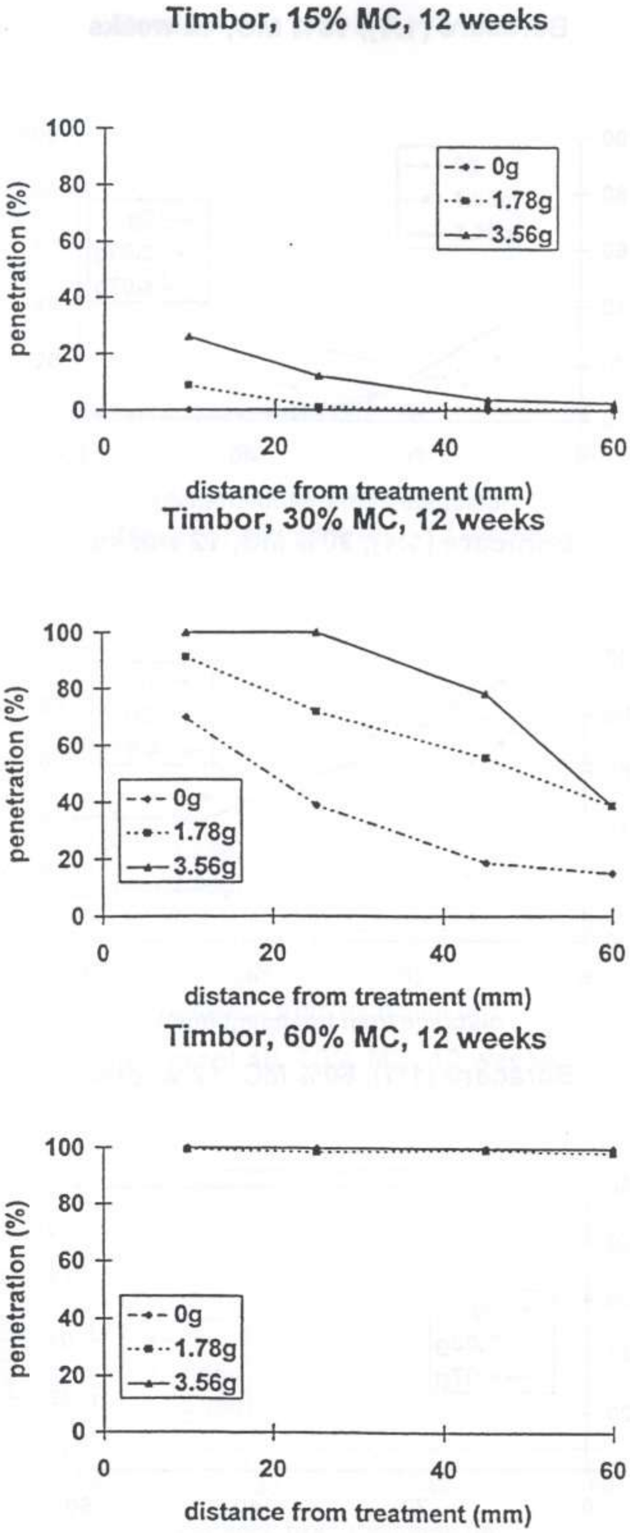
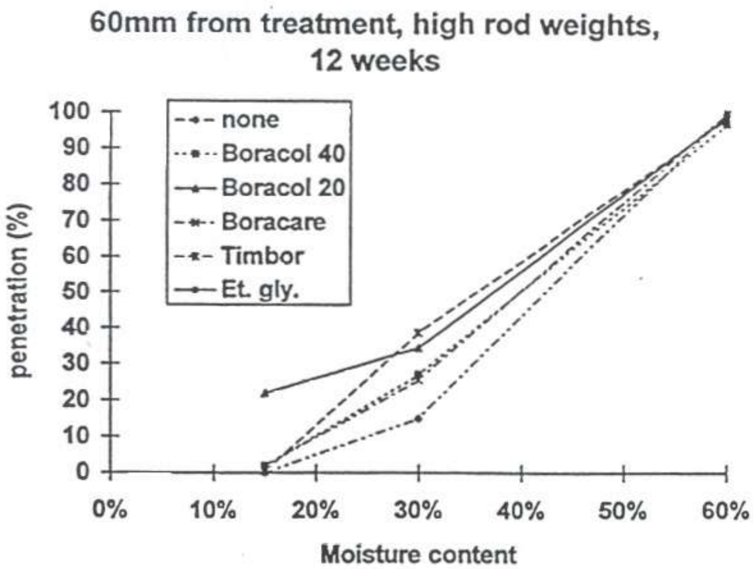


Figure I-13. Penetration of boron in cross sections cut from various distances from holes drilled in Douglas-fir heartwood blocks conditioned to 15. 30 or 60% moisture content and treated 12 weeks earlier with fused boron rod plus selected levels of 10% Timbor to produce a dosage of 3.1 g boric acid equivalent per block.



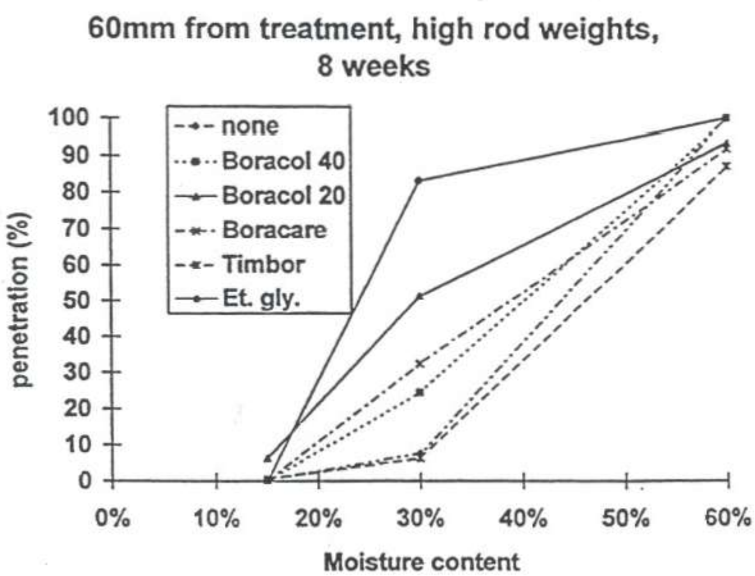


Figure I-14. Boron penetration 60 mm from the ends of Douglas-fir heartwood blocks 8 or 12 weeks after application of various boron treatments.

solubilize the boron rod may have been a more important factor than the boron content of the glycol formulation.

