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*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

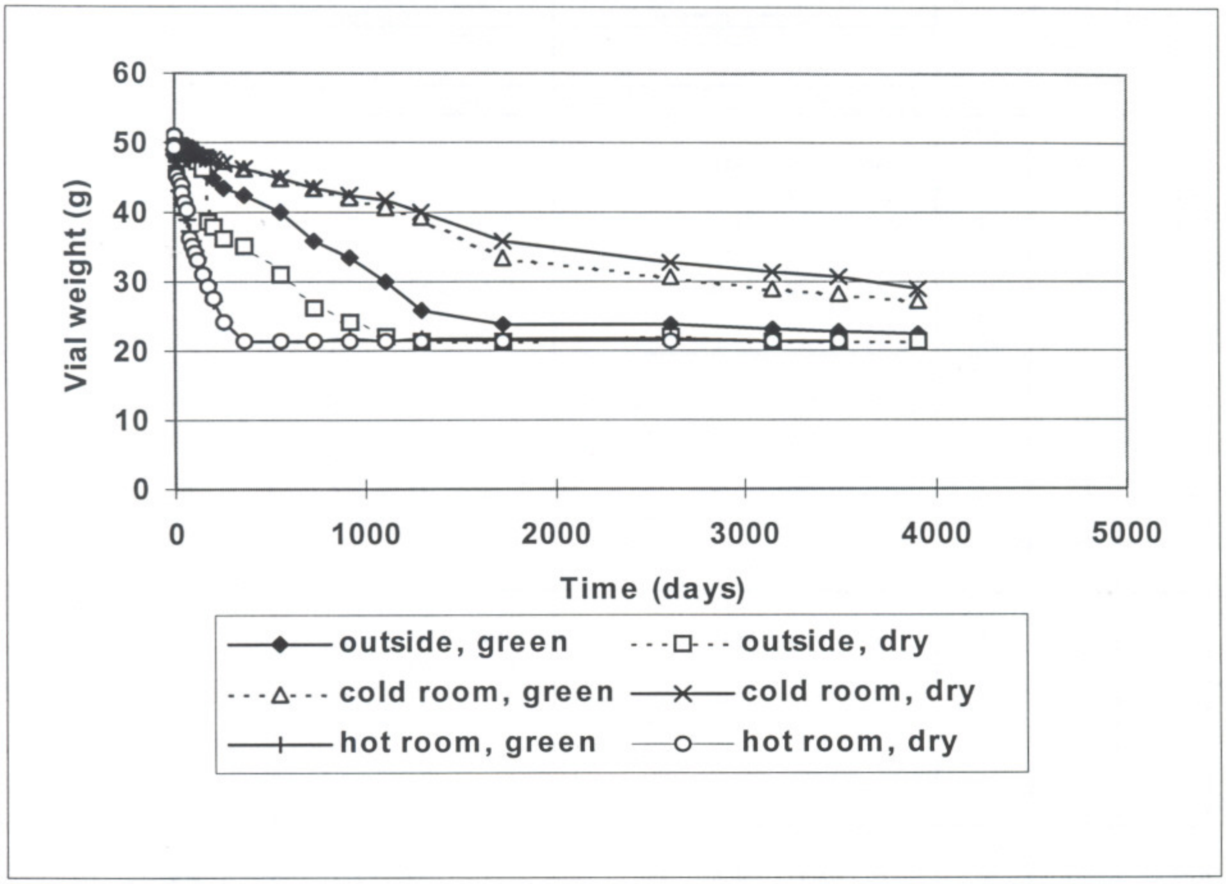


Figure I-1. Residual MITC in MITC-FUME ampules 1 to 10 years after application to Douglas-fir pole sections incubated at 5 C, 32 C, or in an outdoor exposure

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

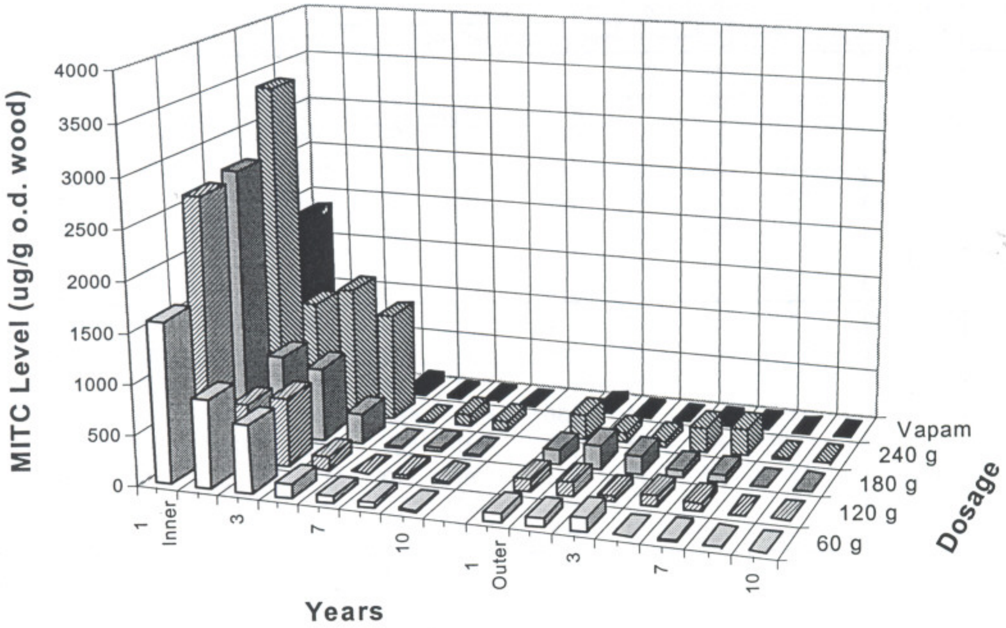
Table I-1. Residual MITC levels in Southern pine and Douglas-fir poles one to ten years after treatment with MITC-Fume.

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
		0.75										
-0.3 m	Inner	1	94	1259	917	1600	118	269	256	1047	522	94
below		2	880	744	829	666	425	580	582	935	553	49
ground		3	536	368	284	277	257	186	219	202	127	44
line		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
		0.75										
-0.3 m	Outer	1	325	201	156	269	7	146	242	309	334	12
below		2	78	148	158	125	83	89	99	192	167	23
ground		3	30	31	56	163	2	18	81	65	55	2
line		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
		0.75										
Ground	Inner	1	1603	2625	2697	3377	1870	2269	2314	3285	3960	712
Line		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
		0.75										
Ground	Outer	1	80	131	146	246	64	84	400	290	1386	38
Line		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
		0.75										
Center	Inner	1										
of		2										
Treated		3										
Zone		5										
		7										
		9	17	172	80	283	27	12	8	12	19	8
		10										
		0.75										
Center	Outer	1										
of		2										
Treated		3										
Zone		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	Inner	1	194	206	281	170	83	86	320	679	237	73
above		2	219	265	209	192	36	167	254	318	367	183
Treated		3	77	139	91	135	19	92	142	122	107	24
Zone		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	Outer	1	18	39	24	30	6	9	11	61	172	10
above		2	5	20	20	10	2	28	43	111	224	11
Treated		3	21	42	61	36	2	37	48	59	99	8
Zone		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	Inner	1	0	7	5	2	0	19	154	64	26	53
above		2	5	5	27	22	1	67	63	87	156	21
Treated		3	2	12	12	8	0	34	26	32	48	8
Zone		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	Outer	1	2	8	8	7	0	21	33	28	24	8
above		2	1	4	3	1	2	60	27	13	48	2
Treated		3	1	4	6	5	0	26	40	27	20	4
Zone		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	Inner	1	0	0	0	0	0	1	4	1	12	2
above		2	0	1	0	0	0	4	0	1	71	0
Treated		3	0	0	1	2	0	3	6	5	0	2
Zone		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	Outer	1	0	0	0	0	0	3	2	1	2	2
above		2	0	0	1	0	0	25	2	0	27	0
Treated		3	0	1	1	2	0	3	3	5	0	4
Zone		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.

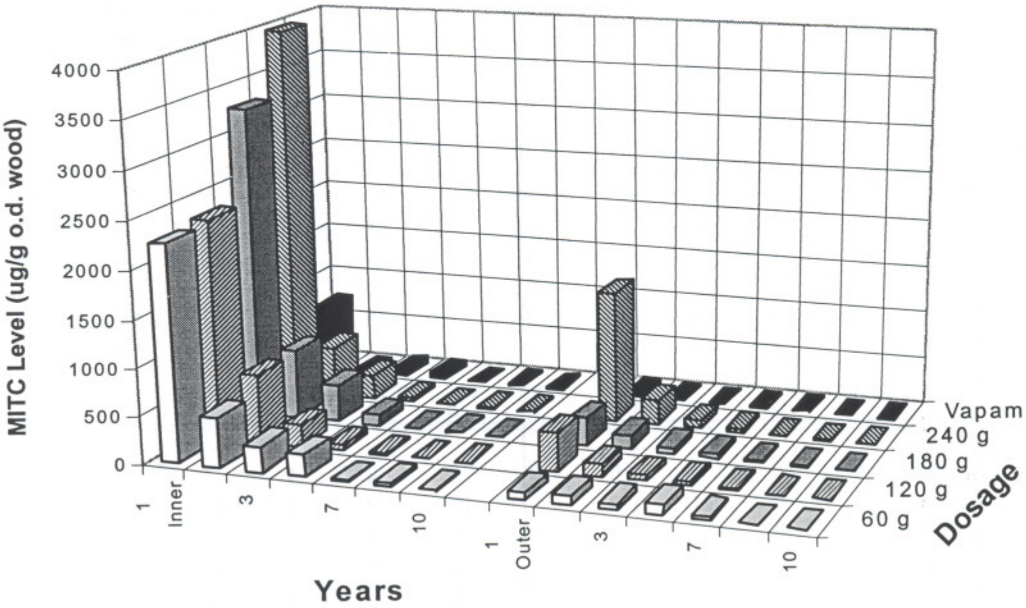


Table I-2a. Fungal inhibition as measureed by closed tube bioassay of increment cores taken at or below groundline from southern pine or Douglas-fir poles 1-10 years after treatment with MITC-Fume.

			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.

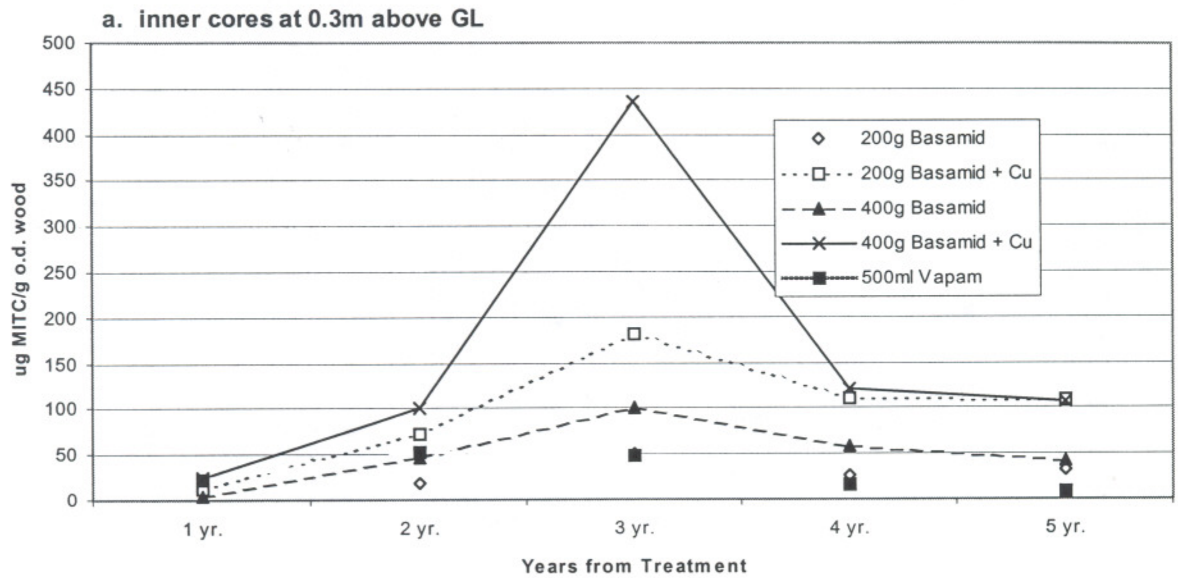
Chemical Treatment	Dosage	Yr	MITC Content (ug/g of wood)[a]							
			0.3 m		1.3 m		2.3 m		3.3 m	
			inner	outer	inner	outer	inner	outer	inner	outer
Basamid	200 g	1	8 (21)	2 (7)	5 (9)	13 (23)	0 (0)	0 (1)	1 (4)	1 (2)
		2	18 (20)	29 (37)	8 (11)	7 (16)	4 (6)	1 (4)	4 (8)	4 (7)
		3	51 (44)	50 (63)	19 (21)	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)

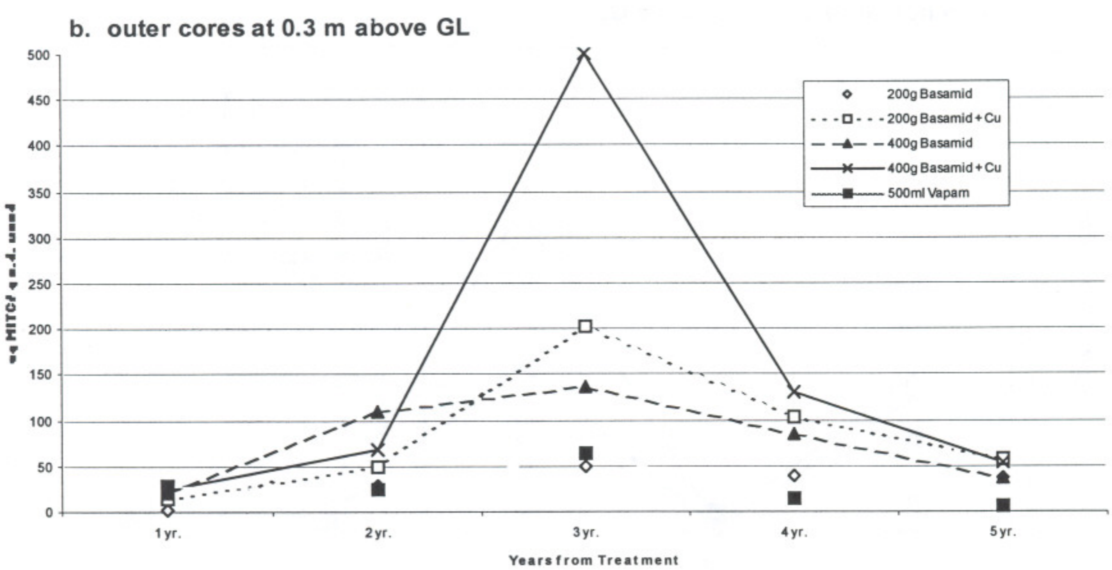
Table I-6 continued.

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)

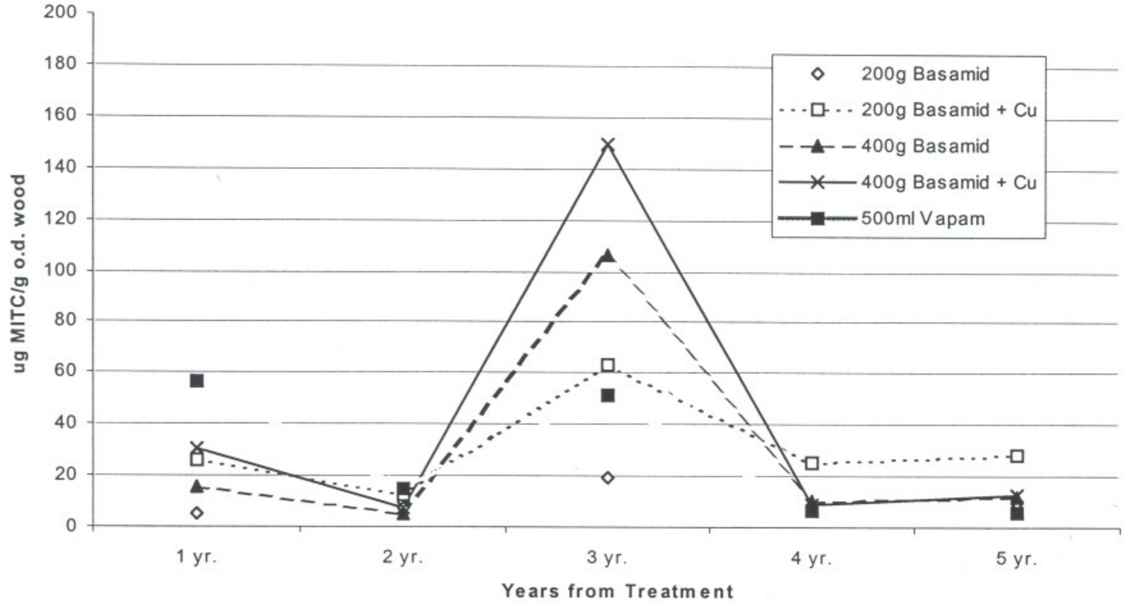
[a] Numbers in parentheses represent one standard deviation.

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



d. outer cores at 1.3 m above GL

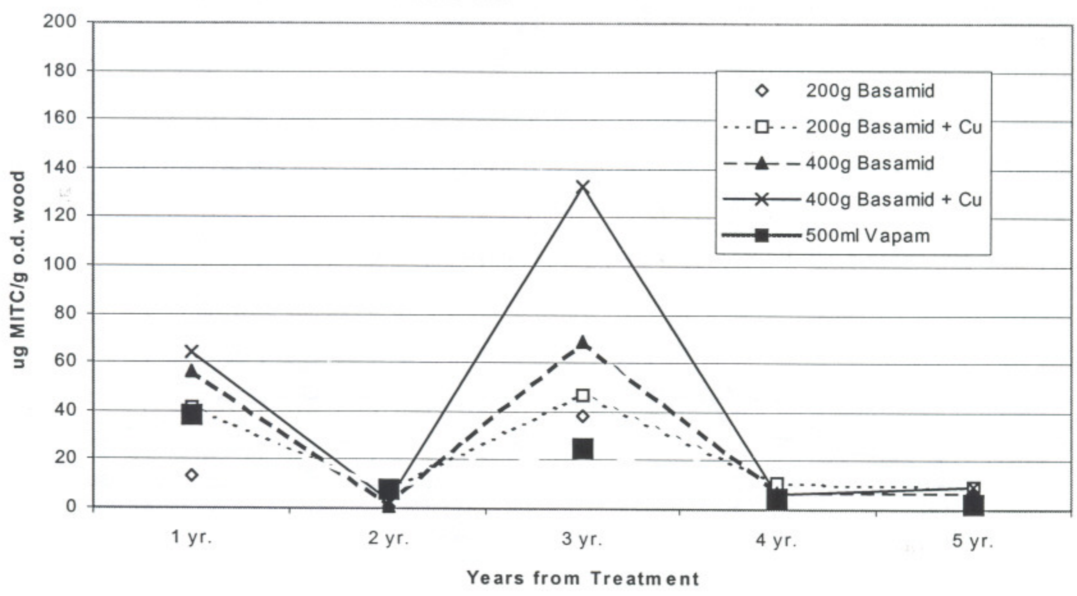


Table I-7. Frequency of fungal isolations from basamid and methan sodium treated poles.

Treatment	Dose	Copper Sulfate Added	Isolation Frequency %[a] Distance above GL: 0.3 m					1.3 m				2.3 m				3.3 m			
			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.

<u>Laboratory trials</u>: 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.

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.

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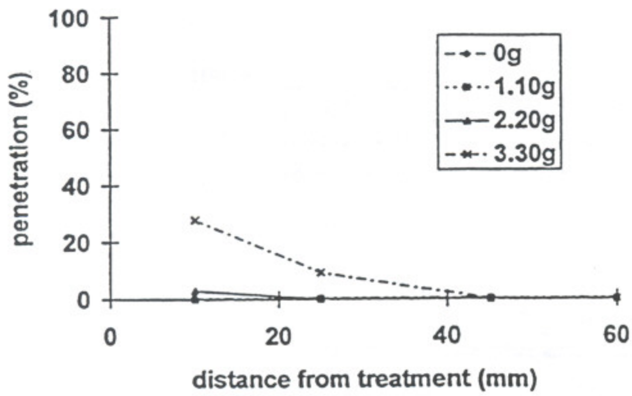
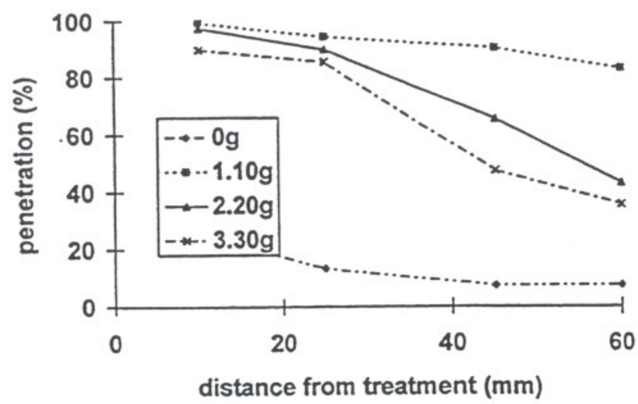
Ethylene glycol, 15% MC, 8 weeks



Ethylene glycol, 30% MC, 8 weeks



Ethylene glycol, 60% MC, 8 weeks

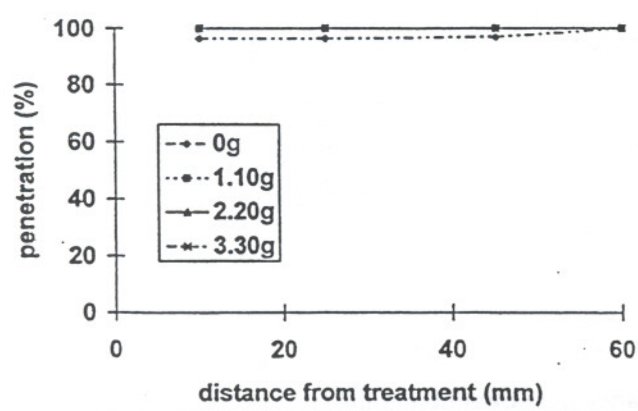
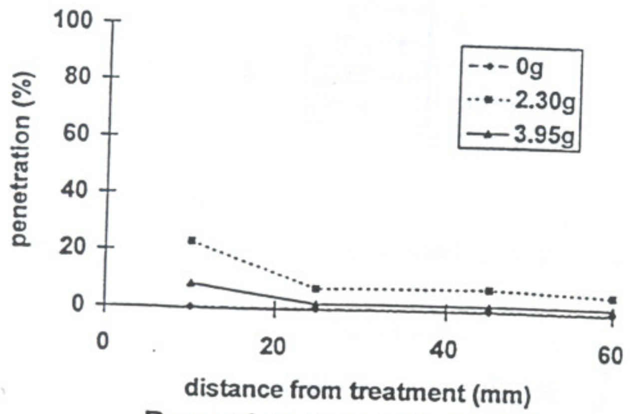
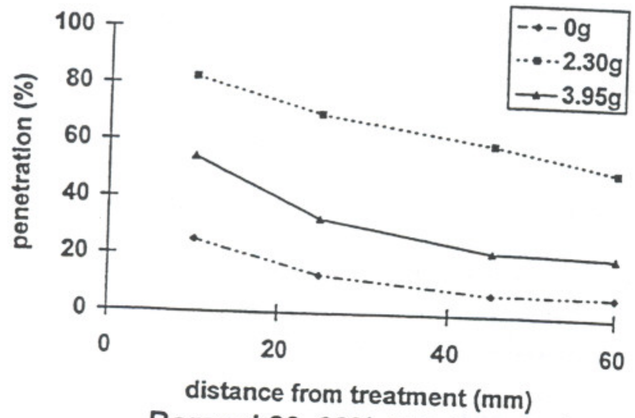


Figure I-4. Penetration of boron in cross sections cut from various distances from holes drilled in Douglas-fir heartwood blocks conditioned to 15. 30 or 60% moisture content and treated 8 weeks earlier with fused boron rod plus selected levels of polyethylene glycol to produce a dosage of 3.1 g boric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

Boracol 20,15% MC, 8 weeks



Boracol 20, 30% MC, 8 weeks



Boracol 20, 60% MC, 8 weeks

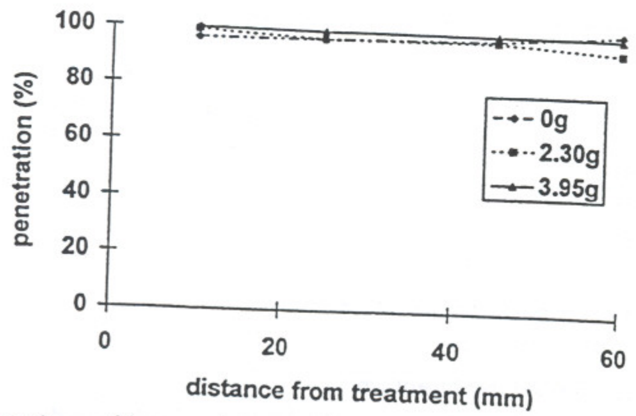


Figure I-5. Penetration of boron in cross sections cut from various distances from holes drilled in Douglas-fir heartwood blocks conditioned to 15. 30 or 60% moisture content and treated 8 weeks earlier with fused boron rod plus selected levels of Boracol 20 to produce a dosage of 3.1 g boric acid equivalent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

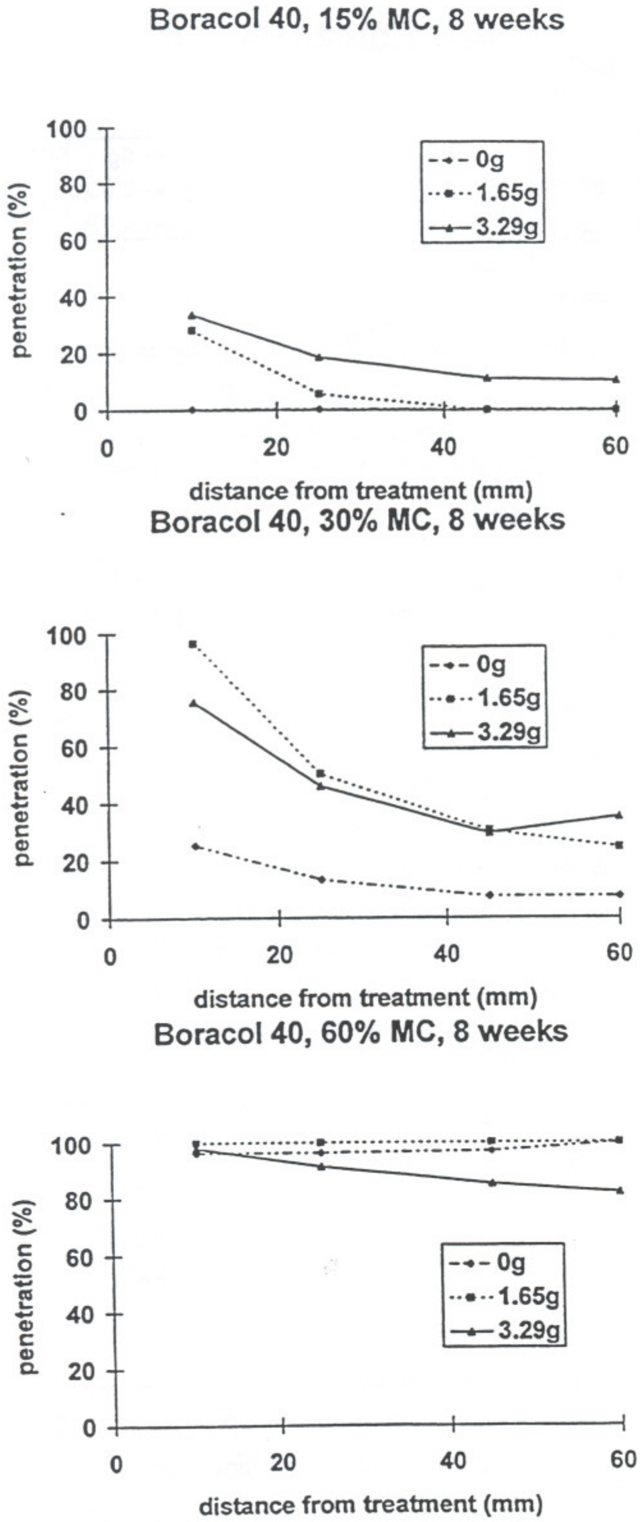


Figure I-6. Penetration of boron in cross sections cut from various distances from holes drilled in Douglas-fir heartwood blocks conditioned to 15. 30 or 60% moisture content and treated 8 weeks earlier with fused boron rod plus selected levels of Boracol 40 to produce a dosage of 3.1 g boric acid equivalent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

