ABSTRACT

Evaluations of previously established field trials indicate that chloropicrin and Vorlex continue to provide a diminishing level of protection to Douglas-fir poles. Tests of solid methylisothiocyanate (MITC), now in their thirteenth year, indicate that this chemical continues to prevent recolonization of Douglas-fir poles by decay fungi. MITC appears to provide equivalent or better protection than Vorlex.

Gelatin encapsulated MITC and chloropicrin also continue to perform well in field trials. Although the gelatin is water soluble and must decompose to release the chemical, the addition of water to the treatment holes did not appear to significantly enhance long-term MITC performance.

Laboratory trials to identify safer fumigants indicate that sodium n-methyldithiocarbamate decomposition occurs even in dry wood, although the rate of decomposition is enhanced by the presence of some moisture. A gelled 40 % NaMDC formulation has also been evaluated for its ability to eliminate decay fungi from Douglas-fir heartwood. This formulation has performed better than liquid metham sodium. Field trials are planned with both the solid and gelled NaMDC.

Laboratory trials have also been performed to evaluate the toxicity of fused borate rods to Antrodia carbonica and Postia placenta. These two fungi are important decayers of Douglas-fir utility poles. The results indicate that the boron moved well through both wood species, but complete elimination of the test fungus required 6 to 8 weeks. Antrodia carbonica was generally more tolerant of boron than P. placenta. Field trials of fused borate rods indicate that the boron has moved downward from the point of application, but no evidence of upward movement was noted.

Trials to evaluate the efficacy of glass-encapsulated MITC in Douglas-fir

and southern pine poles are now in their second year. The results continue to indicate the MITC levels are higher in Douglas-fir poles. The reasons for this descrepancy are unclear, but may reflect an increased MITC loss from the more permeable southern pine poles. Controlled studies of MITC release rates from the glass vials show that the tubes retain chemical for 1 to 2 years under normal conditions. Faster losses occur under more tropical conditions, while little loss occurs in cold conditions.

Evaluations of additives to enhance Basamid decomposition in Douglas-fir pole sections indicate that the presence of copper sulfate and pH 12 buffer markedly improve the rate of decomposition to MITC one year after chemical application. More controlled laboratory studies are underway to better understand this effect.

The trials to evaluate the effects of voids on fumigant movement continue to indicate that the void has little effect on chemical concentration. These results indicate that fumigant treatment of poles with voids is feasible provided the wood retains adequate strength.

Laboratory trials to develop diffusion coefficients for chloropicrin movement through Douglas-fir heartwood have been developed. As expected, chloropicrin movement was most rapid longitudinally and at the fiber saturation point. Drier wood retained more chemical, slowing diffusion. The diffusion coefficients will be employed in the fumigant model currently being evaluated on MITC. The model indicates that MITC movement was greatest at moderate moisture levels (22 or 44 %), while higher or lower moisture regimes limited chemical movement. The results obtained using the model will be confirmed through laboratory trials and by comparison with the results of chemical analyses performed on the glass-encapsulated MITC trials.

The trials to identify potential replacements for pentachlorophenol for

remedial treatments are continuing. A number of chemicals have been identified for both the protection of field drilled bolt holes and the spray treatment of western redcedar sapwood. Spray treatments of the most promising chemicals will be applied to western redcedar poles in service.

The identification of small scale tests for detecting decay or estimating residual strength are continuing. We also continue to evaluate the effectiveness of various pretreatments for improving treatment and performance of poles. The effects of through boring and radial drilling patterns on treatment were evaluated on a glue-laminated Douglas-fir pole. While some differences were noted in the patterns, the pole was too well-treated to permit effective separation of the various patterns.

The air-seasoning studies are now completed. Evaluation of the final pahse of this study showed that decay fungi began to colonize the pole sections after only 3 months of air-seasoning. Examination of weather data failed to provide a conclusive relationship between climate and colonization, possibly due to the array of variables to which the seasoning wood is subjected. The test suggests that most poles are adequately dried within three months of air-seasoning so that short air-seasoning exposures could be feasible. Sterilization at some point during the treatment cycle should still be considered as an integral part in the proper treatment of poles.

Field trials to evaluate the performance of modified groundline wrap systems are continuing at both the Corvallis site and on a test line near Modesto, CA. The results at the Corvallis site indicate the copper naphthenate, boron, and fluoride are all moving well into the wood eighteen months after application. More controlled laboratory trials on one formulation suggest that the water soluble copper naphthenate can migrate for some distance into the wood within six months after application. As expected, wet wood permits more

substantial diffusion.

Evaluation of copper naphthenate treated western redcedar stakes in a fungus cellar suggests that the specified treatment levels are providing adequate protection, although some decay is occurring. Stakes which were obtained from weathered sapwood appear to be failing more rapidly those cut from freshly sawn lumber, possibly because the former stakes have a more open structure which permits leaching losses and subsequent fungal colonization.

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OBJECTIVE I
DEVELOP SAFE, ENVIRONMENTALLY ACCEPTABLE CHEMICALS TO CONTROL INTERNAL DECAY OF DOUGLAS-FIR POLES

A. EVALUATE PREVIOUSLY ESTABLISHED TESTS OF FUMIGANT PERFORMANCE IN DOUGLAS-FIR

Over the years, the Cooperative Pole Research Program has installed a number of field trials to evaluate the performance of the various fumigants in active utility lines (Table I-1). These trials provide valuable data on chemical performance under actual conditions as well as identifying problems which can arise in the commercialization of formulations.

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

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

1. Douglas-fir poles treated with Vapam, Vorlex or Chloropicrin: The initial Bonneville Power Administration test line established near Corvallis, Oregon to evaluate Vapam, Vorlex, and chloropicrin is now 22 years old. This line was not inspected in 1990 and we are currently evaluating the data on this test to determine if further sampling is necessary.

2. Douglas-fir poles treated in 1977 with allyl alcohol, methylisothiocyanate, or Vorlex: In 1977, Douglas-fir transmission poles containing small decay pockets were treated with 1 liter of allyl alcohol, 100 % methylisothiocyanate (MITC), 20 % MITC in diesel oil, or Vorlex. The MITC was melted prior to application and some difficulties were experienced in delivering the full dosage of the 100 % MITC. The allyl alcohol treated poles were retreated with metham sodium in 1987. The poles have been sampled annually by

% methylisothiocyanate (MITC), 20 % MITC in diesel oil, or Vorlex. The MITC was melted prior to application and some difficulties were experienced in delivering the full dosage of the 100 % MITC. The allyl alcohol treated poles were retreated with metham sodium in 1987. The poles have been sampled annually by removing increment cores from 3 equidistant points around the pole 0, 1.2, 1.8, and 2.4 m above the groundline. One set of cores was cultured on malt extract agar for the presence of decay fungi. A second set of cores was evaluated in a closed tube bioassay to measure residual fumigant protection. The outer and inner 2.5 cm of each core was placed into a test tube containing a test fungus, Postia placenta, growing on malt agar. The tube was sealed and inverted so that the wood was at the bottom and the fungus near the top of the tube. Any vapors present in the wood could then diffuse upward to inhibit growth of the test fungus. Fungal growth in comparison to growth in similar tubes without wood provides a relatively guide to the residual protection provided by the fumigant. Previous tests have shown that this method is nearly as sensitive as gas chromatography for detecting residual MITC.

Culturing of increment cores revealed that fungal colonization remained low in the MITC and Vorlex treatments (Figure I-1). The allyl alcohol and control treatments were retreated with metham sodium in 1987 and are no longer being sampled. As expected, the 20 % MITC treatment is experiencing a slightly higher degree of fungal colonization than the 100 % MITC treatment. However, only one 20 % MITC and one Vorlex pole contained a decay fungus, suggesting that the degree of reinfestation in these poles is slight (Table I-2). The 20 % MITC treatment was included as a comparison with the Vorlex treatment which contains 20 % MITC in chlorinated C_3 hydrocarbons. Previous studies have shown that Vorlex provides 17 to 20 years of protection to Douglas-fir poles, and a portion

Table I-2. Effectiveness of fumigants in Douglas-fir poles treated in 1977 as measured by culturing increment cores removed from the treated poles for the presence of decay fungi.[1]

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

[1]Poles were treated with fumigants in 1977, and annually thereafter three cores were removed at five heights from the groundline and cultured for fungi. Superscripts denote poles remaining in test since 1981. Others were inadvertently treated with Vapam by a commercial applicator.
[2]Diluted in diesel oil.
[3]The allyl alcohol poles were re-treated with Vapam in 1987.
[4]These poles were not inspected in 1989.

Table I-3. Residual fumigant vapors in Douglas-fir poles twelve years after fumigant treatment as measured using a closed-tube bioassay.[1]

Meters above ground	Segment location from surface (cm)	Growth of the assay fungus (as % of control): Vorlex 1989	Vorlex 1990	Methylisothiocyanate 20% 1989	Methylisothiocyanate 20% 1990	MITC 100% 1989	MITC 100% 1990
2.4	0-2.5	81	96	70	93	-	76
	12.5-15	65	93	76	100	65	100
1.8	0-2.5	49	90	100	87	57	83
	12.5-15	62	100	89	93	59	100
1.2	0-2.5	32	67	86	96	29	72
	12.5-15	92	99	98	90	62	100
0	0-2.5	54	96	81	72	27	79
	12.5-15	68	79	57	93	73	100
Control	(no wood)	37	29 mm^2				

[1]For the closed-tube bioassay, a core was removed at each height from four to six poles. A 2.5-cm-long core segment was sealed in a test tube below an agar slant inoculated with Postia placenta. Suppressed growth of P. placenta compared to growth of the fungus where no wood was present (control) indicates the presence of fungitoxic vapors. Lower percentages indicate increased inhibition.
[2]In diesel oil.
[3]Average growth in 7-10 tubes.

of this protective effect was attributed to the chlorinated compounds. This test suggests that the MITC is a more important factor in the performance of this treatment and that the chlorinated hydrocarbons do not enhance protection to any significant degree. It is likely that the chlorinated components do not migrate significant distances through the wood, although no chemical analyses have been performed to confirm this idea.

Closed tube bioassays revealed that there is little evidence of fungitoxic vapors in the cores removed from both the MITC and Vorlex treatments (Table I-3). The loss of fungitoxicity in the 20 % MITC and Vorlex treatments follows a trend which has been occurring for several years; however, the loss in the 100 % MITC poles has occurred very rapidly. Cores removed from these poles decreased growth of the assay fungus by approximately 50 % last year, but had little or no effect on growth in assays performed this year. The lack of protection suggests that all three of the treatments should now begin to experience reinvasion by decay fungi, although previous trials suggest that this rate of reinvasion is relatively slow.

The results indicate that MITC treatments continue to perform as well or better than Vorlex. These results are consistent with the presence of MITC in Vorlex. MITC is also the presumed primary fungitoxic product of metham sodium decomposition.

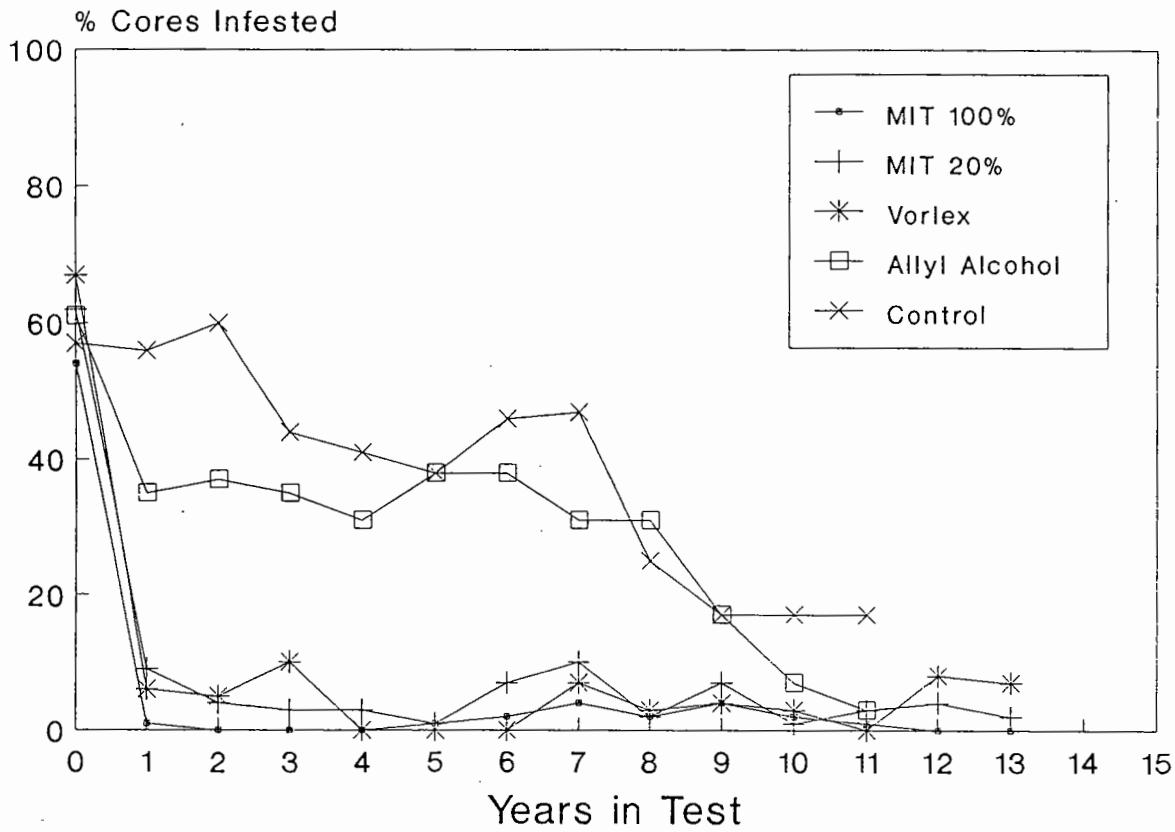


Figure I-1. Percent of cores removed from various sites on Douglas-fir transmission poles treated with Vorlex, 20 % MITC in diesel oil, 100 % MITC, allyl alcohol/metham sodium, or left untreated which contain basidiomycetes, a class of fungi containing many important wood decayers.

3. New York field test of encapsulated fumigants: The evaluations of gelatin encapsulated MITC in poles located near Hamburg, New York were begun in 1981. These poles were not sampled for 2 years owing to concerns about the number of sampling holes created by annual sampling. These poles will be sampled in 1991 to assess the effectiveness of the treatments 10 years after application.

4. Treatment of Douglas-fir poles with encapsulated MITC-effect of moisture content on chemical release: Moisture has a significant effect on the movement of fumigants through wood. At high moisture levels, the void volume of the wood decreases, blocking fluid flow. At low moisture levels, fumigants appear to strongly sorb to the wood, increasing chemical levels at a given location, but potentially decreasing the distance which the chemical travels away from the point of application. This effect is complicated when chemicals are encapsulated in materials which are dependent on moisture for release. In 1980, studies were begun to evaluate the use of gelatin for encapsulating MITC. Gelatin has many advantages for this application; it provides a tight seal from which the MITC cannot escape and it can be broken down in the presence of moisture. Laboratory studies indicated that gelatin contained the chemical until moisture was added, then rapidly released the chemical to effectively control decay fungi established in small wood blocks. Field trials were installed to test the performance of these poles in CCA treated Douglas-fir transmission poles in New York.

A second test was installed in 1983 to evaluate the effect of simultaneous application of water on the release of MITC from gelatin capsules. Poles were treated with 528 ml of gelatin encapsulated MITC (22 ml per capsule) distributed among 6 treatment holes beginning at groundline and spiraling around the pole at 120 degree increments 0.9 m apart vertically. Each hole received 88 ml of MITC in 4 gelatin capsules along with 0 (dry), 40 (moist), and 70 (wet) ml of water.

The holes were plugged with tight fitting wood dowels to retard fumigant loss.

The initial degree of fungal colonization was assessed by culturing drill shavings collected from each treatment hole. The poles have been sampled annually by removing increment cores from 3 locations around the pole 0, 0.9, 1.8, 2.7, 3.6, 4.5, and 5.4 m above the groundline. The outer and inner 2.5 cm of each core have been evaluated for residual fumigant using the closed tube bioassay. The remainder of each core has been cultured for the presence of decay fungi.

MITC continues to provide excellent protection at all three moisture levels 7 years after treatment (Table I-4). No decay fungi were isolated from any of the cores, a slight decline from the previous year when limited isolations were made from each of the treatments. Although there was an initial difference in the degree of fungal colonization between the various moisture contents, these differences have disappeared, indicating that initial moisture has little effect on long term performance of the chemical.

Closed tube bioassays of the increment cores also indicated that a substantial ihibitory effect remains in the poles 7 years after treatment (Table I-5). This effect is most noticeable with increasing distance above the groundline and may reflect continued diffusion of chemical upward. Closed tube bioassays of cores removed from regions closer to the groundline indicate that the levels of inhibition in this zone are declining, although they remain sufficient to decrease growth of the test fungus by nearly 50 %. As stated in previous reports, it is difficult to quantify the relationship between bioassay results and prevention of fungal attack. Fungal spores and hyphal fragments represent the most likely method by which decay fungi reinvade the wood. These fungal stages represent the most sensitive stages in the fungal life cycle.

Table I-4 Frequency of decay fungi isolated from Douglas-fir poles treated with gelatin encapsulated methylisothiocyanate (MITC).

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

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

Chemical levels which inhibit the growth of actively growing cultures of a decay fungus should therefore be inhibitory to spores. Thus, the closed tube bioassay responses, although somewhat diminished, may still be adequate to provide protection against reinvasion.

Table I-5. Fungal inhibition of increment cores removed Douglas-fir poles treated with 588 ml of MITC and varying degrees of water as shown by a closed tube bioassay using Postia placenta as the test fungus.