Boron levels tended to increase with incubation time (12 weeks), although the differences were sometimes slight. Penetration was virtually complete in blocks conditioned to 60 % MC, reflecting the ability of boron to move with free water.

Boron movement in blocks conditioned to 15 % MC appeared to increase slightly between 8 and 12 weeks in blocks receiving both Boracol treatments, but changed little in the other treatments. The lack of a substantial time effect likely reflects the relatively short period after treatment when free water was present for diffusion. Increasing the incubation period would have little effect at this moisture level.

The results indicate that increasing moisture contents exert a greater influence on boron release from fused boron rods than glycol additives. While glycol additives did improve boron diffusion, the effect was most beneficial when the wood was at the fiber saturation point (30 % MC). At this moisture level, the addition of any free liquid immediately enhances the prospects for diffusion. The added liquid is rapidly dispersed at lower MC's, and is unavailable for diffusion, while the supplemental liquid is unnecessary at higher moisture levels.

Chemical analyses have also been completed. Because of analytical limitations, two methods of analysis were employed. The majority of samples were analyzed by ICP, but the remaining samples were analyzed using the azomethine H method. Duplicate analysis of split samples by both methods suggested that the ICP results were somewhat higher. The differences, however, were generally slight and should not affect the data interpretation.

As expected, boron levels at a given distance from the treatment site generally increased with moisture content as well as incubation period, although there were some notable exceptions (Table I-10). Boron levels in the 15 % MC blocks were generally well below those required for fungal inhibition. For the purposes of this discussion we will assume that levels above 1.1 kg/m^3 will provide fungal inhibition. Using this level as a guide, only the 10 mm zone from the 2.1 g borate rod plus 3.3 g of ethylene glycol and the 3.95 g Boracol 20 treatments contained enough boron in the 15 %MC blocks after 8 weeks. Diffusion improved slightly with an additional 4 weeks of incubation to the point where effective levels of boron were present at the 10 mm location in six of 20 treatment combinations at 15 % MC. Boron levels further away from the treatment zone were far below fungicidal levels. These results confirm those found using the indicator and illustrate the relatively minor effect of glycol addition on boron movement at lower moisture contents.

Boron levels in blocks equilibrated to 30 % moisture content were far higher than those at 15 %. The addition of glycol with or without boron had a marked effect on both the levels of boron detected and the distance to which this chemical diffused at effective levels. Boron levels 10 mm away from the treatment site were all above the minimum levels required for fungal

Table I-10. Boron retention 10-60 mm away from the treatment hole in blocks treated with various combinations of Impel rods and glycol mixtures. Values in bold were analyses by ICP and those in regular type by the azomethine method.

Treatment				8 Weeks			12 Weeks		
ID	Rod	Suppliment	Distance	15% MC	30% MC	60% MC	15% MC	30% MC	60% MC
				(kg BAE/m3 wood)			(kg BAE/m3 wood)		
1	2.1	None	10	0.03	1.67	5.05	**0.13**	**7.03**	**6.22**
			25	0.02	0.33	4.26	0.00	1.40	4.35
			45	0.02	0.09	3.89	0.00	**0.85**	0.42
			60	0.03	0.12	4.22	0.00	0.56	**5.51**
2	1.58	Boracol 40 1.65 g	10	**0.55**	**11.73**	**7.30**	**0.55**	**6.99**	**6.65**
			25	**0.07**	1.58	5.15	0.10	1.26	4.15
			45	0.00	0.45	4.46	0.04	**0.59**	3.90
			60	0.03	**0.78**	**5.18**	**0.22**	**0.71**	**5.60**
3	1.05	Boracol 40 3.29 g	10	**0.73**	**4.45**	**7.88**	**2.38**	**12.44**	**5.60**
			25	0.31	1.86	3.51	0.13	2.46	3.68
			45	0.22	1.74	3.47	**0.22**	0.72	3.29
			60	**0.27**	**1.92**	**3.81**	**0.41**	**1.48**	**8.20**
4	0	Boracol 40 3.29 g	10	**0.76**	**10.19**	**3.30**	**1.45**	**10.00**	**3.03**
			25	0.16	2.63	2.02	0.17	2.27	1.51
			45	**0.11**	0.83	1.91	**0.08**	0.67	1.43
			60	**0.11**	**2.62**	**3.09**	**0.15**	**0.78**	**2.30**
5	0	Boracol 40 1.65 g	10	**0.54**	**3.42**	**1.62**	**0.51**	**5.46**	**1.95**
			25	0.02	0.43	0.44	**0.16**	0.64	1.05
			45	**0.08**	0.07	0.92	0.05	**0.46**	1.14
			60	0.04	**0.17**	0.35	**0.18**	--	**1.79**
6	1.73	Boracol 20 2.30 g	10	**0.50**	**12.10**	**10.58**	**1.01**	**5.19**	**8.18**
			25	**0.24**	2.09	4.84	0.38	0.49	4.69
			45	**0.02**	0.18	3.25	0.27	0.31	3.53
			60	0.24	**3.10**	**5.42**	**0.91**	**0.78**	**5.43**
7	1.47	Boracol 20 3.95 g	10	**0.67**	**6.44**	**8.77**	**1.33**	**9.51**	**7.31**
			25	0.15	1.15	4.56	0.10	1.00	3.80
			45	**0.36**	**0.86**	0.03	0.03	0.13	3.86
			60	0.10	0.99	**5.47**	**0.10**	**0.45**	**5.81**
8	0	Boracol 20 3.95 g	10	**1.25**	**5.89**	**2.24**	**3.11**	**5.36**	**1.90**
			25	**0.15**	**1.33**	**1.44**	1.14	2.38	1.26
			45	**0.12**	**0.51**	**1.24**	1.25	1.64	1.34
			60	**0.15**	**0.77**	**1.65**	**0.37**	**1.15**	**2.10**
9	0	Boracol 20 2.30 g	10	**0.23**	**2.43**	**1.29**	**0.80**	**2.95**	**1.17**
			25	**0.03**	5.93	0.30	0.20	0.52	0.81
			45	0.00	2.09	0.83	0.16	0.28	0.83
			60	--	**0.56**	**1.16**	**0.30**	--	**1.35**
10	1.76	Boracare (1:1) 2.03 g	10	**0.28**	**5.57**	**7.86**	**8.27**	**9.55**	**0.46**
			25	**0.26**	1.33	4.77	5.02	0.93	0.00
			45	0.03	0.53	3.29	3.59	0.12	0.00
			60	0.08	**1.15**	**4.91**	**5.73**	**0.46**	**0.13**
11	1.43	Boracare (1:1) 4.07 g	10	**0.35**	**6.52**	**7.22**	**0.65**	**14.50**	5.09
			25	0.02	0.03	0.70	0.06	2.92	3.92
			45	**0.12**	0.86	1.36	0.03	0.80	0.82
			60	0.04	**1.23**	**4.72**	**0.08**	**1.03**	**5.57**
12	0	Boracare (1:1) 4.07 g	10	**0.88**	**4.39**	**2.35**	**2.88**	**6.90**	**2.12**
			25	0.12	1.30	1.44	0.05	0.75	1.97
			45	0.07	**0.97**	1.25	0.02	0.16	1.28
			60	**0.19**	**0.73**	**1.97**	**0.21**	**0.52**	**2.10**
13	0	Boracare (1:1) 2.03 g	10	**0.21**	**3.74**	**1.30**	**0.39**	1.75	0.76
			25	0.05	1.32	0.77	0.11	**0.46**	**0.97**
			45	0.06	0.93	0.68	0.09	0.09	0.75
			60	**0.08**	**0.23**	**1.06**	**0.07**	**0.19**	**1.31**
14	1.95	Timbor (10%) 1.78 g	10	**0.41**	**10.23**	**9.70**	**0.15**	**7.76**	**7.65**
			25	--	--	--	--	1.18	4.18
			45	**0.09**	**0.32**	2.74	0.02	0.23	4.59
			60	0.00	0.07	**3.83**	0.03	**0.30**	**7.53**