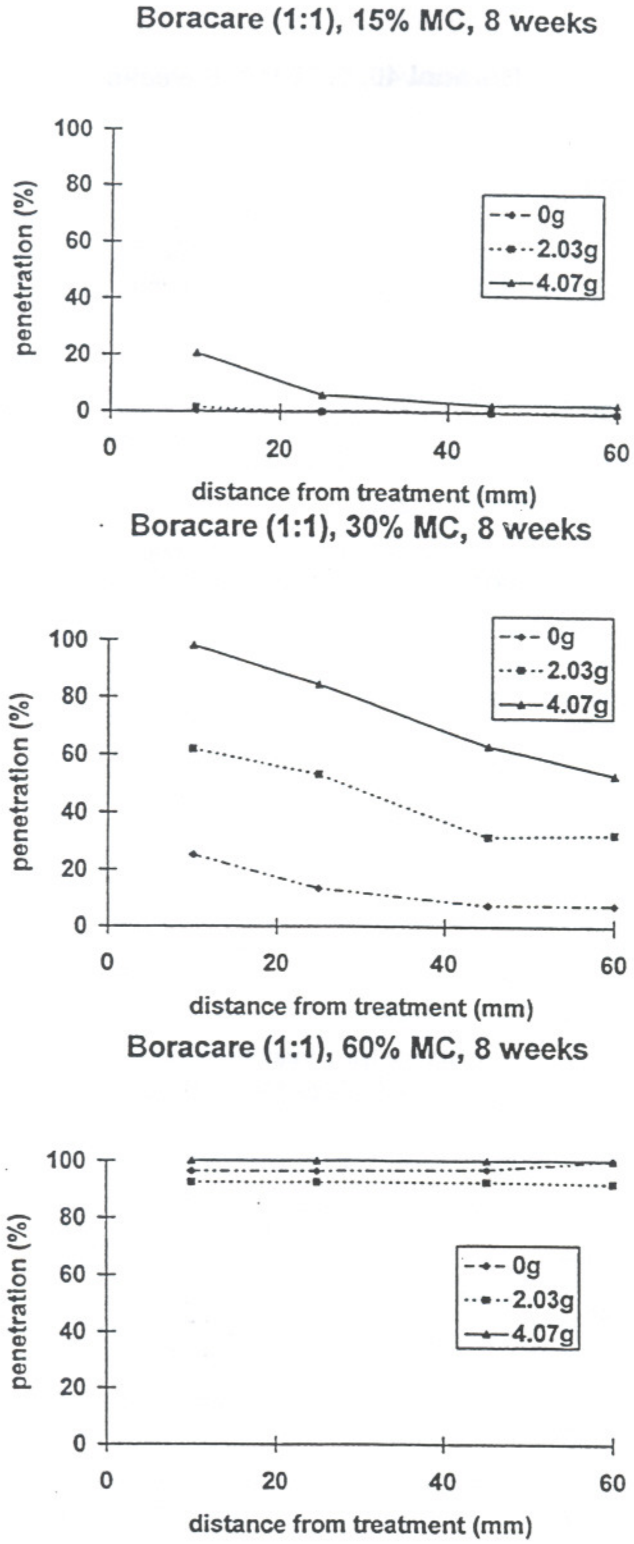
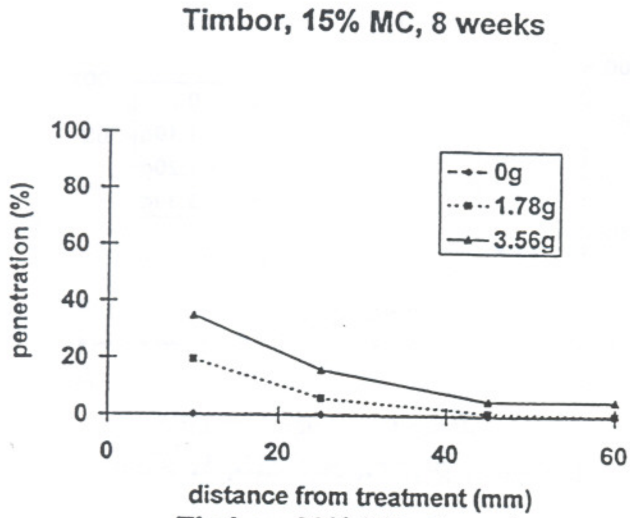
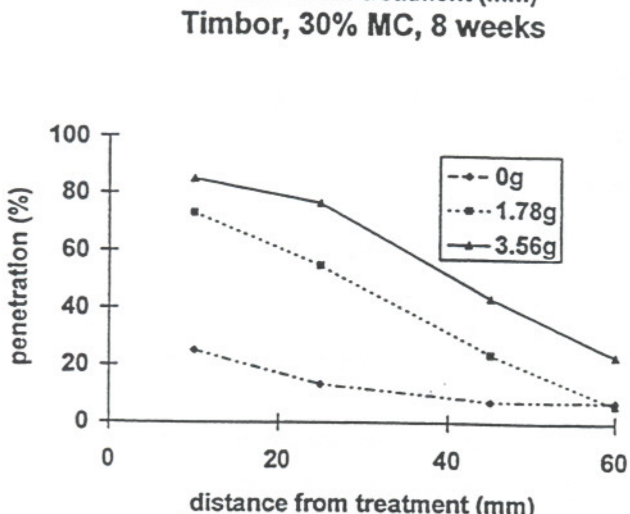


Figure I-7. Penetration of boron in cross sections cut from various distances from holes drilled in Douglas-fir heartwood blocks conditioned to 15. 30 or 60% moisture content and treated 8 weeks earlier with fused boron rod plus selected levels of 10% Timbor to produce a dosage of 3.1 g boric acid equivalent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





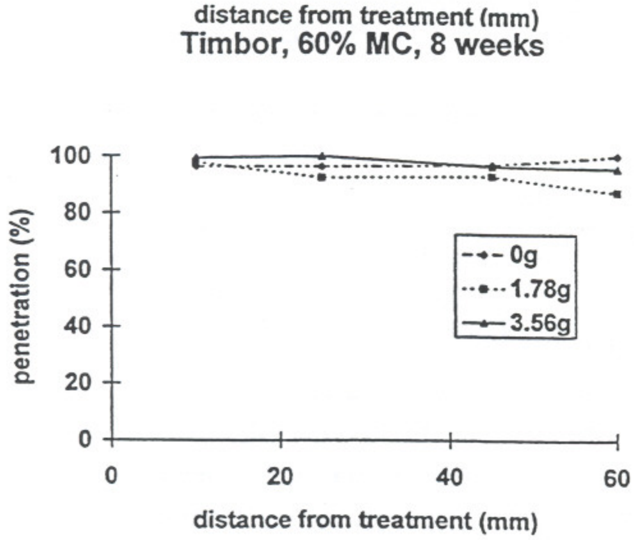


Figure I-8. Penetration of boron in cross sections cut from various distances from holes drilled in Douglas-fir heartwood blocks conditioned to 15. 30 or 60% moisture content and treated 8 weeks earlier with fused boron rod plus selected levels of Boracare to produce a dosage of 3.1 g boric acid equivalent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

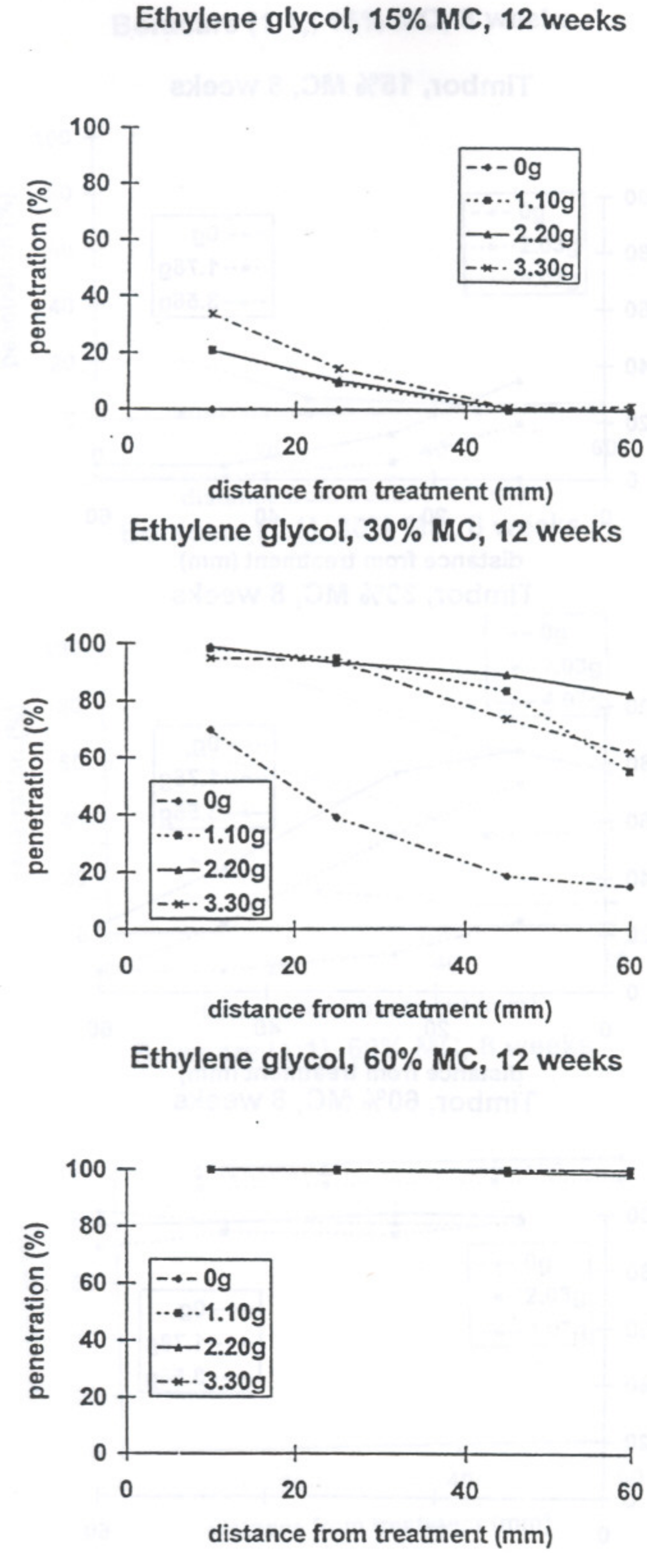


Figure I-9. Penetration of boron in cross sections cut from various distances from holes drilled in Douglas-fir heartwood blocks conditioned to 15. 30 or 60% moisture content and treated 12 weeks earlier with fused boron rod plus selected levels of polyethlyene glycol to produce a dosage of 3.1 g boric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

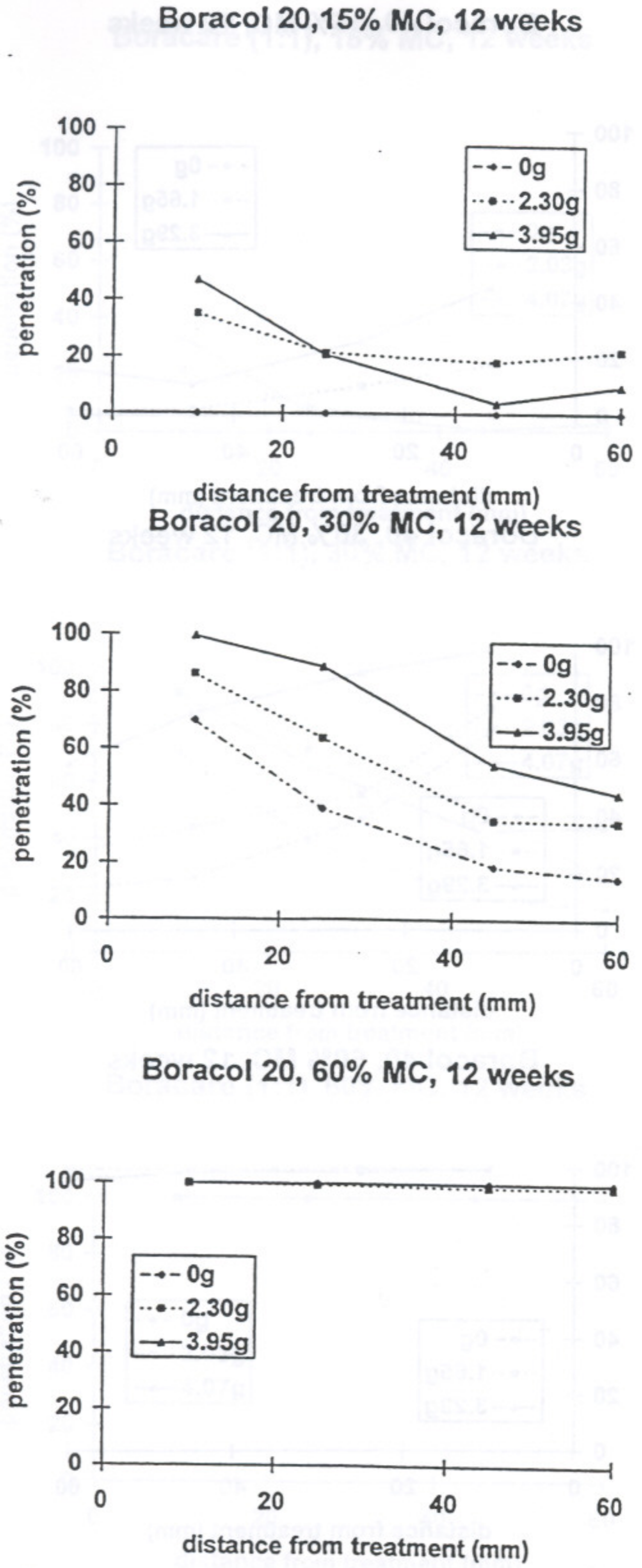


Figure I-10. Penetration of boron in cross sections cut from various distances from holes drilled in Douglas-fir heartwood blocks conditioned to 15. 30 or 60% moisture content and treated 12 weeks earlier with fused boron rod plus selected levels of Boracol 20 to produce a dosage of 3.1 g boric acid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

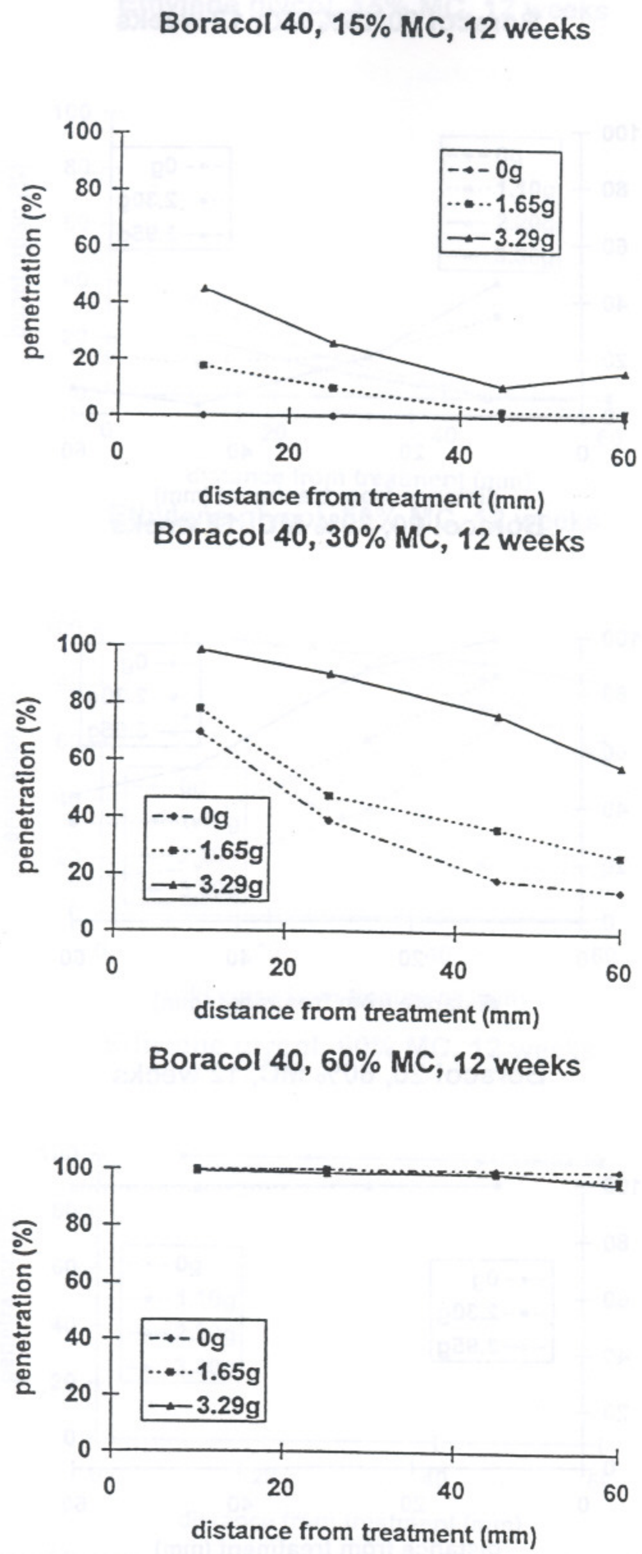
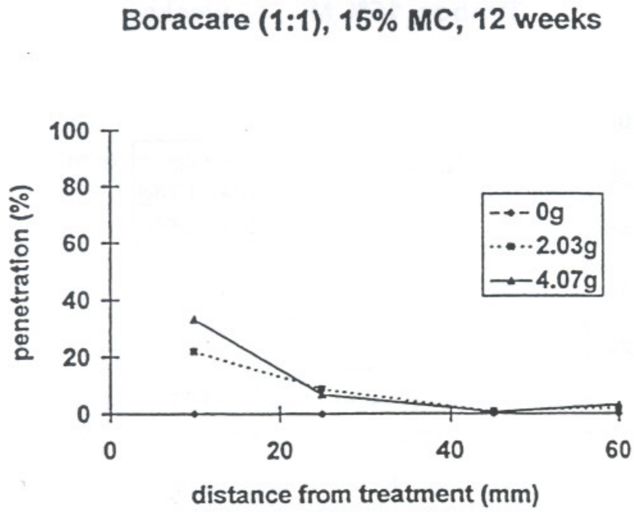
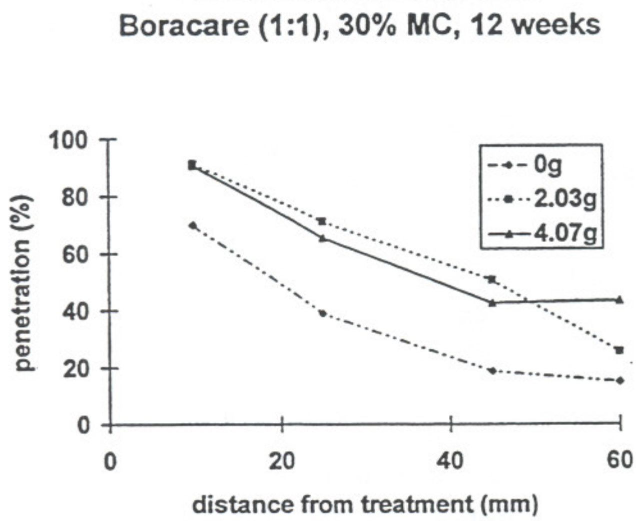


Figure I-11. Penetration of boron in cross sections cut from various distances from holes drilled in Douglas-fir heartwood blocks conditioned to 15. 30 or 60% moisture content and treated 12 weeks earlier with fused boron rod plus selected levels of Boracol 40 to produce a dosage of 3.1 g boric acid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





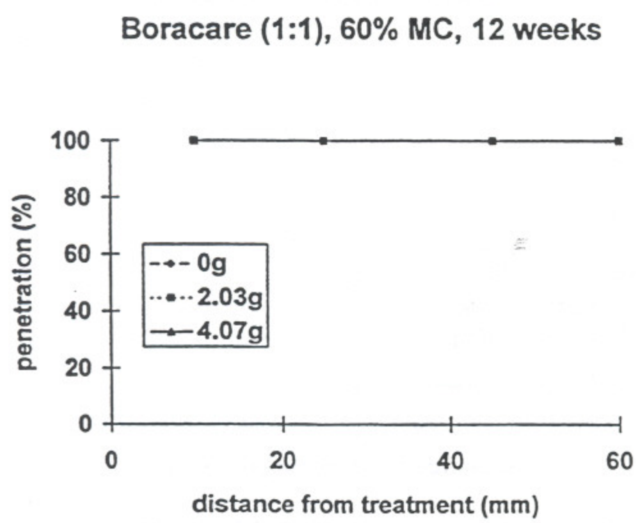


Figure I-12. Penetration of boron in cross sections cut from various distances from holes drilled in Douglas-fir heartwood blocks conditioned to 15. 30 or 60% moisture content and treated 12 weeks earlier with fused boron rod plus selected levels of Boracare to produce a dosage of 3.1 g boric acid equivalent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

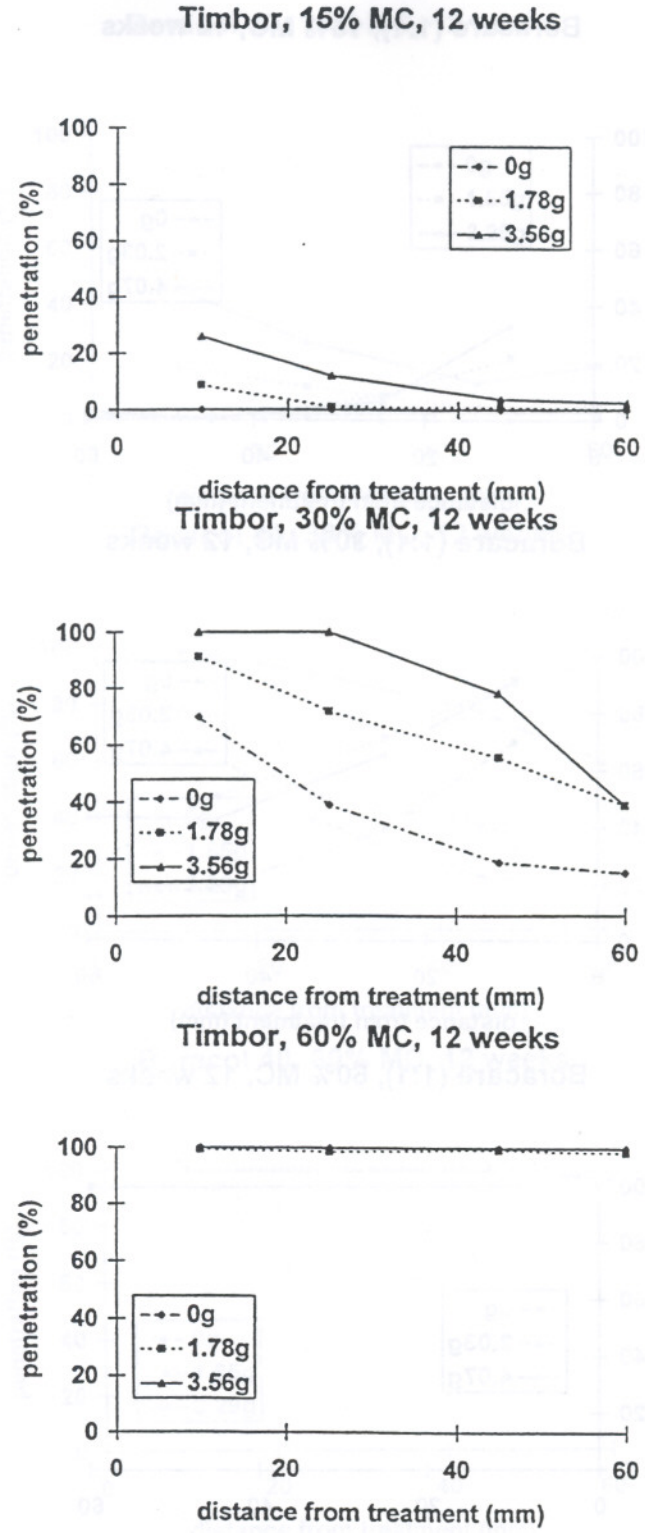
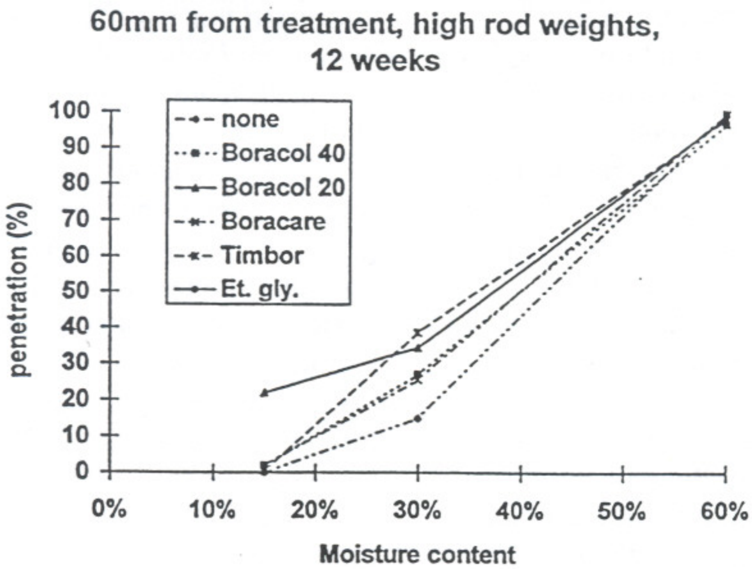


Figure I-13. Penetration of boron in cross sections cut from various distances from holes drilled in Douglas-fir heartwood blocks conditioned to 15. 30 or 60% moisture content and treated 12 weeks earlier with fused boron rod plus selected levels of 10% Timbor to produce a dosage of 3.1 g boric acid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



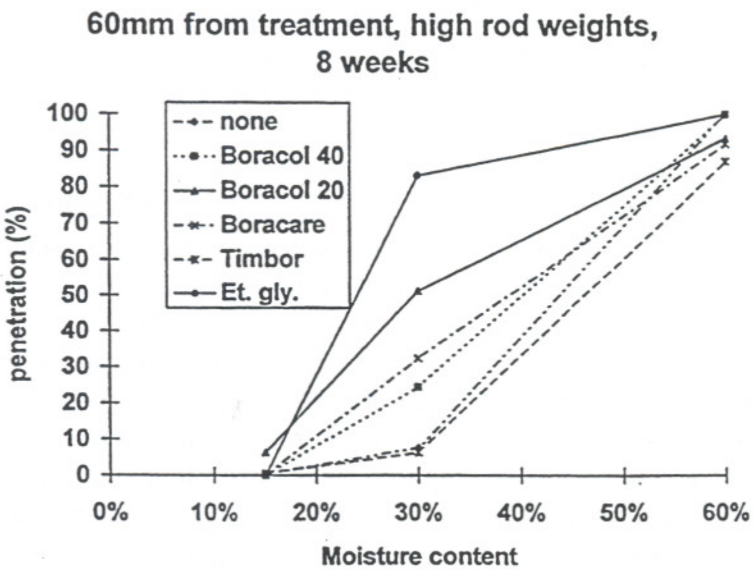


Figure I-14. Boron penetration 60 mm from the ends of Douglas-fir heartwood blocks 8 or 12 weeks after application of various boron treatments.

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			Distance	8 Weeks			12 Weeks		
ID	Rod	Suppliment		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%) 3.56 g	10	0.70	4.14	9.96	**0.28**	**12.37**	**7.38**
			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%) 3.56 g	10	--	**2.46**	**1.09**	--	**1.83**	**1.09**
			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%) 1.78 g	10	--	--	--	--	--	--
			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 1.10 g	10	**0.08**	**8.88**	**7.84**	**0.30**	**13.04**	**6.63**
			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 2.20 g	10	**0.18**	**9.15**	**8.81**	**0.64**	**11.03**	**7.59**
			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 3.30 g	10	**1.13**	**7.41**	**7.56**	**1.29**	**3.54**	**8.69**
			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.

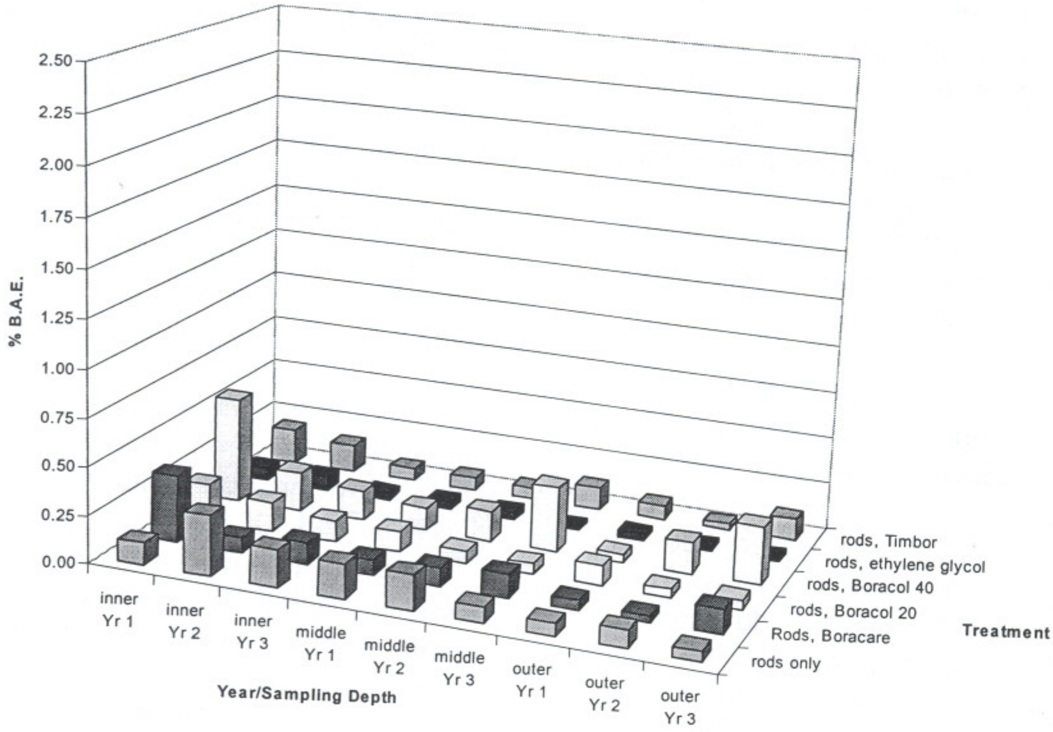


Figure I-16. Boron levels at groundline in Douglas-fir poles treated with borates.