Meters Above Groundline	Core Segment[1] (cm)	Avg Growth of Test Fungus (as % of control)[2] DRY	MOIST	WET
0	0 TO 2.5	57	16	54
	10 TO 12.5	67	35	67
0.9	0 TO 2.5	28	63	54
	10 TO 12.5	54	51	89
1.8	0 TO 2.5	32	19	3
	10 TO 12.5	32	54	28
2.8	0 TO 2.5	32	19	3
	10 TO 12.5	0	35	28
3.7	0 TO 2.5	41	0	13
	10 TO 12.5	0	22	0
4.6	0 TO 2.5	0	0	0
	10 TO 12.5	0	0	0
5.4	0 TO 2.5	9	0	22
	10 TO 12.5	9	3	13

1. The outer, treated shell of each core was discarded and the next 2.5 cm (outer) as well as the inner 2,5 cm (inner) were used in the bioassay.
2. Lower average % growth reflects the presence of increased levels of chemical. Average growth of control tubes without wood was 31.5 mm.

5. Treatment of through-bored Douglas-fir poles with gelatin encapsulated MITC or chloropicrin: The field trials to evaluate gelatin encapsulated MITC or chloropicrin in through-bored Douglas-fir poles were established in 1982. These

poles were sampled in 1990 and will not be resampled until the spring of 1992 to provide a ten year report.

6. Above ground treatment with gelatin encapsulated or pelletized MITC: The Douglas-fir poles treated near the crossarm zone with pelletized or gelatin encapsulated MITC were not sampled this year. They will be sampled in 1992 to provide an 8 year evaluation of the effectiveness of these treatments.

B. EVALUATE NEW CHEMICALS FOR CONTROLLING INTERNAL WOOD DECAY

1. Effect of wood moisture content on decomposition of sodium n-methyldithiocarbamate in Douglas-fir: Sodium n-methyldithiocarbamate (NaMDC) is the active ingredient of metham sodium or Vapam. This formulation only contains 32.1 % NaMDC which must then decompose to produce fungitoxic MITC. The number of holes which can be drilled into a decaying wood pole are limited by strength concerns, making it essential to maximize the amount of chemical applied per treatment hole. One method for accomplishing this task is to remove the water from the metham sodium formulation, thereby permitting the application of additional active ingredient. There are a number of factors which will affect the performance of this chemical, but wood moisture content will play the most important role in decomposition since little or no NaMDC decomposition appears to occur in dry wood.

Last year we discussed plans to test the effect of wood moisture content on NaMDC decomposition. Douglas-fir heartwood blocks (2.5 by 2.5 by 10 cm long) were oven-dried (54 C) then pressure-soaked with water. The blocks were aerated until the moisture content, as determined by periodic weighing, had declined to the desired level. Blocks were equilibrated to 10, 30, 60 or 100 % moisture content. The blocks were dipped two times in molten paraffin to retard continued

moisture loss and then stored for 2 to 3 weeks to allow continued equilibration of moisture present in the wood.

A hole (0.9 cm in diameter by 1.9 cm long) was then drilled at the center of the block and 50 or 150 mg of powdered or pelletized NaMDC was added. The hole was sealed using a rubber serum cap and the blocks were incubated at room temperature. NaMDC was prepared by dehydrating metham sodium. Pellets were made by adding a small quantity of water to the powdered NaMDC and placing the moist mixture into a small pellet mold. The water evaporated, leaving a solid pellet which could be easily handled for application. The treated blocks were incubated at room temperature for 1, 4, or 8 weeks.

At each time point, three blocks from each treatment group were randomly selected for analysis. The outer 0.5 cm from each end of the block was cut off and discarded. The next 0.5 cm was cut into 16 equal sized squares and the middle four were placed into a tube containing 5 ml of ethyl acetate. A second set of 0.5 cm thick wafers were cut from a zone 0.5 cm away from either side of the treatment hole and extracted in the same manner. The tubes were stored for a minimum of 48 hours and then the ethyl acetate extract was analyzed for MITC using a Varian 3700 gas chromatograph equipped with a flame photometric detector. The wood in the tubes was then oven-dried (54 C) and weighed. Chemical content was quantified on a ug of MITC per oven-dried gram of wood basis.

Wood moisture content had a marked effect on the release of MITC from the NaMDC treated blocks (Table I-6). As expected, MITC levels were always highest in the 150 mg/block treatments reflecting the larger amount of NaMDC available for decomposition. Chemical levels were generally highest in 10 % MC blocks at all time points after treatment in both the pelletized and powdered treatments. MITC is generally more strongly sorbed by dry wood and the high chemical levels

Table I-6. Effect of wood moisture content on MITC content of Douglas-fir heartwood blocks treated with 50 or 150 g of solid NaMDC.

Moisture content (%)	Dosage (mg/block)	Zone[1]	Water (+/-)[2]	MITC Content (ug/g oven-dry wood) pellets 1 wk	pellets 4 wk	pellets 8 wk	powder 1 wk	powder 4 wk	powder 8 wk
10	50	inner	+	364	264	136	390	355	213
		outer	+	321	254	129	309	369	166
	150	inner	+	3408	1590	1072	2504	1984	1089
		outer	+	3628	1472	980	2293	1253	1180
	150	inner	-	47	169	238	-	-	-
		outer	-	14	82	155	-	-	-
30	50	inner	+	114	108	44	166	47	35
		outer	+	101	94	36	175	27	9
	150	inner	+	2080	340	115	866	509	205
		outer	+	2023	297	111	755	676	200
	150	inner	-	579	381	274	-	-	-
		outer	-	480	370	283	-	-	-
60	50	inner	+	155	113	32	165	40	19
		outer	+	122	92	18	140	27	9
	150	inner	+	2506	474	56	1807	561	132
		outer	+	2319	453	38	1465	588	88
	150	inner	-	1193	345	296	-	-	-
		outer	-	775	270	254	-	-	-
100	50	inner	+	185	144	32	204	69	57
		outer	+	109	113	14	178	76	45
	150	inner	+	2627	789	311	2853	1065	215
		outer	+	2403	924	281	1473	1259	221
	150	inner	-	1203	308	229	-	-	-
		outer	-	497	305	245	-	-	-

1. Inner zone was sampled 0.5 cm away from the treatment site, while the outer zone was 0.5 cm in from the end of the block.
2. Five ml of water water added (+) with some treatments to aid in fumigant release.

detected may reflect increased sorption of the released chemical rather than enhanced decomposition. Increased decomposition at higher moisture content may have resulted in more rapid release of MITC coupled with more rapid loss from the blocks.

The addition of water at the time of treatment appeared to have the greatest effect in drier blocks, where free moisture would be absent. While MITC was detected in dry blocks without added moisture, the levels shortly after treatment were often ten times lower than those in blocks receiving water. This effect decreased at higher moisture contents, although MITC levels were still low 1 week after treatment. MITC content in dry blocks then declined,but the rate of decline was slower than that found in blocks receiving water. At the end of 8 weeks, MITC content of 30 and 60 % MC blocks was actually higher in blocks which did not receive water. These differences may reflect a slower rate of decomposition coupled with a slightly lower wood moisture content in the absence of added water. As a result, the chemical may be more strongly sorbed to the wood.

Residual MITC levels declined with time in most treatments, except in the 150 mg/block treatment of 10 % MC blocks, where they continued to rise over the 8 week exposure period. These blocks had much lower levels of chemical than similar blocks which received 5 ml of water at the time of treatment and the increasing chemical levels probably reflect a much slower decomposition rate in the absence of excess moisture.

The application of pellets in place of powdered NaMDC appeared to have little or no effect on chemical levels detected in the wood, although some treatments appeared to have slightly higher levels of residual MITC when pelletized chemical was applied. The lack of effect with pelletizing is

confusing. Surface area should play a major role in decomposition of NaMDC and powdered formulations, with their greater surface area, should decompose more readily. The absence of effect will be further explored in future trials. The absence of an effect would; however, make application simpler since a successful NaMDC would likely need to be pelletized to avoid health problems associated with exposure to the dust during application.

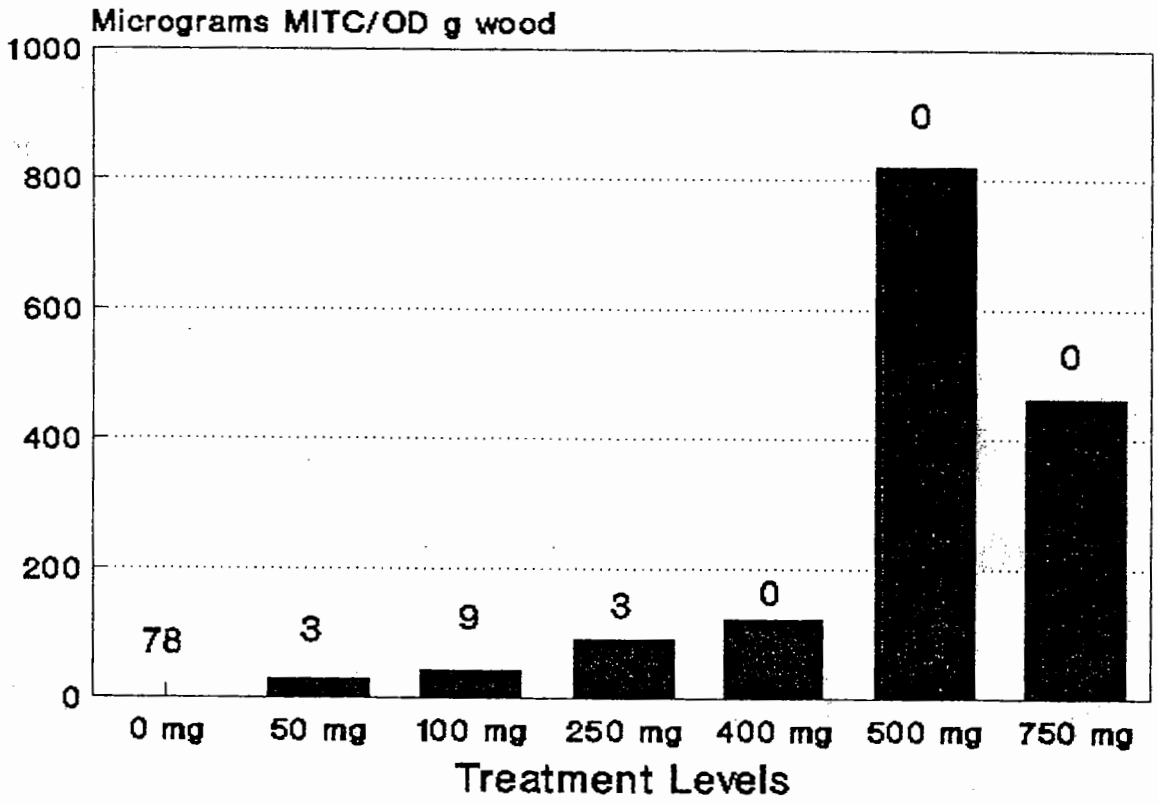
The results suggest that application of pelletized MITC will produce fungitoxic levels of MITC in as little as one week in blocks at a variety of wood moisture contents. The simultaneous application of water to the treatment hole enhances initial NaMDC decomposition to MITC, but this effect is temporary. The results indicate that solid NaMDC can produce sufficient quantities of MITC to effect fungal control. Further laboratory tests and a field trial are planned.

2. Effectiveness of gelled NaMDC against decay fungi established in Douglas-fir heartwood blocks: As discussed in the prior section, decreasing likelihood of spills with metham sodium would markedly improve applicator safety. We recently evaluated a gelled formulation of metham sodium containing 40 % NaMDC. The formulation was supplied in a plastic caulking tube which could be easily applied to conventional treatment holes.

The formulation was evaluated in the standard small block fumigant test in which a test fungus, Antrodia carbonica, was inoculated into wax-coated, pressure soaked Douglas-fir heartwood blocks (2.5 by 2.5 by 10 cm long). The fungus was allowed to colonize the wood for 30 days, then a hole was drilled in the center of the block and 50, 100, 250, 400, 500 or 750 mg of formulation was added. The hole was plugged and the block was incubated for an additional 1 or 4 weeks. At each time point, four blocks per treatment were sampled by cutting three 0.5 cm thick sections from each end of the block. The outer section, which was subjected to some drying during the exposure, was discarded. The next section inward was cut into 16 equal sized cubes and the inner four were placed onto potato dextrose agar. These cubes were observed for evidence of growth of the test fungus, which was used as a measure of chemical effectiveness. The next section was also cut into 16 equal sized cubes and the inner four cubes were extracted in ethyl acetate. The ethyl acetate was then analyzed for residual MITC content by gas chromatography.

After 1 week, gelled metham sodium was highly effective against the test fungus, even at the lowest level tested (50 mg)(Figure I-2). Survival of the test fungus ranged from 3 to 9 % at dosages between 50 and 250 mg of chemical per block. Previous studies of liquid metham sodium suggested an LD_{90} of 400 to 450 mg of formulation per block. The marked increase in performance of the gelled formulation may demonstrate a slower loss of moisture from the gel which, in turn, encourages more efficient decomposition of NaMDC to MITC. Longer term laboratory studies are still underway to better quantify the effectiveness of this chemical.

Gelled metham sodium has other application advantages including reduced risk of spills and decreased loss from checks which are inadvertantly crossed in the treatment hole. This formulation was developed for other agricultural applications, but its excellent performance in our small block test suggest that it has potential in wood poles. For this reason, a small field trial will be established this summer to evaluate various dosages under more realistic conditions.



Numbers are % survival.

Figure I-2. Fungal survival and residual MITC content in Douglas-fir heartwood blocks one week after treatment with selected dosages of liquid and gelled metham sodium formulations.

3. Toxicity of fused borate rods to decay fungi in Douglas-fir heartwood: Fused borate rods exhibit much promise as remedial treatments for decay control, especially above the groundline. Boron has extremely low toxicity to animals, is highly effective against decay fungi, and can diffuse through the wood with moisture. As a part of our evaluation of this chemical, we began studies to determine the levels of chemical required to eliminate decay fungi from Douglas-fir heartwood blocks.

Douglas-fir heartwood blocks (2.5 by 2.5 by 10.0 cm long) were pressure soaked, sterilized, coated with wax, and inoculated with Postia placenta or Antrodia carbonica, the two decay fungi most commonly isolated from Douglas-fir poles in service. One additional set of blocks was inoculated with A. carbonica without pressure soaking to explore the effects of lower moisture contents on boron diffusion. The fungus was allowed to thoroughly colonize the wood, then 50, 125, 250, 500, 750, or 1000 mg of borate rod was measured and added to a hole drilled at the block center. Dosages varied slightly among blocks because of the difficulty of accurately cutting the rods. The hole was plugged and the blocks were incubated for 2 to 8 weeks. A series of three 0.5 cm thick sections were then cut from the blocks. The first was discarded, while the second was cut into 16 equal sized cubes. The center four cubes were then plated on potato dextrose agar and observed for growth of the test fungus which was used as a measure of chemical control. The third section was ground to pass a 20 mesh screen, then extract and analyzed for boron content. The results were expected to provide a measure of the dosage required to eliminate the test fungus from the wood as well as the chemical levels which develop in the wood as the result of differing dosages.

The fungal survival results were presented previously ('88 Annual Report, pg. 19), but the chemical analyses were only recently completed. Both of the test fungi were sensitive to boron treatment, although a longer incubation period was required to completely eliminate both of the test fungi from the blocks at all treatment levels (Table I-7). Postia placenta appeared to be more sensitive to boron and succumbed to a 125 mg dosage after only 2 weeks. Antrodia carbonica was more tolerant, and required 500 mg of boron and a six week incubation period for complete elimination of the fungus from the blocks. Interestingly, the boron levels in blocks did not rise appreciably between the two incubation periods, suggesting the longer exposures to low levels of boron may be as effective as shorter exposures to higher levels. The nature of this varying fungal tolerance to boron is unknown, but suggests that caution must be exercised in protecting Douglas-fir poles against this fungus.

Table I-7. Ability of fused boron rods to migrate through Douglas-fir heartwood to eliminate Postia placenta or Antrodia carbonica as measured by culturing samples removed from the blocks 2, 4, 6, or 8 weeks after chemical application and chemical analysis[1]

Dosage (mg)	A. carbonica								P. placenta			
	Soaked				Dry				Soaked			
	2 wks		6 wks		2 wks		8 wks		4 wks		8 wks	
	survival	Boron	survival	Boron	survival	Boron	survival	Boron	survival	Boron	survival	Boron
	(%)	(%)	(%)	(%)	(%)	(%)	(%)	(%)	(%)	(%)	(%)	(%)
50	100	0.041	25	0.042	100	0.027	25	0.040	53	0.033	0	0.035
125	100	0.073	25	0.078	94	0.068	-	-	3	0.075	0	0.075
250	62	0.143	25	0.130	91	0.115	13	0.045	0	0.136	0	0.141
500	53	0.250	0	0.243	94	0.247	16	0.260	0	0.258	0	0.321
750	-	-	-	-	-	-	-	-	0	0.330	0	0.415
1000	28	0.395	0	0.430	-	-	0	0.400	0	0.406	0	0.587
Control	94	0.007	100	0.004	100	0.008	91	0.006	97	0.002	100	0.001

[1]Percent survival based upon isolations from 32 samples per treatment. Boron reported as percent boric acid equivalent, represents average of 8 analyses per treatment.

The presence of moisture should play an important role in the effectiveness of borate rods; however, moisture did not appear to significant enhance the rate of boron diffusion in this study. Boron levels, although generally lower in drier blocks, did not differ dramatically. Soaked blocks had moisture contents

between 70 and 90 % at the time of chemical treatment, while wet blocks had moisture levels between 30 and 50 %. These results suggest that there is little difference in diffusion rate between these two levels. This lack of effect may occur because of variations in moisture distribution within individual blocks. For example a block with a 30% average MC may have pockets with much higher moisture levels. Wood in service rarely achieves moisture levels above 50 percent in zones above the groundline, but our analyses suggest that MC's below this level will be sufficient for boron diffusion.