Table I-10 continued.

Treatment				8 Weeks			12 Weeks		
ID	Rod	Suppliment	Distance	15% MC	30% MC	60% MC	15% MC	30% MC	60% MC
				(kg BAE/m3 wood)			(kg BAE/m3 wood)		
15	1.81	Timbor (10%)	10	0.70	4.14	9.96	**0.28**	**12.37**	**7.38**
		3.56 g	25	0.04	0.57	5.30	0.12	1.47	5.81
			45	0.10	0.33	3.64	0.03	**0.34**	5.68
			60	0.17	0.60	5.92	0.12	0.59	**6.79**
16	0	Timbor (10%)	10	--	**2.46**	**1.09**	--	**1.83**	**1.09**
		3.56 g	25	--	0.48	0.69	0.10	0.58	0.70
			45	0.00	0.15	0.66	0.05	**0.23**	0.74
			60	0.02	--	**0.99**	--	--	**0.28**
17	0	Timbor (10%)	10	--	--	--	--	--	--
		1.78 g	25	--	0.24	0.75	--	0.32	0.40
			45	--	--	0.32	**0.04**	--	0.38
			60	**0.03**	--	--	**0.05**	--	--
18	2.1	Ethylene Glycol	10	**0.08**	**8.88**	**7.84**	**0.30**	**13.04**	**6.63**
		1.10 g	25	0.04	2.07	5.49	0.09	2.97	4.89
			45	**0.01**	0.36	4.35	**0.08**	0.89	4.67
			60	**0.02**	**0.22**	**5.74**	**0.00**	**1.84**	**6.38**
19	2.1	Ethylene Glycol	10	**0.18**	**9.15**	**8.81**	**0.64**	**11.03**	**7.59**
		2.20 g	25	0.07	1.31	2.58	**0.06**	2.93	4.40
			45	**0.00**	0.48	1.39	0.09	**0.85**	0.46
			60	0.00	**0.60**	7.11	**0.09**	1.24	**6.60**
20	2.1	Ethylene Glycol	10	**1.13**	**7.41**	**7.56**	**1.29**	**3.54**	**8.69**
		3.30 g	25	--	2.00	5.32	0.10	1.14	6.37
			45	**1.63**	1.67	4.25	0.11	2.51	4.92
			60	0.42	**5.67**	**6.20**	**0.08**	**11.96**	**6.22**

inhibition 8 weeks after treatment and eight of 20 treatments contained more than 1.1 kg/m^3 25 mm from the treatment site. Boron levels tended to increase after an additional four weeks of incubation, although there were some variations. Boron levels 25 mm from the treatment site were above the threshold in 11 of 20 treatments at this sampling time. The addition of glycol with or without boron produced more variable effects on boron distribution. For example, boron levels in boron rod alone treatments were somewhat lower than those for the highest Boracol 40 treatment (these treatments contained 2.1 vs 3.1 % BAE) and the resulting boron levels in the wood were correspondingly lower for the rod alone treatment. The combination of boron rod and Boracol 40 produced slightly higher boron loadings near the surface and a protective boron level 60 mm from the treatment site in 30 % MC blocks. Boracol 20 plus rod treatments failed to provide similar enhanced boron movement despite the use of similar total boron levels, nor did combinations of Boracare or Timbor plus boron rods. Glycol alone appeared to consistently enhance boron movement from the rods, a trend that was consistent with the penetration measurements .

Boron movement in blocks at 60 % MC was generally more uniform than at either of the other two moisture contents. In a number of instances, boron levels were nearly uniform across the length of the sample, reflecting the benefits of free water for boron diffusion. Glycol addition, either alone or with boron, appeared to produce a slight improvement in boron levels at various distances from the treatment site, but the levels were generally four to five times that required for protection against fungal attack. As a result, application of glycol to wood at this moisture content is of questionable value since the rods alone result in more than adequate boron levels.

The results indicate that glycol addition to boron rods is most beneficial when the moisture levels are near the fiber saturation point. The benefits of glycol decline as water either becomes limiting or is available in excess. The relative benefits of glycol addition will therefore depend on the moisture content of the wood to which the boron rods are applied. Previous field trials suggest that moisture levels near groundline exceed the fiber saturation point during the wet winter months at the Corvallis site, but are below that level above the groundline. Thus, glycol has little value for ground contact application of borate rods nor will it prove useful for locations well above the groundline, where wood moisture levels would generally be below 30 %. The point for glycol usage may be where the moisture content is in transition. Under these regimes, glycol may aid in boron movement although the effect will be limited in distance from the original treatment site.