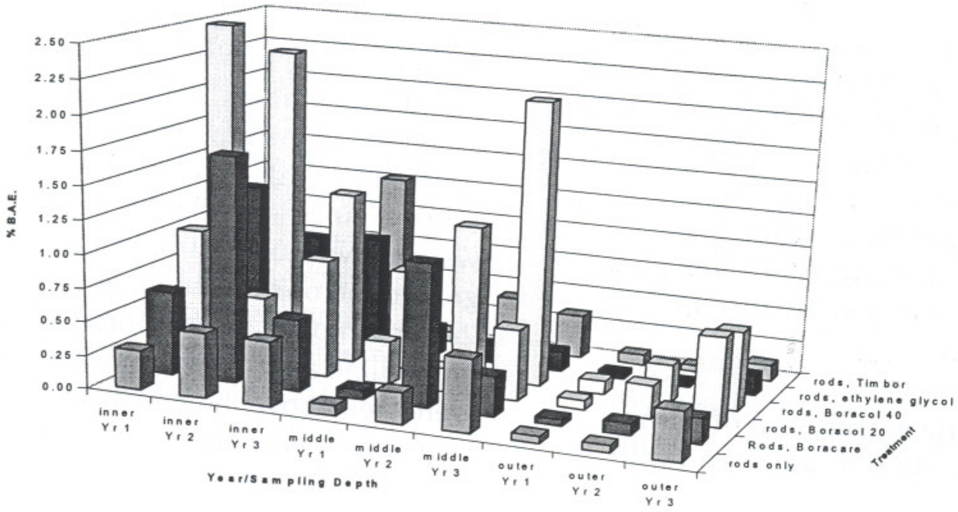


Figure I-17. Boron levels 15 cm above groundline in Douglas-fir poles treated with borates.

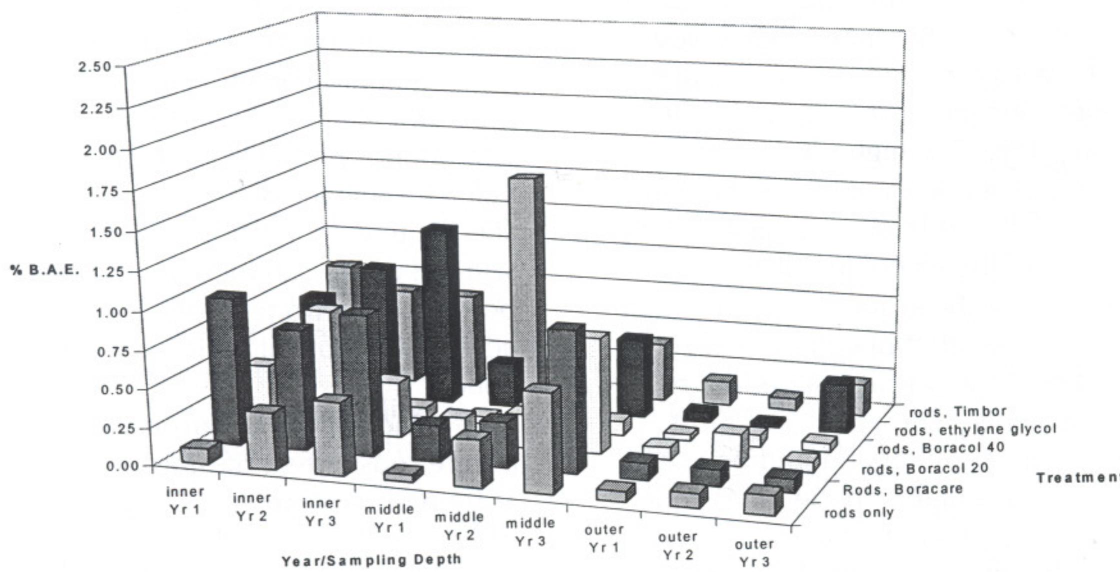
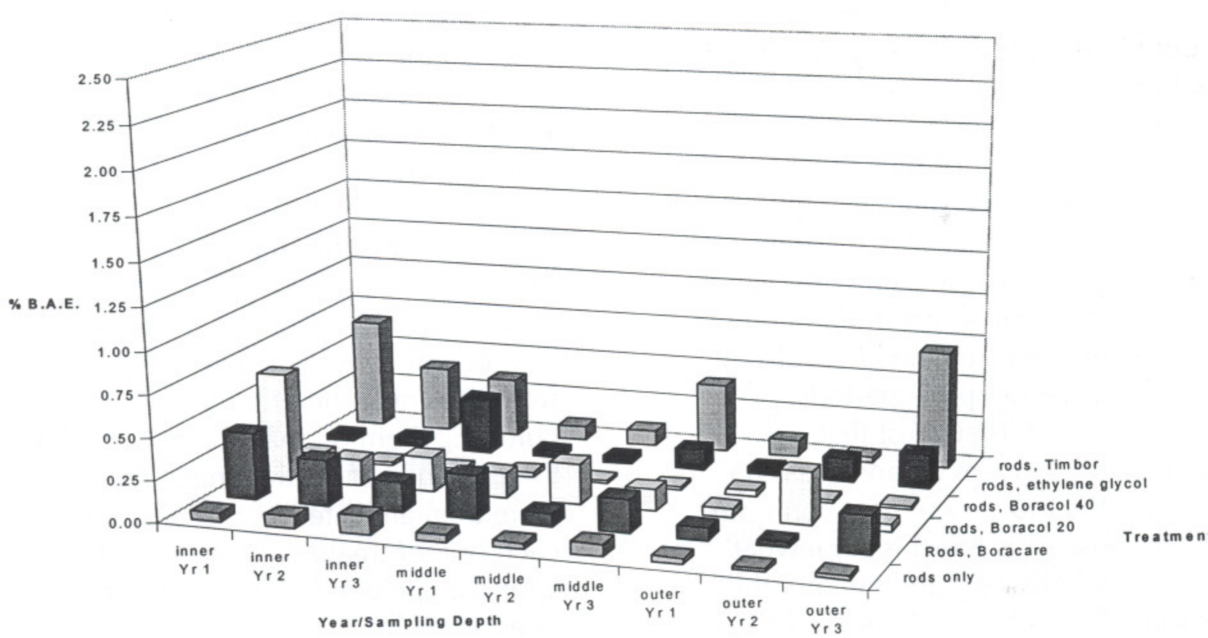


Figure I-18. Boron levels 30 cm above groundline in Douglas-fir poles treated with borates.



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.

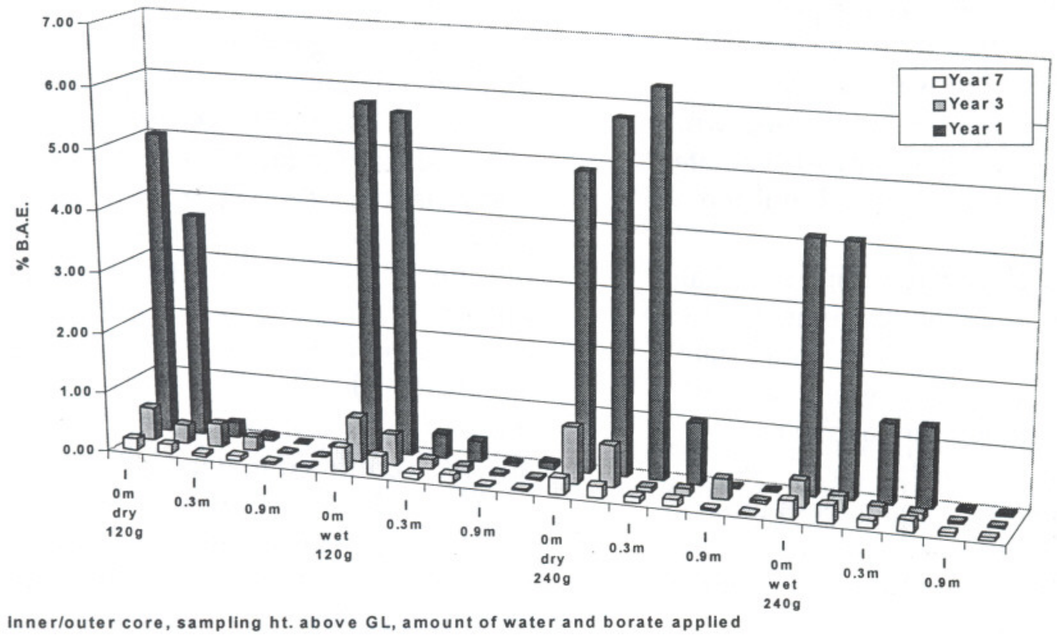


Table I-11. Isolation frequencies of decay and non-decay fungi in Douglas-fir poles prior to treatment and 1 and 7 years after application of 120 or 240 g of fused borate rod with or without supplemental water.

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.

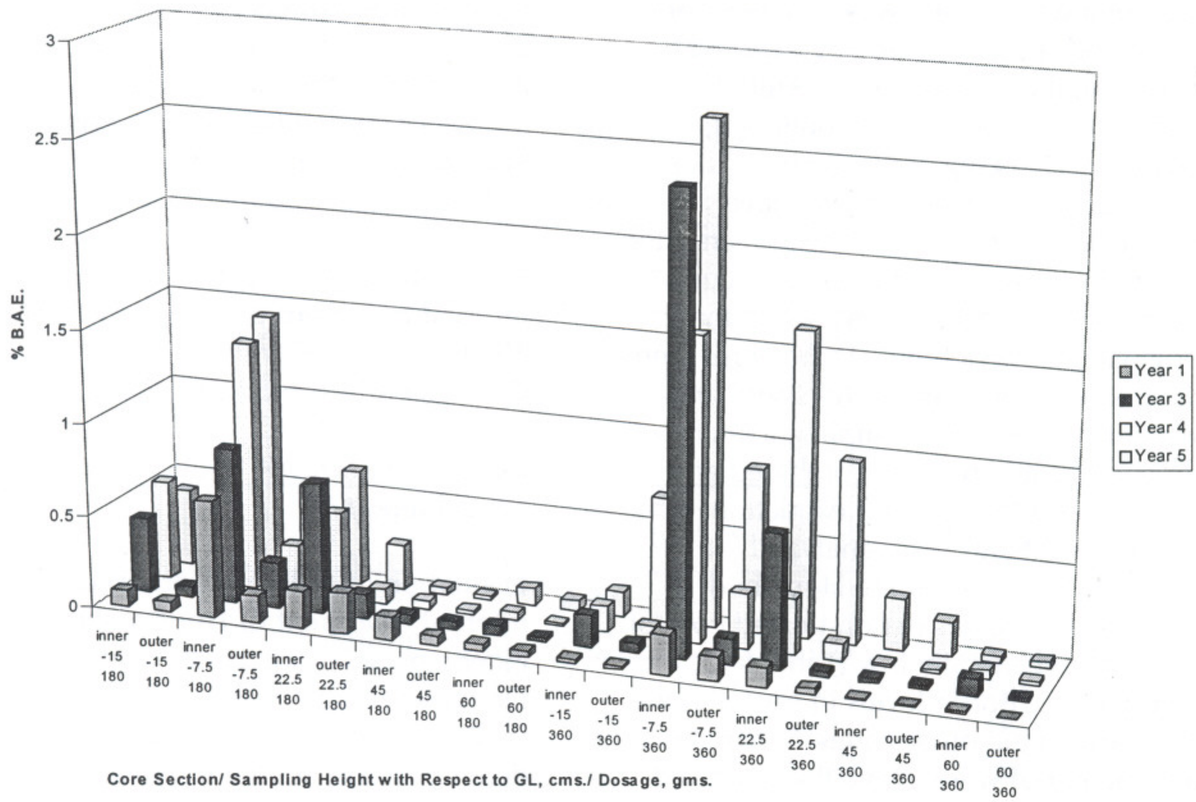
Boron was virtually non-detectable in control poles over the three sampling points (Table I-12) . Boron levels in the two treatment groups were somewhat variable. Boron levels tended to be higher in the inner halves of the cores, regardless of dosage. This trend suggests a general movement of chemical 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.

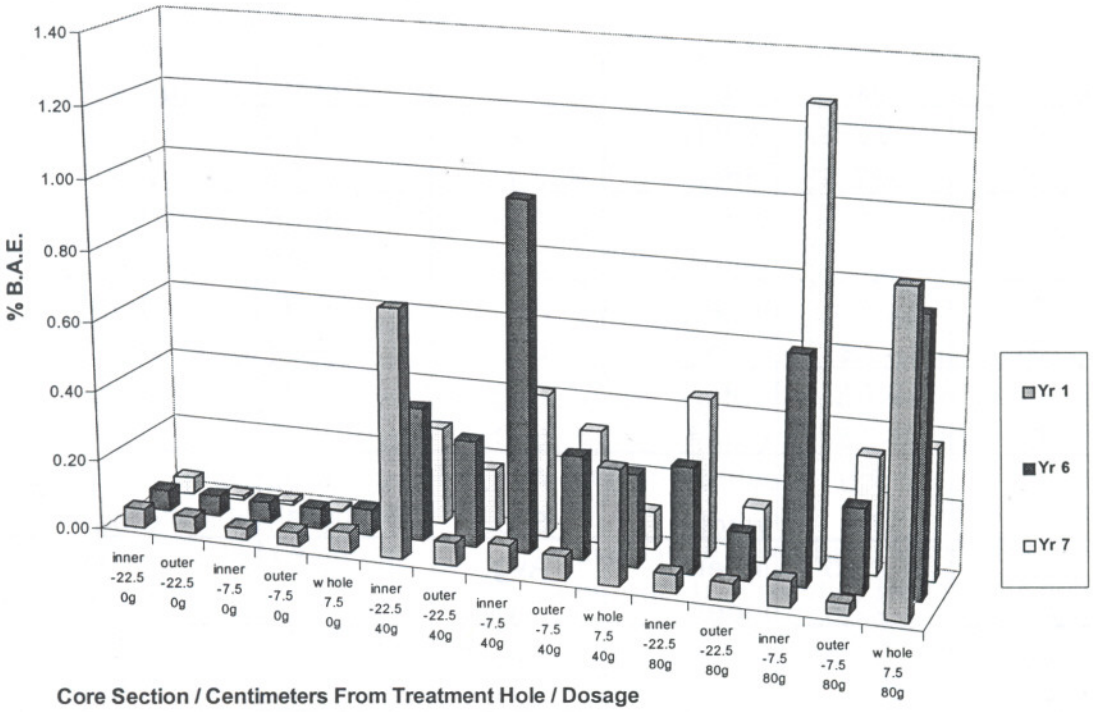
Evaluation of a fluoride/boron rod for internal treatment of Douglas-fir poles: The poles treated with the fluoride/boron rods were inspected in 1998, but the results were not available in time for this report. They will be included in the next annual report.

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

Figure I-21. Boron levels at selected distances below the treatment site in Douglas-fir poles 1 to 7 years after application of 40 or 80 g of fused borate rod.



treated shell was discarded, then the remaining wood was split into inner and outer halves which were ground to pass a 20 mesh screen. The samples were then ashed and the resulting material was resolubilized and analyzed using a specific ion electrode as described in American Wood Preservers' Association Standard A2. The samples are being analyzed by Osmose Wood Preserving on a coded sample basis, but the results of the analysis are not yet available.

In addition to removing cores, we destructively sampled either two or three poles from each treatment to visually assess fluoride penetration. These poles were removed from the ground and cut into a series of 150 mm long sections. The surface of each section was then sprayed with a solution of sodium alizarin sulfonate followed by a mixture of zirconyl chloride and hydrochloric acid according to AWPA Standard A3 Method 7. The appearance of a yellow color indicated that fluoride was present. In general, fluoride was detected only in sections 150 mm and 300 mm below groundline. These sections were further examined by removing a series of cubes at 25 mm intervals from the wood surface. These samples were ground to pass a 20 mesh screen and analyzed for fluoride as described above.

Results from years 1 and 2 have indicated that fluoride penetration is essentially limited to the zone around the groundline and results from year 3 of this study confirm this (Table I-15, Figure I-22). These results correspond closely with previous chemical analyses and illustrate the importance of moisture in fluoride movement. Fluoride levels near the pith tended to be higher, particularly 150 mm below groundline. Fluoride levels 300 mm beneath the groundline were also elevated toward the center, but there was little effect with increased dosage.

The low fluoride levels in this trial, when compared to boron levels in previous trials is probably due to the differing dosages of these two systems. The amount of fluoride rod applied is somewhat lower than the amount of boron rod commonly applied in field trials. The presence of elevated fluoride levels inside the poles below groundline suggests that these zones are protected from fungal attack; however, the sporadic fluoride distribution above the groundline suggests that these treatments are less suitable for protecting wood not in direct soil contact. We will continue to monitor the remaining poles in each treatment to assess the protective period afforded by this formulation.

Table I-15. Residual sodium fluoride below ground at selected distances from the surfaces of Douglas-fir poles 3 years after treatment with 66 or 132 g of fluoride rod.

Dosage (g)	Height (mm)	Sodium Fluoride Content (% wt/wt)[a]				
		0-25 mm	25-50 mm	50-75 mm	75-100 mm	>100 mm
66	-300	0.019 (0.011)	0.019 (0.010)	0.016 (0.004)	0.029 (0.013)	0.068 (0.029)
	-150	0.055 (0.054)	0.038 (0.033)	0.186 (0.270)	0.200 (0.253)	0.158 (0.201)
132	-300	0.019 (0.019)	0.006 (0.013)	0.039 (0.030)	0.021 (0.029)	0.067 (0.073)
	-150	0.076 (0.086)	0.070 (0.046)	0.173 (0.204)	0.186 (0.216)	0.251 (0.129)

[a] Values represent means of 2 to 4 analyses per position. Figures in parentheses represent one standard deviation.

C. Evaluate basic properties of internal remedial treatments

While internal treatments have generally worked well, there is often little information on the basic properties of these systems in wood. One component of this Objective is to develop more complete fundamental data on the various internal treatments developed for arresting decay in wood poles and other large timbers.

Develop threshold values for sodium fluoride as an internal remedial treatment: As described above, there are currently two rod formulations that contain sodium fluoride as an active ingredient. This chemical has long been used for protecting wood in various application, but the levels required for internal decay control are poorly understood. Previous studies have determined fluoride levels in external bandages which provide protection of wood in direct soil contact but these high levels are probably not necessary for internal applications. Bandage treatments are susceptible to extensive leaching losses, while internal treatments should present a more stable environment with a reduced risk of chemical loss. This would decrease the likelihood of leaching and increase the time period during which a decay fungus would be in contact with the chemical. The threshold data for external bandages was developed using the soil block test, which creates the potential for considerable chemical loss through the feeder strip. This approach seems inappropriate for evaluating internal water diffusible treatments. In an attempt to develop more accurate data on the loadings of diffusible biocides required for protecting against fungal attack out of soil contact, we evaluated a series of boron treatments on Douglas-fir sapwood and heartwood. These results showed that the thresholds were far lower than those found using the soil block test. When used in conjunction with chemical analyses of wood following remedial application, these data provide a better perspective concerning how much chemical is really needed to protect against fungal attack. This past year, we performed similar trials using sodium fluoride.

Douglas-fir sapwood and heartwood wafers (5 by 10 by 30 mm long) were drilled with a single 0.5 mm diameter by 2 mm long hole in one wide face to serve as a fungal inoculation point. The wafers were oven dried at 54 C and weighed. The wafers were then treated with solutions designed to produce wood loadings of 0.05, 0.1, 0.2, 0.3, 0.4, and 0.5 % (wt/wt) of sodium fluoride. The wafers were immersed in the test solution and an 80 kPa vacuum was drawn over the solution for 15 minutes. The vacuum was released and pressure was increased to 800 kPa and held for one hour. The samples were then removed, wiped clean and weighed to determine net solution absorption. Selected blocks from each treatment group were retained for later chemical analysis. The remainder were placed into plastic bags which were sealed and subjected to 2.5 Mrad of ionizing radiation from a cobalt 60 source. The sterile wafers were then placed on glass rods on top of moistened filter paper in glass petri dishes. The glass dishes with filter paper and rods had previously been sterilized by heating at 121 C for 60 minutes.

The wafers were inoculated with either *Gloeophyllum trabeum* (Pers:Fr.) Murr (Isolate Mad. 617), *Postia placenta* (Fries) M. Larsen et Lombard) (Isolate Mad. 698),or *Trametes versicolor* (L.:Fr.) Pilat (Isolate R-105). Agar discs of the test fungus were inoculated into flasks containing 1.5 % malt extract and these flasks were incubated for 7-10 days at room temperature (28 C). The resulting mycelium was collected by filtration and washed with distilled water. The filtrate was re-suspended in distilled water and blended for 10 seconds to break up the mycelium. Each wafer received 50 ul of the resulting suspension through the small hole drilled in the wide face. The plates were sealed with parafilm and incubated at 28 C for 16 or 21 weeks. The longer incubation period was used for the white rot fungus. The procedure allows exposure to moist fluoride treated wafers with a minimal risk of leaching. At the end of the test period, mycelium was scraped from the wafers, which were oven dried and weighed. Differences in weight between initial and final weighing served as the measure of chemical effectiveness.

We have completed tests using the two brown rot fungi, while the white rot tests are still underway and will be reported in the next annual report.

Hyphal growth was abundant on the control wafers as well as the lowest retentions of fluoride. Little or no fungal growth was evident on wafers at higher fluoride loadings, suggesting that the treatment had inhibited germination and or hyphal extension. This system results in intimate contact between the fungicide and the test organisms, in a manner similar to what might be found in a check in a wood pole. In addition, the method also uses hyphal fragments or spores, in a manner that more closely approximated the natural invasion process of viable spores germinating in checks in the wood.

Weight losses in both sapwood and heartwood wafers were somewhat lower than were found in the controls in the previous trials using boron (Table I-16). We suspect that our wood samples remained too wet over the decay period. Excessive moisture limits the amount of oxygen available for fungal growth, which in turn inhibits the potential for substantial wood degradation. Weight losses in wafers treated with fluoride were negligible, even at the lowest dosage (0.05 % wt/wt), but the low weight losses in the controls makes it difficult to make concrete conclusions. We plan to repeat this test using less restrictive drying conditions to improve the weight losses on the fungal exposed controls.

Table I-16. Weight losses of non-treated and sodium fluoride-treated Douglas-fir sapwood and heartwood wafers exposed to two brown rot fungi for 16 weeks in an above-ground decay test.

Fluoride Level (% wt/wt)	Wood Weight Loss (%)[a]			
	Douglas-fir sapwood		Douglas-fir heartwood	
	G. trabeum	*P. placenta*	*G. trabeum*	*P. placenta*
0	9.92 (1.34)	5.47 (1.94)	1.56 (0.48)	2.86 (0.49)
0.5	9.92 (1.34)	0.95 (0.80)	1.10 (0.19)	1.18 (0.18)
0.1	2.71 (1.70)	1.85 (0.25)	1.19 (0.27)	1.17 (0.24)
0.2	1.54 (0.19)	1.49 (0.22)	1.11 (0.22)	1.08 (0.16)
0.3	1.39 (0.17)	1.41 (0.23)	1.00 (0.13)	0.94 (0.35)
0.4	1.23 (0.28)	1.34 (0.19)	0.58 (0.19)	1.04 (0.20)
0.5	1.28 (0.19)	1.18 (0.32)	0.65 (0.42)	0.58 (0.39)

[a] Figures in parentheses represent one standard deviation.

Objective II

IDENTIFY CHEMICALS FOR PROTECTING EXPOSED WOOD SURFACES IN POLES

Preservative treatment using pressure processes produces an excellent barrier against fungal attack. Damage to this barrier can allow entry by decay fungi and insects and leads to the development of internal decay and, eventually, early failure. Most utilities recommend that any cuts or holes made in poles be protected by application of a supplemental preservative. The most common chemical for this purpose is 2 % copper naphthenate. Many utility personnel, however, object to the oily nature of this chemical, which soils their gloves and work garments. Since it is generally impossible to check to determine if a topical treatment has been applied once the attachment has been placed on the pole, there is little incentive for line personnel to apply these chemicals. The result of the failure to treat is exposed untreated wood that remains susceptible to decay for the life of the structure. The risk of decay above ground has been assessed in previous portions of the coop work which showed that around 25 % of the untreated bolt holes sampled eventually had some fungal colonization. Advanced decay, which progresses more slowly above the ground in most regions, was less prevalent, occurring in around 10 % of the poles. The problem with above ground decay is the inability to predict which poles are affected. In addition, the excellent performance of groundline maintenance and treatment programs can extend the lives of many poles far beyond original expectations, increasing the risk that fungal attack will eventually occur above ground.

As a result, there is a continuing need to develop effective topical treatments for protecting field damage to the treated zones of utility poles.

Performance of topical treatments in field drilled bolt holes: This test was established while pentachlorophenol was still the preferred treatment for protecting field drilled bolt holes. A series of eight 25 mm diameter holes were drilled at 90 degree angles into poles beginning 600 mm above the groundline and extending upward at 450 mm intervals to within 450 mm of the top. The holes on a given pole were treated with 10 % pentachlorophenol, powdered ammonium bifluoride (ABF), powdered disodium octaborate tetrahydrate (boron), or 40% boron in ethylene glycol. Each chemical was replicated on eight holes on each of four poles. An additional set of four poles received no chemical treatment, but washers that had been impregnated with a solution containing 37.1 % sodium fluoride, 12.5 % potassium dichromate, 8.5 % sodium pentachlorophenate, 1 % sodium tetrachlorophenate, and 11 % creosote (Patox) were used to attach the bolts to these poles. Holes in an additional 8 poles received no chemical treatment. The holes were plugged with galvanized metal hardware using either metal or plastic gain plates.

Four of the control poles were sampled over the first 5 years of the test to determine when fungi had begun to invade the wood. At that point we began to sample all of the poles by removing increment cores from sites directly below the gain plate on one side of the pole and from directly above the washer on the opposite side. The cores were cultured as described in Section I for fungi.

The field trial is now in its 17th year and shows a steadily increasing level of fungal colonization in many of the treatments (Table II-1, Figure II-1). Fungal isolation levels in poles were highest in those left untreated, treated with 10 % penta or those left untreated but with Patox washers on the exterior. These results are consistent with previous studies. The controls illustrate the risk associated with exposing untreated wood above ground in Western Oregon. While the levels of fungal colonization have varied, 10 to 30 % of the cores from these poles have yielded decay fungi over the past 2 years. The failure of 10 % penta to protect the holes was initially suprising, but the trends have continued over the test. In general, penta will work well where applied, but it lacks the ability to migrate for substantial distances from the point of application. This is a positive attribute in most applications, but it does not allow the chemical to migrate to the point where checks have opened near the bolt hole. The failure of the Patox washers has been discussed previously and probably relates to an inability of the chemical to move at toxic levels from the exterior to the interior of the poles where it was needed.

Fungal levels in the three sets of poles treated with the diffusible boron or fluoride continue to remain lower than those for the penta control. Fewer than 5 % of the cores from the two boron treatments contained decay fungi while 9 % of those removed from the zones around fluoride treated holes yielded decay fungi. These results suggest that the efficacy of the treatments has begun to decline although the levels still remain well below those found with the other treatments.

The results illustrate the benefits of topical treatment, but also suggest that there are practical limits to the longevity of these treatments. This is not surprising, given the relatively small amounts of chemical that can be applied using these techniques. In the case of the diffusibles, the chemical would be expected to continue to diffuse away from the point of application until the levels near the field drilled hole were below those required for fungal protection. At that point, it would be only a matter of time before fungi enter the wood and find a suitable point for growth. This does not preclude the use of topical treatments to protect the wood exposed during drilling since the 15 to 17 years of protection will still slow the progress of any above ground decay, but is does place practice limits on the expectations of such treatments.