The results, coupled with our previous studies which demonstrate the ability of boron to diffuse through Douglas-fir heartwood at varying moisture levels, indicate that boron has excellent prospects for controlling above ground decay. Tests to evaluate this prospect as well as others to examine the effectiveness of this treatment at groundline are underway.

C. EVALUATE PROMISING FUMIGANT FORMULATIONS IN FIELD TRIALS

1. Effectiveness of glass encapsulated MITC in Douglas-fir and southern pine poles: MITC has performed well in a variety of field trials, but the caustic nature of the active ingredient limited commercial application. In 1988, a new formulation was developed which placed the MITC in glass vials which were sealed with rubber stoppers and capped with aluminum. The tubes were then sealed in foam-filled aluminum containers for safe transport to the application site. The glass tube formulation differed substantially from the gelatin treatments previously evaluated and field trials were established to evaluate the effectiveness of this formulation in comparison with metham sodium, the most commonly used wood fumigant.

Douglas-fir and southern pine poles (25 to 30 cm in diameter by 3.6 m long) were treated to a nominal retention of 0.40 kg per cubic meter with chromated copper arsenate. These poles were set to a depth of 0.9 m in the Oregon State University Peavy Arboretum Test Site located near Corvallis, Oregon. A series of 1.9 cm diameter holes were drilled in each pole in a spiral pattern beginning at groundline and moving upward at 120 degree by 15 cm intervals. The poles were treated with 60 (2 vials), 120 (4 vials), 180 (6 vials), or 240 (8 vials) g of glass encapsulated MITC. A control treatment of 500 ml of Metham sodium (32.1 % sodium n-methyldithiocarbamate) was applied in a similar treatment pattern. Each dosage was applied to 6 poles of each wood species. All of the poles were coated with an elastomeric paint in the treated zone to retard fumigant loss and simulate an oil treated shell.

The poles were sampled 6, 12, and 24 months after treatment by removing increment cores for closed tube bioassays and chemical analysis. Cores were removed from two locations 180 degrees apart 0.3 m below the groundline and three locations 120 degrees apart 0, 0.3, 0.9, and 1.5 m above the highest treatment hole. The outer and inner 2.5 cm of each core were either extracted in ethyl acetate and analyzed for residual MITC content or placed in a closed tube bioassay with Postia placenta as the test fungus. In addition, a series of 15 cm deep holes were drilled into the poles 0.3 m below the groundline and 0.3 , 0.9, and 1.5 m above the site of the highest treatment hole. Wooden doweling colonized by a decay fungus, P. placenta, was placed into each hole. These doweling were removed during the inspection and cultured on potato dextrose agar to determine if the fungus survived the chemical exposure. Early in the test, it was realized that drying of the dowel during the exposure period killed the fungus even in non-fumigant treated poles. This problem was minimized by placing

dowels into the holes 3 months prior to sampling to reduce the dessication period. While this reduced the exposure period, it improved survival in the control poles.

MITC has moved well through all of the poles, with detectable levels present in all poles 0.9 m above the highest treatment site. Gas chromatographic analysis of increment cores indicates that MITC was detectable up to 1.5 m in Douglas-fir poles and 0.9 m in southern pine poles 2 years after application (Table I-8). Southern pine is markedly more permeable than Douglas-fir and chemical diffusion would be expected to be greater. The decreased distribution of MITC in southern pine may reflect the increased radial permeability of this species which permits more chemical to be lost through the side grain reducing the amount of chemical available for longitudinal diffusion. These results suggest that fumigant treatment of southern pine will provide a slightly smaller zone of protection, although the chemical should move more rapidly to a given site in the pole. A more rapid chemical loss in southern pine is consistent with limited field tests conducted by R.A. Zabel at SUNY Syracuse. While chemical distribution appears more limited in southern pine, chemical levels in the zone 0.3 m below to 0.9 m above the treatment zone appears to be becoming more uniform between the two wood species, although the levels of chemical at at given sampling height are declining slightly. It is difficult to predict the protective life of the MITC treatments. Previous field trials of this and other MITC-based fumigants have only been evaluated on the basis of closed tube bioassays and culturing for the presence of decay fungi. As a result, there is no data to describe the depletion rate of fumigant from treated poles. This data, will thus prove highly useful for predicting depletion rates and will be employed to verify a fumigant movement model which is currently being refined.

Table 1-8 Residual MITC content in increment cores removed from selected sites above and below the treatment holes of Douglas-fir or southern pine poles 6, 12, or 24 months after treatment with MITC-Fume or metham sodium as measured by gas chromatographic analysis.

Chemical treatment	Dosage (g)	MITC CONTENT (ug/oven dry gram of wood)[1]																									
		0.3m				0				0.3 m						0.9m						1.5 m					
		Outer		Inner		Outer		Inner		Outer			Inner			Outer			Inner			Outer			Inner		
		12 mos	24 mos	12 mos	24 mos	12 mos	24 mos	12 mos	24 mos	6 mos	12 mos	24 mos	6 mos	12 mos	24 mos	6 mos	12 mos	24 mos	6 mos	12 mos	24 mos	6 mos	12 mos	24 mos	6 mos	12 mos	24 mos
SOUTHERN PINE																											
MITC-FUME	60	105	125	369	2031	93	127	2031	2054	0	38	T	1	239	285	0	T	T	0	T	T	0	0	0	0	0	0
	120	179	306	1534	1996	147	120	2777	1798	1	94	40	14	316	353	0	12	T	0	12	T	O	0	0	0	0	0
	180	170	204	1282	2028	169	426	3009	2033	3	30	33	12	212	322	0	13	T	0	9	T	O	0	0	0	0	0
	240	320	185	1644	1754	275	140	3425	2381	2	29	13	6	184	281	0	10	T	0	T	46	O	0	0	0	0	0
Metham sodium	500	10	213	147	535	85	18	1986	319	0	9	T	2	96	54	0	0	0	0	0	0	0	0	0	0	0	0
DOUGLAS-FIR																											
MITC-FUME	60	164	140	292	1322	119	219	2525	1191	5	26	46	132	128	256	0	34	84	2	24	149	0	5	T	0	T	T
	120	346	168	270	1541	485	200	2879	1928	84	12	94	296	349	459	2	94	60	115	198	117	0	T	T	0	T	T
	180	401	404	1327	2161	280	192	3745	1600	132	149	177	534	1052	363	0	25	40	4	26	92	0	T	T	0	T	T
	180[2]	303	525	1202	2660	420	195	3014	2091	3	8	83	304	320	543	0	54	T	0	205	169	0	T	T	0	T	T
	240	439	273	441	1240	1500	322	3985	1242	132	206	311	624	262	554	0	34	72	2	31	165	0	T	49	0	21	120
Metham sodium	500		15		143	41	31	978	34	4	11	22	352	105	306	0	10	T	2	102	49	0	T	0	0	0	0

Analyses were performed on the outer and inner 2.5 cm segments of each increment core.

[1]Poles received 240 ml of water (40 ml/hole) at the time of treatment.

As with the chemical assays, closed tube bioassays revealed that inhibitory MITC levels were present 0.3 m below the groundline and 0.9 m above the treatment zone in Douglas-fir poles, while the protective zone was limited to 0.3 m above the groundline in southern pine poles (Table I-9). As expected, treatment efficacy improved with dosage, although there were slight variations in performance regardless of dosage. Metham sodium treated poles exhibited little or no evidence of residual protection in southern pine, but did exhibit some evidence of protection near the treated zone in Douglas-fir. This finding is consistent with previous studies have shown that metham sodium produces some residual fungitoxic effect for 2 to 3 years after treatment. Closed tube bioassays normally provide a guide to the residual protection afforded by a given chemical treatment. In these trials, the results confirm those found by chemical analyses.

Culturing of doweling exposed in the pole sections suggests that residual fungitoxic levels are present 0.3 m above the highest treatment site in both species (Table I-10). Fungal survival was also lower in dowels exposed 0.9 and 1.5 m above the highest treatment hole in the Douglas-fir poles; however, control was incomplete at these locations. Fungal survival in dowels placed in metham sodium treated poles was lower at sites immediately adjacent to the highest treatment hole, but rose further away from the treatment site. Once again, fungal inhibition was greater in the Douglas-fir poles.

Culturing of increment cores indicated that none of the southern pine poles contained decay fungi, although the cores contained high levels of non-decayers (Table I-11). Control Douglas-fir poles are beginning to experience some fungal colonization, particularly in the groundline region. A decay fungus was also isolated from one 120 g MITC-Fume treated pole 0.9 m above the highest treatment

Table I-9 Closed tube bioassays of increment core segments from selected sites on Douglas-fir 12 or 24 months after treatment with selected dosages of sodium.

Chemical treatment	Dosage (g)	% fungal inhibitor (as a % of control)[1]																			
		-0.3m				0				+0.3 m				+0.9m				+1.5 m			
		Outer		Inner		Outer		Inner		Outer		Inner		Outer		Inner		Outer		Inner	
		12 mos	24 mos	12 mos	24 mos	12 mos	24 mos	12 mos	24 mos	12 mos	24 mos	12 mos	24 mos	12 mos	24 mos	12 mos	24 mos	12 mos	24 mos	12 mos	24 mos
SOUTHERN PINE																					
MITC-FUME	60	12	17	0	0	16	0	0	0	80	83	40	0	100	90	60	57	100	97	100	100
	120	0	0	0	0	3	7	0	0	0	36	0	0	73	77	33	63	100	100	100	94
	180	0	20	0	0	11	30	0	0	21	33	0	13	95	94	92	35	100	100	100	80
	240	0	0	0	0	0	0	0	0	41	33	0	0	100	100	100	48	100	100	50	57
Metham sodium	500	23	100	14	0	40	100	0	0	63	100	45	13	90	100	86	60	100	87	97	70
DOUGLAS-FIR																					
MITC-FUME	60	34	16	0	0	0	16	0	0	65	40	16	16	79	43	27	20	63	53	95	77
	120	25	6	12	0	0	0	0	10	32	23	12	13	64	43	26	0	100	47	100	43
	180	4	20	0	0	0	0	0	0	4	0	0	0	27	23	22	16	62	60	68	30
	180[2]	19	0	0	0	0	0	0	0	31	0	27	0	36	50	4	0	75	100	66	0
	240	0	0	0	0	0	0	0	0	0	0	0	0	19	24	8	0	48	100	50	67
Metham sodium	500	77	20	49	16	10	12	0	0	67	0	15	33	70	60	39	33	86	100	84	67

[1]Values represent percent growth of Postia placenta in comparison to similar tubes without wood. Complete inhibition (0) represents high chemical levels. Assays were performed on the outer and inner 2.5 cm of each core.

[2]Water added to treatment holes at time of chemical application.

Table I-10 Survival of Postia placenta in hem-fir dowels exposed for 3 or 6 months in Douglas-fir and southern pine pole sections which were treated with MITC-Fume or metham sodium 6, 12, or 24 months prior to exposure.

		Fungal Survival (%)									
		0 m	0.3 m			0.9 m			1.5 m		
Chemical Treatment	Dosage (g)	24 mos	6 mos	12 mos	24 mos	6 mos	12 mos	24 mos	6 mos	12 mos	24 mos
MITC-FUME	60	50	27	0	12	33	17	40	50	6	75
	120	0	27	11	0	33	17	56	44	11	40
	180	0	5	0	0	39	0	73	62	11	75
	240	0	16	6	0	67	39	82	83	33	100
											100
Metham sodium	500	20	13	6	62	67	1	67	67	17	100
Control	-	80	27	6	80	44	0	70	50	6	87
DOUGLAS-FIR											
MITC-FUME	60	0	5	0	0	5	11	25	22	33	33
	120	0	5	0	20	14	33	14	38	78	60
	180	0	0	6	0	5	22	33	56	28	50
	180[2]	0	8	0	17	8	44	43	8	67	17
	240	0	0	0	0	11	33	10	50	67	12
Metham sodium	500	0	0	77	33	13	80	67	20	87	83
Control	-	40	33	100	71	39	100	73	39	100	45

[1] Wood dowelling infested with Postia placenta was implanted at 3 points (120° apart) around the pole at selected heights above the highest treating hole. The dowels were removed after 3 months and cultured on malt agar/benomyl plates.

[2] Water was added to the treatment holes at the time of chemical application.

TABLE I-11. INCIDENCE OF DECAY AND NON-DECAY FUNGI IN DOUGLAS-FIR AND SOUTHERN PINE POLES 12 OR 24 MONTHS AFTER TREATMENT WITH MITC-FUME OR METHAM SODIUM.

Chemical treatment	Dosage (g)	Cores containing decay (non-decay) fungi (%)								
		Distance above or below treatment (m)								
		-0.3 m	0		0.3 m		0.9 m		1.5 m	
		24 mos	12 mos	24 mos	12 mos	24 mos	12 mos	24 mos	12 mos	24 mos
		SOUTHERN PINE								
MITC-FUME	60	0 (50)	0 (67)	(0)	0 (100)	0 (100)	0 (100)	0 (100)	0 (100)	0 (100)
	120	0 (50)	0 (83)	0 (17)	0 (100)	0 (83)	0 (100)	0 (100)	0 (100)	0 (100)
	180	0 (28)	0 (30)	0 (57)	0 (100)	0 (100)	0 (100)	0 (100)	0 (100)	0 (100)
	240	0 (0)	0 (50)	0 (0)	0 (100)	0 (100)	0 (100)	0 (100)	0 (100)	0 (100)
Metham sodium	500	0 (40)	0 (40)	0 (40)	0 (100)	0 (80)	0 (100)	0 (100)	0 (100)	0 (100)
Control	-	0 (100)	0 (100)	0 (100)	0 (100)	0 (100)	0 (100)	0 (100)	0 (100)	0 (100)
		DOUGLAS-FIR								
MITC-FUME	60	0 (0)	0 (25)	0 (33)	0 (33)	0 (50)	0 (50)	0 (100)	0 (100)	0 (100)
	120	0 (57)	0 (29)	0 (29)	0 (71)	0 (100)	0 (64)	7 (100)	10 (40)	0 (100)
	180	0 (50)	0 (16)	0 (17)	0 (58)	0 (67)	0 (75)	0 (67)	0 (71)	0 (67)
	180[2]	0 (25)	0 (75)	0 (0)	13 (50)	0 (75)	13 (87)	0 (75)	30 (90)	0 (75)
	240	0 (33)	0 (29)	0 (17)	0 (25)	0 (67)	0 (8)	0 (100)	25 (75)	0 (100)
Metham sodium	500	0 (60)	0 (60)	0 (40)	0 (40)	10 (60)	10 (50)	10 (80)	0 (40)	10 (80)
Control	-	33(100	0 (100	33 (100)	0 (50)	25 (100)	8 (33)	8 (100)	0 (33)	0 (100)

[1]Values reflect average of 15 cores per position. Figures in parentheses represent non-decay fungi isoalted from the same cores.

[2]Water was added to treatment holes at time of chemical application.

site. Metham sodium treated Douglas-fir poles are also experiencing some fungal colonization in the above ground sections, reflecting the lower levels of chemical protection away from the treatment site.

All of the results indicate that the MITC is moving well through both species. While there are slight differences between the species, these variations are consistent with previous trials and reflect the differing permeabilities.

2. Effect of exposure conditions on release rate of MITC-Fume from glass vials in Douglas-fir poles sections: The MITC-Fume formulation allows release of chemical from a small hole at the top of a glass tube. The small hole should limit the rate of MITC release and might alter the chemical distribution in the pole. The effect of glass encapsulation on MITC release rate was explored by treating green or air-dry end-coated Douglas-fir pole sections with one vial of MITC-Fume applied through a single hole at the center of each 60 cm long pole section. The treatment hole was plugged with a tight fitting rubber plug. Pole sections were stored in a hot wet room (90 F/90 % relative humidity), cold room (37 F/65 % RH), and outside in Corvallis, OR. At periodic intervals, the MITC-FUME tubes were removed and weighed to determine gross chemical loss. The tubes were then returned to their respective treatment holes.

MITC-FUME tubes weigh approximately 50 g at the time of application, including about 20 g of glass. MITC-Fume escaped most rapidly from tubes exposed under hot wet conditions, but total release still required nearly one year under these conditions (Figure I-3). These results compare favorably with those obtained in field trials in Los Banos, Republic of the Philippines where hot humid conditions predominate. Exposure to ambient Corvallis conditions produced slower MITC release and a small amount of MITC remains over 700 days after

treatment. Tubes exposed under cold conditions have lost little chemical and will take many years for complete release. Poles at higher elevations under shaded conditions might fall into this category.

The presence of residual chemical in the treatment hole for long periods after treatment has raised concern among a number of potential MITC-Fume users. While slow release of chemical is a desirable trait for long term protection against fungal attack, the presence of concentrated chemical in the treatment hole does pose a slight risk should the pole fail in the region near the treatment site. Recent tests; however, suggest that the risk to utility personnel is minimal provided the pole is properly tagged to identify the type of chemical treatment applied.