<u>Field Trials</u>: Diffusion of boron from fused borate rods alone and with borate or ethylene glycol additives: Corvallis test site: Douglas-fir poles sections (25 to 30 cm in diameter by 2.1 m long) were set to a depth of 0.6 m in the ground at the Corvallis test site. A series of three steeply sloping 20 mm diameter holes were drilled at equidistant points around the pole beginning at the groundline and moving upward 150 mm. The holes received 227 g of boron as boron rodalone or in combination with boron solution, boron/glycol solutionor glycol. The holes were then plugged with tight fitting wooden dowels.

The poles were sampled 1, 2, and 3 years after treatment by removing increment cores from sites located 300 mm below the groundline, at groundline, and 150 and 300 mm above groundline. The cores were divided into three equal segments and then ground to pass a 20 mesh screen. The resulting sawdust was analyzed for boron as described above.

Boron levels in these tests are expressed as % boric acid equivalent (BAE). For comparison, the threshold for fungal inhibition is generally believed to be 0.25 % BAE. For Douglas-fir, this would translate to 1.12 kg of boric acid/m^3 of wood. Boron levels in poles receiving boron rods only were below the threshold at all sampling locations one year after treatment, and, with the exception of the groundline zone, generally increased over the intervening 2 years (Figures I-15 - I-18) . Boron levels were above the threshold below the groundline only in the inner zone at the 2-year sampling point. Boron levels at groundline and 15 mm above groundline were well above the threshold 2 and 3 years after treatment . Boron levels

Figure I-15. Boron levels 30 cm below groundline in Douglas-fir poles treated with borates.

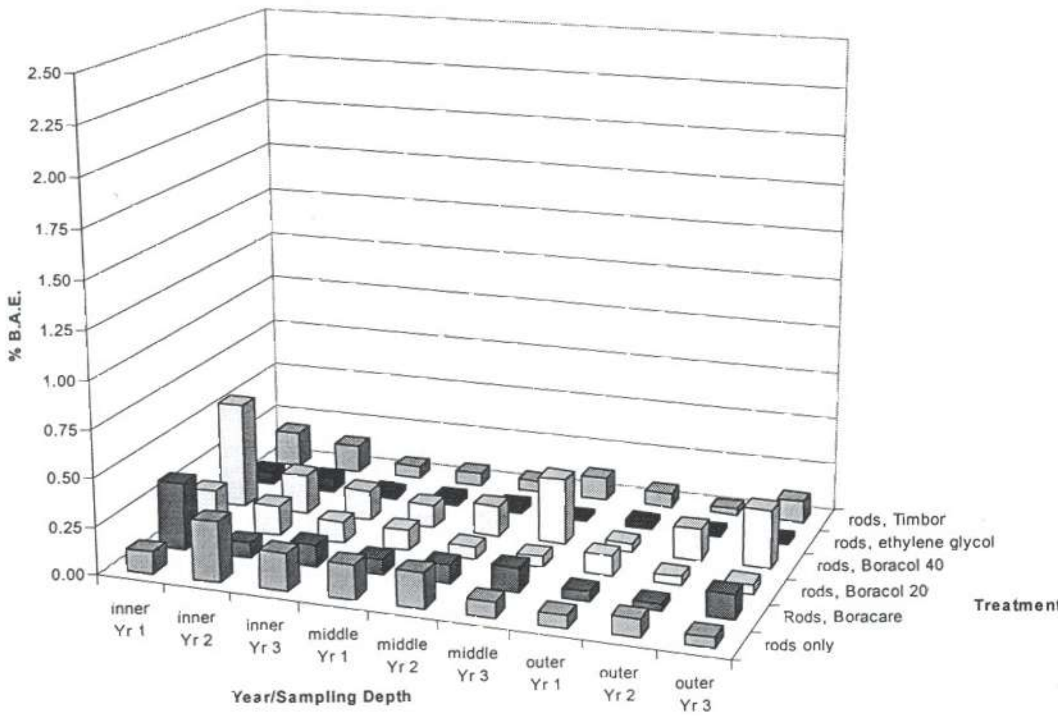


Figure I-16. Boron levels at groundline in Douglas-fir poles treated with borates.

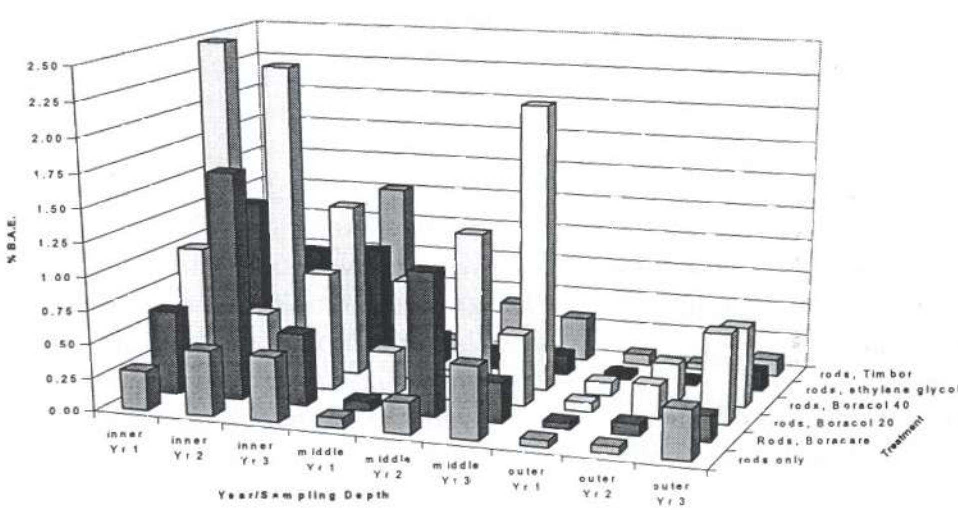


Figure I-17. Boron levels 15 cm above groundline in Douglas-fir poles treated with borates.