Table II-1 Percentage of increment cores removed from around field drilled bolt holes that contain basidiomycetes and non-basidiomycetes.

treatment	n	0 yr	1 yr	2 yr	3 yr	4 yr	5 yr	6 yr	7 yr	8 yr	9 yr	10 yr	11 yr	12 yr	13 yr	14 yr	16 yr	17 yr
NH_4HF_2	32	0 ^{41}					2 ^{17}	0 ^{5}	0 ^{16}	0 ^{19}	2 ^{44}	2 ^{9}	2 ^{47}	2 ^{39}	2 ^{39}	5 ^{39}	6 ^{35}	9 ^{53}
Boracol 40	32	0 ^{57}					3 ^{44}	0 ^{19}	2 ^{46}	0 ^{33}	0 ^{64}	3 ^{16}	0 ^{71}	3 ^{42}	8 ^{60}	9 ^{80}	10 ^{57}	9 ^{53}
Patox	32	3 ^{60}					10 ^{41}	5 ^{13}	5 ^{22}	8 ^{31}	16 ^{67}	11 ^{39}	11 ^{55}	8 ^{46}	14 ^{49}	14 ^{55}	27 ^{71}	33 ^{72}
10% penta	32	0 ^{44}					5 ^{56}	2 ^{25}	2 ^{19}	8 ^{31}	5 ^{53}	7 ^{25}	5 ^{80}	6 ^{61}	15 ^{67}	13 ^{64}	19 ^{70}	17 ^{59}
Polybor	32	0 ^{38}					5 ^{27}	0 ^{11}	0 ^{25}	0 ^{28}	2 ^{38}	2 ^{14}	2 ^{75}	0 ^{40}	7 ^{60}	3 ^{69}	7 ^{46}	3 ^{97}
Control	64	0 ^{63}	5 ^{8}	5 ^{10}	7 ^{35}	3 ^{99}	6 ^{55}	2 ^{32}	4 ^{33}	12 ^{53}	7 ^{66}	9 ^{35}	11 ^{86}	3 ^{56}	6 ^{81}	9 ^{68}	30 ^{77}	14 ^{67}

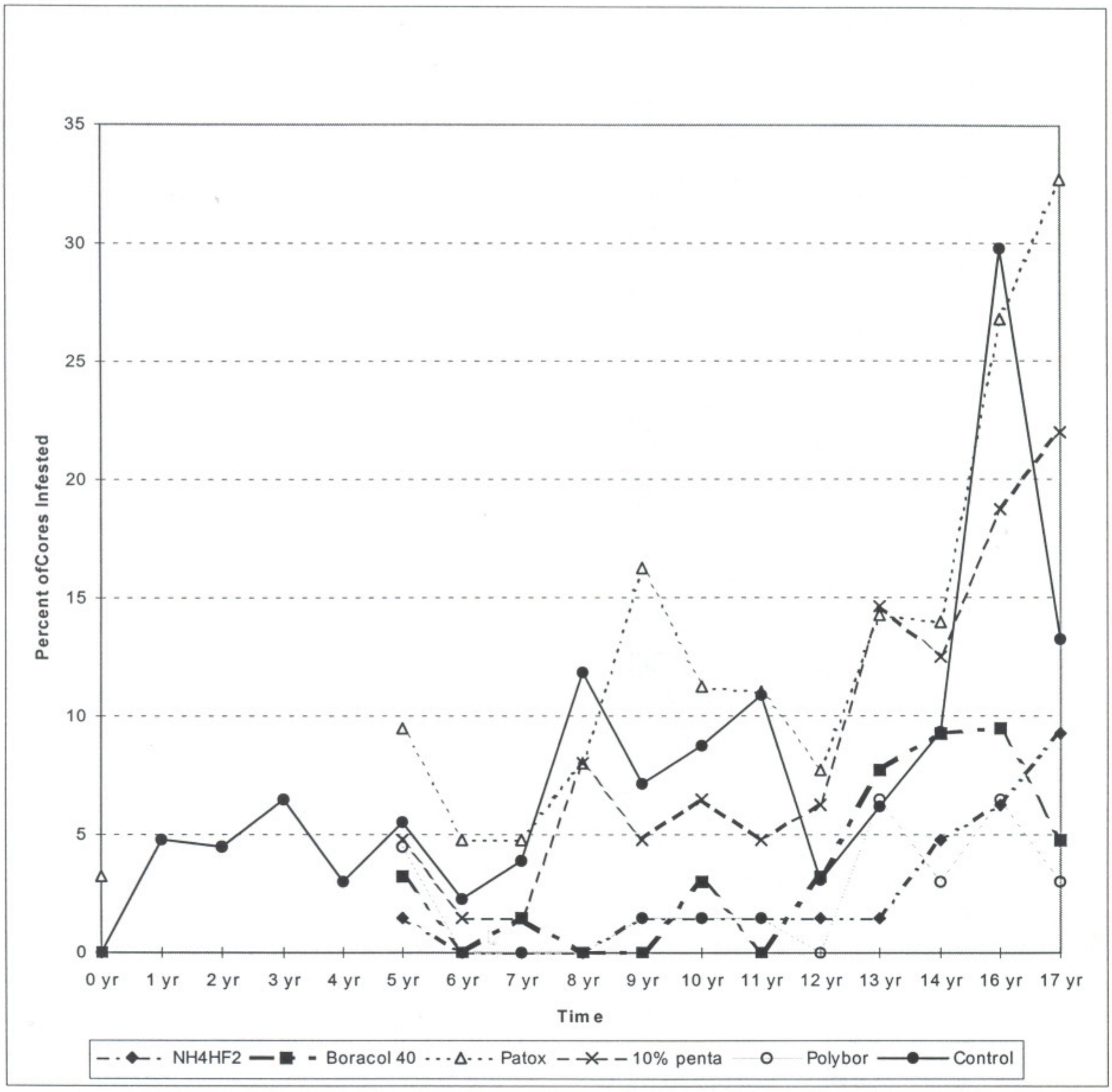


Figure II-1 Effect of topical treatments to field drilled bolt holes in Douglas-fir poles on the percentage of increment cores containing basidiomycetes 1 to 17 years after treatment.

OBJECTIVE III

EVALUATE PROPERTIES AND DEVELOP IMPROVED SPECIFICATIONS FOR WOOD POLES

A. A Survey of Utility Maintenance and Remedial Treatment Practices

Last year, we provided preliminary reports on a survey of utility practices across the United States. The goals of this survey were to determine how utilities maintained the poles of various species within their systems as well as to determine how they perceived the performance of their wood products. The initial survey was mailed to 1100 utility engineers across the United States. The initial response to this survey was limited (173 usable responses and 70 surveys returned for incorrect addresses). We initiated a second mailing to those who did not respond to the initial request and received an additional 87 responses for a 25.2 % total response rate. The results of the survey are still being analyzed, but a portion of the data has been analyzed for discussion.

A total of 260 utilities provided usable responses. The bulk of these utilities maintained 10,000 to 50,000 poles within their systems (Figure III-1). The upper voltage limit for using wood for most utilities was 230 kv, although over 60 utilities continued to specify wood poles at higher transmission voltages (345 kv) (Figure III-2). Utility purchases in 1997 varied widely. Most utilities responding to the survey purchased fewer than 500 poles/year, although nearly 20 utilities purchased more than 10,000 poles (Figure III-3). The overall replacement rates within utility systems remain relatively low and illustrate the overall good performance of wood poles within the systems. Most utilities appeared to be concerned about the initial quality of the poles entering their system as evidenced by the use of either in house or third party quality control systems (Figure III-3. Over half of the utilities surveyed (53.5 %) used a third party inspection agency to monitor pole quality, while an additional 25.8 % used an in-house monitoring. Fewer than 20 % of all utilities (17.3%) depended solely on in-plant monitoring, while an additional 7.3 % did not believe that their poles were monitored. The results indicate that a majority of poles are produced using multiple layers of quality control to reduce the potential for poorly treated poles to enter the utility system. This degree of oversight bodes well for future pole performance.

A majority of respondents did not use Douglas-fir in their systems (Figure III-4). This finding reflects the preponderance of smaller cooperatives, public utility districts and municipals in the response pool. Most utilities using Douglas-fir tended to specify some type of groundline pretreatment as a means of improving penetration and limiting the potential for groundline decay in this species. The most common method specified was deep incising, followed by through-boring, and finally, radial drilling. The inclusion of these procedures in Douglas-fir specification indicates that a majority of utilities have taken steps to reduce their risk of internal decay in this wood species which should translate into reduced maintenance costs and longer service.

Figure III-1. Number of poles per utility system

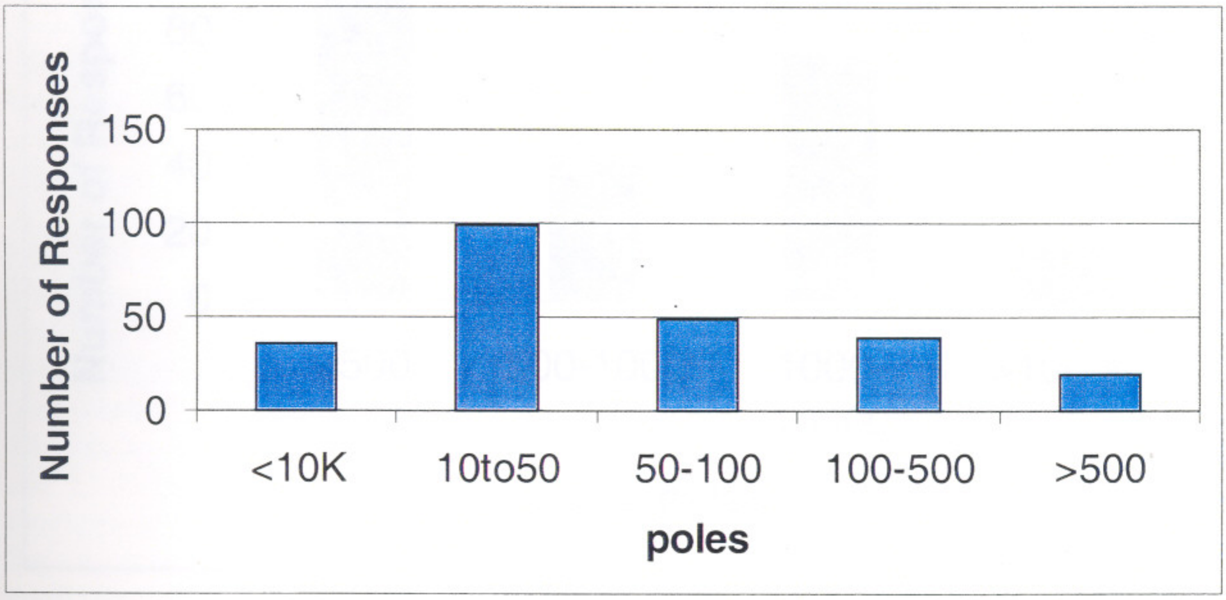


Figure III-2. Upper voltage limit for wood poles by various utilities across the U.S.

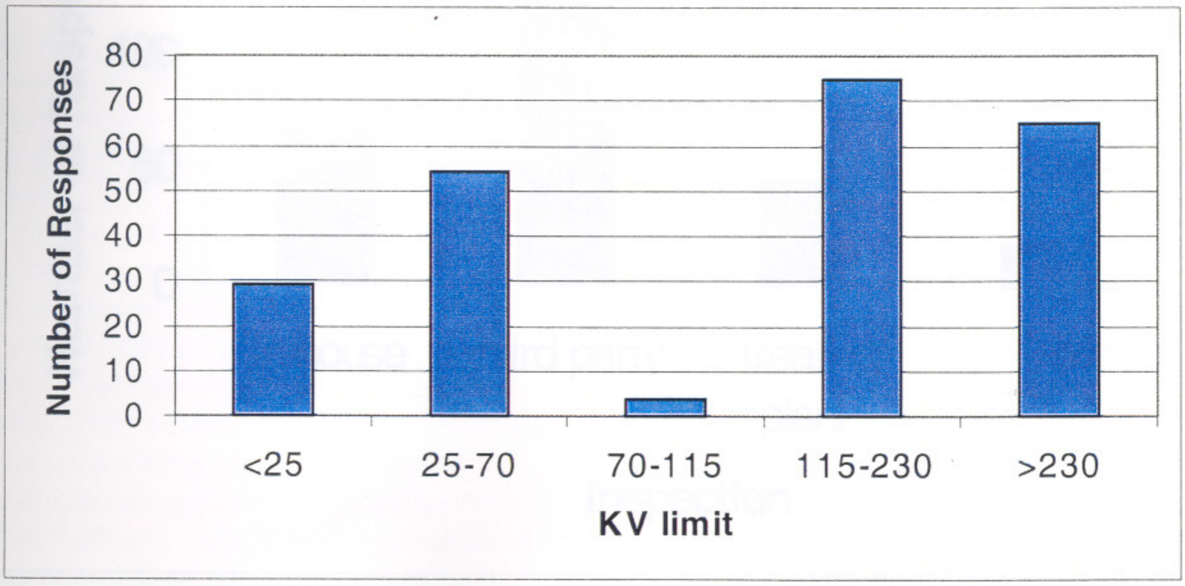


Figure III-3. Number of poles purchased per year per utility

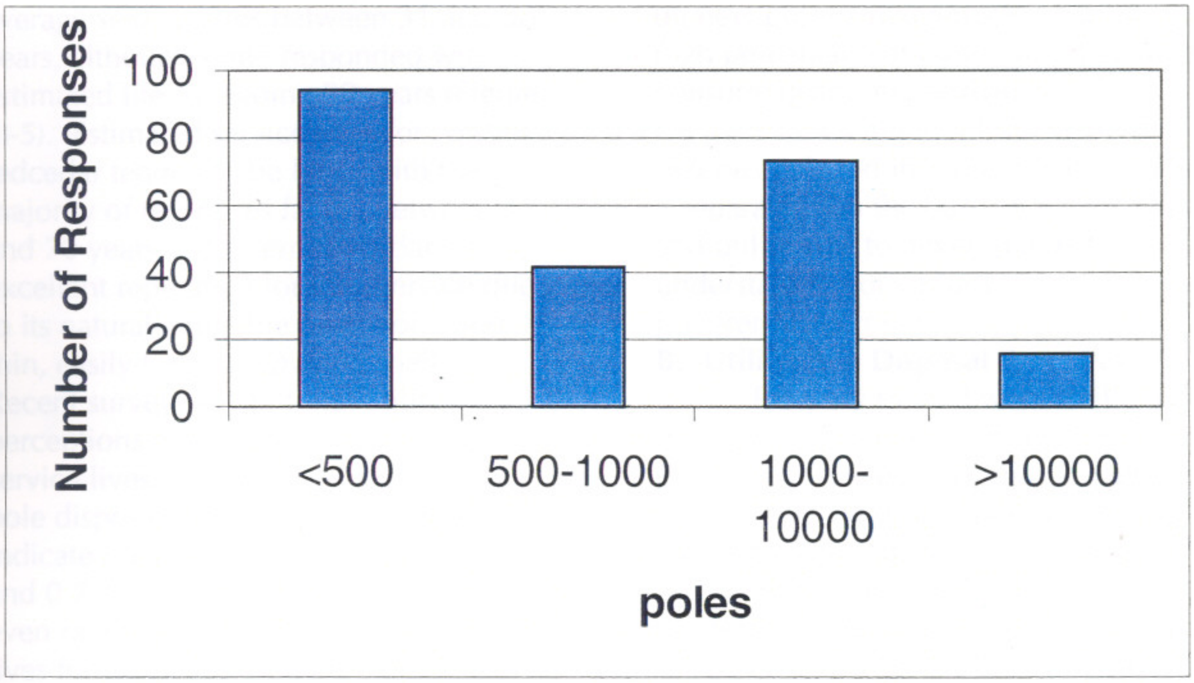
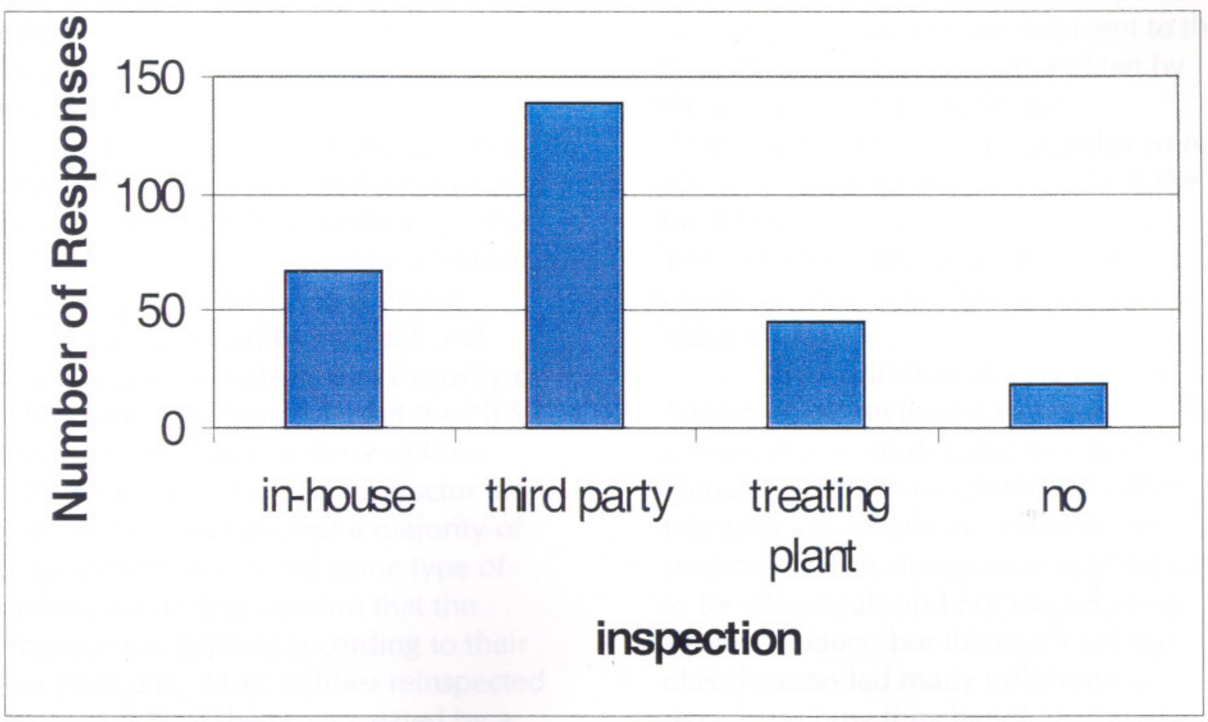


Figure III-4. Frequency of post treatment pole quality inspection by utilities, third party inspection agencies or treating plants.



Utilities were also asked to provide an estimate of service life for the wood species in their system. Not surprisingly, most utilities felt that their poles had average service lives between 31 and 50 years, although some responded with an estimated life exceeding 90 years (Figure III-5). Estimated service lives for western redcedar tended to be long, with the majority of responses falling between 41 and 70 years. Western redcedar has an excellent reputation for long service due to its naturally durable heartwood and thin, easily treated sapwood shell. Recent surveys suggest that utility perceptions differ somewhat from actual service lives. For example, surveys of pole disposal in the Pacific Northwest indicate replacement rates between 0.5 and 0.7 % per year. If one assumes an even rate of replacement, average service lives for poles in this region for all causes would be between 71 and 100 years. Clearly, wood poles are performing well beyond the typical 30 to 40 years. These figures have important implications for utilities contemplating the use of alternative materials that claim long service life.

Maintenance practices have not yet been fully analyzed, but a majority of respondents (87.8 %) indicated that they had a regular inspection and maintenance program (Figure III-6). This level is similar to that found by Goodell and Graham, and indicates that a majority of utilities are attempting to meet the NESC requirements. Most of these utilities (63.8 %) used an outside contractor to perform this program, but a majority of these utilities performed some type of internal auditing to confirm that the program was applied according to their specifications. Most utilities reinspected less than 5 % of the poles treated by a contractor, while some claimed to reinspect over 50 % of their poles. We suspect that these responses actually pertained to the frequency of inspection on new poles since reinspecting such a high percentage of poles would be time consuming and expensive.

The remainder of the responses will be analyzed in more detail including a separation on the basis of decay hazard and utility size to develop a better understanding of various utility preferences across the U.S.

B. Utility Pole Disposal Practices

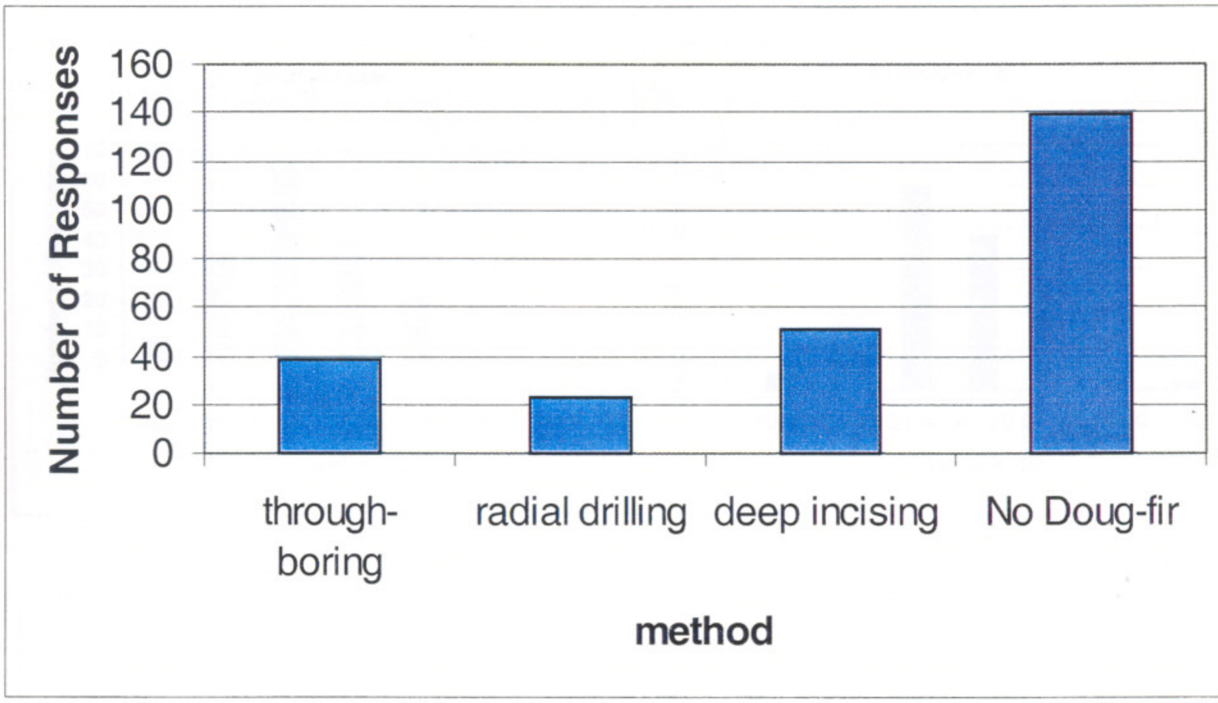
Properly treated wood utility poles provide long, reliable service life. Eventually, however, even a properly treated pole must be replaced. Poles can sometimes be removed for reuse within the system. This is particularly true for western redcedar poles, but it can also hold true for poles of other species. Some poles, however, are not salvageable and are subject to disposal.

Utilities have long disposed of poles with little concern. In rural areas, the poles were given to landowners adjacent to the right-of-way or were cut up and left by the side of the road, and they disappeared. The remaining poles were placed in a dumpster and hauled to the local landfill.

The increased regulation of wood preservatives changed this approach for many utilities.

The Environmental Protection Agency (EPA) reviewed all wood preservatives and decided to classify creosote, pentachlorophenol, and the inorganic arsenicals as restricted-use pesticides. This designation applied only to the chemicals and not the resulting treated product, but the restricted use classification led many utilities to reevaluate how they handled treated

Figure III-5. Frequency of utilities that incorporate radial drilling, through boring, or deep incising into their Douglas-fir pole specification.



wood. One common response was to provide a consumer information sheet to those receiving poles to ensure that they understood the handling aspects of the products.

The EPA also began to evaluate disposal of a wide variety of materials into the nation's landfills and began requiring the use of a Toxicity Characteristics Leaching Procedure (TCLP) to characterize the risk posed by wastes containing regulated materials such as wood preservatives. For wood, this procedure involved grinding the wood to a powder-like consistency, extracting the material, and analyzing the extract for EPA priority pollutants. Regulated levels were established based on the Clean Water Act and in addition, some states devised their own biological tests. Material that failed either test would be subject to disposal in a secure, lined landfill specifically designed to accept hazardous wastes.

Fortunately, extensive testing of treated wood using the TCLP procedures showed that virtually all materials passed these procedures and were disposable in any landfill. Some utilities still experienced local difficulties in pole disposal, but these problems appeared to reflect a hesitancy on the party of landfill operators to accept large volumes of wood, which was relatively bulky for a given weight.

While the EPA continues to endorse reuse as the preferred disposal method, landfilling remains a viable option for poles that cannot otherwise be recycled.

The concerns about disposal of treated wood by utilities are in no way inconsequential. It is estimated that utilities have 160 to 170 million wood poles in service. Even at a 1% annual rate of replacement, utilities would

Figure III-6(a-f). Estimated service lives of a) southern pine, b) Douglas-fir, c) western redcedar, d) ponderosa pine, e) lodgepole pine or f) other pole species.

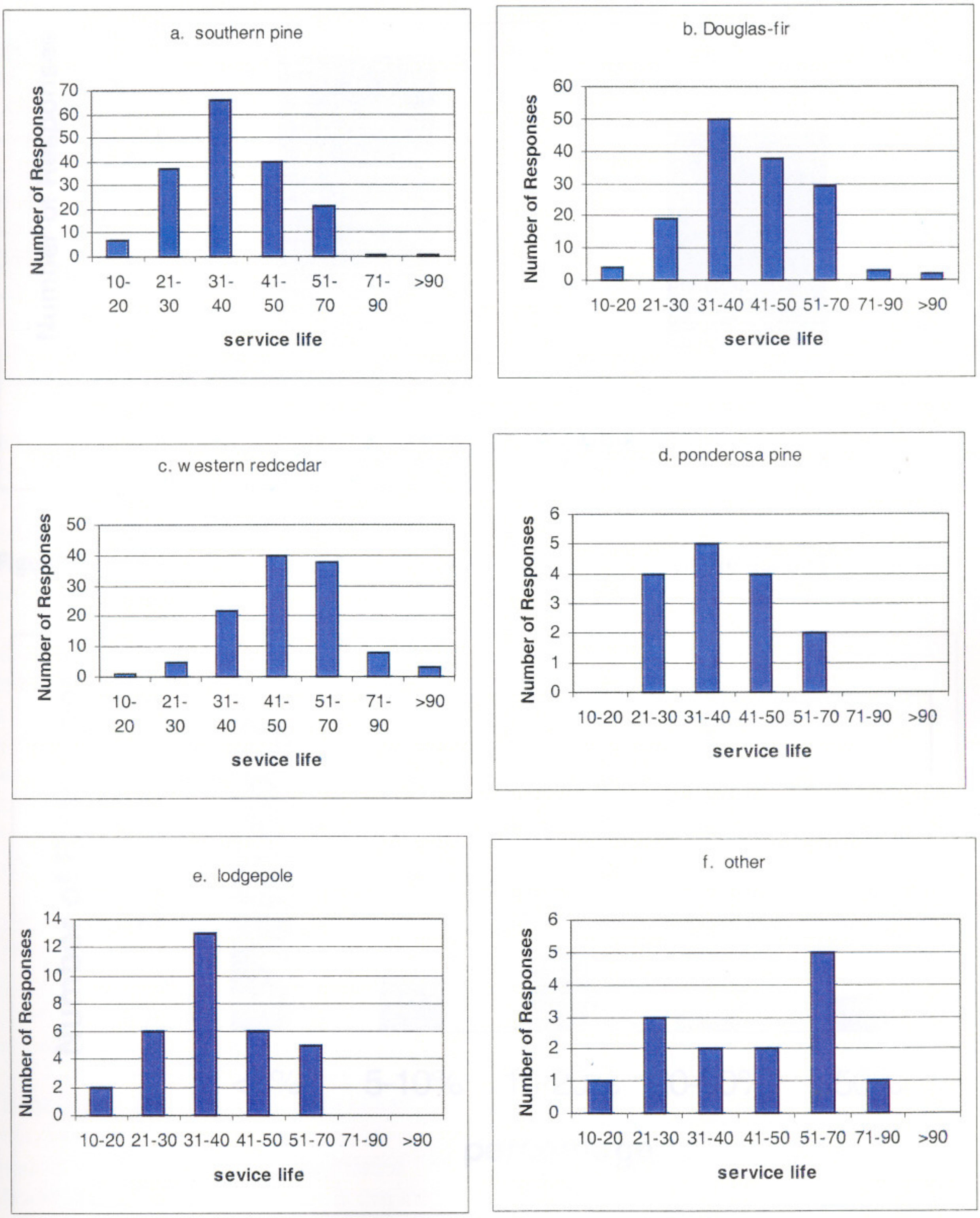


Figure III-7. Number of utilities that operate or outsource a regular inspection and maintenance program.

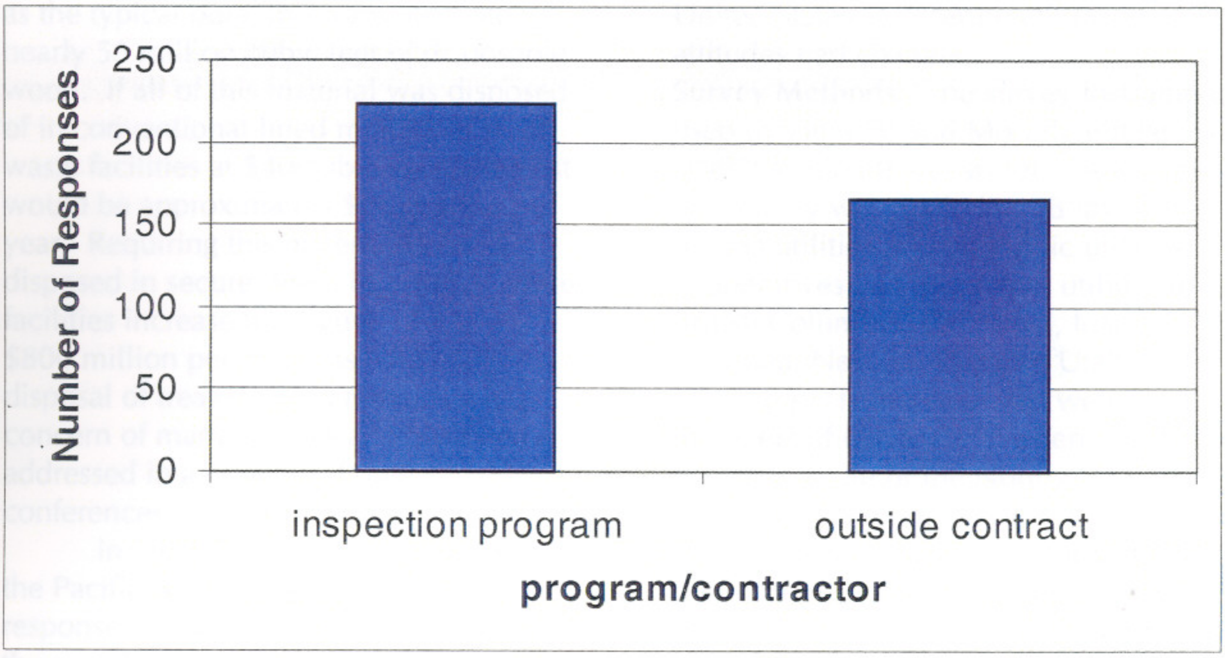
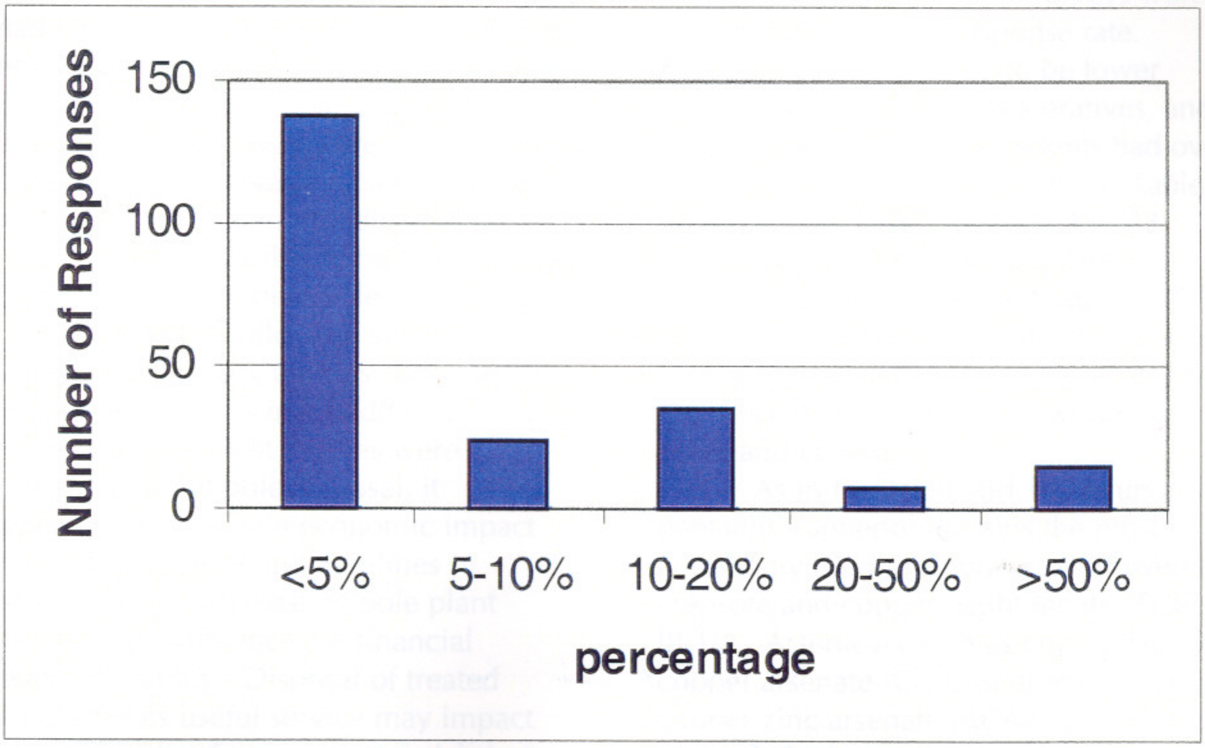


Figure III-8. Percentage of poles inspected by a third party which are audited.



dispose of 1.6 to 1.7 million poles per year. Using a Class 4, 40-foot long pole as the typical pole, this translates into nearly 55 million cubic feet of disposable wood. If all of this material was disposed of in conventional lined municipal solid waste facilities at $40/cubic yard, the cost would be approximately $88 million per year. Requiring this material to be disposed in secure, lined hazardous waste facilities increase this figure 10-fold to $800 million per year. As a result, disposal of treated wood remains a key concern of many utilities and has been addressed in a number of pole conferences.