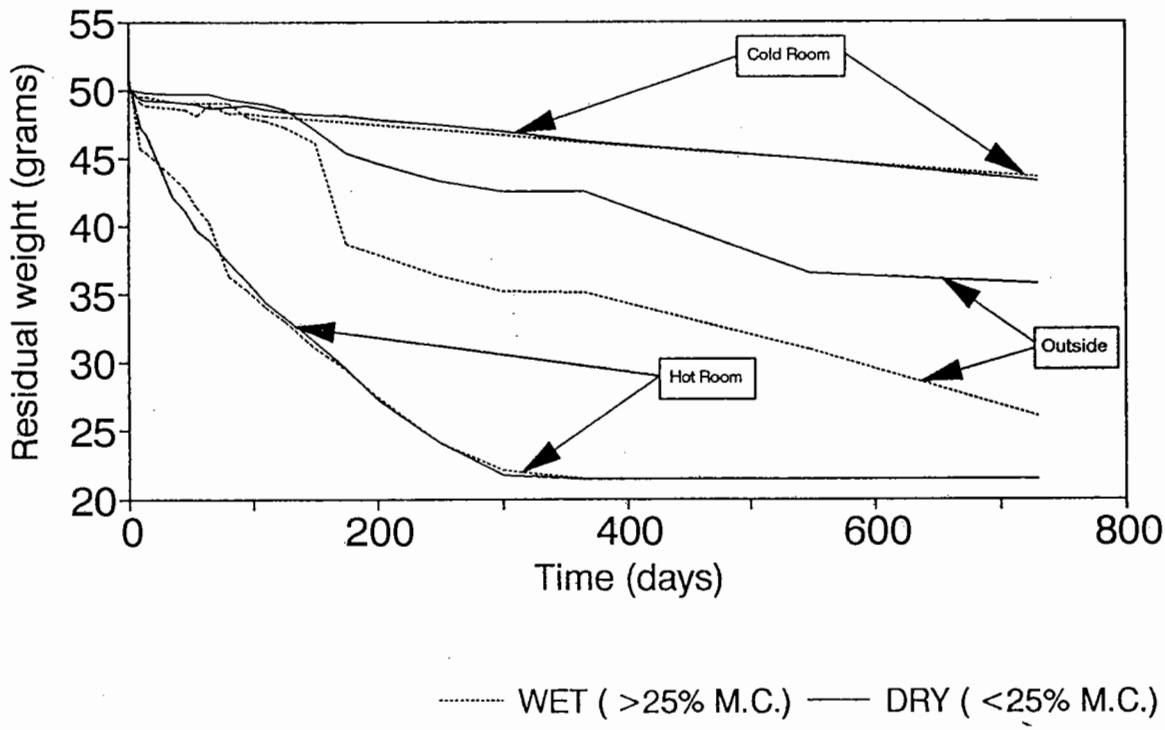


Figure I-3. Rate of MITC release from MITC-Fume treated Douglas-fir pole sections exposed under cold, ambient and hot/wet conditions as determined by weight loss of treatment vials.

3. Preliminary field trials to evaluate Basamid in Douglas-fir heartwood: Basamid is a solid chemical which decomposes to produce MITC among its fungitoxic products. This chemical has excellent stability at room temperature, a property which makes it an ideal candidate for improved applicator safety, but one which decreases its effectiveness as a wood treatment. Preliminary laboratory trials suggest that Basamid decomposition is more efficient at higher pH's. Unfortunately, the pH of Douglas-fir heartwood ranges from 3.0 to 3.5, far below the optimum levels of Basamid decomposition. As an alternative, it may be possible to alter the pH around the treatment hole to encourage Basamid decomposition by addition of selected high pH buffers.

Preservative treated Douglas-fir pole sections (1.8 m long) were treated with 75 g of Basamid distributed between 3 holes at the center of section. One set of three poles received 100 ml of pH 10 buffer, a second set received a similar amount of pH 12 buffer and the third received no supplemental liquid. The holes were plugged with tight fitting wood dowels and the poles were exposed outdoors at the Forest Research Laboratory.

The poles were sampled by removing 3 increment cores from around the pole at 120 degree intervals 0.3 m above and below the treatment holes. The outer and inner 2.5 cm of each core were extracted in ethyl acetate and analyzed for residual MITC content by gas chromatography. Chemical levels remain detectable at all sites and levels in the poles, although the levels are considerably lower than those found in poles treated with MITC-Fume (Table I-12). The presence of pH 12 buffer appeared to enhance decomposition over the other two treatments, although the differences were slight. The results suggest that Basamid can decompose in Douglas-fir heartwood to release MITC, but the level of MITC necessary to protect the wood remains to be tested.

Table I-12. Residual MITC content at selected heights above or below the treatment site in Douglas-fir pole sections treated with 75 g of Basamid alone or in combination with pH 10 or 12 buffer as measured by gas chromatographic analysis of wood extracts.

Treatment	Dosage (g)	Total MITC (ug/oven dry g of wood)[1]							
		+0.9m		+0.3 m		-0.3 m		-0.9m	
		outer	inner	outer	inner	inner	outer	inner	outer
Basamid (dry)	75	0.2	0.0	2.1	2.5	7.0	2.3	0.0	0.0
Basamid (pH 10)	75	0.0	0.0	5.1	4.2	6.4	1.7	0.0	0.0
Basamid (pH 12)	75	0.0	0.2	4.6	4.9	14.0	4.7	0.1	0.0

1. Outer zone represents 0 to 2.5 outer segment, while inner represents 12.5 to 15.0 cm from the wood surface.

4. Effect of selected additives on the decomposition of Basamid in Douglas-fir pole sections: As noted above, Basamid exhibits some promise as a wood fumigant, but its slow decomposition rate limits effectiveness. Two years ago we reported on the installation of a field test to evaluate the effect of various additives on the rate of Basamid decomposition as measured by MITC production. Seventy five pole sections (25 to 30 cm in diameter by 1.5 m in length) were treated with one of the following chemicals:

1. Control (no chemical)
2. Basamid
3. Basamid plus 1.0 % copper sulfate
4. Basamid plus 10 % glucose
5. Basamid plus 10 % lignin
6. Basamid plus 5 % boric acid
7. Basamid plus 50 ml acetone
8. Basamid plus 50 ml methanol
9. Basamid plus 50 ml ethanol
10. Basamid plus 50 ml water
11. Metham sodium

The treatments were equally distributed in 3 holes drilled around the center of the pole section. One set of poles received dry chemical, while the other set received dry chemical plus 7.5 g of powdered pH 12 buffer.

Chemical levels in the poles were evaluated 6 and 12 months after treatment by removing increment cores from above and below the treatment site. Cores were removed from three equidistant locations around each pole section 15 cm above and below the treatment site 6 months after treatment. An additional set of cores was removed 45 cm above and below the treatment site in the 12 month sample. The outer and inner half of each core was extracted in 5 ml of ethyl acetate and the extracts were analyzed for MITC content by gas chromatography.

MITC was detected in all pole samples treated with Basamid after 6 months and the levels continue to rise in these poles, while levels in the metham sodium treated poles have declined (Table I-13). As expected, MITC levels were generally highest in the inner zone near the site of application, but chemical had diffused 45 cm from the application site. Basamid alone resulted in low concentration of MITC at all locations sampled, while the addition of Basamid with water appeared to inhibit MITC release. The other additives produced variable effects on MITC release. The 1 % copper sulfate, copper sulfate plus pH 12 buffer, lignin plus pH 12 buffer, and glucose plus pH 12 buffer all markedly improved MITC production. This effect was most noticeable with the copper sulfate plus buffer treatment, where chemical levels approached those found in similar tests with MITC-Fume. Interestingly, the presence of pH 12 buffer had little effect on MITC production. The remaining chemicals appeared to provide little enhancement to the decomposition of Basamid into MITC, although they may have enhanced the production of other decomposition products.

The results suggest that Basamid decomposition can be significantly enhanced to provide both rapid initial decomposition while providing a longer term, slow release control. These field trials will be sampled shortly to

further evaluate decomposition and companion laboratory studies to better understand the nature of Basamid decomposition in wood will continue.

Table I-13. Effect of selected additives on the decomposition of Basamid to MITC in Douglas-fir pole sections 6 or 12 months after application as measured by chromatographic analysis of wood samples extracted in ethyl acetate.

	MITC CONTENT (ug/oven dry gram of wood)								
	+45 cm		+15 cm		-15 cm		-45 cm		
Treatment	outer	inner	outer	inner	outer	inner	outer	inner	Avg.
Vapam	9.6	79.1	29.9	80.4	19.8	54.5	12.2	34.5	40.0
Basamid plus:									
$CuSO_4$	20.8	17.8	11.2	45.7	13.5	48.6	0.0	3.9	20.2
$CuSO_4$ plus buffer	8.2	76.3	22.0	120.8	21.4	203.1	6.7	64.3	65.4
Glucose (10%)	0.5	0.2	1.7	17.1	4.8	32.8	2.6	3.7	7.9
Glucose plus buffer	1.8	20.0	6.8	76.9	81.7	14.2	33.1	21.6	32.0
Lignin (10%)	1.4	2.8	2.9	24.9	4.8	93.1	2.1	14.0	18.3
Lignin plus buffer	3.2	17.4	7.0	63.6	16.1	79.6	5.5	3.0	24.4
Boron (5%)	0.4	11.3	6.6	30.8	15.0	49.6	0.1	5.2	14.9
Boron plus buffer	0.0	11.8	7.7	24.2	17.2	33.5	1.0	5.6	12.6
Ethanol	0.0	2.1	0.4	15.3	0.2	7.3	0.0	0.0	3.2
Methanol	0.0	0.1	0.0	3.7	0.2	9.5	0.3	0.6	1.8
Acetone	4.3	18.3	9.3	17.0	15.2	26.1	15.6	12.9	14.8
Alone	5.2	13.7	9.7	10.8	5.9	26.5	1.1	5.6	9.8
Water	0.0	1.2	0.0	2.3	0.4	8.3	0.0	0.0	1.5
pH 12 buffer	0.0	5.7	0.2	13.5	11.0	44.8	0.1	10.8	10.8

5. Ability of fused borate rods to move through Douglas-fir heartwood: Last year, we established a second trial to evaluate the ability of fused borate rods to diffuse through Douglas-fir heartwood. In this trial, 50 Douglas-fir pole sections (1.05 m long by 25 to 30 cm in diameter) were surface dried and dipped for 5 minutes in a 2.0 % solution of CCA-Type C. The dipped poles were stored under cover for 24 hours to complete any fixation reactions, then air-dried. A 1.9 cm diameter hole was drilled through each pole section 40 cm from the top and a galvanized bolt with a slot cut perpendicular to the threads was inserted into the hole. A 1.9 cm diameter by 20 cm long hole was then drilled at a 90 degree angle in the poles 25 cm below the pole top.

The poles were treated with 40 or 80 g of fused borate rod (1 or 2 rods per hole) and the hole was plugged with a tight fitting wood dowel. The pole sections were capped with plywood to limit end-grain wetting and exposed on a rack above ground in either Corvallis, OR or Hilo, Hawaii.

Increment cores were removed from 15 cm above, immediately adjacent to and 15 cm below the treatment hole in the poles exposed at the Corvallis site 6 months after installation. These cores were stained with the salicylic acid/curcumin indicator for boron. These preliminary results indicate that boron was detectable immediately adjacent to and 15 cm below the treatment hole, but had not moved upward. These results provide a preliminary guide to boron movement in the poles and will be followed up by a more extensive sampling in the next month. At that time, increment cores will be removed from above and below the treatment site. These cores will be split lengthwise and half of the core will be stained with the boron indicator. The remainder of the core will be cultured for the presence of decay fungi. Culturing should be particularly useful at the Hilo site where conditions are more conducive to rapid decay.

D. EVALUATE FUNDAMENTAL PROPERTIES OF WOOD FUMIGANTS

1. Effect of wood voids on movement of fumigant through Douglas-fir heartwood: Fumigant application must frequently be made to poles which contain small voids as a result of internal decay. There is considerable debate as the to efficacy of treating voids. While fumigant treatment will arrest internal decay, voids are often connected to deep checks. Fumigant application directly into the void can lead to substantial loss of chemical through the adjacent check; however, most inspection procedures suggest drilling into solid wood above and below a void. This procedure limits the risk that the chemical will be applied directly to the void, but it has been suggested that the void will still limit fumigant movement into the wood. This problem was explored by cutting 12 pentachlorophenol treated Douglas-fir poles in half and drilling a 5 cm diameter

by 15 cm long hole into each cut end of the pole. The poles were reassembled and the edge between the two cut ends was sealed using an elastomeric paint to retard fumigant movement from the void. The poles were then treated with 80 or 160 ml of metham sodium or chloropicrin applied to holes drilled above the void. Each treatment was applied to 3 poles. A similar number of poles without voids were treated and all of the poles were exposed outdoors at the Forest Research Laboratory.

Closed tube bioassays of cores removed 2 years after treatment revealed that chloropicrin was well distributed around poles with and without voids, while no detectable inhibition was noted with metham sodium treated poles.

The poles were more extensively sampled 3 and 4 years after treatment by removing increment cores from 3 equidistant sites around the pole 0.3 and 0.9 m above and below the void. The outer and inner 2.5 cm segment of each core was placed in ethyl acetate for metham sodium treated poles or hexane for chloropicrin treated wood. The cores were extracted for a minimum of 48 hours, then the extract was analyzed for MITC or chloropicrin content using a Varian 3700 gas chromatograph.

The presence of a void appears to have little influence on distribution of either chloropicrin or MITC in the poles (Table I-14). Fumigant levels in both void and sound poles appear to be highest 0.3 m above or below the void and in the inner zone, but there was no consistent effect of the presence of a void. In general, chloropicrin levels for both void and non-void poles were higher than those found with metham sodium treatments. This difference most likely reflects the higher level of active ingredient applied. Chloropicrin contains 96 % active ingredient while metham sodium contains 32.1 % active ingredient which decomposes

Table 1-14. Residual MITC or chloropicrin concentrations at various sites above or below voids in Douglas-fir poles 3 or 4 years after treatment with selected dosages of metham sodium or chloropicrin.

			Fumigant content (ug MITC or chloropicrin/g wood)[1]															
			-0.9 m				-0.3 m				+0.3 m				+0.9 m			
			Outer		Inner		Outer		Inner		Outer		Inner		Outer		Inner	
Chemical Treatment	Dosage (g)	Void (+/-)	3 yr	4 yr	3 yr	4 yr	3 yr	4 yr	3 yr	4 yr	3 yr	4 yr	3 yr	4 yr	3 yr	4 yr	3 yr	4 yr
Metham sodium	80	(+)	3.7	16.7	3.0	14.8	9.7	148.7	15.9	121.8	12.4	82.3	11.0	260.0	4.2	17.5	3.4	23.3
		(-)	-	0	2.5	14.0	8.1	8.1	57.7	147.3	9.4	46.2	15.1	136.0	-	0	3.9	13.5
	160	(+)	4.2	0	10.5	21.5	13.1	62.5	32.4	277.5	8.9	129.5	20.0	724.5	-	22.0	5.3	77.0
		(-)	2.1	21.5	4.5	28.0	15.4	327.0	30.3	376.5	20.4	206.3	28.1	908.7	3.4	2.5	3.9	14.8
Chloropicrin	80	(+)	-	8.1	-	114.4	-	205.0	-	442.1	-	93.3	-	339.0	-	4.3	-	26.3
		(-)	-	14.1	-	55.0	-	150.7	-	507.3	-	253.1	-	607.6	-	14.3	-	107.3
	160	(+)	-	27.0	-	223.8	-	357.8	-	821.8	-	236.3	-	620.9	-	21.7	-	335.5
		(-)	-	11.7	-	215.4	-	166.9	-	585.2	-	145.6	-	488.0	-	28.1	-	232.8

[1] As determined by gas chromatographic analyses of ethyl acetate or hexane extracts. Values represent averages of 9 samples per location.

at a 40 % efficiency to MITC. In addition, previous studies suggest that chloropicrin is more strongly bound to the wood.

The absence of a void effect suggests that the void, while important as a potential reservoir of liquid fumigant in the event a treatment hole intersects this zone, has little influence on diffusion of gaseous chemical. This finding reflects the relatively slow exchange rate of air in the void. While fumigant is rapidly lost from the wood surface, the void is relatively sheltered from air-exchange. The void will initially draw chemical from the wood above the void, but once the air is saturated, the zone below the void will begin to sorb chemical from the air. Eventually, both sides of the void will equilibrate, as shown by the four year data on the test poles.

The results indicate that the presence of small voids should not decrease the effectiveness of fumigant treatment provided the chemical is delivered into sound wood around the void.

2. Steady state diffusion of chloropicrin through Douglas-fir under controlled temperature and moisture conditions: Chloropicrin remains among the most effective wood fumigants, yet relatively little is known about its movement through the wood or the effect of various wood parameters on movement. Previously, we have reported on the sorption/desorption of chloropicrin and noted the presence of weak wood/chloropicrin bonds; however, there is no data on diffusion of this chemical through wood. This data would be especially useful for applying the recently developed fumigant movement model to the diffusion of chloropicrin through Douglas-fir poles.

Douglas-fir heartwood discs (54 mm in diameter) were prepared from air-dry, defect free lumber. Samples were cut so that the wide face of the disc was

oriented with the transverse, tangential or radial face exposed. Tangential and radial samples were 2.2 mm thick, while transversely oriented samples were 20 mm thick. The edges of each wafer were coated with several layers of epoxy to retard fumigant loss from these zones. The wafers were either oven-dried (103 C for 24 hrs.) or conditioned to 30 % moisture content prior to testing.

Chloropicrin diffusion was evaluated in a cup apparatus which exposed the wafer to concentrated chloropicrin on one side and air on the other side (Figure I-4). A magnetic stir bar in the lower air cell was used to evenly disperse diffusing chemical in the cell. The diffusion cup was assembled in a continuous flow system which permitted routine air-sampling to assess chloropicrin concentrations on either side of the wafer (Figure I-5).