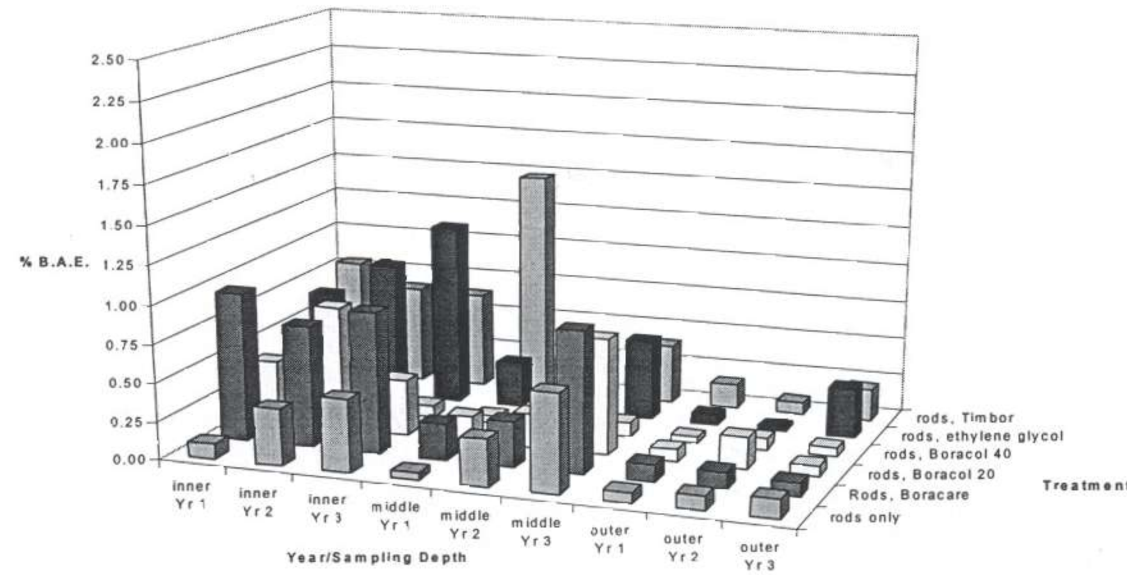
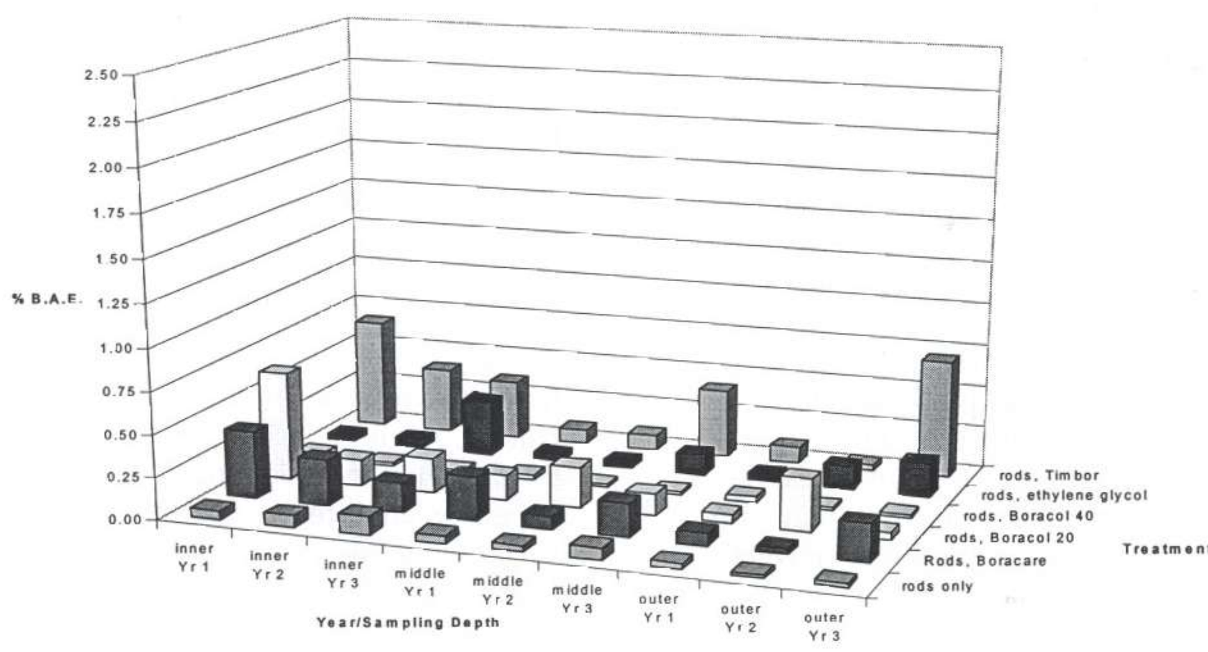


Figure I-18. Boron levels 30 cm above groundline in Douglas-fir poles treated with borates.



tended to be higher in the inner and middle zones, but there was some variation between sampling times.

The addition of glycol, glycol with boron or boron in water solution along with the rods resulted in markedly higher levels of boron in the inner zone below groundline 1 year after treatment, but this effect declined somewhat at the 2 and 3 year sampling. The higher moisture contents present below ground may have encouraged boron loss, negating the long term value of the glycol in this zone. Boron levels at the groundline and 15 cm above this zone continued to remain elevated over the 3 year test period in most treatments. This effect was most noticeable in the inner and middle zones and was more variable in the outer zone closer to the original pentachlorophenol in oil treatment. Boron levels 30 cm above the groundline were more variable than those closer to the groundline, reflecting the tendency for moisture content to decline with distance above ground. Boron levels 30 cm above groundline were well below the threshold for boron rod alone, boron rod plus Boracol 40, and boron rod plus ethylene glycol, but were at or near the protective level for boron rods plus Boracol 20 or Timbor. It is unclear why these two chemicals were associated with higher boron movement above the groundline, but the effect has remained consistent over the three sampling periods.

The results suggest that supplemental glycol compounds can enhance the movement of boron from borate rods. This effect is somewhat temporary below groundline, but this elevated boron level within the first year after treatment may be especially useful since it can arrest active decay occurring in this region. Declines in boron level below the threshold over time in the region must also be considered since fungi can then begin to re-invade the below- ground portions of the wood. Glycol compounds had a more persistent effect on boron levels at or above the groundline and it is here that these compounds probably have the greatest value for enhancing release. The results suggest that application of glycol with or without boron can increase the rates of boron release from boron rods, thereby accelerating fungal inhibition in these zones.

Movement of boron from fused borate rods: effect of moisture addition at time of treatment: Owego, NY test site: Fused borate rods provide an ideal method for applying a concentrated dosage of boron to the wood, but one problem with these treatments is the need for moisture for boron release. One approach to accelerating boron movement is to add small amounts of water to the treatment holes at the time the rods are applied. In 1991, we initiated a test to assess the effect of water addition on boron movement in Douglas-fir.

Pentachlorophenol treated Douglas-fir transmission poles in a line located near Owego, NY were pre-sampled by removing increment cores from sites near the groundline and culturing them on malt extract agar for the presence of decay fungi. The poles were then allocated so that six poles in each of four treatment groups had approximately the same level of fungal infestation.