In 1988, Hess surveyed utilities in the Pacific Northwest and received 65 responses. Most utilities indicated that they used pentachlorophenol-treated wood and more than half of them provided personnel training concerning safe handling of these materials. A majority of utilities gave poles away and made efforts to ensure that those receiving the wood were aware of its characteristics. Most poles that were not recycled or given away were transported to municipal solid waste facilities. Only six respondents stated that disposal of treated wood was influencing their choice of preservatives for new poles.

In 1997, a follow-up survey suggested that many utilities continued to dispose of the poles in a traditional manner. While most utilities were concerned about pole disposal, it appeared to have little economic impact.

The benefits and liabilities associated with an existing pole plant may strongly influence the financial health of a utility. Disposal of treated wood after its useful service may impact the "bottom line" on use of wood poles.

As a part of the Utility Pole Conference, we re-surveyed utilities in the western United States to determine if disposal attitudes had changed.

Survey Methods: The survey instruments used by Hess (3) and Morrell and James (1997) formed the basis for a new survey. The survey was mailed to 18 investor-owned utilities and 90 public utilities, cooperatives and municipal utilities in British Columbia, California, Idaho, Montana, Nevada, Oregon, Utah, and Wyoming. Those surveyed were members of either the Western Electric Power Institute or the Northwest Public Power Association.

The responses were tabulated and duplicate responses from the same utility were compared and if they were similar, only one response was tabulated. The results were also compared with those from 1997 to determine if attitudes and programs had changed (Table III-1a-h).

A total of 51 usable surveys were returned for a 42.6% response rate. Response rates appeared to be lower among public utilities, cooperatives, and municipalities. The respondents had over 6.2 million poles in their systems (Table III-1c) and disposed of nearly 44,188 poles per year (Table III-1d). These figures imply a replacement rate of 0.7 % per year, an excellent testimony to the longevity of wood. A majority of utilities that responded used treated wood for poles and crossarms.

As in the 1988 and 1997 surveys, pentachlorophenol remains the most commonly used preservative, followed by creosote and copper naphthenate (Table III-1h). Arsenicals such as chromated copper arsenate (CCA) or ammoniacal copper zinc arsenate (ACAZ) are still used on a relatively small percentage of the poles in the utility system. It is interesting to note that the number of utilities with some copper naphthenate in their systems more than doubled over the last 10 years but the levels remain low. This preservative continues to be touted as a penta replacement, but it is clear that most utilities remain satisfied with their existing treatment options.

Most utilities provided training concerning treated wood to their personnel, although the frequency of this training varied (Table III-1e). A slight majority of utilities provided protective clothing to line personnel, but this appeared to primarily constitute supplying gloves (Table III-1h).

A majority of utilities responding continue to give poles away. Only seven respondents sent poles to a hazardous waste landfill and a number of these only did so when unable to give away the wood. Five utilities either sold their used poles or re-sawed the wood for other products. This was a slight decline from the 1997 survey.

Of the utilities giving poles away, 76% provided a consumer information sheet to the receiver and required that the receiver sign an indemnification agreement. Nearly all of those requiring this document maintained a permanent record of the transaction. These levels represent a slight increase from 1997. These results indicate that, while utilities continue to give away used poles, they continue to take steps to ensure that those receiving this wood understand its properties. Similarly, 27 percent of respondents labeled poles to warn against burning, nearly double the 1997 level.

Pole disposal appeared to represent a relatively minor cost to the majority of utility respondents. Forty-seven of the respondents stated that they spent less than $50,000 per year on pole disposal and a number of these spent nothing. Two utilities spent $50,000 to $100,000 per year. With a few exceptions, disposal costs appear to represent a relatively minor utility expense.

Most utilities (23%) reported that they had no difficulty in locating landfills willing to accept treated wood. This level was similar to the 1997 survey. The lack of difficulty in identifying disposal options and the relatively small cost of disposal suggests that this factor should have little effect on selection of preservatives for new poles. However, 24% of respondents stated that disposal options had influenced their preservative selection. Only six of 65 respondents (9%) gave a similar answer in the 1988 survey, while 44% gave this response in 1997. These variations suggest that many utilities remain uncertain about the risks associated with pole disposal. While the current status of disposal frames this as a minor issue, it is clear that conflicting messages from disparate sources continue to affect utility perceptions of this issue. These results suggest that utility perceptions concerning pole disposal deviate from the reality. Wood pole and crossarm producers must continue to educate utilities concerning the economical disposal options available.

Table III-1 (a-h). Results of utility pole disposal survey

a.

Commodities Subject to Disposal	No. of Respondents	
	1997	1999
Poles	62	51
Crossarms	57	47
Construction Timbers/Beams	26	23

b.

Preservative Used	No. of Respondents	
	1997	1999
Pentachlorophenol	59	47
Creosote	14	17
Inorganic Arsenicals	3	11
Copper Naphthenate	20	9

c.

Number of Poles in System	No. of Respondents	
	1997	1999
<10,000	12	9
10,000-50,000	25	19
50,001-100,000	1	8
100,001-500,000	10	5
>500,001	3	5
Average Standard Deviation	156,860(244,000)	135,294(258,230)

d.

Number of Poles Disposed	No. of Respondents	
	1997	1999
<50	9	7
50-100	15	10
101-500	25	14
501-1,000	2	7
1,001-10,000	4	4
>10,000	1	1
Average Standard Deviation	809(1,352)	1,028(3,129)

e.

Does Utility Provide Training?	No. of Respondents	
	1997	1999
Yes	38(66%)	41(80%)
No	20(34%)	10(20%)

f.

How often is Training Offered?	No. of Respondents	
	1997	1999
Annually	12	14
New Employee Training	11	17
Other	23	19

g.

Is Protective Clothing Provided During:	No. of Respondents	
	1997	1999
Construction		
Yes	31(53%)	26(51%)
No	28(47%)	25(49%)
Maintenance	31(53%)	28(54%)
Yes	27(47%)	24(46%)
No		

h.

Clothing Provided	No. of Respondents	
	1997	1999
Gloves	32	28
Suits	2	1
Pants	1	6
Coveralls	8	12
Jackets	3	7

C. Fire resistance of pentachlorophenol, ammoniacal copper arsenate, or ammoniacal copper zinc arsenate treated Douglas-fir pole sections

Through-boring can markedly enhance the treatment of refractory wood species such as Douglas-fir (Merz, 1959, Brown and Davidson, 1961; Graham and Estep, 1966; Graham et al., 1969; Graham, 1983; Morrell and Schneider, 1994). This improved treatment translates into a reduced incidence of internal decay in the groundline zone (Lindgren, 1989). The improved performance of through-bored poles has led many utilities to incorporate this practice into their specifications.

While through-boring has markedly reduced the incidence of internal decay at groundline, some utilities have expressed concerns about the behavior of these poles during fires. There are concerns that the through-bored holes, which are drilled at a slight angle to allow water drainage, will act as convective pathways, and essentially accelerate burning of the poles. Furthermore, the higher loadings of flammable oil in the through-bored zone may further increase the risk during fires. These concerns came to a head during a large wildfire in Oakland, California, where a number of through-bored poles burned completely through and failed.

In order to further investigate the potential for through-boring to increase the risk of pole failure during wild fires, we undertook the following tests.

MATERIALS AND METHODS

Thirty Douglas-fir (*Pseudotsuga menziesii* (Mirb.) Franco) pole sections (250 to 300 mm in diameter by 1.5 m long) were seasoned to 20 to 25% moisture content prior to use. One half of the poles were through-bored using a standard Bonneville Power Administration pattern consisting of 11 mm diameter holes drilled downward into the poles at a five degree angle 2 feet above and below the intended groundline. The holes were spaced 62.5 mm apart laterally and 262.5 mm apart longitudinally. The remaining poles were left as non-through-bored controls. The poles were treated to a retention of 9.6 kg/m^3 with either pentachlorophenol in P9 Type A oil or ammoniacal copper zinc arsenate according to American Wood Preservers' Association Standard C4 (AWPA, 1998).

Five through-bored and five non-through-bored poles were treated with each chemical. An additional set of ten (five through-bored/five non-through-bored) poles were left untreated. Also included in the test were four poles treated with ammoniacal copper arsenate to an estimated retention of 9.6 kg/m^3. The ACA poles were removed from service after approximately 50 years and included in the test because previous observations suggested that wood treated with this chemical would char in a manner similar to that of chromated copper arsenate-treated wood (Arsenault, 1973). Glow type combustion has also been noted with other copper containing waterborne preservatives such as ammoniacal copper quaternary preservative (ACQ) (Preston et al., 1993)

The pole sections were then seasoned using one of two methods. The penta-treated poles were air-seasoned for 2 months during the summer when there was little or no rainfall. The non-treated and ACZA-treated pole sections were kiln dried using a schedule that gradually ramped the temperature upward to a maximum of 180°F over a four day period using a narrow wet bulb depression. The diameters of each pole were measured in 0.1 m increments along the length to provide a base for later measurements of cross sectional area losses.

The poles were then set to a depth of 0.3 m in a mixture of gravel and soil at a site located near Corvallis, Oregon. The poles were left in the soil for 30 days because of fire restrictions that were imposed on all Oregon forest lands at the end of the dry season. The test site received approximately 25 mm of rainfall 3 days before the tests were initiated

The moisture content of untreated and penta-treated poles was measured at a depth of 50 mm near the groundline and 300 mm above that zone using a resistance type moisture meter.

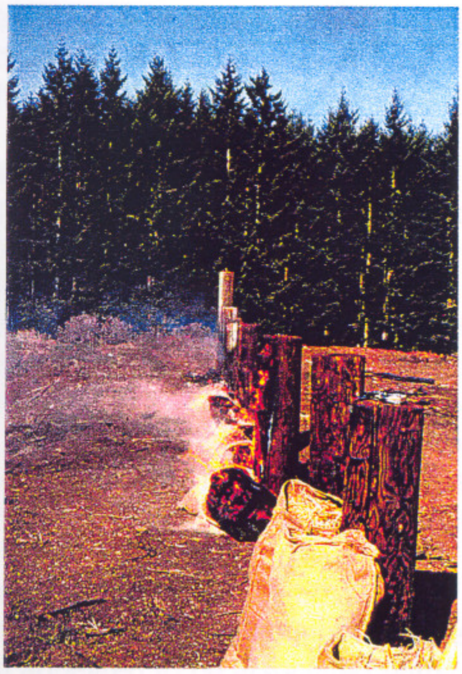


Figure III-9. Burlap bag containing straw that was used to initiate pole ignition.

Figure III-10. Pentachlorophenol treated pole burning during the fire test.

The resistance of each pole to fire was evaluated by placing 3 kg of rye straw into a burlap bag and placing this bag against the side of a pole at groundline (Figure III-9). The bags were ignited and provided a burn time of approximately 9 minutes/pole. The poles were observed as the fires were ignited and then periodically over the next 3 days (Figure II-10). Heavy rains on the third day extinguished any residual flames approximately 60 hours after ignition.

The degree of damage to each pole was assessed by cutting the pole sections into 100 mm long sections corresponding to the original diameter measurement points (Figure III-11). A grid was placed on the exposed cross section and the residual pole area was measured. The measurement did not include areas that were obviously softened or charred.

As noted, the total time each pole was exposed to a visible flame was approximately 9 minutes. At that point, most of the straw was consumed or had burned to the point where there was minimal contact with the pole. Twelve of the 34 poles burned completely during the test (Table III-2).

Penta-treated pole stubs uniformly caught fire following ignition and many continued to burn for the approximately 60 hours over which the test ran. In a number of cases, the flames were concentrated in checks or at the pole tops and appeared to be associated with edges. Initially, the through-bored holes appeared to act as chimneys, drawing smoke upward and presumably drawing oxygen into the fire; however, only one through-bored pole burned to the point of failure. All of the poles were charred, but the damage was largely superficial. The remaining penta-treated poles experienced varying degrees of damage, but the damage appeared to be primarily associated with checks rather than the through-boring pattern. Through-bored poles, however, tended to lose more cross section area (Table III-3). These averages must be viewed with some caution since they include complete failure of one through-bored pole.

The ACA-treated pole stubs ignited shortly after the straw fire and continued to slowly char over the test period. One pole had failed within 24 hours, and a second failed by the conclusion of the trial. The remaining pole experienced relatively little damage, suggesting that the straw failed to ignite the metals in the wood.

The ACZA-treated pole sections generally ignited shortly after the straw was consumed and continued to burn over the next 60 hours (Figure III-12). Two non-through-bored poles had failed within 24 hours and another six failed by the conclusion of the test. The two remaining through-bored poles experienced relatively light charring near the groundline and more substantial damage further up the pole. The results indicate that ACZA, which had been touted as being fire resistant, did not provide protection under the conditions employed. The results also differ from those reported by Preston et al. (1993) who noted that ACZA treated pole sections were "significantly more resistant to fire than ACQ or chromated copper arsenate-treated samples." The 9 minute burn period in our trials was relatively severe. Zahora (personal communication, 1999), in tests on resistance of ammoniacal copper quaternary ammonium system (ACQ) used only 1 kg

Figure III-11. Cross sections cut from selected locations along the length of a pentachlorophenol treated Douglas-fir pole following fire exposure.

because of concerns that the test poles would fail to ignite with the smaller fuel load.

Although non-treated wood is generally viewed as flammable, only one of the untreated control poles burned completely through. The remaining poles experienced relatively minor damage as the surface of the wood charred and inhibited further damage. The pole that failed was a through-bored pole, but the remaining through-bored poles experienced levels of damage that were similar to those found for the non-through-bored materials.

The results indicate that the presence of zinc in ACZA failed to reduce the flammability of this system in comparison with ACA. Through-boring did not appear to be consistently associated with elevated fire damage, although the holes clearly acted as chimneys during the flame period. Overall, however, through-boring did not markedly increase the risk of pole fires.

This work could not have been completed without the generous donation of treated pole sections by J.H. Baxter & Co., Eugene, Oregon and the efforts of Tim Foelker of that company to ensure that the material was properly treated.

Table III-2. Percentage of untreated and pentachlorophenol, ACA, or ACZA treated poles that failed following exposure to a 9 minute burn.

Treatment	Through-boring	Poles Remaining (%)
Control (untreated)	-	100
	+	80
Pentachlorophenol	-	100
	+	80
ACZA	-	0
	+	40
ACA	-	50

[a]Values represent tests on five poles per treatment except for the ACA which included only four poles.

Figure III-12. ACZA-treated Douglas-fir pole exhibiting extensive cross sectional area loss around the groundline following exposure to a 9 minute straw fire.

Table III-3. Average percentage of cross section area remaining along the length of untreated and pentachlorophenol, ACZA or CCA treated Douglas-fir pole sections subjected to a 9 minute burn test.

Treatment	Through boring	Cross Sectional Area Remaining (%)[a]										
		Butt	10 cm	20 cm	30 cm	40 cm	50 cm	60 cm	70 cm	80 cm	90 cm	Top
None	-	98 (2)	92 (5)	92 (5)	95 (4)	96 (3)	97 (0)	98 (2)	100 (3)	98 (3)	96 (7)	97 (7)
	+	67 (41)	66 (42)	69 (41)	73 (42)	79 (44)	79 (44)	79 (44)	79 (44)	78 (43)	79 (44)	81 (45)
Penta	-	89 (10)	82 (14)	79 (17)	80 (18)	74 (24)	75 (20)	76 (18)	72 (18)	67 (27)	68 (26)	69 (27)
	+	71 (42)	70 (40)	68 (40)	53 (41)	52 (42)	52 (43)	48 (43)	47 (41)	47 (42)	53 (38)	55 (38)
ACZA	-	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
	+	34 (46)	27 (37)	28 (39)	27 (37)	30 (42)	30 (44)	31 (46)	27 (43)	24 (43)	22 (43)	20 (46)
ACA	-	43 (50)	40 (46)	41 (47)	43 (50)	45 (52)	47 (54)	46 (53)	46 (53)	48 (55)	48 (56)	49 (57)

[a]Values represent mean measurements of 5 poles per position except the ACA treatment where only 4 poles were evaluated. Values in parentheses represent one standard deviation

D. Ability of selected inspection devices to assess the condition of Douglas-fir poles

While most utilities maintain active pole inspection and maintenance programs that include regular inspection and application of supplemental treatments to limit the potential for biodeterioration, one aspect of these programs that continues to frustrate utility engineers is the inability to accurately assess the residual strength of a structure. This difficulty is not surprising given the variability of wood and the myriad of possible decay patterns that can occur in a pole, but the frustration has encouraged a continuing search for inspection devices that can detect internal defects and estimate residual pole strength. The result has been the development of a number of acoustic devices, controlled drills and computer programs for predicting strength. These devices have been used by a variety of utilities, but there is relatively little comparative information on their performance. For this reason we elected to develop a comparative test of selected commercial inspection devices. The trials were initially performed on Douglas-fir poles, although plans are also underway to include similar tests on western redcedar.

Thirty Douglas-fir poles in the PacifiCorp system located in the Willamette Valley in Western Oregon that were slated for removal were selected. Some of the poles had been identified for replacement by the regular inspection program, while the others were slated for removal as the line was upgraded.

The poles were inspected within the groundline zone by first sounding with a hammer, then each pole was inspected using a Purl1, an EDM Pole Tester, and a Resistograph. The poles were then removed from service and returned to OSU for testing. Many of these poles were classified as joint-poles and we are still awaiting removal of the telecommunication component from 12 poles. In addition, two other poles were unable to be evaluated further because they were too short. The remaining 16 poles were tested with PoleCalc and then tested to failure in cantilever loading. We recorded total load and deflection and, with pole circumference, calculated Modulus of Rupture at groundline (MOR-GL). We also recorded the height at which the pole failed.

Following mechanical testing, a series of increment cores was removed from each pole at three equidistant sites around the pole at 300 mm increments along the length. These increment cores were cultured for the presence of decay and non-decay fungi on malt extract agar. To ensure that the devices were used as specified, the proponents of the various systems performed the inspections on the poles and provided their data to OSU.

Poles tested had been in service from 19 to 45 years and were primarily penta or creosote treated. Two poles had been treated with penta using the Cellon process. The poles were primarily class three and four poles between 30 and 45 feet long. Seven of the poles tested to failure had been removed from service due to decay, while the remainder had been removed as a part of an upgrade.

Most of the test poles failed in bending at groundline (Table III-4). Modulus of Rupture at groundline ranged from 3,220 to 10,827 psi, and 14 of 15 poles failed below the ANSI specified value. This finding was not suprising, given the fact that these poles had been in service for years. The most recently installed pole tested well above the ANSI value.

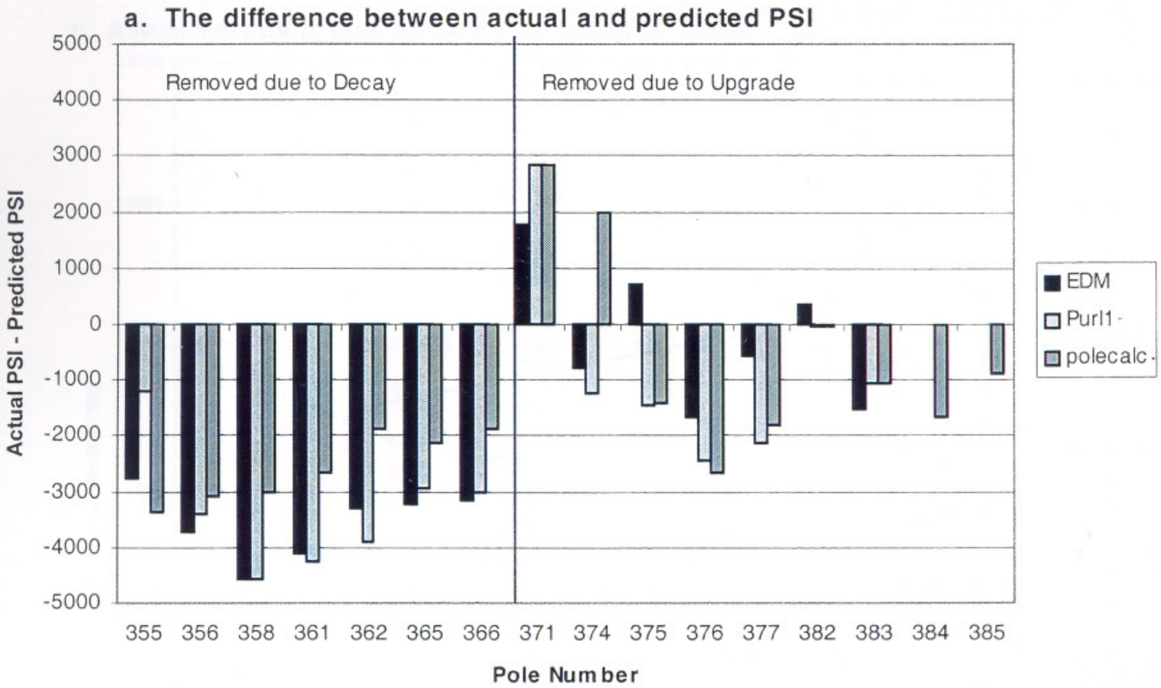
All of the non-destructive inspection devices tended to over-estimate pole strength in comparison to actual bending tests(Figure III-13(a-c)). Pole Test over-estimated strength in 11 of 14 tests, Purl 1 over-estimated strength in 12 of 14 tests, and PoleCalc over-estimated strength in 12 of 16 cases. Pole inspection is a delicate balance between identifying and removing unsafe poles without removing an excessive number of sound poles. In most instances, utilities take fairly conservative approaches to pole inspection since the cost of an unplanned outage can easily exceed the cost of removing a marginal pole.

Conversely, utilities entering their first maintenance cycle are often suprised by the number of reject poles indentified and seek to "save" these poles within their systems. The primary benefit of the non-destructive inspection devices is the ability to rapidly assess a pole without causing any damage, however, the devices must reliably predict when a pole should be further inspected. In a number of cases, the devices failed to detect poles that were far weaker than the ANSI values for Douglas-fir poles. These results suggest that the NDE devices are supplemental tools for assessing material properties, rather than stand-alone systems that eliminate the need to perform more physical inspections.

Table III-4. Material properties of Douglas-fir poles used to evaluate internal inspection devices.

Pole #	Treatment	Class Length	Age (yr)	GL Circ.	Failure Ht	Breaking Circum.	MOR-GL	EDM	Purl 1	PoleCalc	Reason for Removal
355	Penta	4-40	1965	36.5	2.0	36.6	3926	6700	5144	7280	Decay
356	Penta	3-40	1962	41.0	GL	41.0	3220	6950	6624	6288	Decay
358	Creo	3-35	-	34.0	GL	34.0	3435	8000	8000	6440	Decay
361	Penta	4-35	1963	35.0	GL	35.0	3731	7850	8000	6400	Decay
362	Penta	3-30	1962	36.5	1.6	35.0	4084	7390	8000	5952	Decay
365	Penta	5-35	?	30.6	GL	30.6	4248	7460	7176	6392	Decay
366	Penta	3-35	?	34.0	GL	34.0	4951	8100	7968	6832	Decay
371	Creo	3-40	1980	36.0	GL	36.0	10827	9050	8000	8000	Upgrade
374	Cellon	4-45	1962	37.0	GL	37.0	6765	7530	8000	3792	Upgrade
375	Creo	3-55	1966	42.0	GL	42.0	6530	5830	8000	7960	Upgrade
376	Creo	4-40	?	34.0	GL	34.0	5336	6990	7776	8000	Upgrade
377	Penta	4-45	1973	36.0	GL		5865	6450	8000	7688	Upgrade
382	Penta	5-30	1954	38.0	GL	38.0	7974	7610	8000	7992	Upgrade
383	Creo	3-55	1962	44.0	GL	44.0	6925	8450	8000	8000	Upgrade
384	Penta	4-40	1960	36.0	GL	36.0	4882	-	-	6560	Upgrade
385	Cellon	4-40	1962	35.5	GL	35.5	3706	-	-	4584	Upgrade

Figure III-13(a-c). Inspection results from 16 Douglas-fir poles showing bending strength as well as output from PoleTest, Purl1, PoleCalc and the Resistograph.