The apparatus was employed to evaluate the effects of low (20 C) and high (35 C) temperature and wood moisture content (~0 % and ~30 %) at low and high chemical concentrations. Two low concentrations (10 and 18 ug chloropicrin/ml air) and two high concentrations (40 and 100 ug chloropicrin/ml air) were evaluated for each wafer orientation. Diffusion coefficients were calculated by measuring the steady state concentration of chloropicrin in the air flows on both sides of the wafer. Chloropicrin concentrations were varied by placing an excess of chloropicrin in tubes which produced varying surface areas of liquid. The high vapor pressure of this chemical produced a steady evolution of gas which was dependent on the surface area exposed. Chloropicrin concentrations were determined by withdrawing air samples from the tube exiting the diffusion cup. The sample (0.5 ml air) was withdrawn in a syringe containing 0.5 ml of hexane so that the air bubbled through the hexane. The syringe needle was plugged and the barrel was rotated several times to trap air-borne chloropicrin in the hexane. The hexane was injected into 1.0 ml of hexane. This sample was then

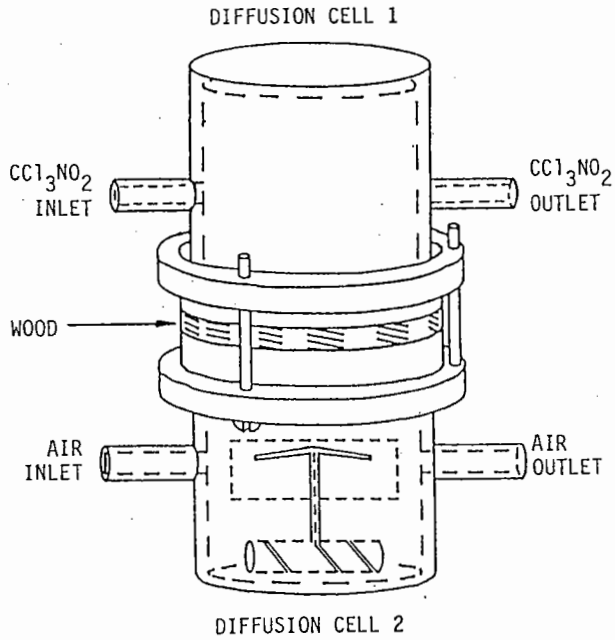


Figure I-4. Stainless-steel cups used to evaluate steady state diffusion of chloropicrin through Douglas-fir heartwood.

further diluted by placing 0.75 ml into 9.25 ml of hexane. Samples were further diluted as required. The resulting extract was analyzed for chloropicrin using a Varian 3700 Gas Chromatograph equipped with an electron capture detector specific for halogen compounds.

This information, in combination with the flow rate of air on the low-concentration side, was used to calculate the diffusion coefficient using Fick's Law: $J= -D\ (dC/dx)$

$D= -J/(dC/dx)$

$D=-(1/A)(dq/dt)(dC/dx)$

where: J= flux, $g/(cm^2)(s)$

A= area perpendicular to the direction of flow (cm^2)

dq/dt= rate of transfer, g/s

dC/dx= concentration gradient, (g/cc)/cm

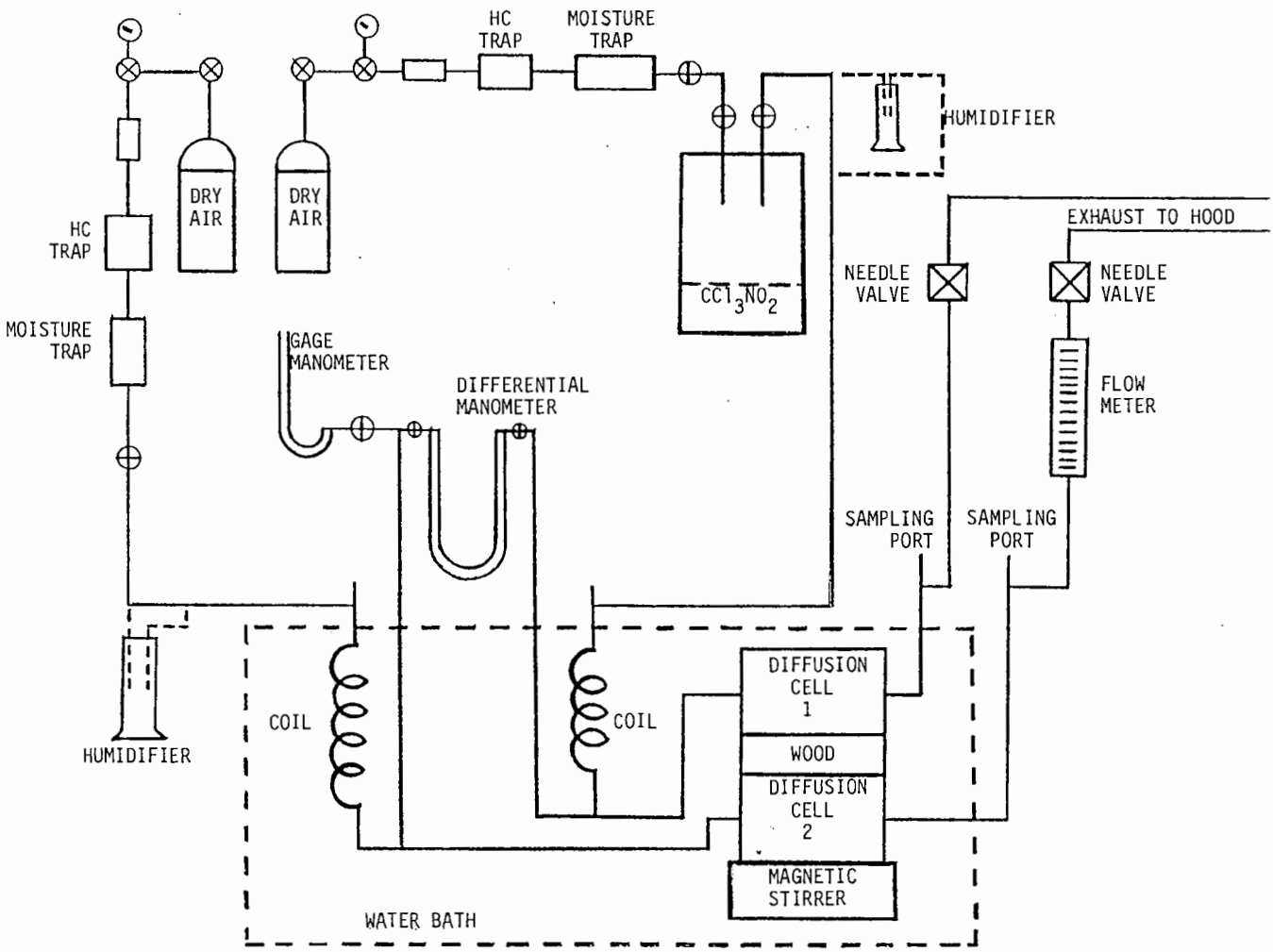


Figure I-5. Apparatus employed to delivery chloropicrin to the diffusion cups containing transversely, radially, or tangentially oriented Douglas-fir wafers.

Diffusion was, as expected, most rapid in the longitudinal direction. Diffusion coefficients were approximately 1000 times greater in the longitudinal direction (Table I-15). In previous diffusion studies using MITC, diffusion coefficients were approximately 1000 times higher in all directions. This difference may reflect the smaller number of MITC sorption sites in the wood. Relative differences between longitudinal, radial and tangential movement, however, were consistent with those found in the present study. Radial and tangential diffusion coefficients for chloropicrin differed little at a given moisture content, but did increase by 30 to 50 % in the tangential and radial directions at fiber saturation (Figure I-6). Previous studies suggest that chloropicrin will interact with hydroxyl groups in the wood. At higher moisture contents, water molecules will compete for these sites, decreasing chloropicrin/wood interactions and increasing the diffusion rate. At the same time, wood swelling at higher moisture contents may physically reduce access to the wood cell wall, thereby decreasing interactions and speeding diffusion. The absence of a moisture effect in the longitudinal direction probably reflects the more substantial impact of flow through tracheids which masks any moisture effect. As moisture levels rise, void volume would decrease, and the effects of moisture on longitudinal diffusion would become more apparent.

Table I-15. Effect of wood moisture content and wood orientation on steady state diffusion of chloropicrin through Douglas-fir heartwood.

ORIENTATION	MOISTURE CONTENT	DIFFUSION COEFFICIENT	
TANGENTIAL	OVEN-DRY	5.9792E-06	4.3869E-06
RADIAL	" "	4.1504E-06	6.1560E-06
TRANSVERSE	" "	7.4052E-03	7.3524E-03
TANGENTIAL	FIBER SATURATION	9.3092E-06	9.5518E-06
RADIAL	" "	1.0048E-05	9.5992E-06
TRANSVERSE	" "	8.3517E-03	8.2658E-03

Diffusion coefficients did not differ at high or low chloropicrin concentrations, indicating that the fumigant followed Fick's law and validating the use of this approach to studying fumigant movement (Figure I-7). Diffusion coefficients also appeared to be unaffected by temperature (Figure I-8), at both high and low fumigant concentrations.

Further studies are planned to determine adsorption/desorption ratios of this chemical. Eventually, the results of these studies will be employed in the fumigant model currently being developed.

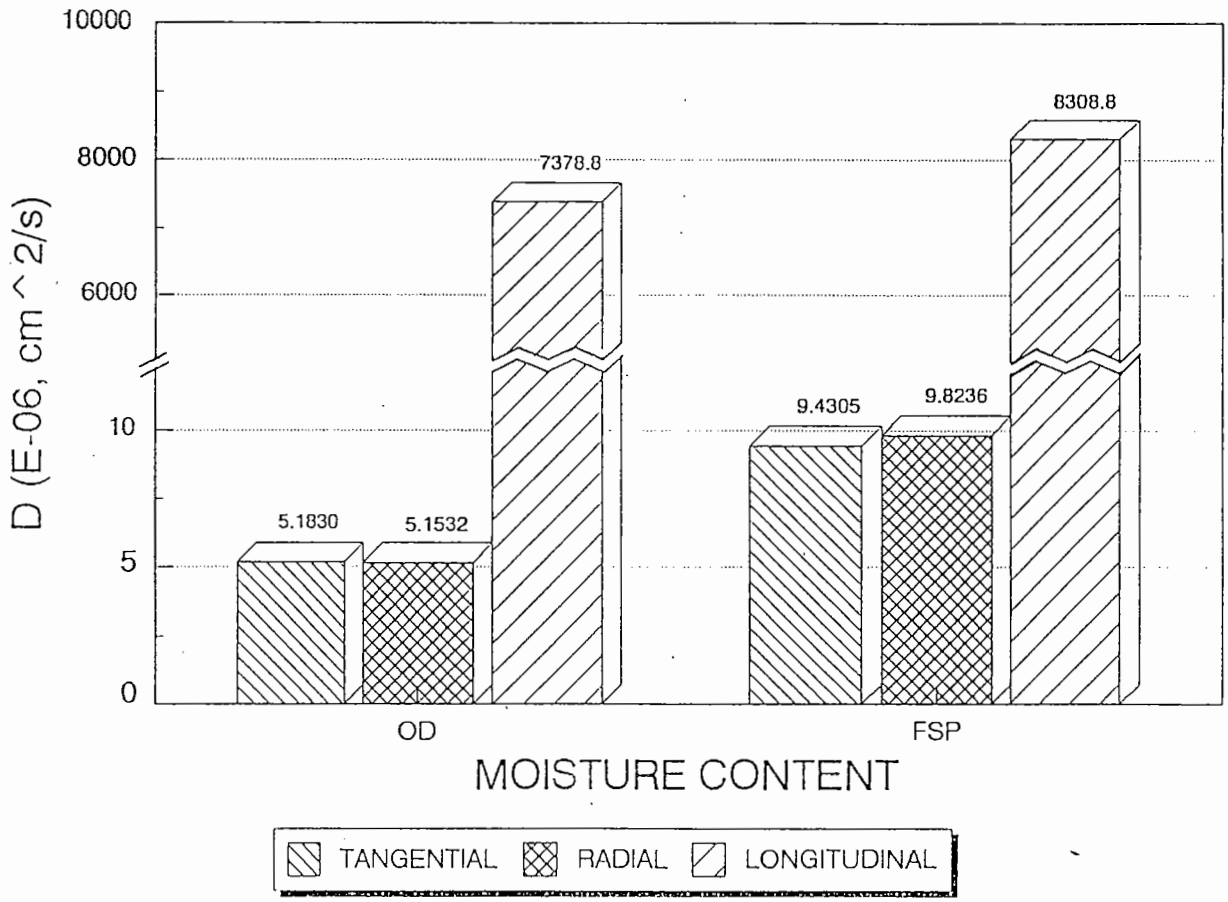


Figure I-6. Effect of direction of flow on diffusion of chloropicrin through oven dry and wet (30 % MC) Douglas-fir heartwood.

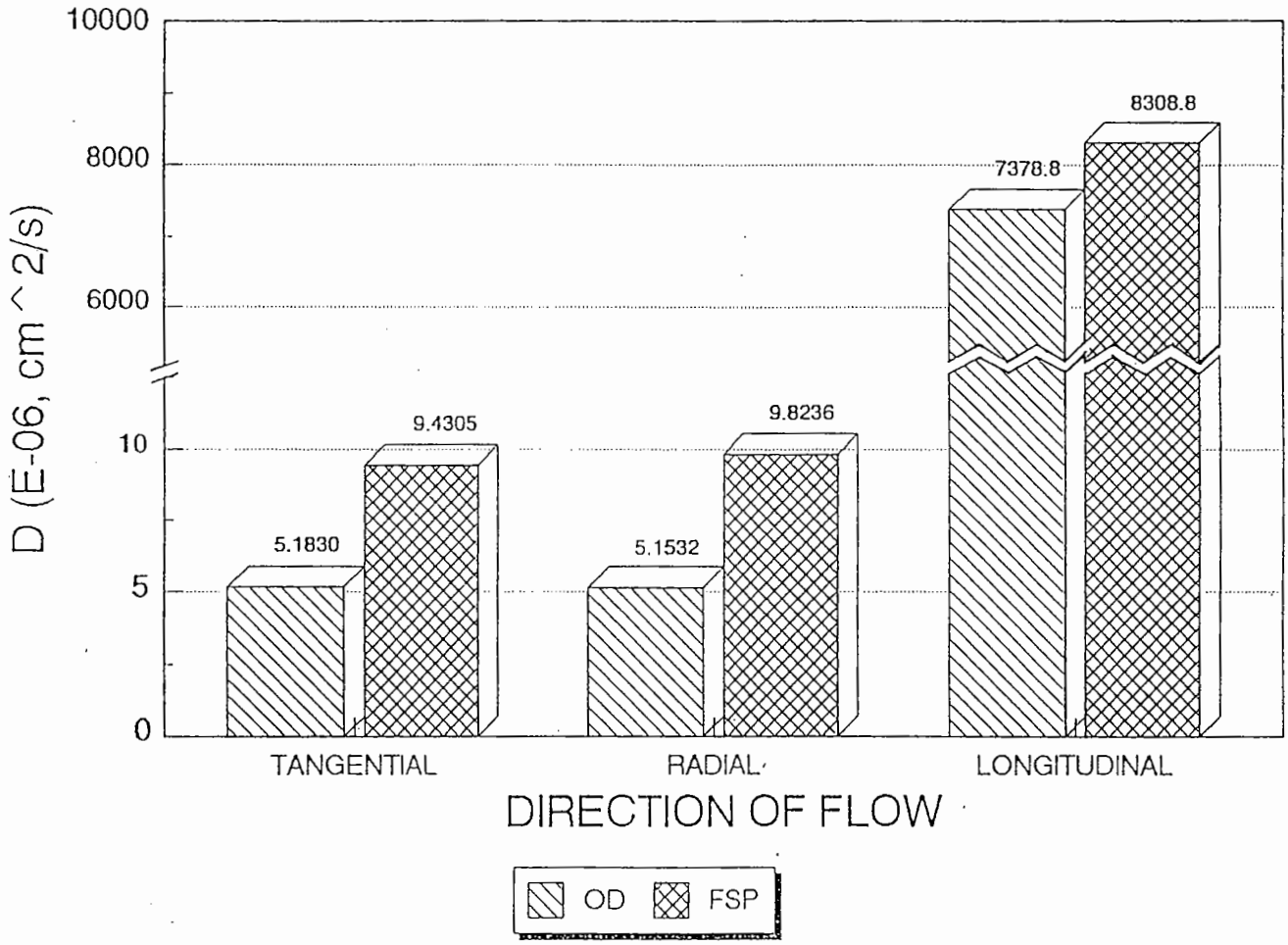


Figure I-7. Effect of wood moisture content on diffusion of radial, tangential and longitudinal diffusion of chloropicrin through Douglas-fir heartwood.