Holes (20 mm in diameter by 200

mm long) were drilled at three equidistant points around the pole beginning at groundline and moving upward at 150 mm intervals. The poles received either three or six fused borate rods (120 or 240 g). Holes in one half of the poles receiving each boron dosage also received 150 ml of water equally distributed among the three holes, while the remainder were left dry to evaluate the benefits of supplemental moisture on boron release.

The poles were sampled 1, 3 and 7 years after treatment by removing three increment cores from three equidistant sites around the pole at groundline as well as 300 or 900 mm above the groundline. The treated zone was discarded and the remainder of the core was divided into inner and outer halves. The respective zones for a given height and treatment were combined and ground to pass a 20 mesh screen prior to hot water extraction. The extracts were analyzed by the azomethine H method. In addition to the chemical analysis, additional increment cores were removed from the same sampling locations 1 and 7 years after treatment for culturing.

Boron levels were generally quite high 1 year after treatment, and were well above the accepted threshold for fungal protection (Figure I-19). Chemical levels dropped rapidly between 1 and 3 years, particularly at the groundline. Boron levels were more variable between treatments above the groundline, but protective levels were present 0.3 m above ground in the high dosage treatments 3 and 7 years after treatment. There were few consistent differences in boron levels between the two dosages, although the levels were higher at the 0.3 m height in poles that received the higher dosage. Little or no boron was detected 0.9 m above groundline, indicating that the chemical was not capable of diffusing for long distances upward from the point of application.

Culturing revealed that 15 of the 24 poles contained decay fungi prior to treatment (Table I-11). Decay fungi were detected at the groundline in one pole one year after treatment with 120 g of borate rod without supplemental moisture. The presence of a very limited number of fungi one year after treatment with a water diffusible compound was not surprising given that these chemicals diffuse slowly with moisture. Chemical analysis confirmed that the boron levels in these poles were still below the toxic threshold in many locations within the pole. Sampling after 7 years, however, showed that three poles contained viable decay fungi at groundline, while two poles each were found to contain viable decay fungi 0.3 and 0.9 m above groundline. All but one of these poles was in the 120 g treatment without supplemental moisture. The remaining pole was in the 120 g treatment with moisture. The presence of viable decay fungi would imply that the lower dosage of boron produced an inadequate level of boron in the wood. More likely, however, the results imply that the lower dosage produces a more uneven distribution which allows decay fungi to survive in pockets within the poles. The poles in this test were fairly large Class 1 Douglas-fir poles that probably required more than the standard three-rod treatment. We will sample these poles at the 10 year point to determine if the incidence of decay fungi has increased.

Figure I-19. Boron levels at various locations in Douglas-fir poles 1,3 and 7 years after treatment with 120 or 240 g of fused borate rod per pole with or without supplemental water.

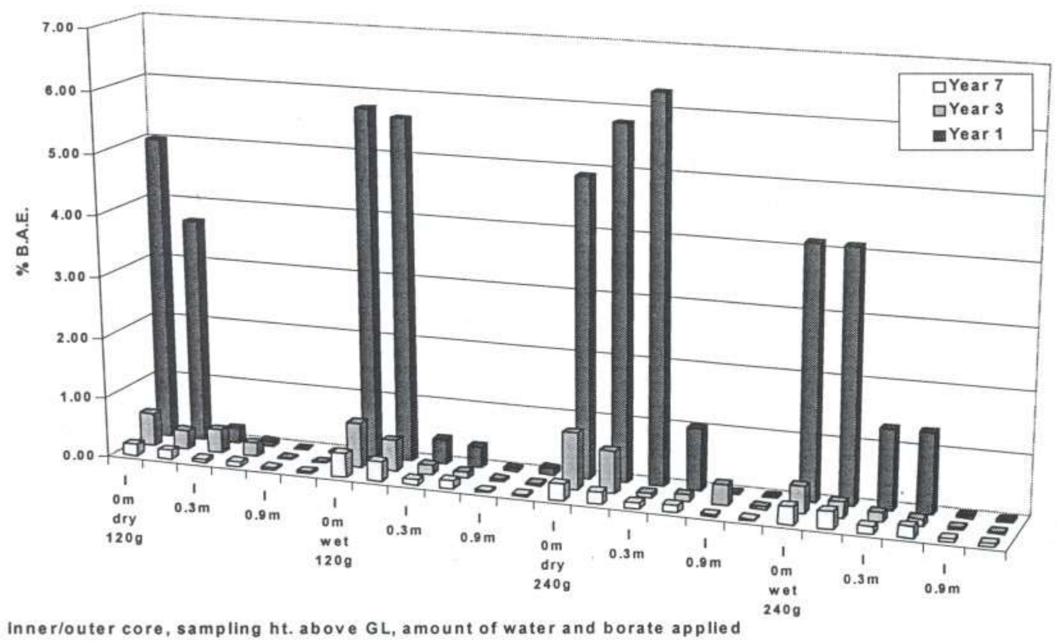


Table I-11. Isolation frequencies of decay and non-decay fungi in Douglas-fir poles prior to treatment and 1 and 7 years after application of 120 or 240 g of fused borate rod with or without supplemental water.

Dosage (g)	Water (+/-)	Degree of Fungal Colonization (%)[a]						
		Groundline			0.3 m		0.9 m	
		0 Yr	1 Yr	7 Yr	1 Yr	7 Yr	1 Yr	7 Yr
120	-	33^{6}	6^{6}	6^{94}	0^{22}	11^{89}	0^{17}	11^{61}
120	+	28^{81}	0^{11}	11^{72}	0^{22}	0^{39}	0^{6}	0^{44}
240	-	25^{89}	0^{17}	0^{78}	0^{11}	0^{61}	0^{0}	0^{17}
240	+	33^{87}	0^{7}	0^{67}	0^{20}	0^{56}	0^{13}	0^{61}

[a] Values represent frequencies of decay fungi from 18 cores per location. Superscripts denote frequency of non-decay fungi in the same cores.

Diffusion of boron from fused borate rods: Corvallis test site: When borate rods were first introduced into the U.S., we established a series of small scale pole section tests at our Peavy Arboretum test site. We have continued to monitor these tests to develop longer term data on boron movement and have established additional trials using this material.