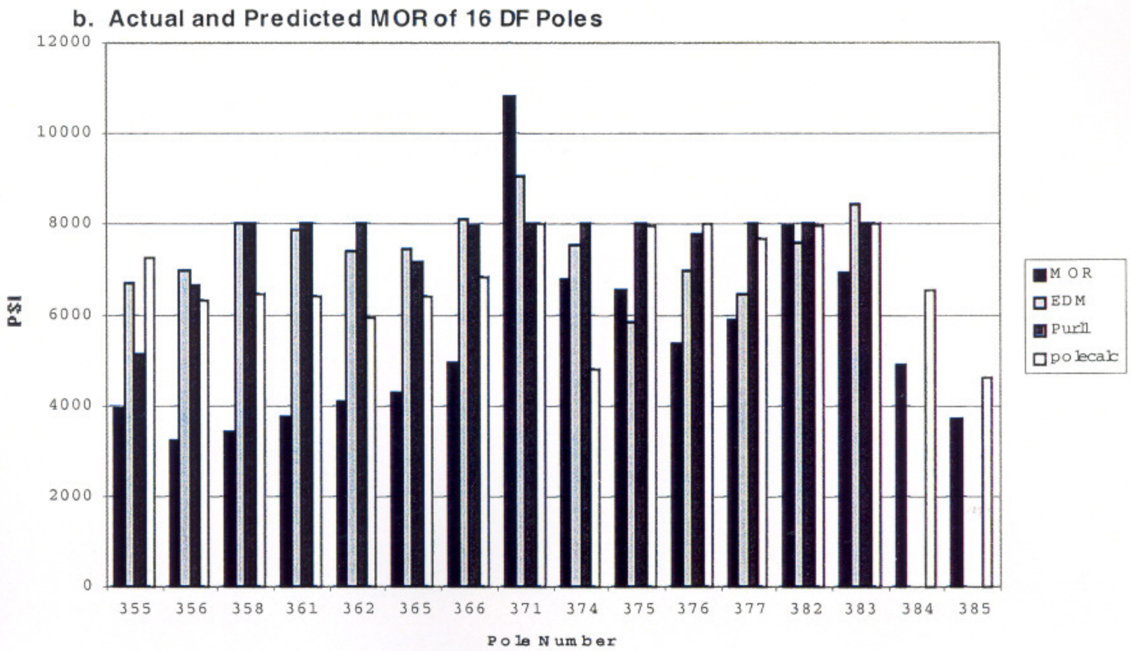
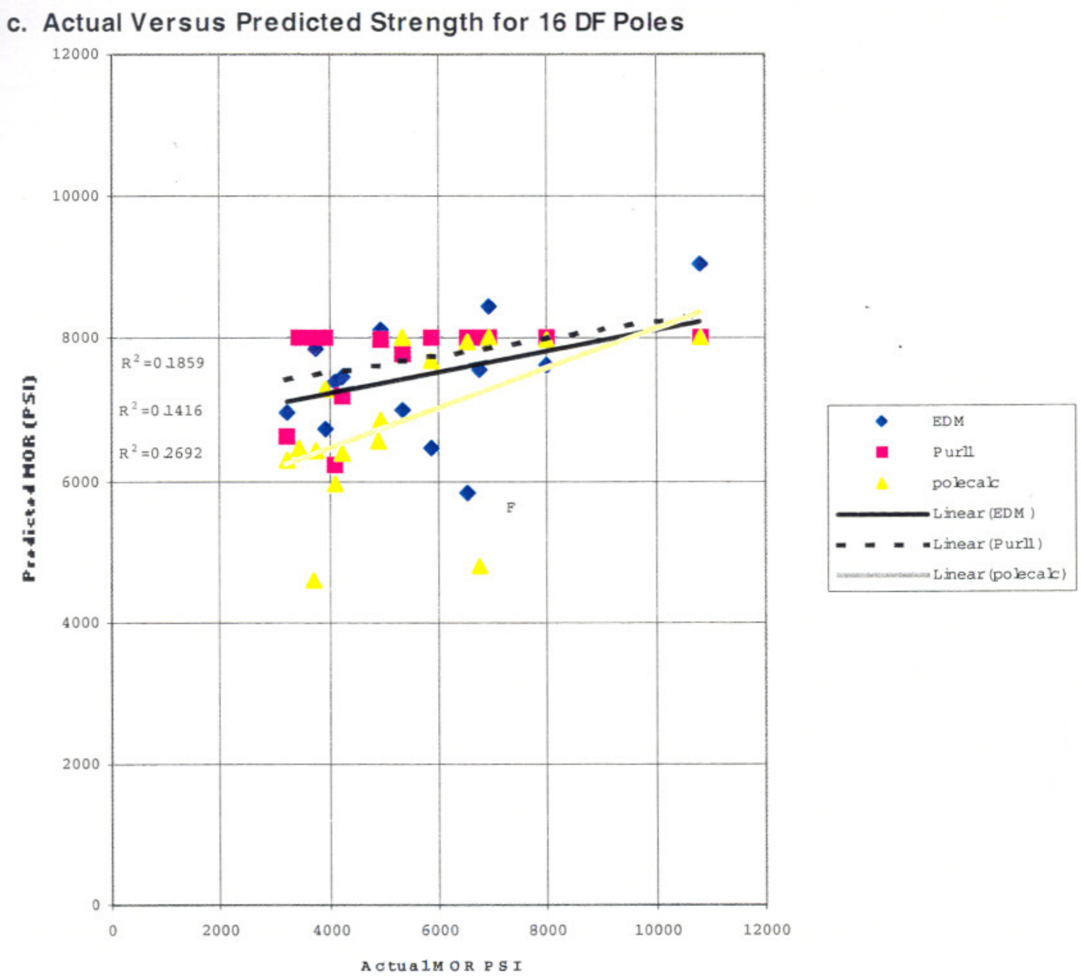
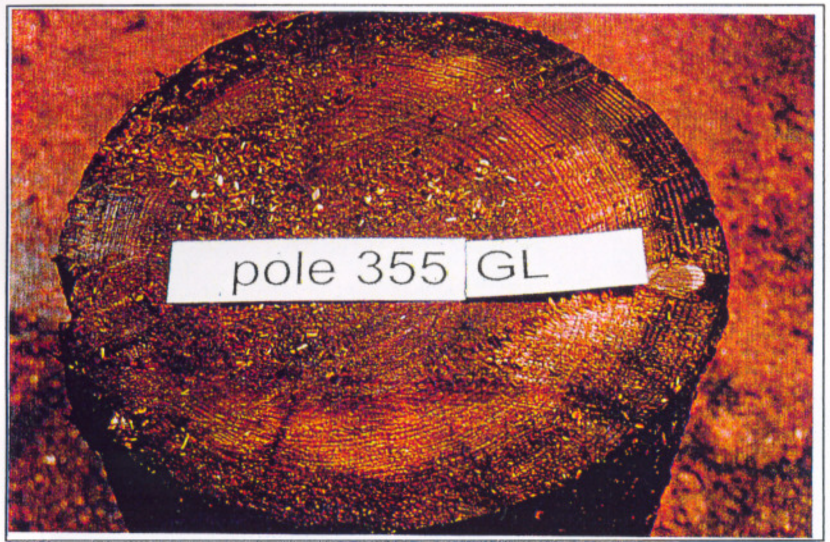


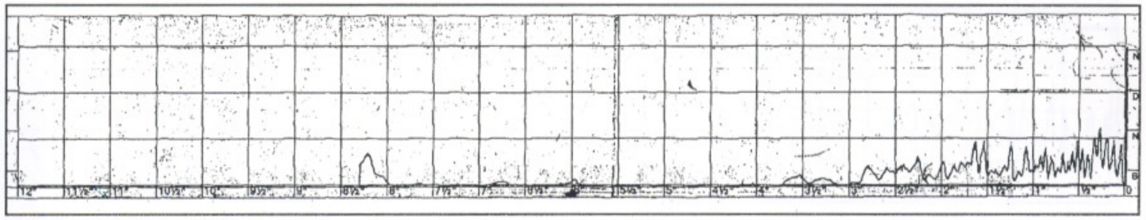
Figure III-13 continued.

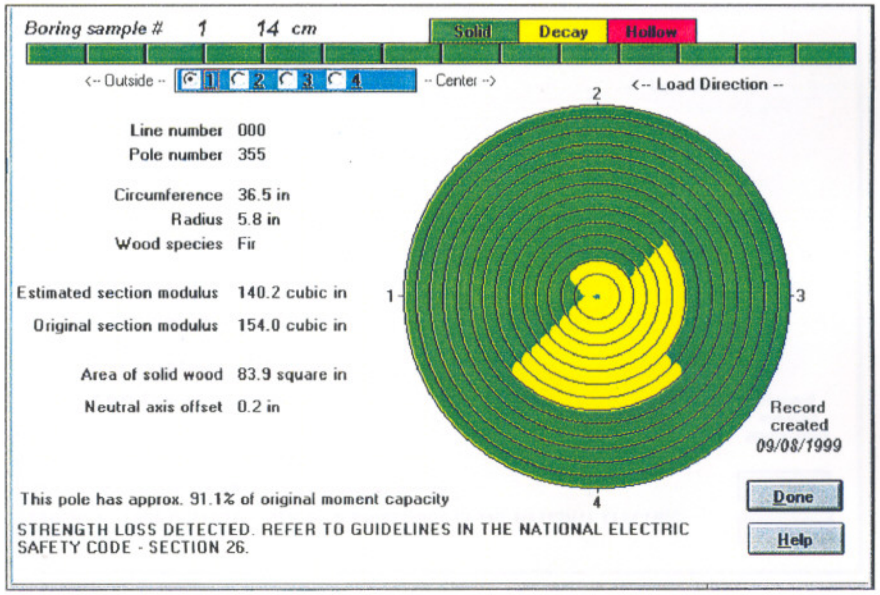


Tag No. 355

Pole #	Treatment	Class	Length	Year	GL Cir in	Break Ht ft	Tested MOR lbs	Est. EDM lbs.	Est. Purl1 lbs	Est. Polecalc lbs	Reason Removed
295622	penta	4	40	1965	36.5	2	3926	6700	5144	7280	decay



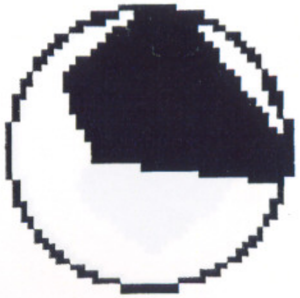




Position 1

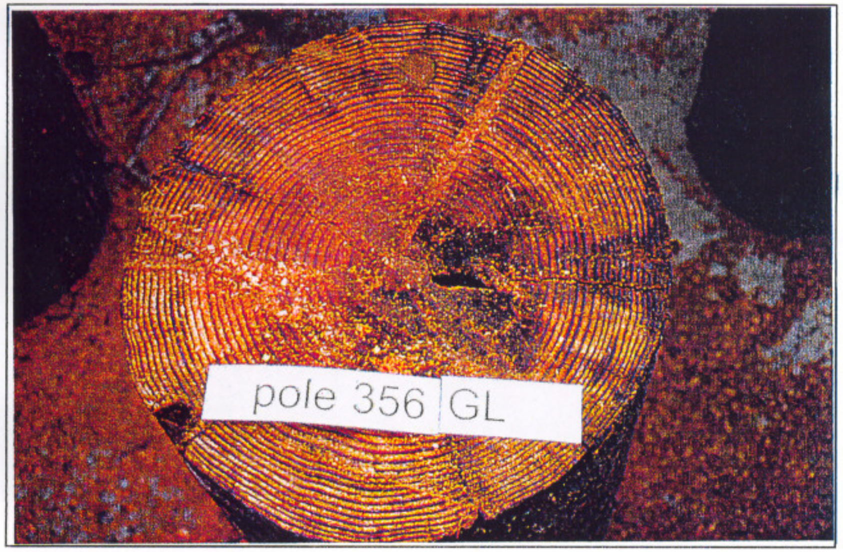
Height Above Butt : 1 inch

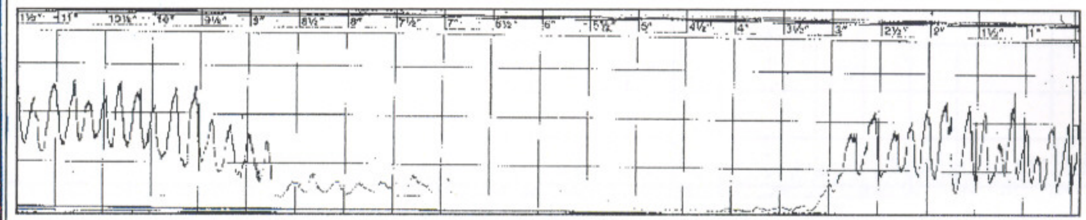
Co-ordinates of Centroid :	
X	-2.08039
Y	15.95621
Strength about Vertical Axis :	64.29874 %
Strength about Horizontal Axis :	51.17142 %
Minimum Strength of Section :	**64.29874 %**
Angle of Axis to the horizontal neutral axis about which the pole is bent to give the minimum strength :	14.5 °

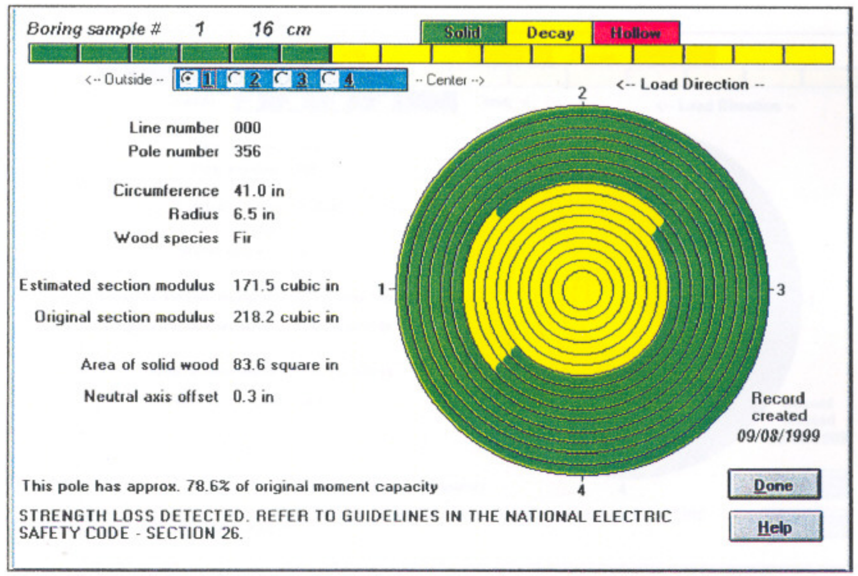


Tag No. 356

Pole #	Treatment	Class	Length	Year	GL Cir in	Break Ht ft	Tested MOR lbs	Est. EDM lbs.	Est. Purl1 lbs	Est. Polecalc lbs	Reason Removed
294800	penta	3	40	1962	41	GL	3220	6950	6624	6288	decay







Position 1

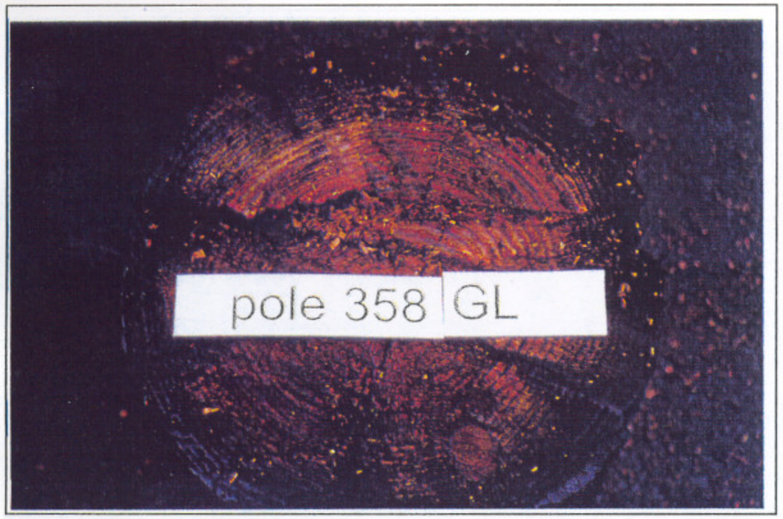
Height Above Butt : 1 inch

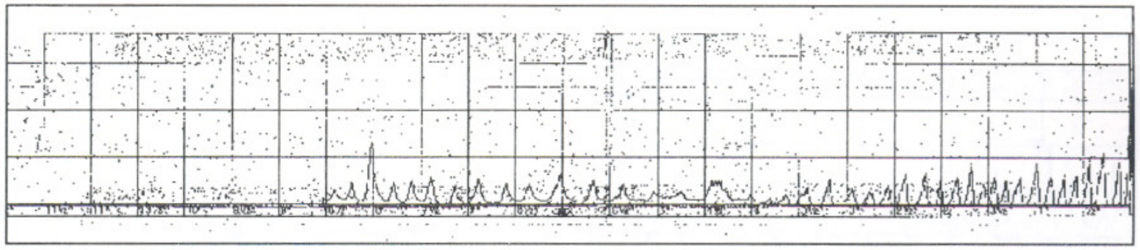
Co-ordinates of Centroid :

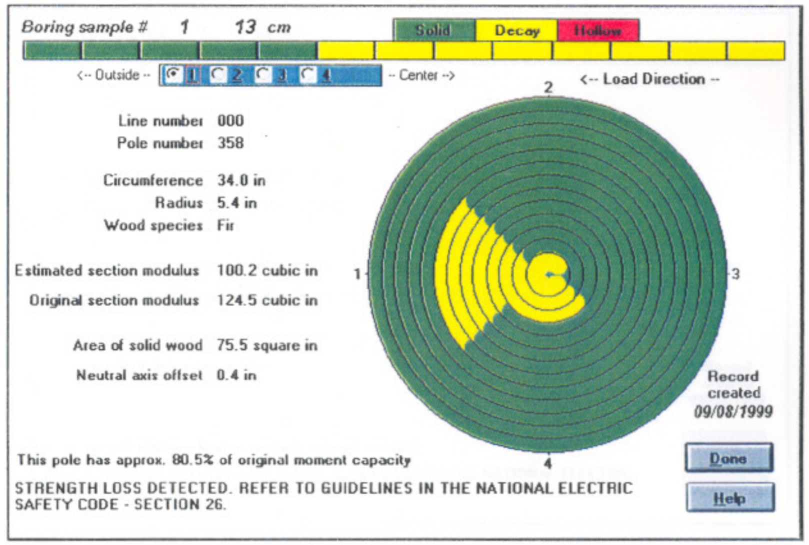
X	-1.00882	
Y	20.02519	
Strength about Vertical Axis :	82.84790	%
Strength about Horizontal Axis :	81.03149	%
Minimum Strength of Section :	**82.84790**	**%**
Angle of Axis to the horizontal neutral axis about which the pole is bent to give the minimum strength :	31.0	°

Tag No. 358

Pole #	Treatment	Class	Length	Year	GL Cir in	Break Ht ft	Tested MOR lbs	Est. EDM lbs.	Est. Purl1 lbs	Est. Polecalc lbs	Reason Removed
171800	creosote	4	35	?	34	GL	3435	8000	8000	6440	decay

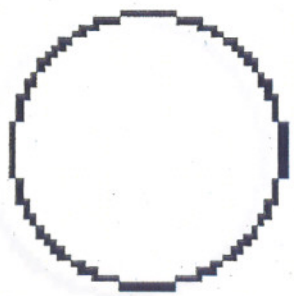






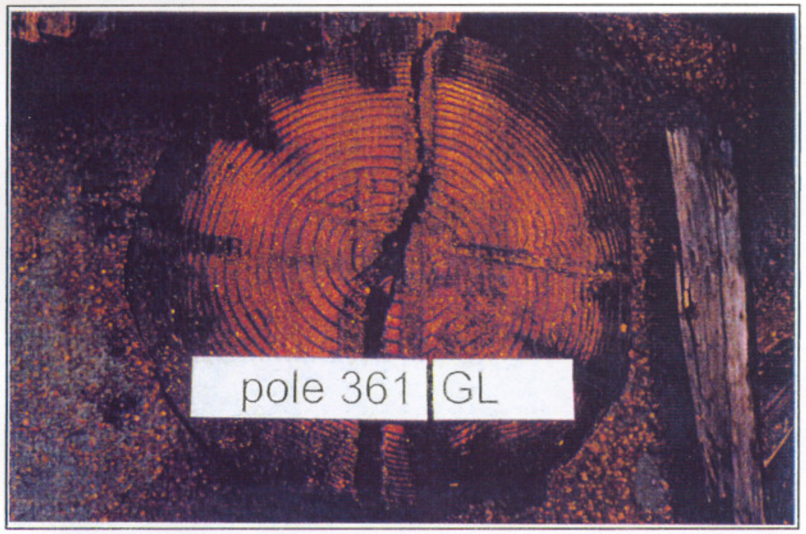
Position 1
Height Above Butt : 1 inch

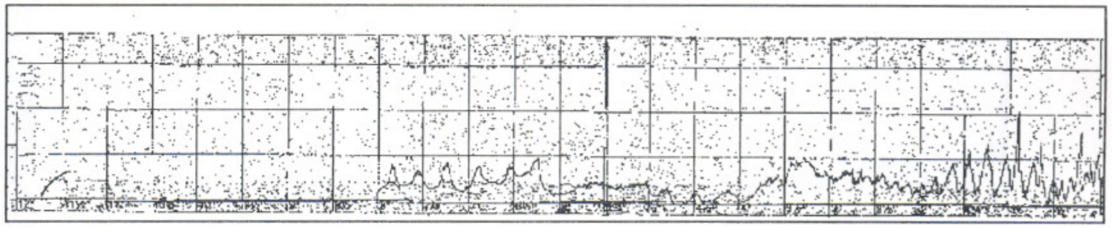
Co-ordinates of Centroid :		
X	0.00000	
Y	20.00000	
Strength about Vertical Axis :	100.00000	%
Strength about Horizontal Axis :	100.00000	%
Minimum Strength of Section :	**100.00000**	**%**
Angle of Axis to the horizontal neutral axis about which the pole is bent to give the minimum strength :	90.0	°

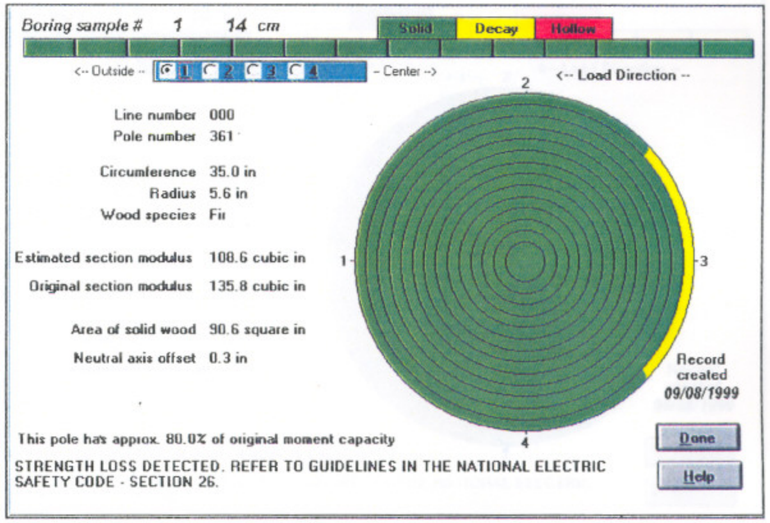


Tag No. 361

Pole #	Treatment	Class	Length	Year	GL Cir in	Break Ht ft	Tested MOR lbs	Est. EDM lbs.	Est. Purl1 lbs	Est. Polecalc lbs	Reason Removed
323006	penta	4	35	1963	35	GL	3731	7850	8000	6400	decay





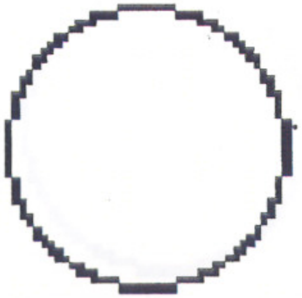


Position 1

Height Above Butt : 1 inch

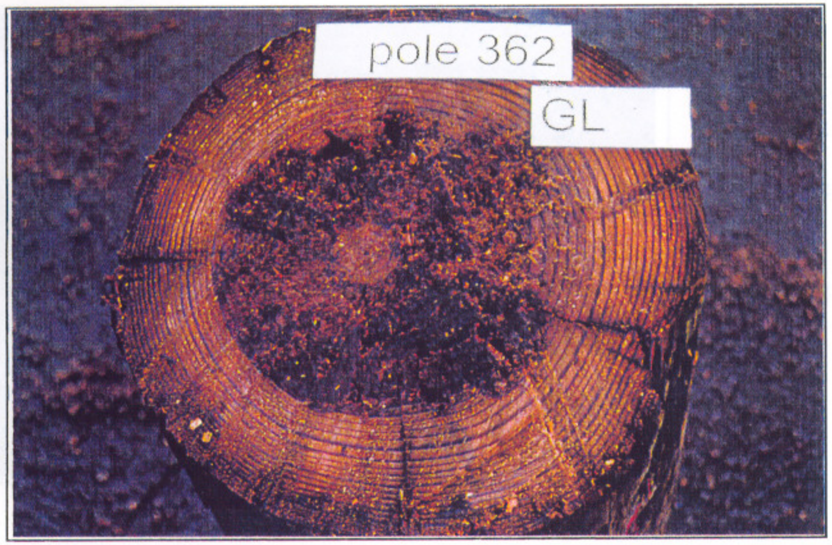
Co-ordinates of Centroid :

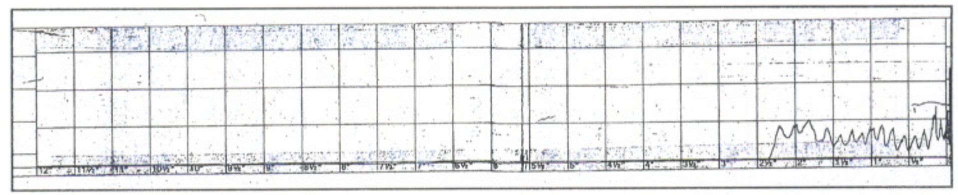
X	0.00000	
Y	20.00000	
Strength about Vertical Axis :	100.00000	%
Strength about Horizontal Axis :	100.00000	%
Minimum Strength of Section :	**100.00000**	**%**
Angle of Axis to the horizontal neutral axis about which the pole is bent to give the minimum strength :	90.0	°

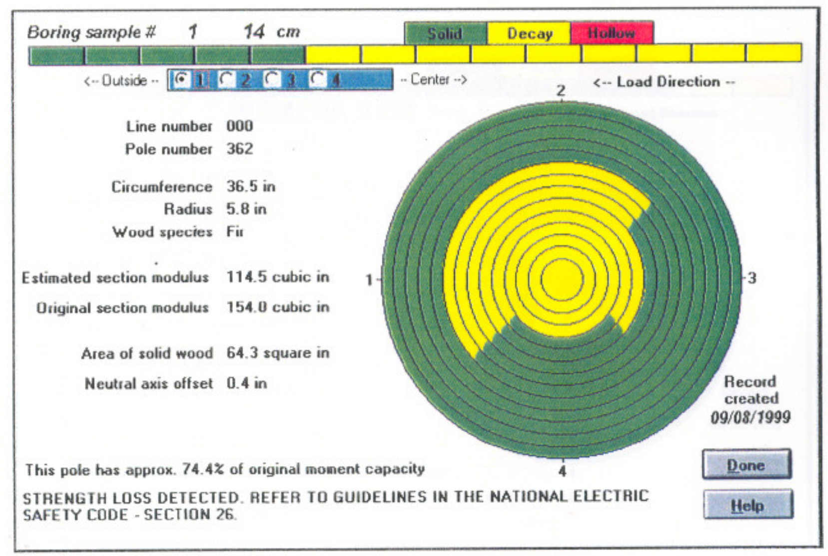


Tag No. 362

Pole #	Treatment	Class	Length	Year	GL Cir in	Break Ht ft	Tested MOR lbs	Est. EDM lbs.	Est. Purl1 lbs	Est. Polecalc lbs	Reason Removed
364601	penta	4	40	1962	36.5	1.6	4084	7390	8000	5952	decay





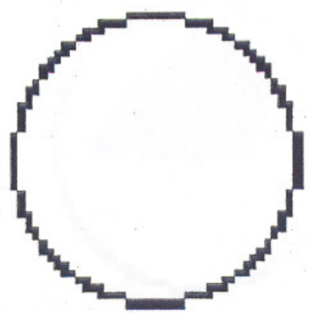


Position 1

Height Above Butt : 1 inch

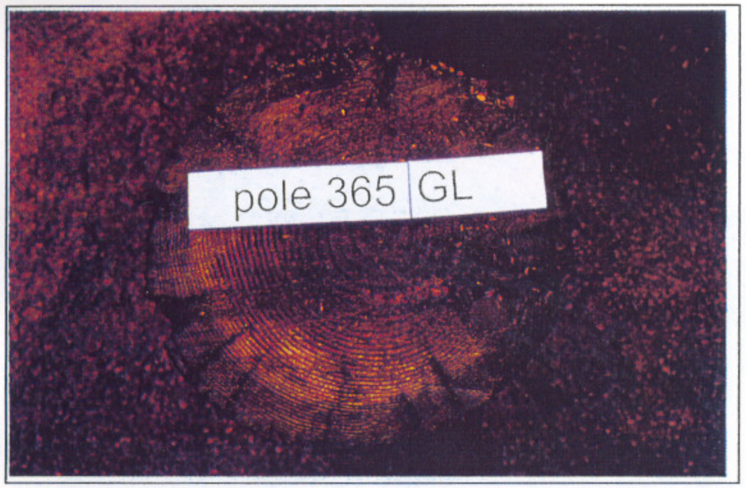
Co-ordinates of Centroid :

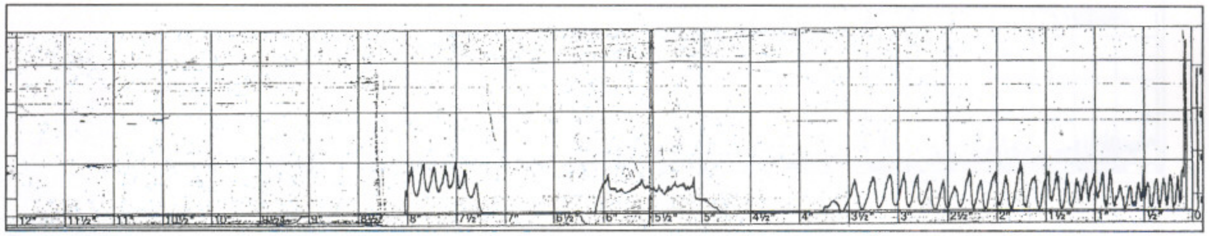
X	0.00000	
Y	20.00000	
Strength about Vertical Axis :	100.00000	%
Strength about Horizontal Axis :	100.00000	%
Minimum Strength of Section :	**100.00000**	**%**
Angle of Axis to the horizontal neutral axis about which the pole is bent to give the minimum strength :	90.0	°

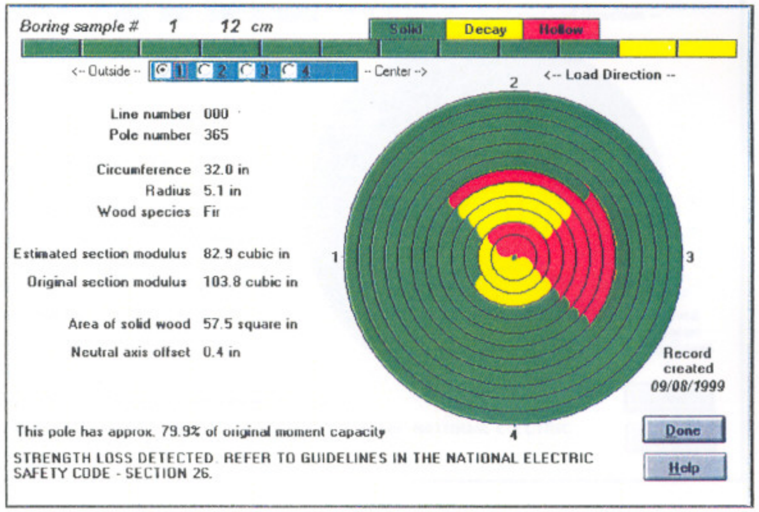


Tag No. 365

Pole #	Treatment	Class	Length	Year	GL Cir in	Break Ht ft	Tested MOR lbs	Est. EDM lbs.	Est. Purl1 lbs	Est. Polecalc lbs	Reason Removed
295901	penta	5	35	?	30.6	GL	4248	7460	7176	6392	decay