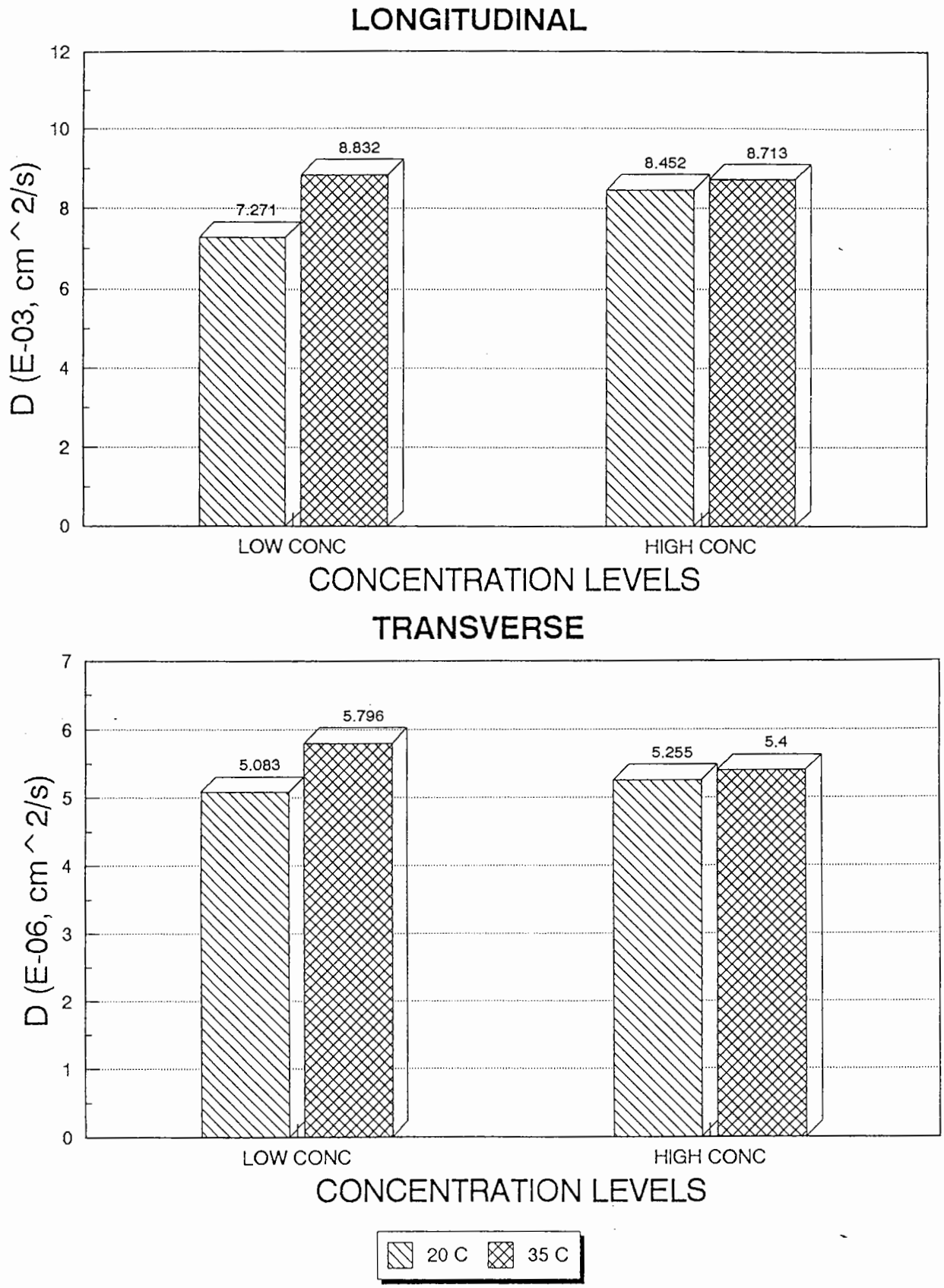


Figure I-8. Effect of temperature and airborne chloropicrin concentration on a.) longitudinal and b.) radial/tangential chloropicrin diffusion through Douglas-fir heartwood.

3. Development of a three-dimensional model which simulates binding and diffusion of MITC through Douglas-fir poles: The development of fumigant treatments for controlling wood decay fungi has largely been accomplished through practical testing with little thought to the more fundamental relationships between the wood and the chemical. As we develop more fundamental information on wood/fumigant interactions, it becomes possible to develop models which predict fumigant movement under a variety of conditions. Although this can be viewed as an esoteric computer game, the results of such models can be used to improve fumigant dosages or to tailor application patterns to maximize chemical delivery. Last year ('90 Annual Report, pg. 37-42), we reported on the development of an improved fumigant model which permitted evaluation of movement in three directions. Work to improve the accuracy of this model has continued.

The model uses Turbo Pascal 5.5 and accounts for the sublimation and subsequent diffusion of MITC within a 180 degree section of timber. The program views the pole as a collection of horizontal layers and each layer is viewed as a collection of sectors (Figure I-9). Fumigant diffusion among all sectors is calculated over an interval of time and MITC concentrations are redefined in readiness for the next time interval.

The change in concentration between any two adjacent sections of the pole over some time period can be found using the simple steady-state formula:

$$M = (k(c_1-c_2)At)/L$$

Where M= ug of MITC transferred

k= the diffusion coefficient in $cm^2/min.$

(c_1-c_2)= MITC concentration gradient in ug/cm^3

L= the conducting length between sectors in cm.

A= common surface area in cm^2

t= the time interval in minutes

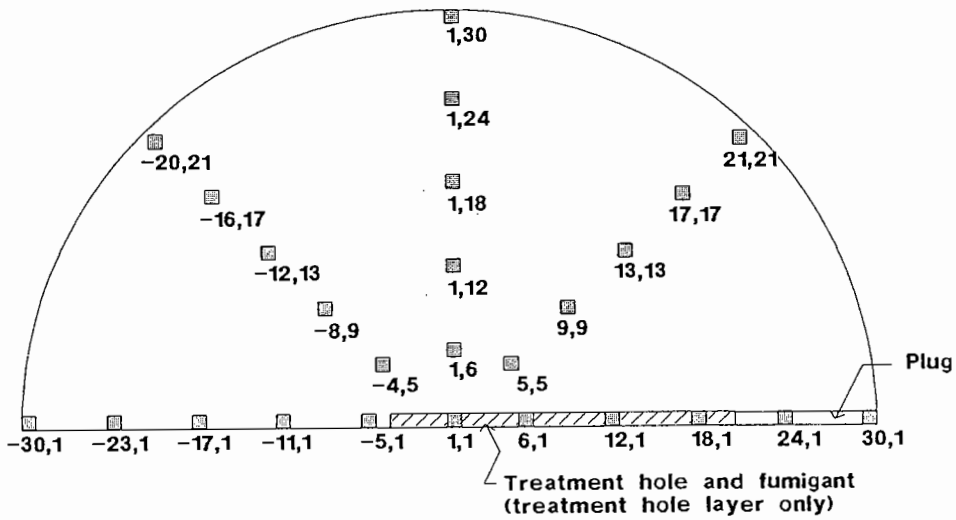
Diffusion coefficients were implicitly corrected for flow direction (radial, tangential or longitudinal), the presence of heartwood/sapwood, and wood moisture content. Pole length, diameter, number of days simulated, and characteristics such as moisture content, wood density, chemical dosage, and placement and size of the treatment hole are defined by the user. Output consists of the amount of MITC remaining in the treatment hole, the amount lost from the top, bottom, or sides of the pole, and the concentration of chemical present in the air, water, or bound to the wood at a given location. While the time requirements for running the program are long using an IBM-AT, further studies of the model will use more sophisticated computing facilities.

Last year, we reported on the loss of chemical from the treatment hole and on vapor concentrations after 50 days 1 cm from the base. These results were very preliminary and some errors were found in the original program. This past year, we have concentrated on streamlining the program and evaluating the various parameters.

Most recently, we have employed the program to model the movement of 30 g of MITC from a single, horizontal treatment hole drilled in a pole section 32 cm in length (Figure I-9). The treatment hole was located 1 cm from the bottom of the section and chemical was permitted to diffuse out the pole top and bottom. The configuration was employed to evaluate MITC movement and distribution over a 7 day period when the pole was at 14, 22, 40, or 80 % moisture content. Each test run of 7 days took approximately 5 hrs to complete, but reductions in time would be easily obtained by using faster processors.

Fumigant movement was generally greater at 22 and 40 percent wood moisture content than at 14 or 80 percent moisture (Table I-16, 17, 18). After 7 days, fumigant movement was detected in all pole layers and sectors at all four moisture levels evaluated with one exception. At 14 percent moisture, MITC did not reach the outer 3 cm of the pole in the pole quadrants opposite the treatment hole (sectors [-23,1], [-29,1], [-16,17], [-20,21], [1,24] and [1,30]. This degree of movement appears to be consistent with laboratory studies on MITC movement in 10 cm long blocks where MITC applied at the center of the block was detected near the end 7 days after fumigant application at levels which are lethal to an established decay fungus. We plan further laboratory studies to confirm both the degree and level of chemical movement predicted by the model.

The higher degree of movement at 22 and 40 percent moisture content may reflect reduced interactions between the wood and MITC, as sites which normally interact with MITC bind to water. At 80% moisture, free water present in tracheid lumens may have restricted fumigant movement longitudinally, and, to a lesser extent, transversely (Figure I-11). The decreased degree of sorption by wetter wood also appeared to affect the rate of chemical loss from the treatment hole. Wood at 80 % MC retained more chemical in the treatment hole than similarly treated wood at 14, 22 or 40 % MC (Figure I-10). Slower loss of chemical from the treatment site may not be disadvantageous at higher MC's because the fungus would be more active at these moisture levels and would, therefore, be more susceptible to chemical treatment. Fungi are less active at lower moisture levels (14 and 22 %) and are therefore more difficult to eliminate from the wood. Thus, the higher sorption of MITC to dry wood has important implications for long-term fumigant protection.



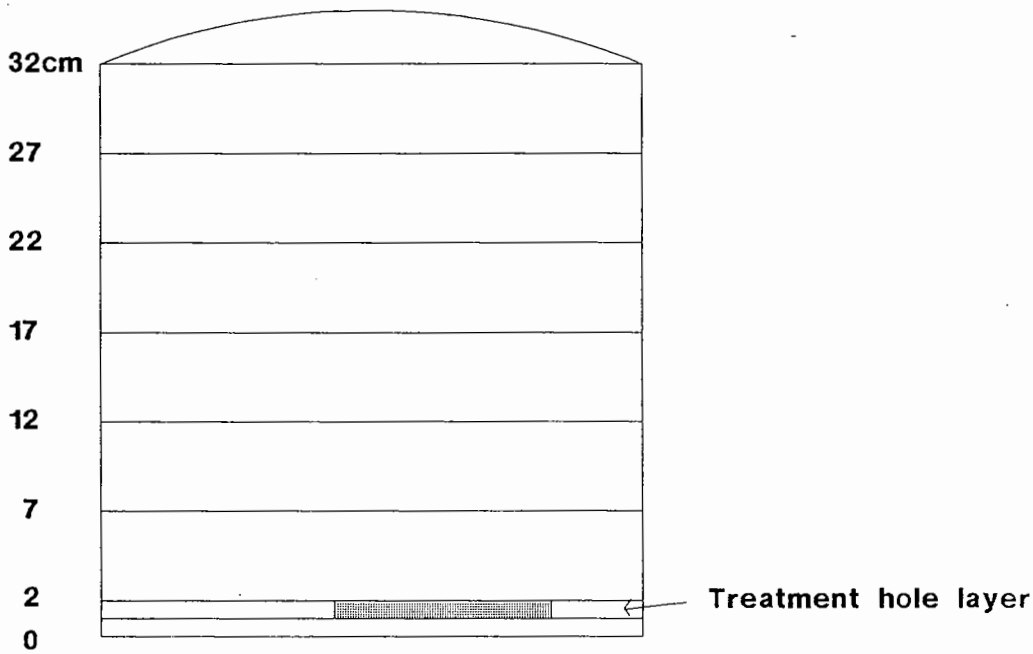


Figure I-9 Diagram showing a.) cross section of a pole layer and the sectors selected for data output, and b.) the vertical division of the pole into layers.

Although the length time for which the model was run was short, there were already substantial differences in the amounts of chemical exiting the wood. Interestingly, top, bottom and side loss are lowest at the two moisture extremes (Figure I-11). These results highlight the potential effects of moisture on MITC/wood interactions and will be explored more fully in the coming year.

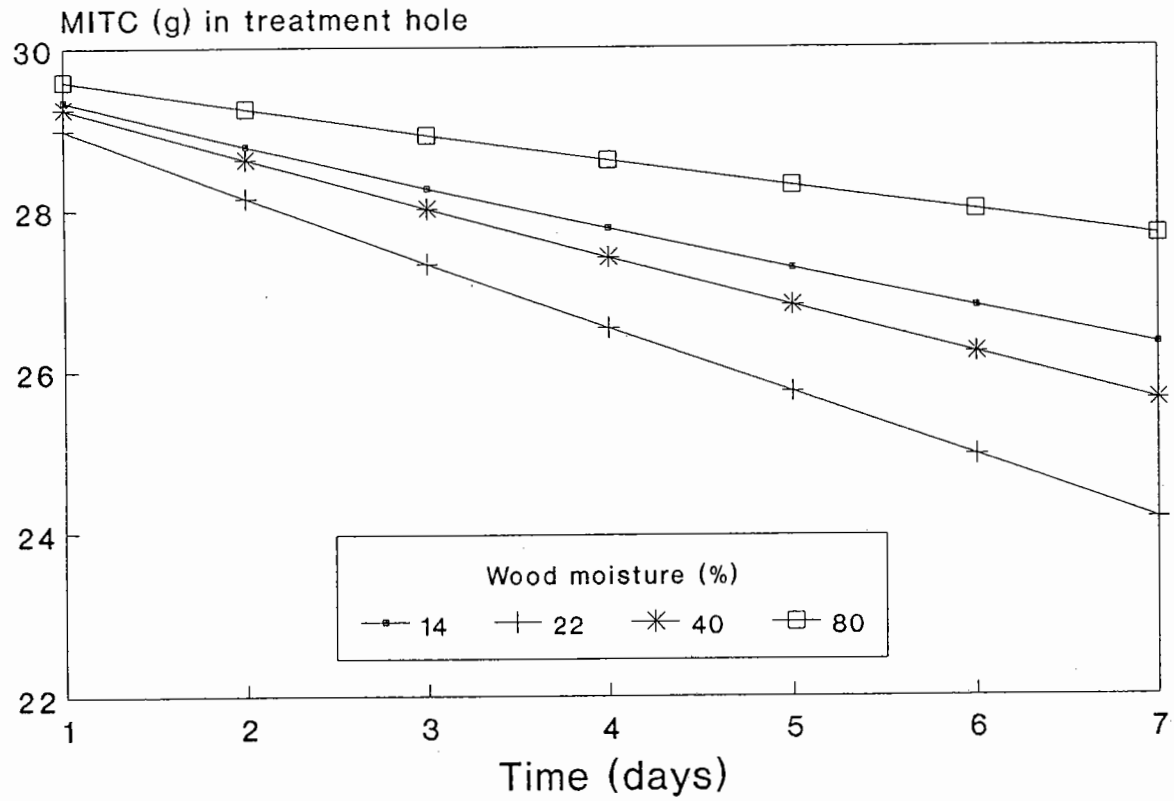
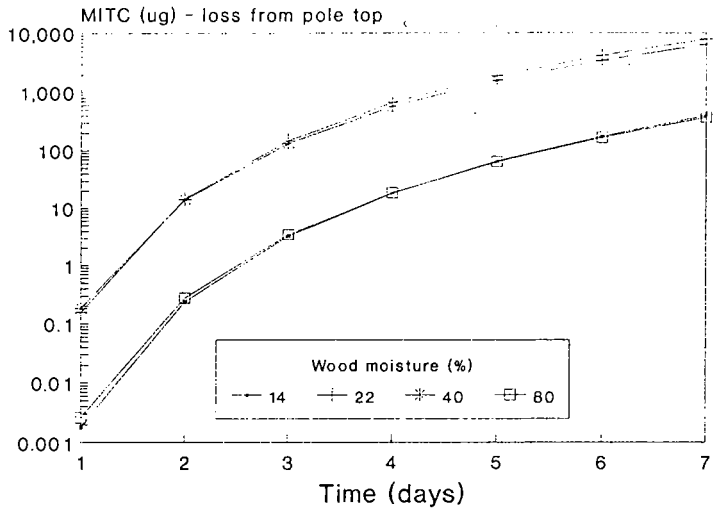
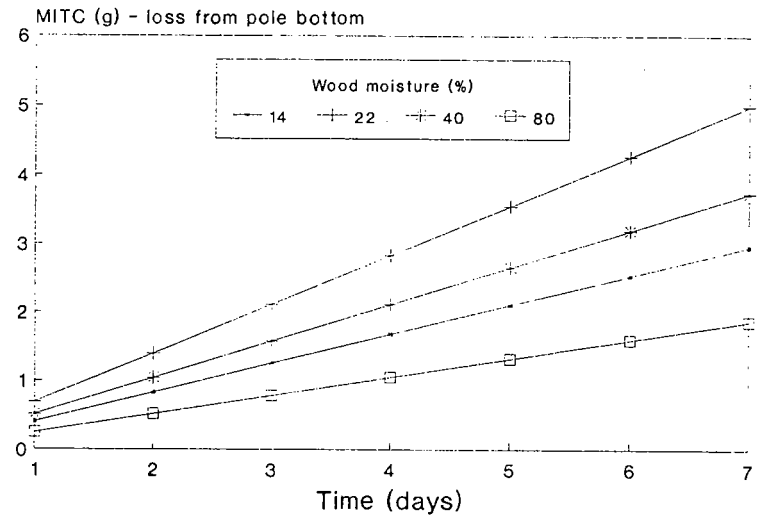


Figure I-10 Rate of MITC loss from the treatment hole in a 32 cm long Douglas-fir pole section at 14, 22, 40, or 80 % MC over a 7 day period following application of 30 g of active ingredient, as calculated by a three dimensional model.





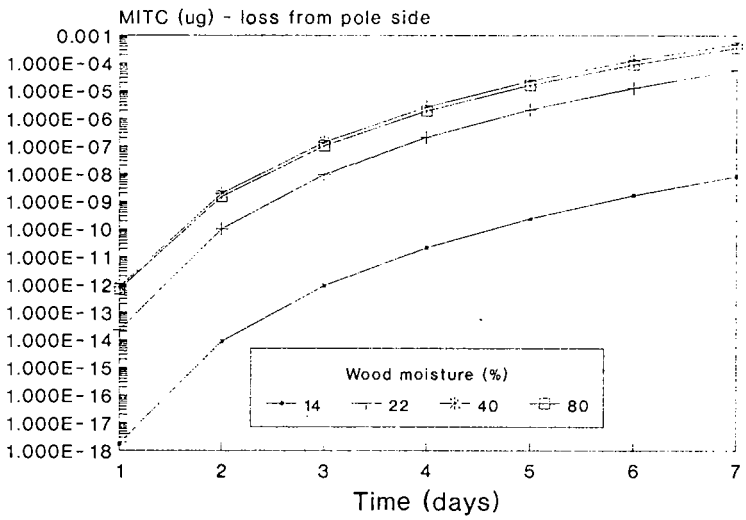


Figure I-11. Rate of MITC loss from the top, bottom, and side of a 32 cm long Douglas-fir pole section at 14, 22, 40, or 80% MC over a 7 day period following application of 30 g of MITC, as calculated by a three-dimensional model.