In 1993, thirty pentachlorophenol treated Douglas-fir poles sections (250 to 300 mm in diameter by 2 m long) were internally treated with 180 or 360 g of fused borate rod applied to three holes drilled perpendicular to the grain direction beginning at groundline and moving upward at 150 mm increments and spiraling around the pole 120 degrees. Each treatment was replicated on ten poles (ten poles were left as non-treated controls). The poles were stored for 2 months before being set to a depth of 0.6 m at the Corvallis test site.

The poles were sampled 1, 3, 4 and 5 years after treatment by removing increment cores from sites 22.5, 45.0 and 60.0 cm above the highest treatment site as well as 7.5 and 15.0 cm below the groundline. The outer treated shell was discarded, then the remainder of the core was divided into outer and inner halves. The core sections from a given height and treatment were combined and ground to pass a 20 mesh screen. The resulting sawdust was extracted in hot water and this extract was analyzed for boron content. The first year samples were analyzed by ICP, while the 3 and 4 year samples were analyzed using the azomethine H method.

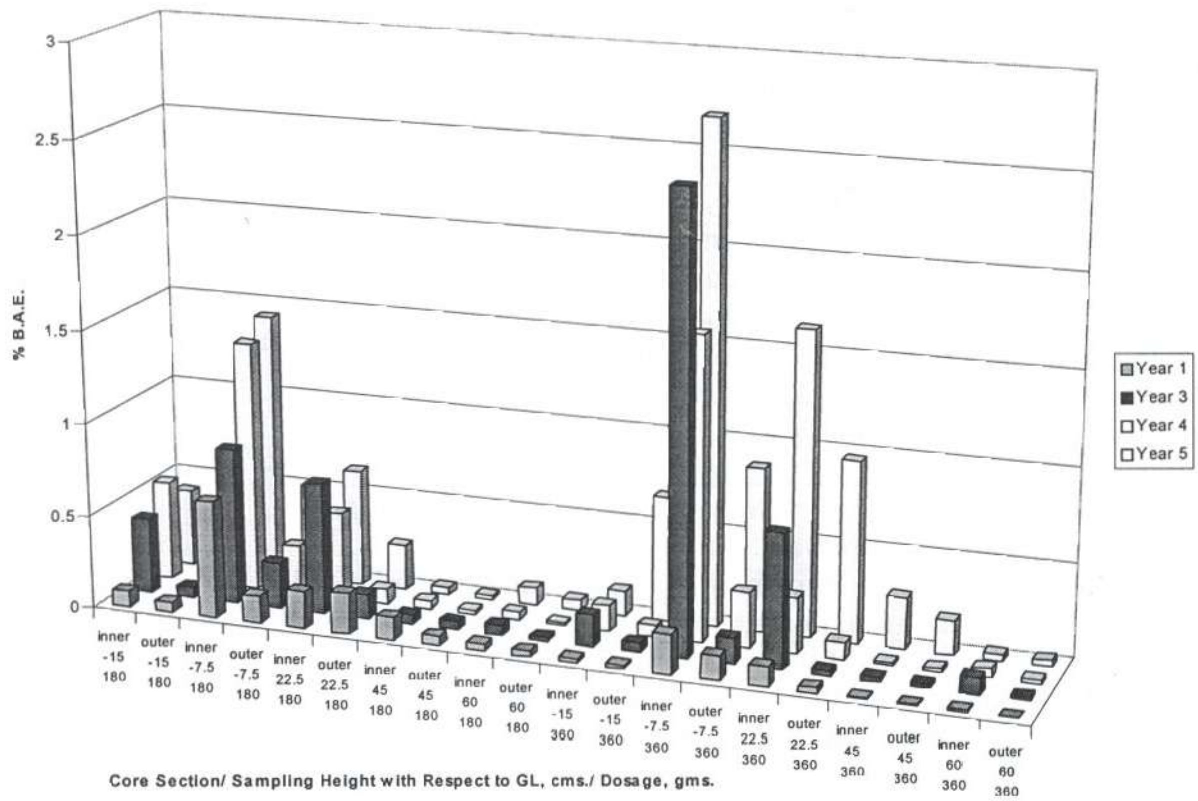
Boron was virtually non-detectable in control poles over the three sampling points (Table I-12) . Boron levels in the two treatment groups were somewhat variable. Boron levels tended to be higher in the inner halves of the cores, regardless of dosage. This trend suggests a general movement of chemical toward the center of the pole and away from the treated shell. This movement has important implications for protection since preferential movement inward would tend to conserve chemical, potentially increasing the length of time that boron would remain in the pole.

While the highest levels of boron were found just below the groundline in the 360 g dosage, boron levels further beneath the groundline were much lower in poles receiving the higher boron dosage (Figure I-20). The reasons for this anomaly are unclear. In a number of field tests, boron levels in wood treated with higher dosages of boron have tended to be equal to or lower than in wood treated with lower dosages. We have attributed this to water absorption by the higher rod dosage that limited free moisture levels around the treatment holes. These trends continue to appear in this test. In general, boron levels below the groundline were at or above the threshold for fungal attack. Chemical levels further up the poles were far below those required for protection indicating that protection by the rod treatments in that zone is limited.

Table I-12. Boron levels in Douglas-fir poles treated with fused borate rods at the Peavy Arboretum test site.

Dosage grams	Sampling Height	Core Section	Year 1 B.A.E. (%)	Year 3 B.A.E. (%)	Year 4 B.A.E. (%)	Year 5 B.A.E. (%)
control	-15	inner	0.004	0.020	0.005	0.010
control	-15	outer	0.004	0.020	0.004	0.015
control	-7.5	inner	0.004	0.013	0.014	0.007
control	-7.5	outer	0.004	0.016	0.004	0.005
control	22.5	inner	0.002	0.018	0.006	0.011
control	22.5	outer	0.002	0.016	0.004	0.008
control	45	inner	0.007	0.013	0.005	0.006
control	45	outer	0.004	0.022	0.005	0.005
control	60	inner	0.004	0.018	0.004	0.060
control	60	outer	0.002	0.020	0.006	0.024
180	-15	inner	0.085	0.404	0.534	0.412
180	-15	outer	0.054	0.056	0.108	0.254
180	-7.5	inner	0.629	0.837	1.344	1.429
180	-7.5	outer	0.145	0.246	0.260	0.518
180	22.5	inner	0.199	0.705	0.468	0.629
180	22.5	outer	0.219	0.129	0.078	0.245
180	45	inner	0.121	0.049	0.047	0.038
180	45	outer	0.049	0.045	0.024	0.021
180	60	inner	0.040	0.054	0.043	0.092
180	60	outer	0.031	0.020	0.014	0.055
360	-15	inner	0.020	0.170	0.138	0.135
360	-15	outer	0.016	0.051	0.061	0.670
360	-7.5	inner	0.214	2.429	1.622	2.681
360	-7.5	outer	0.132	0.136	0.297	0.877
360	22.5	inner	0.107	0.717	0.301	1.630
360	22.5	outer	0.029	0.031	0.094	0.970
360	45	inner	0.009	0.025	0.019	0.278
360	45	outer	0.004	0.020	0.015	0.185
360	60	inner	0.011	0.087	0.048	0.036
360	60	outer	0.004	0.020	0.020	0.035

Figure I-20. Residual boron levels at selected heights above or below the treatment site in Douglas-fir poles sections 1 to 5 years after treatment with 0, 180 or 360 g of fused borate rod.