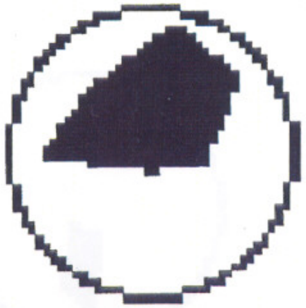




Position 1

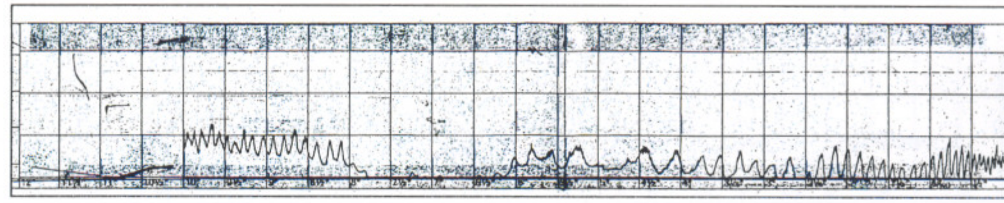
Height Above Butt : 1 inch

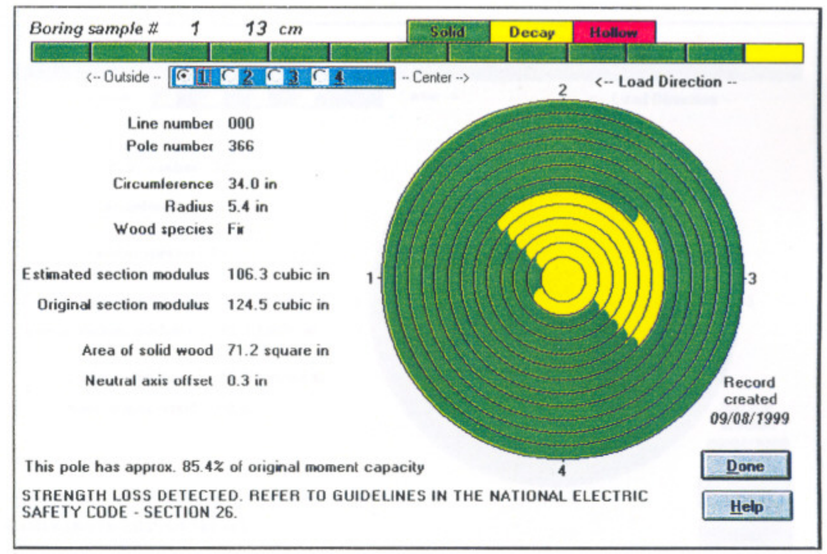
Co-ordinates of Centroid :		
X	0.00216	
Y	17.86530	
Strength about Vertical Axis :	89.73390	%
Strength about Horizontal Axis :	73.56197	%
Minimum Strength of Section :	**89.73390**	**%**
Angle of Axis to the horizontal neutral axis about which the pole is bent to give the minimum strength :	11.5	°



Tag No. 366

Pole #	Treatment	Class	Length	Year	GL Cir in	Break Ht ft	Tested MOR lbs	Est. EDM lbs.	Est. Purl1 lbs	Est. Polecalc lbs	Reason Removed
203400	penta	3	35	?	34	GL	4951	8100	7698	6832	decay

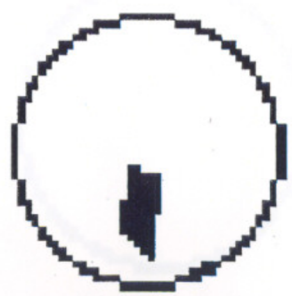




Position 1

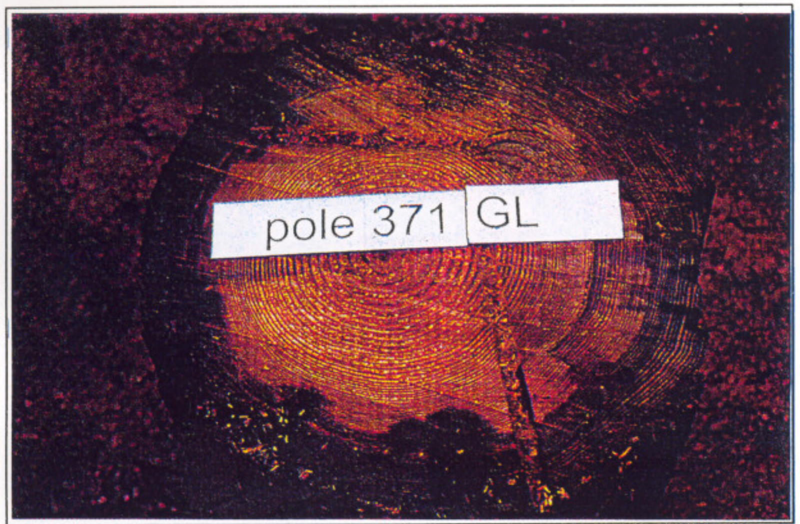
Height Above Butt : 1 inch

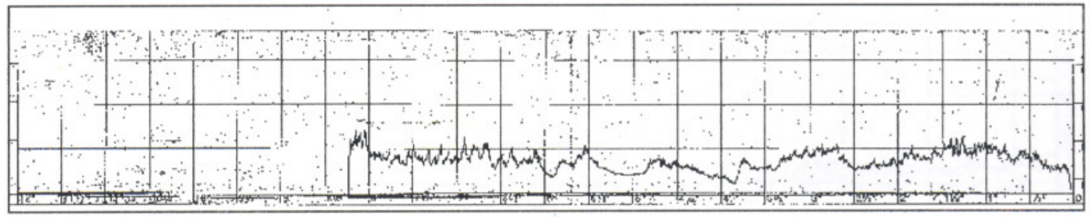
Co-ordinates of Centroid :		
X	0.03200	
Y	20.43849	
Strength about Vertical Axis :	99.60675	%
Strength about Horizontal Axis :	93.53270	%
Minimum Strength of Section :	**99.60675**	**%**
Angle of Axis to the horizontal neutral axis about which the pole is bent to give the minimum strength :	1.0	°

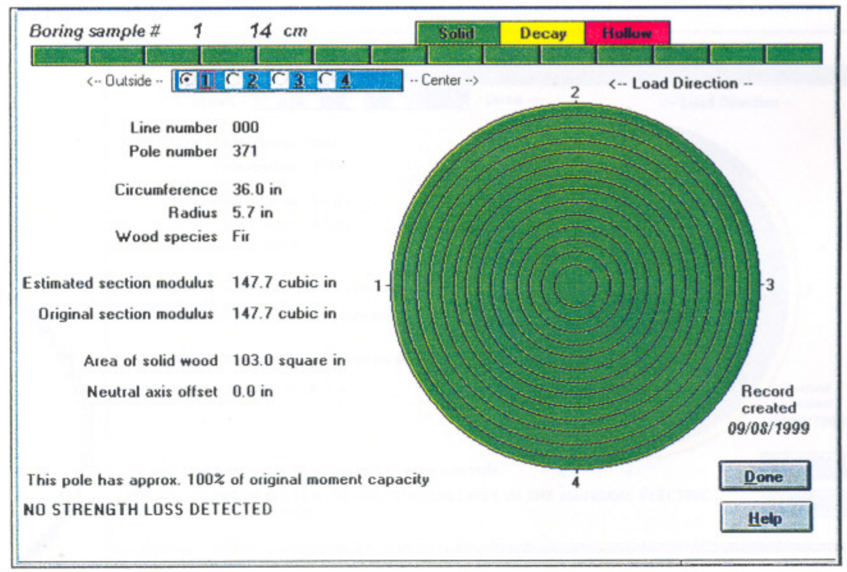


Tag No. 371

Pole #	Treatment	Class	Length	Year	GL Cir in	Break Ht ft	Tested MOR lbs	Est. EDM lbs.	Est. Purl1 lbs	Est. Polecalc lbs	Reason Removed
101906	creosote	3	40	1980	36	GL	10827	9050	8000	8000	upgrade

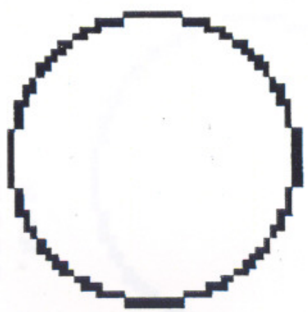






Position 1

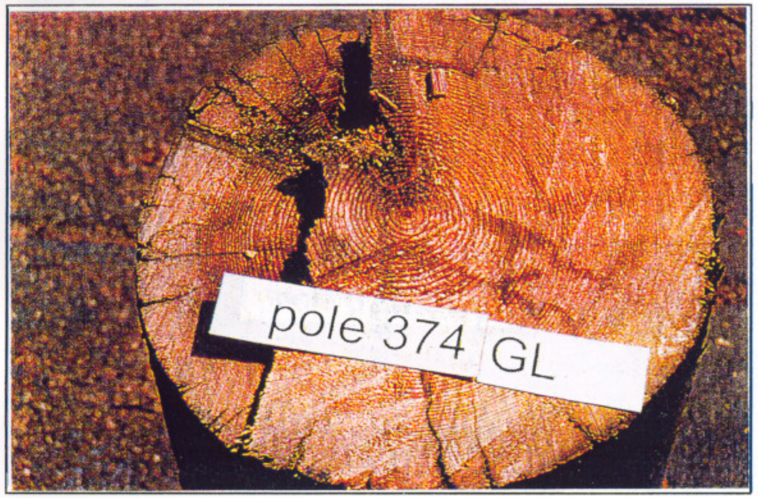
Height Above Butt : 1 inch

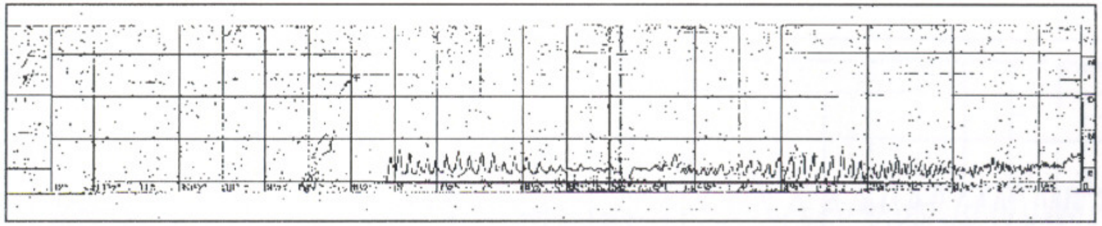


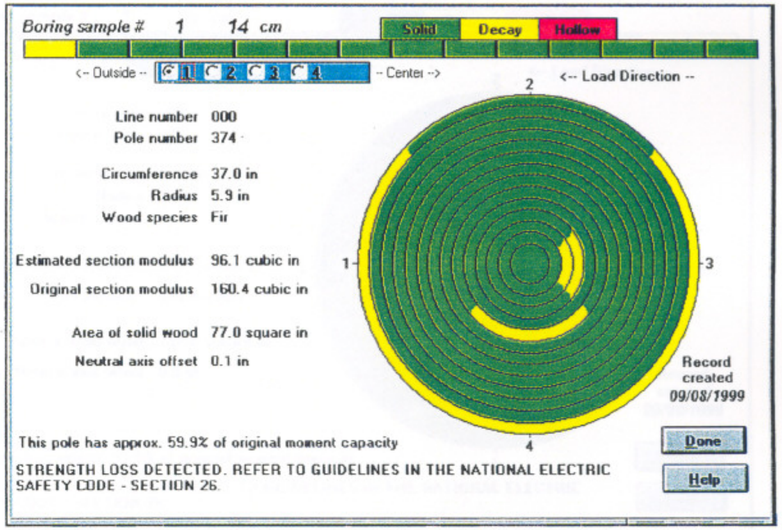
Co-ordinates of Centroid :		
X	0.00000	
Y	20.00000	
Strength about Vertical Axis :	100.00000	%
Strength about Horizontal Axis :	100.00000	%
Minimum Strength of Section :	**100.00000**	**%**
Angle of Axis to the horizontal neutral axis about which the pole is bent to give the minimum strength :	90.0	°

Tag No. 374

Pole #	Treatment	Class	Length	Year	GL Cir in	Break Ht ft	Tested MOR lbs	Est. EDM lbs.	Est. Purl1 lbs	Est. Polecalc lbs	Reason Removed
31105	cellon	4	45	1962	37	GL	6765	7530	8000	4792	upgrade

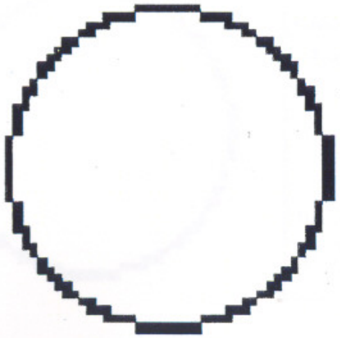






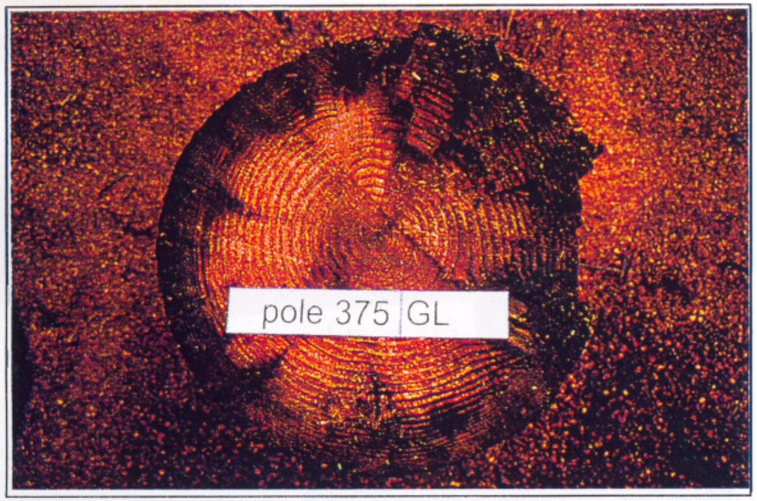
Position 1
Height Above Butt : 1 inch

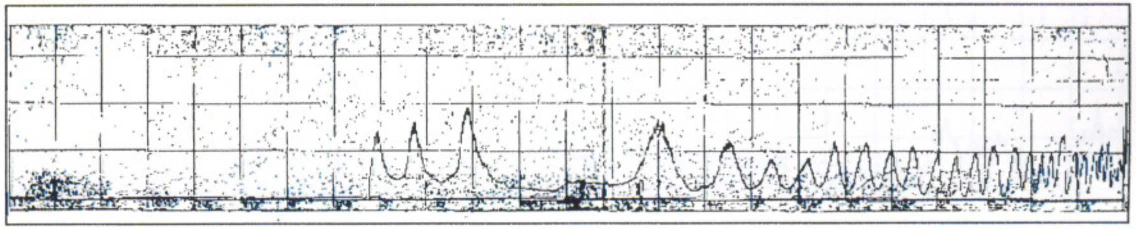
Co-ordinates of Centroid :		
X	0.00000	
Y	20.00000	
Strength about Vertical Axis :	100.00000	%
Strength about Horizontal Axis :	100.00000	%
Minimum Strength of Section :	**100.00000**	**%**
Angle of Axis to the horizontal neutral axis about which the pole is bent to give the minimum strength :	90.0	°

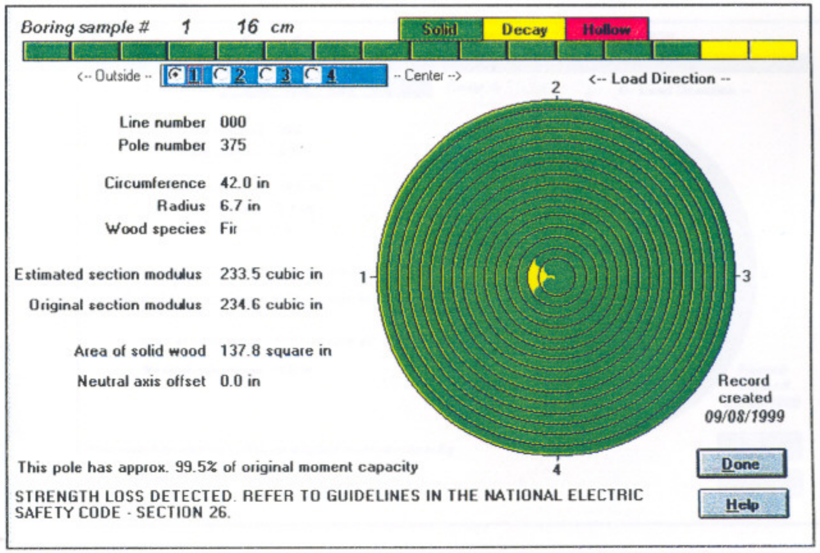


Tag No. 375

Pole #	Treatment	Class	Length	Year	GL Cir in	Break Ht ft	Tested MOR lbs	Est. EDM lbs.	Est. Purl1 lbs	Est. Polecalc lbs	Reason Removed
31201	creosote	3	55	1966	42	GL	6530	5830	8000	7960	upgrade



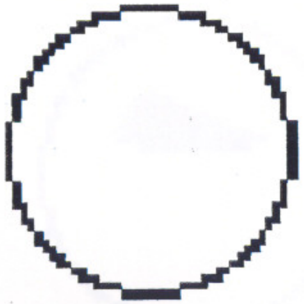




Position 1

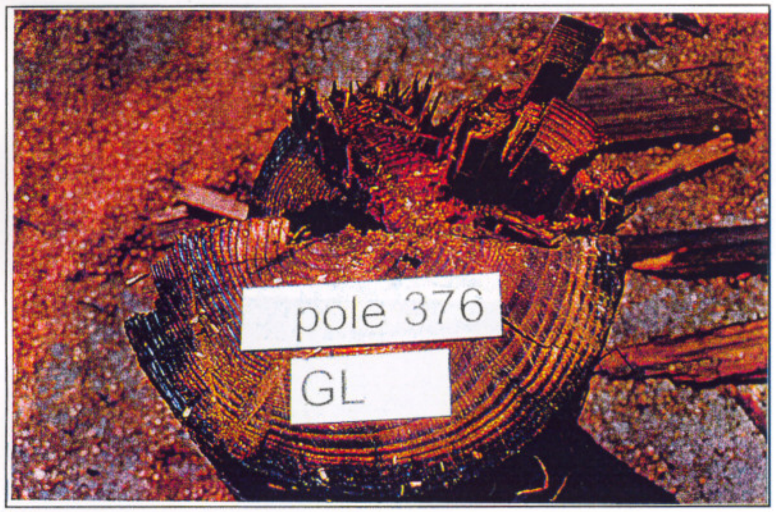
Height Above Butt : 1 inch

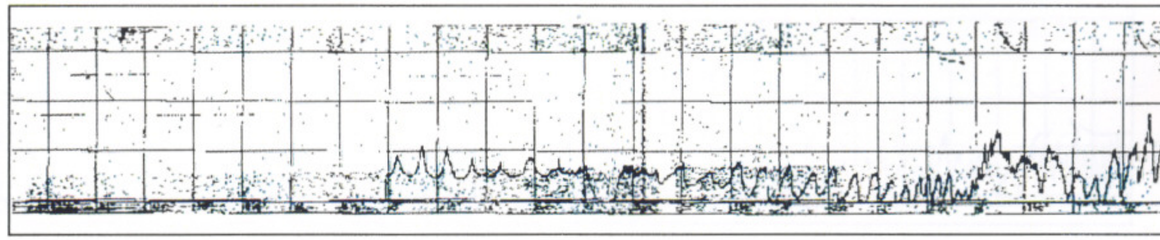
Co-ordinates of Centroid : X	0.00000	
Y	20.00000	
Strength about Vertical Axis :	100.00000	%
Strength about Horizontal Axis :	100.00000	%
Minimum Strength of Section :	**100.00000**	%
Angle of Axis to the horizontal neutral axis about which the pole is bent to give the minimum strength :	90.0	°

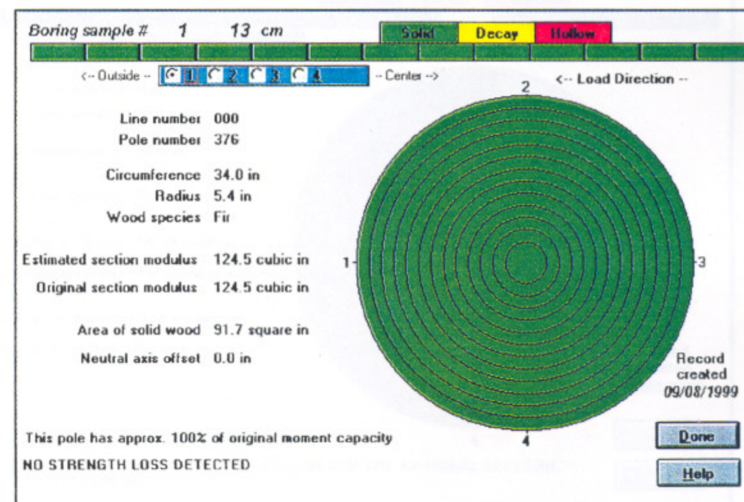


Tag No. 376

Pole #	Treatment	Class	Length	Year	GL Cir in	Break Ht ft	Tested MOR lbs	Est. EDM lbs.	Est. Purl1 lbs	Est. Polecalc lbs	Reason Removed
31701	creosote	4	40	?	34	GL	5336	6990	7776	8000	upgrade







Position 1

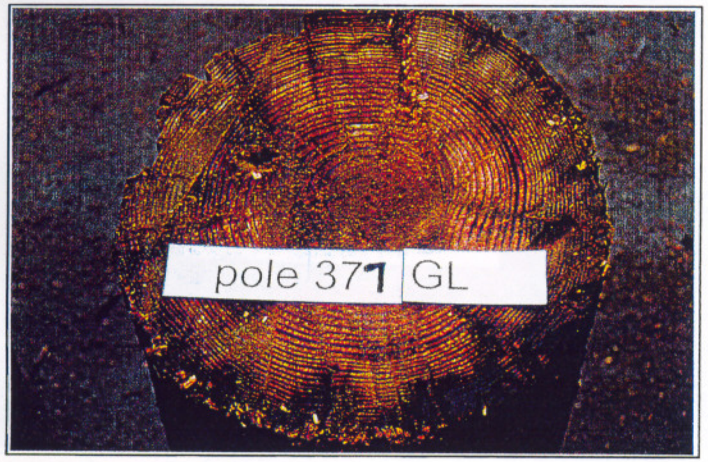
Height Above Butt : 1 inch

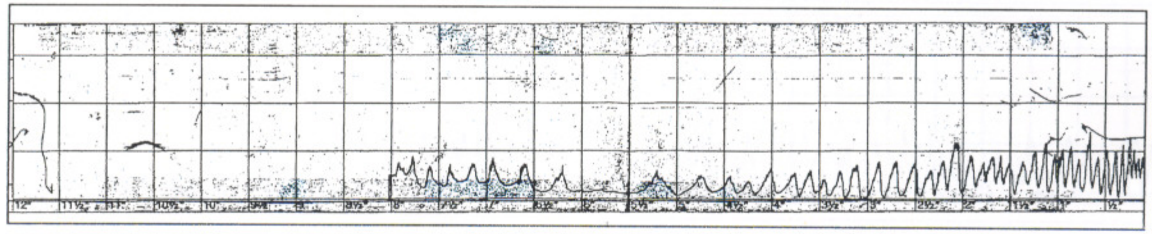
Co-ordinates of Centroid :

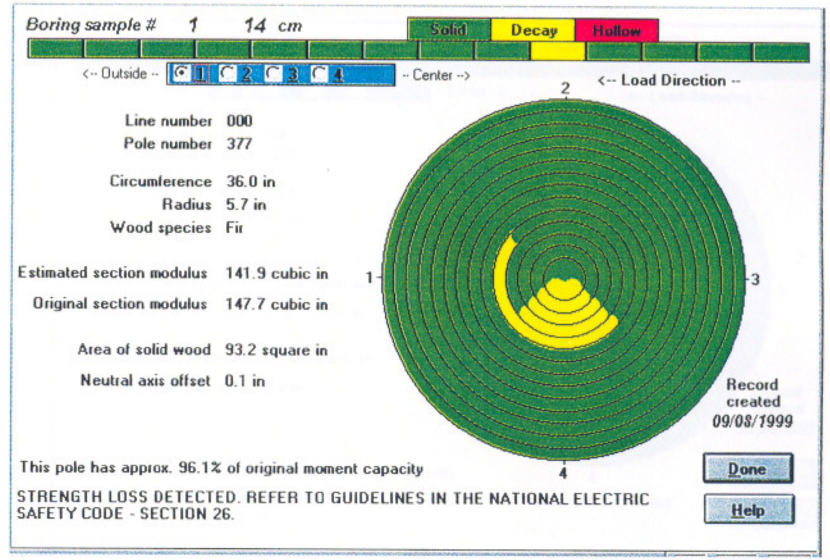
X	0.17775	
Y	19.53922	
Strength about Vertical Axis :	97.15178	%
Strength about Horizontal Axis :	94.85680	%
Minimum Strength of Section :	**97.15178**	**%**
Angle of Axis to the horizontal neutral axis about which the pole is bent to give the minimum strength :	162.0	°

Tag No. 377

Pole #	Treatment	Class	Length	Year	GL Cir in	Break Ht ft	Tested MOR lbs	Est. EDM lbs.	Est. Purl1 lbs	Est. Polecalc lbs	Reason Removed
31602	penta	4	45	1973	36	GL	5865	6450	8000	7688	upgrade





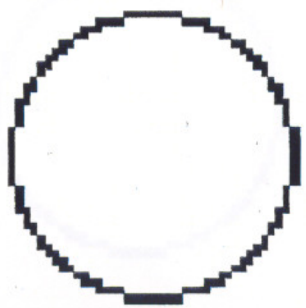


Position 1

Height Above Butt : 1 inch

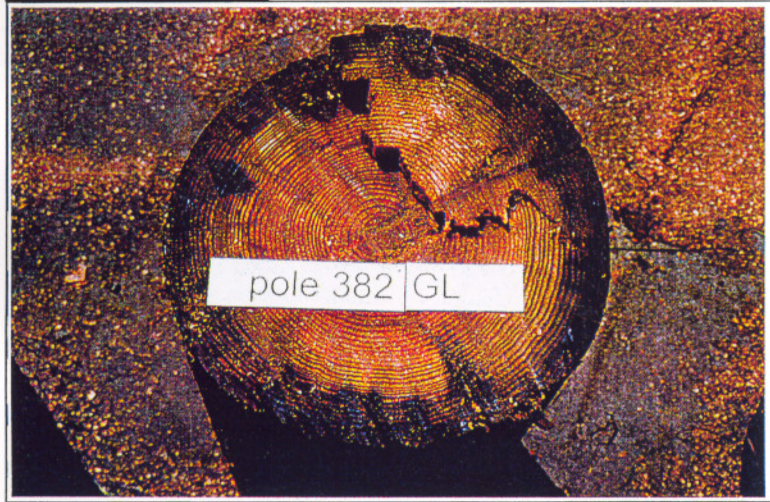
Co-ordinates of Centroid :

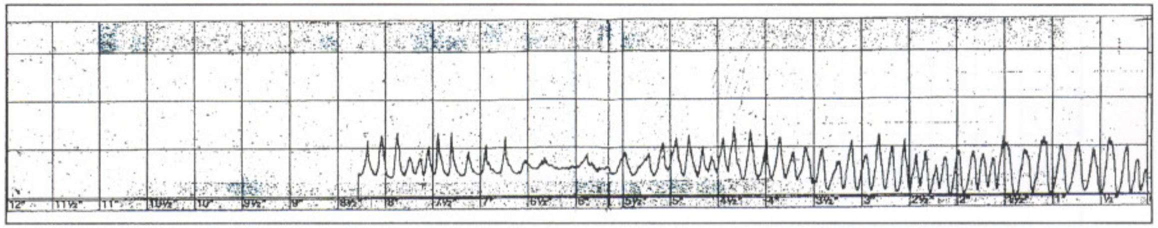
X	0.00000	
Y	20.00000	
Strength about Vertical Axis :	100.00000	%
Strength about Horizontal Axis :	100.00000	%
Minimum Strength of Section :	**100.00000**	**%**
Angle of Axis to the horizontal neutral axis about which the pole is bent to give the minimum strength :	90.0	°



Tag No. 382

Pole #	Treatment	Class	Length	Year	GL Cir in	Break Ht ft	Tested MOR lbs	Est. EDM lbs.	Est. Purl1 lbs	Est. Polecalc lbs	Reason Removed
31501	penta	4	45	1954	38	GL	7974	7610	8000	7992	upgrade