Table I-16. Concentration of MITC 0 to 5 cm above the treatment hole in a Douglas-fir pole at 4 moisture contents, as calculated by a three-dimensional model. Sector locations can be found in Figure I-9.

		MITC, µg/g wood in sector						
MC%	Time (Days)	1,1	-5,1	-4,5	1,6	5,5	18,1	24,1
14	1	14700	2.2	7.91E-08	2.03E-07	4.42E-06	14700	8.31E-05
	2	21300	10.5	3.08E-06	7.93E-06	8.46E-05	21500	0.002
	3	24400	23.4	2.26E-05	5.84E-05	4.22E-04	24700	0.008
	4	26100	39.1	8.66E-05	2.25E-04	0.001	26400	0.022
	5	27000	56.3	2.36E-04	6.15E-04	0.003	27500	0.048
	6	27700	74	5.19E-04	0.001	0.005	28100	0.087
	7	28100	92	9.94E-04	0.003	0.009	28600	0.144
22	1	17100	35.7	4.18E-04	2.76E-04	5.95E-03	17300	0.021
	2	20700	123	0.011	0.008	0.086	21000	0.027
	3	21800	216	0.061	0.044	0.340	22100	1.01
	4	22300	301	0.180	0.138	0.832	22700	2.29
	5	22700	376	0.393	0.314	1.60	23100	4.11
	6	22900	441	0.719	0.595	2.65	23300	6.39
	7	23100	498	1.17	0.997	3.99	23500	9.09
40	1	11800	42.5	0.002	9.53E-04	0.020	12000	0.046
	2	14200	137	0.043	0.023	0.259	14400	0.053
	3	15000	230	0.210	0.122	0.961	15200	1.80
	4	15300	309	0.574	0.354	2.23	15500	3.84
	5	15500	375	1.17	0.768	4.09	15800	6.53
	6	15700	430	2.01	1.39	6.51	15900	9.72
	7	15800	476	3.10	2.24	9.44	16000	13.30
80	1	688	26.8	0.001	5.82E-04	0.014	6940	0.028
	2	954	104	0.035	0.017	0.212	9670	0.391
	3	1070	196	0.192	0.101	0.892	1080	1.51
	4	11200	285	0.576	0.325	2.27	11400	3.54
	5	11600	363	1.25	0.752	4.41	11700	6.40
	6	11800	429	2.24	1.43	7.30	12000	9.95
	7	11900	486	3.53	2.37	10.90	12100	14.00

Table I-17. Concentration of MITC 15 to 20 cm above the treatment hole in a Douglas-fir pole at 4 moisture contents, as calculated by a three-dimensional model. Sector locations can be found in Figure I-9.

		MITC, µg/g wood in sector						
MC%	Time (Days)	1,1	-5,1	-4,5	1,6	5,5	18,1	24,1
14	1	3.4	6.33E-04	1.91E-11	4.91E-11	1.16E-09	3.4	2.19E-08
	2	41.1	0.032	1.07E-08	2.75E-08	2.93E-07	41.9	5.36E-06
	3	151	0.261	3.10E-07	8.04E-07	5.63E-06	155	1.01E-04
	4	345	1.03	2.95E-06	7.67E-06	4.07E-05	358	7.07E-04
	5	619	2.76	1.55E-05	4.05E-05	1.75E-04	646	0.003
	6	956	5.88	5.69E-05	1.49E-04	5.45E-04	1010	0.009
	7	1340	10.7	1.63E-04	4.29E-04	0.001	1420	0.022
22	1	31.8	0.097	1.07E-06	7.06E-07	1.62E-05	32.4	5.67E-05
	2	267	3.07	3.47E-04	2.43E-04	0.003	277	0.008
	3	724	16.4	0.006	0.005	0.034	759	0.099
	4	1300	44.9	0.039	0.031	0.176	1370	0.471
	5	1890	88.2	0.144	0.116	0.560	2010	1.39
	6	2460	143	0.377	0.317	1.33	2630	3.08
	7	2990	205	0.798	0.697	2.63	3200	5.69
40	1	25.2	0.148	7.80E-06	3.81E-06	8.02E-05	25.7	1.82E-04
	2	197	3.82	0.002	8.86E-04	0.009	203	0.019
	3	514	18.4	0.025	0.015	0.109	534	0.198
	4	898	47.2	0.138	0.087	0.514	939	0.849
	5	1290	88.1	0.455	0.306	1.52	1350	2.31
	6	1660	137	1.10	0.784	3.42	1740	4.82
	7	2000	190	2.18	1.63	6.41	2100	8.44
80	1	2.22	0.012	6.46E-07	2.86E-07	6.86E-06	2.3	1.40E-05
	2	23.3	0.436	1.89E-04	9.22E-05	0.001	23.9	0.002
	3	77.4	2.72	0.004	0.002	0.017	80.2	0.027
	4	165	8.64	0.026	0.015	0.098	171	0.148
	5	278	19.3	0.104	0.064	0.352	289	0.488
	6	408	34.8	0.296	0.195	0.932	425	1.20
	7	547	54.8	0.676	0.471	2.01	568	2.42

Table I-18. Concentration of MITC 25 to 30 cm above the treatment hole in a Douglas-fir pole at 4 moisture contents, as calculated by a three-dimensional model. Sector locations can be found in Figure I-9.

		MITC, µg/g wood in sector						
MC%	Time (Days)	1,1	-5,1	-4,5	1,6	5,5	18,1	24,1
14	1	0.003	5.00E-07	1.23E-14	3.15E-14	8.04E-13	0.003	1.52E-11
	2	0.161	1.29E-04	4.05E-11	1.05E-10	1.13E-09	0.164	2.08E-08
	3	1.33	0.002	2.91E-09	7.55E-09	5.31E-08	1.37	9.47E-07
	4	5.30	0.017	5.03E-08	1.31E-07	6.91E-07	5.51	1.20E-05
	5	14.30	0.069	4.10E-07	1.07E-06	4.58E-06	14.9	7.74E-05
	6	30.20	0.205	2.11E-06	5.53E-06	2.00E-05	31.9	3.29E-04
	7	54.30	0.486	7.93E-06	2.09E-05	6.59E-05	57.8	0.001
22	1	0.112	3.24E-04	2.99E-09	1.96E-09	4.79E-08	0.114	1.69E-07
	2	4.00	0.048	5.36E-06	3.74E-06	4.06E-05	4.15	1.29E-04
	3	22.6	0.555	2.24E-04	1.65E-04	0.001	23.9	0.003
	4	64.2	2.47	0.002	0.002	0.010	68.3	0.027
	5	128	6.76	0.012	0.010	0.047	137	0.114
	6	208	13.90	0.041	0.034	0.143	224	0.325
	7	297	23.60	0.104	0.091	0.338	320	0.719
40	1	0.001	6.38E-04	3.25E-08	1.58E-08	3.40E-07	0.001	7.71E-07
	2	3.23	0.068	3.04E-05	1.64E-05	1.74E-04	3.34	3.50E-04
	3	17.1	0.677	9.87E-04	5.81E-04	0.004	17.9	0.008
	4	46.6	2.74	0.009	0.006	0.033	49.0	0.053
	5	90.5	7.00	0.041	0.028	0.134	95.2	0.201
	6	144	13.60	0.124	0.089	0.382	152	0.528
	7	203	22.20	0.291	0.221	0.850	213	1.10
80	1	0.003	1.47E-05	7.30E-10	3.22E-10	7.92E-09	0.003	1.62E-08
	2	0.115	0.002	1.00E-06	4.91E-07	5.91E-06	0.118	1.07E-05
	3	0.831	0.031	4.55E-05	2.44E-05	2.02E-04	0.863	3.31E-04
	4	2.99	0.170	5.51E-04	3.2E-04	0.002	3.12	0.003
	5	7.42	0.563	0.003	0.002	0.011	7.75	0.015
	6	14.60	1.38	0.013	0.009	0.040	15.30	0.051
	7	24.80	2.75	0.038	0.027	0.112	25.90	0.132

OBJECTIVE II

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

A. ACCELERATED FIELD TRIALS OF POTENTIAL PENTACHLOROPHENOL REPLACEMENTS FOR PROTECTING WESTERN REDCEDAR

While the heartwood of western redcedar has excellent natural durability, the sapwood of this species has no resistance to decay. Despite this absence of natural durability, many utilities specify butt-treated western redcedar poles. Over many years, the sapwood on the above ground portion of the pole decays, becoming separated from the more durable heartwood. As lineman climb these poles, the sapwood separates from the remainder of the pole, causing the lineman's spurs to cut out. This damage and the associated risk to lineman can be limited by regular spraying of the above ground surface with a preservative. For many years, pentachlorophenol (penta) was the preferred chemical for this treatment, but environmental concerns forced a shift to copper naphthenate. Although this chemical has performed well in other applications, interest continues in identifying even safer chemicals which can be used for this application.

1. Peavy Arboretum Pole Exposures: A series of chemical formulations were applied to western redcedar sapwood stubs in 1981. The condition of these poles has been monitored since that time by removing increment cores for evaluation of residual chemical content via the Aspergillus niger bioassay. In this test, the cores are placed on the surface of an agar media seeded with spores of the test fungus. Any chemical present in the wood diffuses outward into the media and inhibits either growth or sporulation of the fungus. The degree of inhibition is measured and provides a relative guide to the residual chemical in the wood.

Plugs were also removed from the pole sections and were evaluated for residual decay resistance. These poles were last evaluated in 1988 and will be examined this coming year.

2. Evaluation of Small Cedar Blocks: While field trials on full size specimens provides the most applicable data, it is difficult to obtain a sufficient number of weathered western redcedar poles which have not received some form of chemical treatment. This problem surfaced during the second phase of the Peavy Arboretum trials and negated the results. To overcome this problem, poles which had received no chemical treatment were identified by chemical analysis of cores. These pole sections were cut into smaller blocks (15 by 15 by 10 cm in length). All but the exposed sapwood face were covered with an elastomeric paint to retard wetting and minimize leaching. The sapwood face of each block was then dipped in one of the test chemicals (Table II-1). The blocks were dried and exposed on a south facing test fence located in Corvallis, Oregon. The blocks were watered daily during the dry summmer months to stimulate chemical leaching. At selected time intervals, increment cores were removed from the exposed face of each sample and evaluated for residual chemical content using the Aspergillus bioassay. An additional plug was removed from each face for evaluation of decay resistance. This plug was segmented into sections corresponding to 0 to 3, 3 to 6, 6 to 9, and 9 to 12 mm from the wood surface. The decay resistance of each wafer was assayed using a soil block test with Postia placenta as the test fungus. Wood weight loss in comparison with similar, but untreated wafers, was used as the measure of residual protection provided by the chemical treatments.

Aspergillus bioassays indicated that 11 of 31 treatments produced a measurable zone of effect 3 years after treatment (Table II-2). Two of these

treatments, penta and tributyl tin oxide (TBTO) produced substantially greater zones of effect (ZOE) than any of the other chemicals. This higher ZOE may reflect slightly higher water solubility or greater sensitivity of the fungus rather than higher chemical loadings. Previous studies have shown that Aspergillus is very sensitive to low levels of penta. The remaining chemicals which produced measurable ZOE's were the oil borne formulations of copper 8 quinolinolate (copper 8), diiodomethyl paratolyl sulfone, 3 iodo-2-propynyl butylcarbamate, isothiazolone alone or in formulations, and thiocyanamethylthiabenzothiazole (TCMTB). In general, ZOE's were produced to a depth of 12 mm from the surface, indicating that each chemical was capable of penetrating into the wood and exhibited some resistance to leaching. The Aspergillus bioassay provides a relative measure of residual chemical levels, but can not detect chemicals which are strongly bound to the wood.

Soil block tests were performed to evaluate the degree of chemical protection afforded by each treatment. Wood weight losses of wafers removed from untreated control blocks experienced wood weight losses ranging from 29 to 48 % indicating that the fungus was active over the test period. Wood weight losses of the chemically treated blocks varied widely reflecting the variation in degree of protection afforded by each chemical (Table II-3).

The treatments were segregated into groups based upon the degree of protection afforded. The best treatments were those which protected the wood in at lowest two zones from the wood surface, the next category provided protection in at least the outer zone, and the third category included those which provided little or no protection to any zone sampled. In the two year assays, seven chemicals provided excellent protection against fungal decay, while an additional 9 formulations protected the outer zone. Evaluation of samples from these same

wood sections after an additional year of weathering indicated that chemical protection continued to decline in some treatments. Three of the chemicals which provided excellent protection after 2 years declined substantially in the third year of exposure. One percent Amical 48, 4 % Busan 1009 and 3.5 % isothiazolone/6 % Arquad C-50 both provided little or no protection to the sapwood, while 8 % Nuodex 100ss only protected the first zone sampled. Once again, penta, TBTO, isothiazolone and isothiazolone plus Busperse 47 provided excellent protection against fungal attack. The continued performance of TBTO in a high leaching exposure is of interest since this chemical has failed in other similar exposures.

As with the group providing protection to more than one zone, chemicals in the second tier also declined in their protective effects. Of the nine chemicals in the this category after 2 years, five no longer protected the wood following an additional year of testing. Both concentrations of Busan 1009/Busperse and Busan 1030/Busperse 47 as well as the Busan 1030 alone provided no protection to the cedar sapwood after the third year. These chemicals apparently lacked resistance to leaching and do not appear to be appropriate for this application. It was interesting to note that decay resistance of wafers treated with copper 8 quinolinolate actually improved between the second and third years of exposure. This "increased" performance probably reflects slight variations in sampling or variations in chemical distribution in the wood. Several other chemicals continued to provide adequate protection to the outer wood zone including 2 % copper naphthenate and 4 % Busan 1030/Busperse. In addition, 2 % zinc naphthenate (M-550), Arquad C-50, and 0.3 % copper 8 quinolinolate provided little protection in the 2 year sample, but exhibited some degree of protection in the 3 year sampling.

The remaining chemicals all failed to provide any degree of protection to the samples tested. While many of these formulations perform well in other exposures, it is apparent that the severe leaching and UV exposures which characterize the surface of a western redcedar pole sharply limit the number of chemicals which will provide wood protection.

Table II-1. Chemicals tested as potential pentachlorophenol replacements in western redcedar.

Chemical	Source	Carrier	Concentration
Azaconazole	Janssen Pharm.	water	0.15/0.30
ACAR 86013		water	1.0
86013		water	1.0
Copper-8-quinolinolate	Chapman Chem. Co.	oil	0.12 (Cu)
Copper-8-quinolinolate	Nuodex	water	0.3 (Cu)
Copper naphthenate	Tenino Wood Presv.	oil	2.0
CWP 44	Chapman Chem. Co.	water	10.0
Diiodomethyl-paratolyl sulfone	Akzo Chemie	oil	1.0
Dodecyl dimethyl ammonium salt	Nuodex	oil	8.0
		water	8.0
3-iodo 2-propynyl butyl carbamate (IPBC)	Troy	water	2.0
	Beecham (DAP)	oil	0.5
Isothiazolone	Rohm and Haas	oil	1.0
Methylene bisthiocyanate (MBT) plus	Buckman Laboratories	water	4.0
Thiocyanomethylthio Benzothiazole (TCMTB)			2.0
TCMTB	Buckman Laboratories		4.0
Trimethylcocammonium chloride (TMCAC)	Akzo Chemie	water	5.0
Zinc naphthenate (a)	Mooney Chemical	water	4.0
			2.0
Zinc naphthenate (b)	Mooney Chemical	water	4.0
Pentachlorophenol	Chapman Chem. Co.	oil	10.0
Tributyltinoxide		oil	5.0
IPBC/Busperse 47 (B-47)	Troy-Buckman	oil	1.0/5.0
Isothiazolone/B-47	Rohm & Haas/Buckman	oil	1.0/5.0
TMCAC/IPBC	Akzo Chemie/Troy	oil	4.0/2.5
TCMTB/B-47	Buckman	water	4.0/5.0
			2.0/2.5
(MBT/TCMTB)/B-47	Buckman	water	4.0/5.0
			2.0/2.5
Isothiazolone/TMCAC	Rohm & Haas/Akzo Chemie	oil	3.5/6.0

Table II-2. Aspergillus niger zone of effect (ZOE) produced by increment cores removed from western redcedar poles 3 years after treatment with selected biocides.

Chemical	Carrier	Concentration	ZOE	
			0-6	6-12 mm
Azaconazole	water	0.30	0	0
Azaconazole	water	0.15/0.30	0	0
ACAR 86013	water	1.0	0	0
86013	water	1.0	0	0
Copper-8-quinolinolate	oil	0.12 (Cu)	0	0
Copper-8-quinolinolate	water	0.3 (Cu)	1	1
Copper naphthenate	oil	2.0	0	0
CWP 44	water	10.0	0	0
Diiodomethyl-paratolyl sulfone	oil	1.0	3.5	2
Dodecyl dimethyl ammonium salt	oil water	8.0 8.0	0 0	0 0
3-iodo 2-propynyl butyl carbamate (IPBC)	water oil	2.0 0.5	0 3	0 2
Isothiazolone	oil	1.0	4	4
Methylene bisthiocyanate (MBT) plus Thiocyanomethylthio Benzothiazole (TCMTB)	water	4.0 2.0	0 0	0 0
TCMTB		4.0	0	2
Trimethylcocammonium chloride (TMCAC)	water	5.0	0	0
Zinc naphthenate (a)	water	4.0 2.0	1 0	1 0
Zinc naphthenate (b)	water	4.0	0	0
Pentachlorophenol	oil	10.0	11	10
Tributyltinoxide	oil	5.0	23	22
IPBC/Busperse 47 (B-47)	oil	1.0/5.0	0	0
Isothiazolone/B-47	oil	1.0/5.0	4	4
TMCAC/IPBC	oil	4.0/2.5	0	0
TCMTB/B-47	water	4.0/5.0	1	1
		2.0/2.5	0	0
(MBT/TCMTB)/B-47	water	4.0/5.0	0	0
Isothiazolone/TMCAC		0.5/3.0	2	3
CONTROLS	-	-	0	0

Samples were tested from zones 0 to 6 mm and 6-12 mm from the wood surfac Higher zoe represent greater effects on fungal growth.