Release of boron from Fused borate rods applied above the groundline near field-drilled bolt holes: One attractive potential application for boron rods is around field drilled bolt holes. The exposed untreated wood around these holes is supposed to be remedially treated prior to insertion of pole hardware, but few line personnel follow these recommendations. One approach to increasing the likelihood of treatment would be to require drilling a second hole near the first and inserting a borate rod into that hole. The chemical could then diffuse to protect the bolt hole. One potential difficulty with this approach is the limited moisture available for diffusion above the groundline. In order to better assess the potential for this application, we established the following test.

Douglas-fir pole sections (250-300 mm in diameter by 1.2 m long) were dipped in 2 % chromated copper arsenate then stored under cover for 24 hours to allow fixation reactions to occur. A 19 mm diameter hole was drilled through the pole 400 mm from the top and a single galvanized bolt was inserted into the hole. A second 200 mm long hole was drilled 150 mm above the bolt and 40 or 80 g of fused boron rod (one or two rods) were added. The holes were plugged with tight fitting wooden dowels, then the poles were exposed on racks out of ground contact in either Corvallis, Oregon or Hilo, Hawaii. The poles at the Hilo site experienced severe checking to the point where there was concern that boron rods might be directly exposed to rainfall in the checks. As a result, this portion of the test was discontinued; however, checking at the Corvallis site was much less severe and we have sampled these poles 1, 6 and 7 years after treatment by removing increment cores from sites 7.5 and 22.5 cm below the original treatment hole. These cores were divided into inner and outer zones and wood from the same sampling locations for each treatment were combined and ground prior to hot water extraction. The hot water extracts were analyzed for boron by the azomethine H method.

Boron levels in non-treated control poles were generally low (Table I-13, Figure I-21). Boron levels in treated poles were low in the outer zones 1 year after treatment, but were above the threshold for fungal attack in the inner zones 22.5 cm from the original treatment hole. Interestingly, boron levels 7.5 cm away were below the threshold, suggesting that the boron levels at this time point were extremely variable. Boron levels were generally above the threshold for fungal attack at all sampling sites 6 years after treatment, indicating that the boron was eventually capable of diffusing in the drier wood out of direct soil contact. Boron levels varied somewhat between 6 and 7 years after treatment, but the differences were not consistent. As in previous tests, there was little consistent improvement in boron levels when higher dosages were applied. The results indicate that boron was capable of diffusing at fungitoxic levels from sites not directly in soil contact. This implies that fused borate rods may represent an alternative method for remedially treating the zones around field-drilled bolt holes. They may also prove useful for insertion in holes that are no longer needed.

Evaluation of a fluoride/boron rod for internal treatment of Douglas-fir poles: The poles treated with the fluoride/boron rods were inspected in 1998, but the results were not available in time for this report. They will be included in the next annual report.

Evaluation of sodium fluoride for internal treatment of Douglas-fir poles: Fifteen 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 holes were drilled at equidistant points around each pole in a spiral pattern beginning at groundline and moving upward at 150 mm intervals. Each hole received one or two sodium fluoride rods, then a tight fitting wooden dowel was used to plug the hole. Each treatment was assessed on either seven or eight poles. Fluoride movement was assessed 1, 2, and 3 years after treatment by removing increment cores from three sites around each pole 150 mm below groundline as well as at groundline, 225 mm and 450 mm above groundline. The outer preservative

Table I-13. Boron levels in Douglas-fir pole sections treated with fused boron rods above bolt holes and exposed at the Peavy Arboretum test site.

dosage	height	inner outer		B.A.E. % wt/wt Oct-91	B.A.E. % wt/wt Jun-96	B.A.E. % wt/wt Jul-97
0	-22.5	inner	Avg.	0.05	0.06	0.05
0	-22.5	inner	S.D.	0.03	0.02	0.08
0	-22.5	outer	Avg.	0.05	0.06	0.01
0	-22.5	outer	S.D.	0.02	0.01	0.01
0	-7.5	inner	Avg.	0.03	0.06	0.01
0	-7.5	inner	S.D.	0.02	0.02	0.01
0	-7.5	outer	Avg.	0.04	0.06	0.01
0	-7.5	outer	S.D.	0.02	0.01	0.00
0	7.5	whole	Avg.	0.06	0.07	0.01
0	7.5	whole	S.D.	0.03	0.04	0.01
40	-22.5	inner	Avg.	0.71	0.38	0.28
40	-22.5	inner	S.D.	1.31	0.29	0.21
40	-22.5	outer	Avg.	0.07	0.30	0.17
40	-22.5	outer	S.D.	0.03	0.18	0.13
40	-7.5	inner	Avg.	0.08	0.99	0.41
40	-7.5	inner	S.D.	0.11	1.23	0.47
40	-7.5	outer	Avg.	0.07	0.29	0.32
40	-7.5	outer	S.D.	0.05	0.17	0.35
40	7.5	whole	Avg.	0.33	0.26	0.11
40	7.5	whole	S.D.	0.38	0.25	0.09
80	-22.5	inner	Avg.	0.05	0.30	0.44
80	-22.5	inner	S.D.	0.03	0.29	0.28
80	-22.5	outer	Avg.	0.05	0.13	0.15
80	-22.5	outer	S.D.	0.04	0.13	0.10
80	-7.5	inner	Avg.	0.07	0.64	1.27
80	-7.5	inner	S.D.	0.13	0.73	0.90
80	-7.5	outer	Avg.	0.03	0.24	0.33
80	-7.5	outer	S.D.	0.02	0.17	0.28
80	7.5	whole	Avg.	0.89	0.78	0.37
80	7.5	whole	S.D.	0.81	1.34	0.41