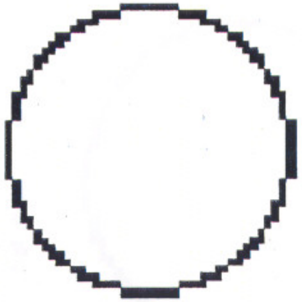


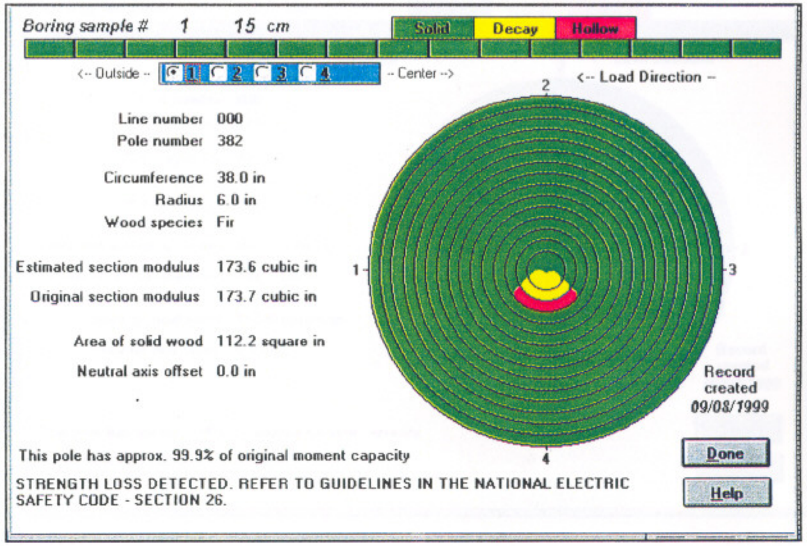


Position 1

Height Above Butt : 1 inch

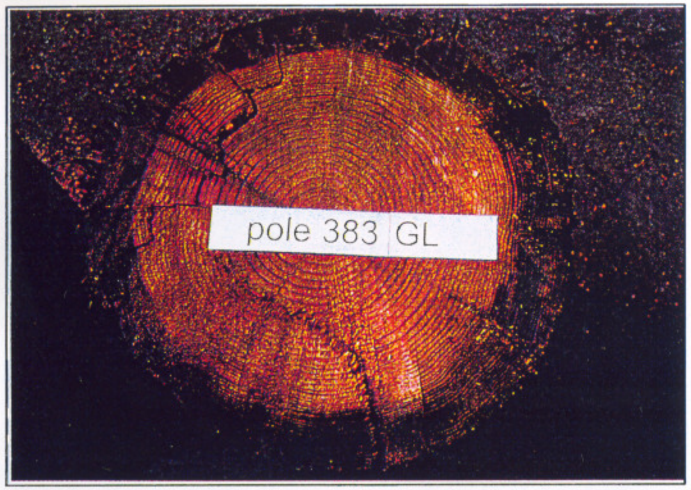
Co-ordinates of Centroid : X	0.00000
Y	20.00000
Strength about Vertical Axis :	100.00000 %
Strength about Horizontal Axis :	100.00000 %
Minimum Strength of Section :	**100.00000 %**
Angle of Axis to the horizontal neutral axis about which the pole is bent to give the minimum strength :	90.0 °

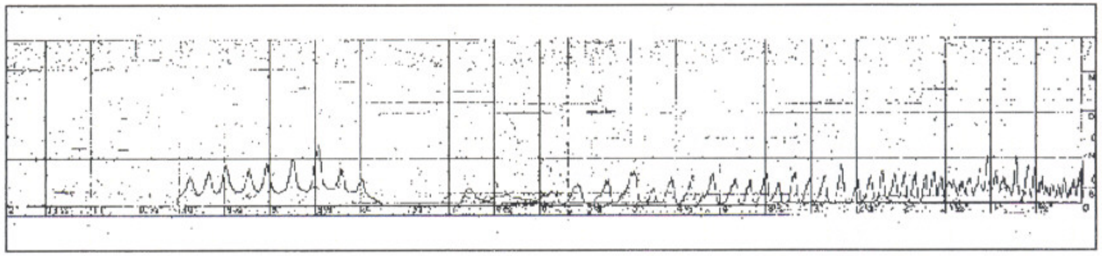


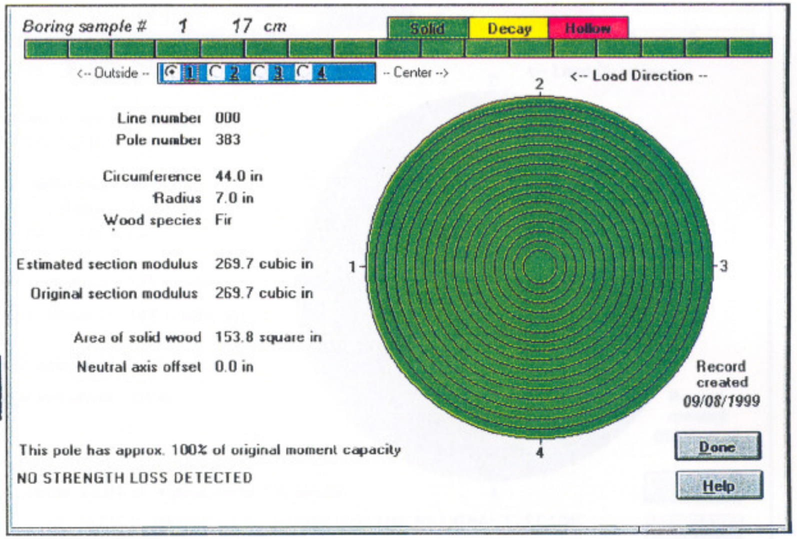


Tag No. 383

Pole #	Treatment	Class	Length	Year	GL Cir in	Break Ht ft	Tested MOR lbs	Est. EDM lbs.	Est. Purl1 lbs	Est. Polecalc lbs	Reason Removed
31502	creosote	3	55	1962	44	GL	6925	8450	8000	8000	upgrade





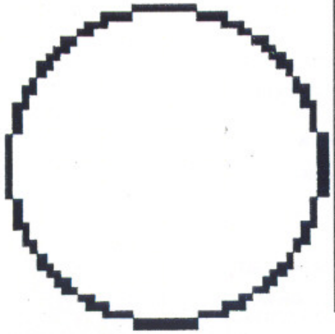


Position 1

Height Above Butt : 1 inch

Co-ordinates of Centroid :

X	0.00000	
Y	20.00000	
Strength about Vertical Axis :	100.00000	%
Strength about Horizontal Axis :	100.00000	%
Minimum Strength of Section :	**100.00000**	**%**
Angle of Axis to the horizontal neutral axis about which the pole is bent to give the minimum strength :	90.0	°

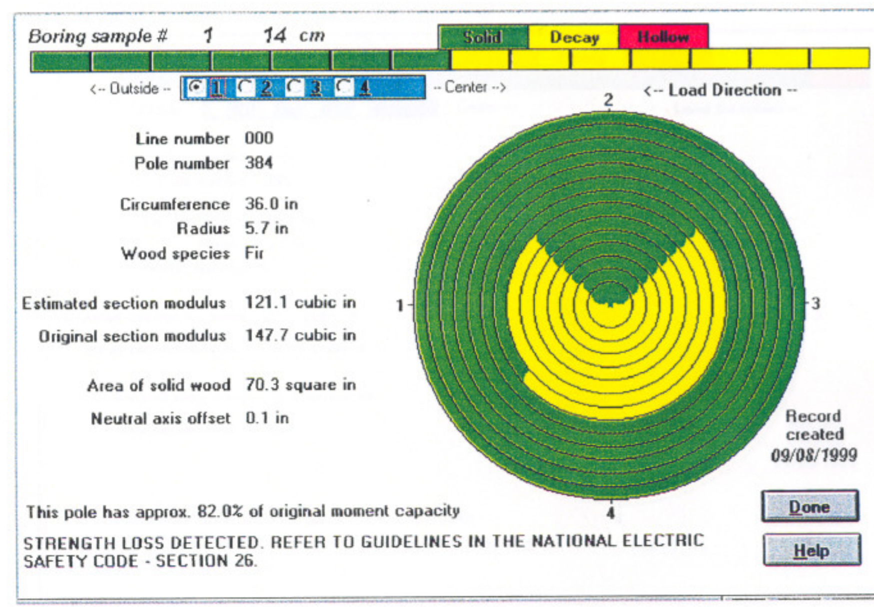


Tag No. 384

Pole #	Treatment	Class	Length	Year	GL Cir in	Break Ht ft	Tested MOR lbs	Est. EDM lbs.	Est. Purl1 lbs	Est. Polecalc lbs	Reason Removed
?	penta	4	40	1960	36	GL	4882	NT	NT	6560	upgrade

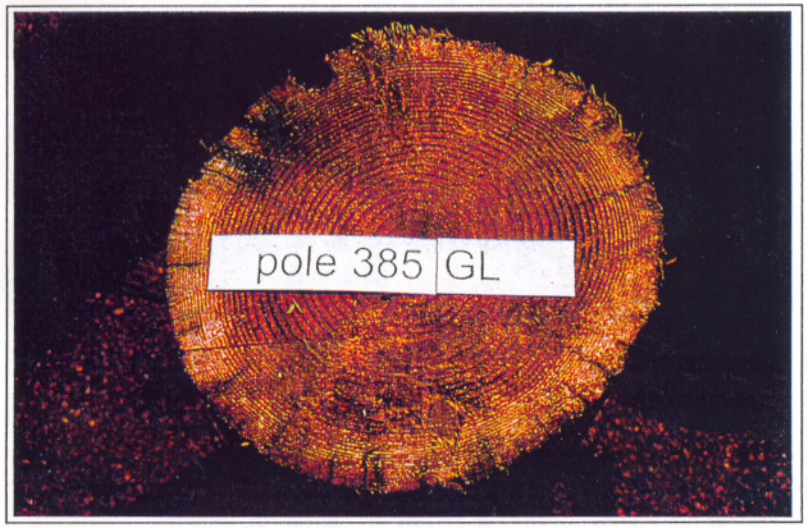
Not Sampled

Not Sampled

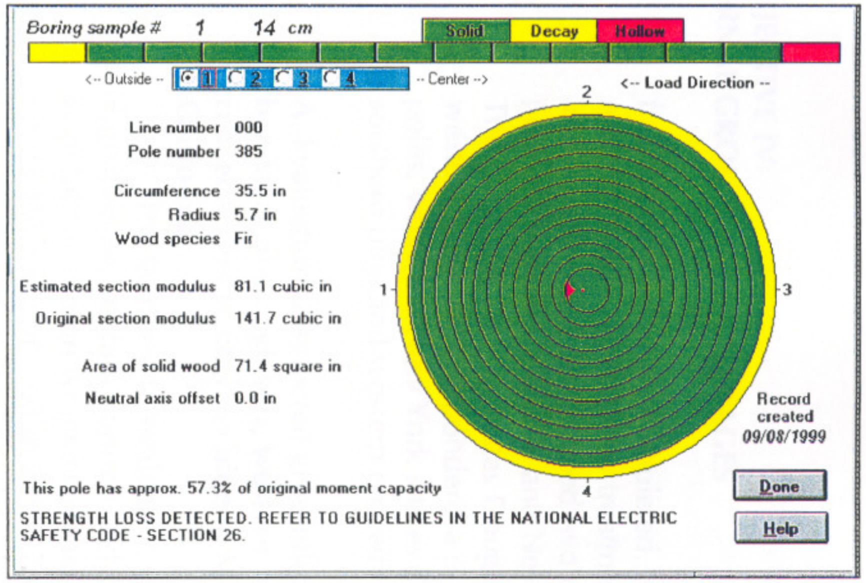


Tag No. 385

Pole #	Treatment	Class	Length	Year	GL Cir in	Break Ht ft	Tested MOR lbs	Est. EDM lbs.	Est. Purl1 lbs	Est. Polecalc lbs	Reason Removed
?	cellon	4	40	1962	35.5	GL	3706	NT	NT	4584	upgrade



Not Sampled



Not Sampled

OBJECTIVE IV
PERFORMANCE OF EXTERNAL GROUNDLINE BANDAGES

Pressure treatment of wood with conventional preservatives continues to be the most effective method for preventing fungal and insect attack. Over time, however, the effectiveness of some preservatives declines and, for optimum performance, should be supplemented by application of external remedial preservatives. Typically, external preservative pastes have been used to treat creosote or pentachlorophenol-treated southern pine along with butt-treated western redcedar and Douglas-fir treated by the Cellon or Dow Processes. These systems are also recommended for supplemental treatment when poles are moved or when they are set in concrete or other materials that will preclude future groundline inspections.

The preservatives formerly used for this purpose included pentachlorophenol, creosote and sodium dichromate. The decision to restrict the use of these preservatives to those who are licensed by their respective states has encouraged many utilities to seek alternative systems. Over the past decade, copper naphthenate, boron and sodium fluoride have emerged as the external preservatives of choice for supplemental groundline treatment. Despite their prior use in other preservative formulations, there was relatively little data on the performance of these systems on utility poles. In order to assist utilities in making better decisions regarding their external decay control programs, we established three field tests with various pole species. The first, in Corvallis, evaluated systems on untreated Douglas-fir. This test is largely completed, but we recently added several new treatments. In addition, we have established two utility field test sites in California and New York. The California site evaluates Douglas-fir, western redcedar and ponderosa pine poles, while the New York site evaluates southern pine and western redcedar.

A. Evaluation of selected groundline bandages in Douglas-fir, western redcedar and ponderosa pine in Merced, California

The field test to evaluate copper naphthenate, sodium fluoride and copper naphthenate/boron wraps near Merced, California was sampled in 1997, 7 years after chemical application. These poles are next scheduled for sampling 10 years after treatment.

B. Evaluation of external groundline preservatives in southern pine and Western redcedar poles in New York

The field test in New York was established in a distribution line located near Binghamton. The western redcedar and southern pine distribution poles ranging in age from 13 to 69 years were treated with CUNAP Wrap, CuRap 20, or Patox II. These systems contain copper naphthenate, copper naphthenate plus boron, and sodium fluoride, respectively.

The poles were sampled 2 and 3 years after treatment by removing plugs rom the poles at three equidistant sites around each pole 150 mm below groundline. The cores were cut into zones corresponding to 0 to 4, 4 to 10, 10 to 16, and 16 to 25 mm from the wood surface.

Samples from the same treatment group from a given zone were combined prior to being ground to pass a 20 mesh screen. The resulting wood dust was analyzed for copper by x-ray fluorescence, then for fluoride or boron using the appropriate American Wood Preserver's Association Standard.

Copper levels varied widely between the two copper naphthenate systems (Figure IV-1, 2). Copper levels in the CUNAP Wrap treated poles were generally below 0.5 kg/m^3 in the outer zone, regardless of wood species. Copper levels fell off sharply further inward with western redcedar, but remained stable up to 25 mm from the surface in the southern pine, reflecting the deeper, more permeable sapwood in the latter species. Copper levels were nearly three times higher in the outer zones of southern pine poles treated with CuRap 20, but similar to those found with CUNAP wrap in western redcedar. Copper levels were extremely high in the inner zones of the southern pine poles treated with this chemical. The threshold for copper naphthenate against fungal attack is believed to be around 0.64 kg/m^3 (as copper metal)(0.04 lb/ft^2). Thus, the levels of copper found in the outer zones of the CUNAP Wrap treated poles were below the threshold level. This, however, does not mean that the poles are in imminent danger of fungal attack since the original treatment chemical is also still present in the wood, but it does suggest that the copper from this system is moving less efficiently into the wood.

Boron levels in CuRap 20 treated poles were generally above the 0.5 % boric acid equivalent value accepted as the threshold for fungal attack (Figure IV-3). Boron levels tended to be fairly uniform across the four assay zones 3 years after treatment but tended to be slightly lower in western redcedar poles. The results indicate that the boron has moved well in both wood species and is present at protective levels. In previous tests, boron levels have begun to decline between 2 and 3 years after treatment and it will be interesting to see if this trend also occurs in this test.

Sodium fluoride levels in Patox II treated poles tended to be similar 2 and 3 years after treatment in southern pine poles, but rose sharply in the western redcedar (Figure IV-4). Fluoride levels were generally above the accepted threshold for fungal attack in both species.

The results indicate that all of the treatments are moving at or near fungitoxic levels in both wood species 3 years after treatment.

C. Performance of copper/boron/fluoride wraps in untreated Douglas-fir poles

Seasoned Douglas-fir poles (250 to 300 mm in diameter by 2 m long) were treated with one of two formulations according to manufacturer's instructions. The first formulation was CuRap 20, a mixture containing copper naphthenate and sodium tetraborate decahydrate, while the second contained sodium fluoride, copper naphthenate and sodium octaborate tetrahydrate. The latter formulation is a self-contained system on a foam backing, while the CuRap 20 is

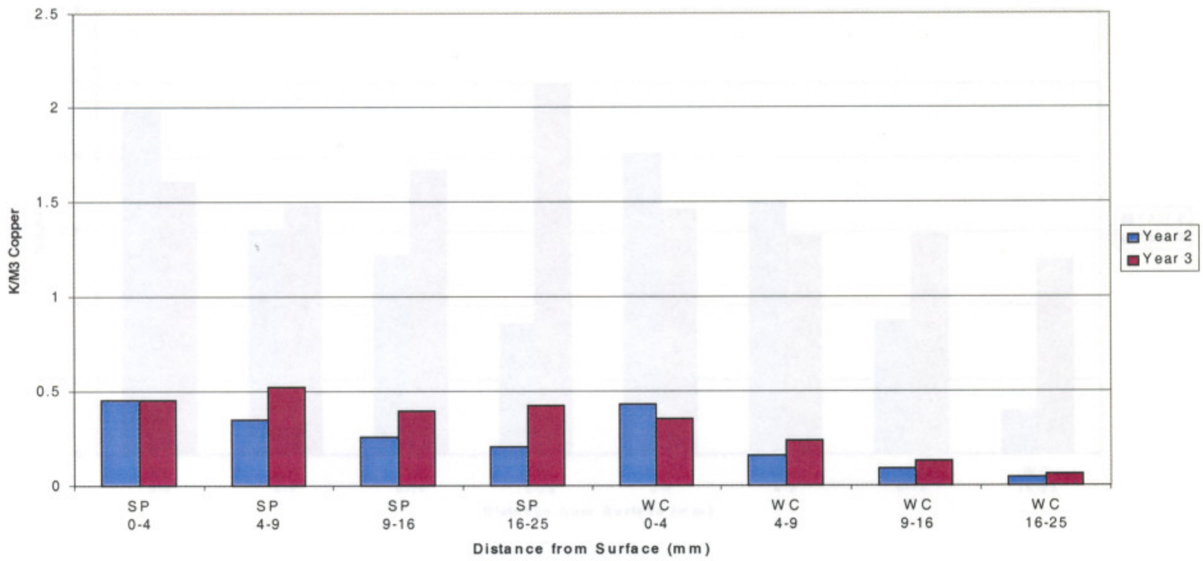


Figure IV-1. Retentions of copper at various depths from the surface of southern pine and western redcedar poles 2 or 3 years after treatment with CUNAP Wrap

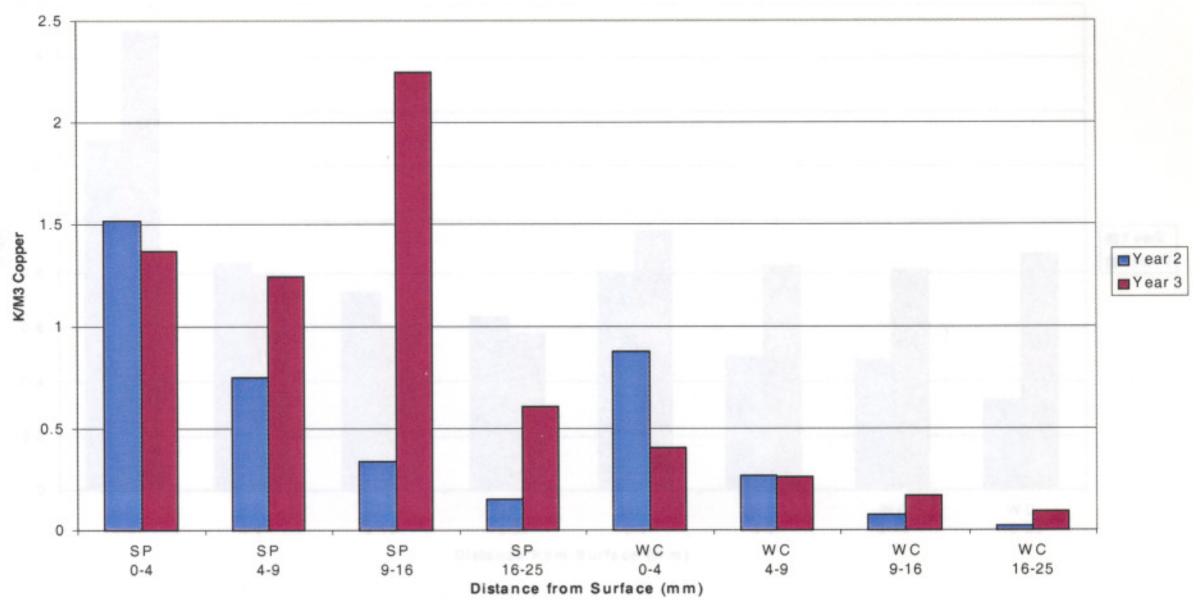


Figure IV-2. Retentions of copper at various depths from the surface of southern pine and western redcedar poles 2 or 3 years after treatment with CURAP 20.

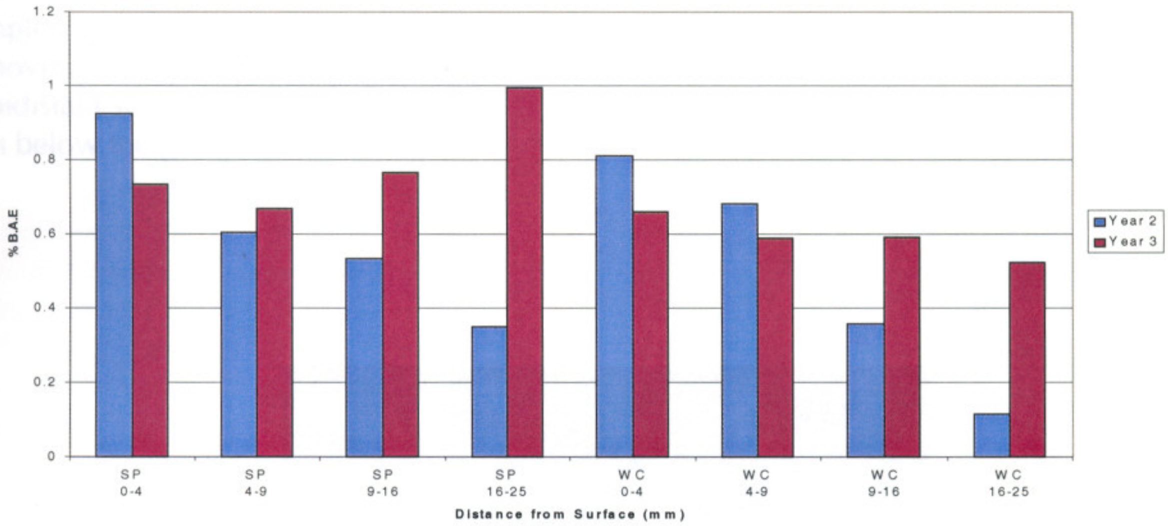


Figure IV-3. Retentions of boron at various depths from the surface of southern pine and western redcedar poles 2 or 3 years after treatment with CURAP 20.

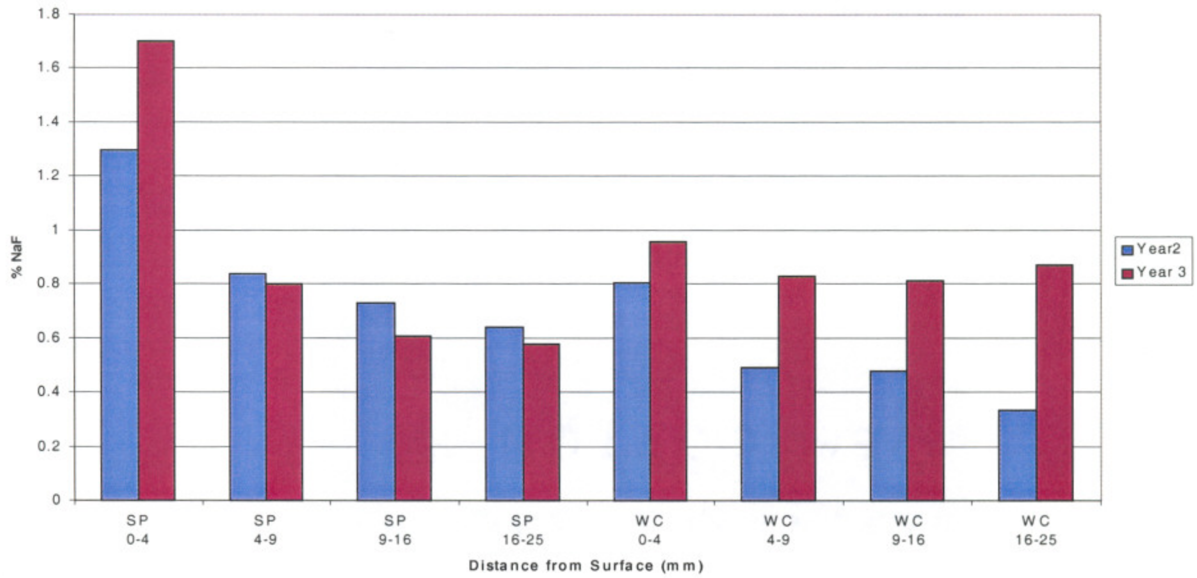
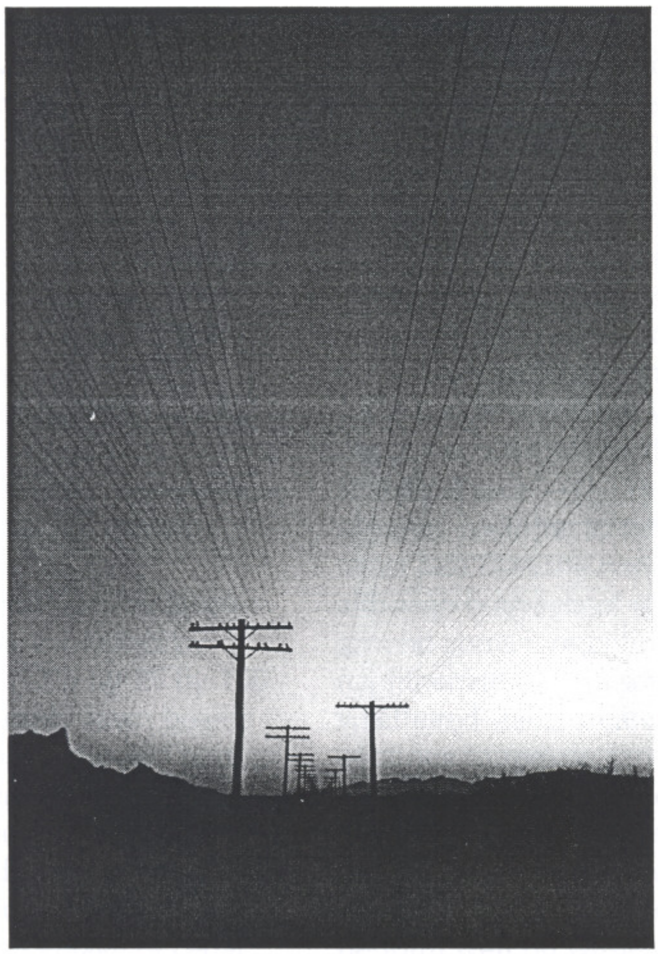


Figure IV-2. Retentions of fluoride at various depths from the surface of southern pine and western redcedar poles 2 or 3 years after treatment with Patox II.

applied as a paste, then covered with polyethylene film.

The pole sections were set to a depth of 0.3 m in the ground and were sampled one year after treatment by removing increment cores from three equidistant sites around the poles 150 mm below the ground. The cores were divided into zones as described above prior to being ground to pass a 20 mesh screen. The samples are in the process of being analyzed and the results will be presented in the next annual report.



OBJECTIVE V
PERFORMANCE OF COPPER NAPHTHENATE-TREATED WESTERN WOOD SPECIES

A. DECAY RESISTANCE OF COPPER NAPHTHENATE-TREATED WESTERN RED-CEDAR 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 is copper naphthenate, a complex of copper and naphthenic acids derived from the oil refining process. Copper naphthenate has been in use 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 aboveground, untreated portion of poles which had been in service for about 15 years. Weathered stakes were included because of a desire by the cooperator to retreat cedar poles 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 ten 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).

The samples continue to follow the same trends noted last year although there are some cases where the ratings increased slightly **(Table V-1)**. The weathered samples continue to deteriorate at a slightly faster rate than the non-weathered samples, although both sets of stakes treated to the ground contact retentions with copper naphthenate remain sound. Non-weathered stakes treated with diesel alone continue to remain serviceable, while weathered stakes treated with diesel alone have largely failed. The results continue to demonstrate that the recommended retention levels of copper naphthenate will perform well on western redcedar.

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 114 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	100 mos	114 mos		6 mos	14 mos	26 mos	40 mos	52 mos	64 mos	76 mos	88 mos	100 mos	114 mos
Control	--	4.7	0.9	0.4	0.1	0	0	0	0	0	0	—	6.6	3.2	1.3	1.1	1.1	1.0	0.9	0.5	0.4	1.9
diesel	--	8.5	6.8	5.3	3.8	3.4	3.4	2.0	1.4	0.8	1.1	--	9.9	8.4	8.0	8.6	8.4	8.0	8.0	7.7	7.3	5.9
0.8	1.6	9.0	8.0	7.5	6.9	5.7	5.6	5.3	5.1	4.8	6.7	0.8	10.0	9.6	9.4	9.5	9.6	9.3	9.3	9.3	9.5	9.2
1.6	1.4	9.5	8.9	8.8	9.0	8.0	7.8	7.4	7.3	6.8	6.6	1.5	10.0	9.4	9.3	9.2	9.4	9.1	9.2	9.2	9.5	8.9
2.4	2.1	9.6	9.2	9.1	8.6	8.2	8.2	7.9	7.7	6.8	6.5	1.9	10.0	9.4	9.4	9.2	9.3	9.2	9.1	9.1	9.5	8.8
3.2	2.7	9.6	9.1	9.0	8.8	8.1	8.1	8.1	8.1	8.0	6.9	2.6	10.0	9.2	9.2	9.0	8.9	8.9	9.1	9.1	9.5	8.7
4.0	4.0	9.9	9.2	9.1	9.1	8.7	8.3	8.2	8.2	8.0	6.3	3.4	10.0	9.5	9.4	9.4	9.3	9.2	9.2	9.2	9.4	8.5

[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.