Table II-3. Decay resistance of western redcedar wafers treated with selected chemicals and exposed for 2 years in Corvallis, OR as measured using a modified soil block test.

Chemical Treatment	Conc. (%)	dispersant	(%) Weight loss of wafer by location from surface (MM)								Performance Rating	
			0-3		3-6		6-9		9-12		2 yr	3 yr
			2 yr	3 yr	2 yr	3 yr	2 yr	3 yr	2 yr	3 yr		
Isothiazolone	1	oil	8	11	5	12	8	13	8	21	A	A
TBTO	5	oil	7	1	7	2	8	2	8	2	A	A
Amical 48	1	oil/acetone	9	20	8	26	11	31	8	25	A	C
Penta	10	oil	10	3	9	2	8	8	10	3	A	A
Isothiazolone + busperse 47	1/5	oil	11	15	8	15	9	19	9	19	A	A
Isothiazolone + Arquad C-50	3.5/6	oil	9	21	9	25	15	26	19	34	A	C
Nuodex 100SS	8	oil	11	17	10	26	21	22	18	23	A	B
Busan 1009	4	water	15	26	17	25	18	28	16	27	A	C
Busan 1009 + Busperse 47	4/5	water	8	28	17	25	27	28	26	22	B	C
Busan 1009 + Busperse 47	2/2.5	water	12	28	17	30	31	43	28	27	B	C
Cu Naph	2 (as metal)	oil	13	12	18	17	29	21	27	23	B	B
Busan 1030 + Busperse 47	4/5	water	15	8	23	29	24	35	25	30	B	B
Busan 1030	4	water	16	24	21	26	31	35	26	28	B	C
Busan 1030 + busperse 47	2/2.5	water	16	23	27	33	40	35	35	29	B	C
Cu-8-10	.12 (as metal)	oil	20	9	17	8	34	22	34	17	B	A
Arquad C-50	5	water	22	16	23	25	22	29	29	32	C	B
Zn Naph M-553	4	water	24	32	29	29	31	32	28	33	C	C
Zn Naph M-553	2	water	33	33	34	31	25	33	34	31	C	C
Zn Naph M-550	2 (as metal)	water	32	12	33	14	36	26	38	31	C	B
CWP 44	10	water	25	19	29	33	39	37	37	39	C	C
3-Iodo-2-(IPBC)	2	water	26	29	30	34	35	38	23	30	C	C
IPBC Woodlife	0.5	oil	28	21	27	25	30	34	31	32	C	C
IPBC + busperse 47	1/5	oil	37	18	35	24	37	31	32	33	C	C
Nuodex 100 WD	8	water	27	26	36	33	42	38	42	31	C	C
Busan 1009	2	water	33	29	30	31	32	32	35	24	C	C
Azaconazole	0.3	water	32	21	36	31	28	25	36	23	C	C
Azaconazole	0.15	water	33	28	35	33	37	29	47	32	C	C
Arquad C-50/ IPBC	4 2.5	oil	34	25	29	35	29	29	31	28	C	C
Cu-8-10 (Nuodex)	.3 cu (as metal)	water	31	11	27	22	45	26	36	28	C	B
Busan 1030	2	water	33	20	40	20	33	33	47	31	C	C
ACAR #86013	1	water	37	31	36	38	33	34	30	30	C	C
ACAR #86032	1	water (>130°F)	28	29	27	35	34	43	30	38	C	C

[1] Where A = protection to the outer 1 to 3 zones, B = protection to the outer zone, and C = minimal protection to any zone.

The variation in degree of protection afforded by treatments in the second performance group probably reflects distributional problems. These specimens were dipped, thereby ensuring chemical contact with virtually the entire surface, and should represent an optimum of the chemical dosage delivered during a spray treatment. In the field, some areas of the wood may receive little or no chemical, while others will receive an excess. As a result, chemicals which provide lower levels of protection or which penetrate the wood to lesser degrees may be less attractive for this application. Chemicals which provide protection to zones deeper into the wood may provide more reliable performance under variable field conditions.

The results of the current chemical trials will be evaluated on western redcedar located east and west of the Cascade Mountains to determine their efficacy.

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

Preservative treatment creates a barrier against fungal and insect attack. Wood poles should remain free from fungal attack as long as sufficient chemical is present and the barrier remains intact. Unfortunately, it is sometimes necessary to cut or fabricate poles after treatment. This process exposes untreated wood to potential fungal attack. Most utilites specify remedial application of preservative to the damaged zone to provide a supplemental barrier. For many years, pentachlorophenol in diesel oil was the preferred chemical for this process; however, environmental restrictions and concerns about public perceptions have led some utilites to substitute alternative chemicals or to eliminate supplemental treatment of field damage entirely. This process creates a risk of above ground decay originating from field damage.

There are a variety of potential chemicals for protecting field damaged wood, but there is little data on the performance of these chemicals in this application. We have taken two approaches to evaluating the effectiveness of these chemicals. We have evaluated a variety of chemicals in a simulated field trial to rapidly develop data on resistance to leaching and ability to restrict fungal attack. We have also installed small poles containing numerous field drilled holes treated with a variety of chemicals. The rate of fungal colonization of these poles has been used as a measure of the protective effect of each treatment.

1. Rapid evaluation of remedial treatments for protecting field drilled bolt holes: Field evaluations of bolt hole treatments have proven to be extremely slow. To overcome this difficulty, we explored the use of small scale trials with pine and Douglas-fir blocks remedially treated with selected preservatives. Last year we reported on the preliminary results of these trials (90 Annual Report, pg. 51-56). These studies are now complete.

This report describes the results of a specially designed laboratory test for rapidly assessing the potential of preservatives to protect field-drilled bolt holes. The capacities of 14 chemicals were evaluated against the capacity of pentachlorophenol to protect the heartwood of Douglas-fir (Pseudotsuga menziesii (Mirb.) Franco) and the sapwood of ponderosa pine (Pinus ponderosa Laws.) exposed to the decay fungus, Postia placenta.

A hole 9 mm in diameter was drilled through the center of the radial face of 3.8 x 8.8 x 3.8 cm blocks of Douglas-fir heartwood and ponderosa pine sapwood. After each hole was plugged at one end with a rubber stopper, 2 ml of test chemical were added, the other end of the hole was plugged, and the block was

agitated for 5 seconds to distribute the chemical evenly along the hole walls. Fifteen chemicals were evaluated in the test (Table II-4), each one applied to nine blocks of each wood species.

After treatment, the plugs were removed and the blocks were air-dried for 1 week. Three blocks in each chemical treatment were then left as unleached controls, while the remaining six were exposed to 2 or 4 months of leaching by means of continuous heating at 30°C and alternating 8-hour water spraying and 16-hour drying. Three blocks from each treatment group were removed after 2 months and three after 4 months of leaching.

The blocks were evaluated for decay resistance with a modified soil-block test. Each block was cut into two 3.8 x 4.4 x 3.8 cm blocks, which were oven-dried at 54°C and weighed to the nearest 0.01 g. The blocks were steamed for 20 minutes at 100°C before exposure to the fungus. Decay chambers were 454-ml glass canning jars containing 100 ml of moist forest soil and a single sapwood feeder strip of western hemlock 30 x 30 x 3 mm thick. The chambers were heated at 121°C for 45 minutes, cooled, and inoculated with agar plugs containing actively growing mycelium of the test fungus, Postia placenta (Madison FP-94267A). The chambers were incubated until the fungus had thoroughly covered the feeder strips, then sterile blocks were placed on the strips, one block per chamber. Decay chambers were incubated for 12 weeks at room temperature (23°-25°C).

The blocks were then removed, scraped clean of adhering mycelium, oven-dried at 54°C, and weighed. Weight loss of the wood over the exposure period was used as one measure of chemical protection. The dry blocks were then cut in half across the drill hole so that the zone of protection along each hole could be measured tangentially.

As measured by weight loss, blocks containing chemically treated holes differed little from those that received no chemical, reflecting the small portion affected by the treatment (Table II-5). Of the chemicals evaluated, only pentachlorophenol provided protection, and its effect on weight loss was relatively minor. Weight loss was generally greater for pine, because of its lower natural durability, than for Douglas-fir.

Although these results suggest that none of the alternative chemicals protected the wood from fungal attack, examination of the zone around the drill hole revealed that several did provide some protection (Figure II-1). As judged by the zone of effect, penta was again most effective, completely penetrating blocks longitudinally from the drill holes. TCMTB, MBT/TCMTB, oxine copper, and TMCAC also provided some protection to both wood species, even after the 4-month leaching period. Several chemicals (AMICAL, oilborne IPBC, ITH, and DDBAN) that did not produce zones of protection in Douglas-fir heartwood, did produce them in ponderosa pine.

The zones of protection were generally greater in pine, because of diffusion of the preservatives through the more permeable wood. The first 2-month leaching exposure appeared to have little effect on the size of the protected zone, but the additional 2 months produced a substantial decline in the zone of protection afforded by copper naphthenate, waterborne IPBC, zinc naphthenate, and NP-1. Since field-drilled bolt holes are normally treated only at the time of installation, the chemicals applied must be resistant to leaching and must provide protection for the life of the structure. The decline suggests that these chemicals may not provide long-term protection to exposed wood.

A comparison of the protection provided by penta and that provided by the other chemicals evaluated shows why it is difficult to identify an acceptable

alternative. Other chemicals that have performed well in field tests, such as borate, provided little or no zone of protection in this test. Borate diffuses with moisture and probably was lost from the drill hole during leaching, or diffused through the wood to sub-threshhold levels over the course of the decay test. However, the aboveground zone around a bolt hole is subjected to less wetting than similar wood in ground contact, and decreased moisture should improve results with diffusible chemicals, as shown by previous field trials. The results obtained with our tests reflect conditions of severe leaching, a methodology that may be inappropriate for evaluating the protective effect of diffusible chemicals in actual use.

It is apparent that any remedial treatment should provide the maximum zone of protection around the area of field damage; however, the zone required for adequate protection against fungal colonization remains poorly defined. In our laboratory method, the wood is exposed to a large quantity of fungal hyphae growing under virtually optimum conditions. In practice, the wood is exposed to individual spores or hyphae in an aboveground situation where decay-accelerating factors such as nutrients or moisture may be limiting. The degree of protection required under these circumstances may be substantially lower than that in the laboratory. As a consequence, the severe exposure afforded by the laboratory trials may provide a safety factor to ensure subsequent good field performance.

Results with this laboratory trial suggest that four chemicals, TMCAC, TCMTB, MBT/TCMTB, and oxine copper provide reasonable protection to Douglas-fir heartwood and ponderosa pine sapwood. The latter three are registered for application to wood. Amical, IPBC, isothiazolone, and DDBAN provided some protection to pine sapwood and may prove useful in these species. All but IPBC have also shown some promise for providing remedial protection to exposed wood

in other situations. It should be noted that copper naphthenate, widely used by electric utility companies for protecting field-drilled bolt holes, has provided moderate protection in other tests of remedial chemicals.

While the other chemicals provided some wood protection, they lacked the resistance to leaching necessary for long-term effectiveness, and thus are probably not appropriate for this application. Since remedial applications to field-damaged wood are rarely repeated, it would seem prudent to choose only those chemicals that provide maximum protection. Under these circumstances, TMCAC, TCMTB, MBT/TCMTB, and oxine copper appear to be potentially most useful; however, further studies will be necessary to refine the test methodology for evaluating diffusible chemicals.

Figure II-1. Ability of selected test chemicals to provide zones of protection around ponderosa sapwood and Douglas-fir heartwood as shown by exposure to Postia placenta in a modified soil-block test.

TABLE II-4. **Chemicals evaluated for their protection of test blocks of Douglas-fir heartwood and ponderosa pine sapwood exposed to the fungus Postia placenta.**

Chemical name	Designation	Source	Solvent	Concentration %
Azaconazole	AZA	Janssen Pharmaceutica, Beerse Belgium	water	0.30
Copper-8-quinolinolate	Oxine copper	Nuodex, Inc. Piscataway, NJ	Oil	1.80[a]
Copper naphthenate	CUNAP	Tenino Wood Preservatives, Seattle, WA	Oil	2.00[a]
Diiodomethyl para-tolyl sulfone	AMICAL	Akzo Chemie, N. Chicago, IL	Oil	1.00
Dodecyl dimethyl ammonium salt of naphthenic acid	DDBAN	Nuodex, Inc. Piscataway, NJ	Oil	8.00
IPBC		Troy Chemical, Rahway, NJ	Water	2.00
IPBC/didecyldi-methyl-ammonium chloride	NP-1	Kop-Coat Inc., Pittsburgh, PA	Water	1.00
Isothiazolone	ITH	Rohm and Haas, Inc. Spring House, PA	Oil	1.00
Methylene bisthio-cyanate plus thiocyanomethyl-thiobenzothiazole	MBT/TCMTB	Buckman Laboratories, Memphis, TN	Water	4.00
Pentachlorophenol	PENTA	Chapman Chemical Co., Memphis, TN	Oil	
Sodium octaborate tetrahydrate	BORATE	U.S. Borax, Anaheim, CA	Water	10.00[b]
Thiocyanomethyl-thiobenzothiazole	TCMTB	Buckman Laboratories, Memphis, TN	Water	4.00
3-iodo 2-propynyl butylcarbamate	IPBC	DAP, Inc., Dayton, OH	Oil	0.50
3-trimethylcocc-ammonium chloride	TMCAC	Akzo Chemie, N. Chicago, IL	Water	5.00
Zinc naphthenate	MGARD	Mooney Chemical Co., Inc Cleveland, OH	Water	4.00[a]

[a] As copper or zinc metal.
[b] As boric-acid equivalent.

Table II-5. Protection given by chemical treatment of Douglas-fir heartwood and ponderosa pine sapwood exposed to Postia placenta and laboratory weathered for 0, 2, and 4 months, as evaluated by weight loss in soil-block tests[a] and visual estimation of the zone of protection.

Test chemical[b]	Douglas-fir						Ponderosa pine					
	Weight loss (%)			Zone of protection (mm)			Weight loss (%)			Zone of protection (mm)		
	0	2 mo	4 mo	0	2 mo	4 mo	0	2 mo	4 mo	0	2 mo	4 mo
Most effective												
Oxine copper	26	26	23	1.0	1.0	1.0	40	39	30	2.5	2.7	4.0
PENTA	21	16	21	7.8	8.0	10.0	23	23	26	8.0	8.5	8.6
TCMTB	24	28	32	2.0	1.3	2.8	49	45	42	3.5	3.4	3.7
MBT/TCMTB	29	29	29	4.0	2.5	4.4	47	44	39	2.5	2.0	4.0
TMCAC	25	23	22	1.0	1.0	3.6	31	36	28	3.0	3.0	3.6
Moderately effective												
AMICAL	24	25	26	1.0	1.0	0.0	35	42	36	1.4	2.0	2.0
AZA	26	25	25	1.0	1.0	0.0	39	42	23	2.5	1.7	2.2
DDBAN	28	27	28	0.0	0.0	0.0	38	39	38	2.0	1.7	1.5
IPBC (oil)	30	32	24	0.0	0.0	0.0	42	37	37	1.0	1.3	2.5
IPBC (water)	32	29	26	1.2	1.2	0.0	38	43	35	2.7	2.7	2.5
Isothiazolone	28	26	21	1.0	1.0	0.0	33	36	36	0.7	1.5	1.5
Zinc naphthenate	26	27	25	1.0	1.0	0.0	39	40	30	1.3	1.2	1.0
Least effective												
Borate	30	31	32	0.0	0.0	0.0	-[c]	-[c]	36	-[c]	-[c]	0.0
Copper naphthenate	26	27	24	0.0	0.0	0.0	47	47	36	0.3	0.5	0.0
NP-1	28	25	26	0.0	0.0	0.0	37	38	32	1.0	1.0	0.0
Control	24	26	29	0.0	0.0	0.0	33	36	41	0.0	0.0	0.0

[a] A modified soil-block test used Postia placenta as the test fungus.
[b] See Table 1 for full names.
[c] Not tested.

2. Evaluate treatments for preventing decay in field drilled bolt holes: In 1981, 28 Douglas-fir poles (5.4 m long by 60 to 70 cm in circumference) were lightly treated with pentachlorophenol in P9 Type A oil. A series of eight 2.5 cm diameter holes were drilled in a pole at 45 cm intervals along the length. Each hole was located 45 degrees around the pole from the previous one beginning 45 cm below the top and ending 60 cm above the groundline. One of four chemical treatments was applied to eight holes in each of four holes. The holes in four poles received no chemical treatment, but chemically impregnated Patox washers were used to attach bolts to these holes. An additional eight poles received no chemical treatment and served as controls. Bolts were inserted in each treatment hole. Half of the holes on each pole were given metal gain-plates on both sides and half received plastic gain plates. The poles were set 1.2 m into the ground in Corvallis, OR. Poles were watered over the summer months to encourage leaching and stimulate fungal growth.

The control poles were monitored for fungal colonization over the first five years, then the treated poles were sampled once the control poles were colonized. Increment cores were removed annually from directly below each bolt hole gain plate on one side of the pole and directly above the washer on the opposite site. These cores have been cultured for the presence of decay and non-decay fungi.

Nine years after treatment, fungal colonization around the untreated bolt holes continues to fluctuate (Table II-6). This variation most probably reflects the limited spread of fungi through the above ground portions of the pole sections coupled with the naturally variability in fungal colonization

patterns. Thus, a fungus may be isolated from a bolt hole one year, but not the next.

Penta, the previous industry standard, continues to provide protection to most of the bolt holes, although decay fungi were isolated from some samples. The three water soluble treatments also continue to protect the bolt holes and are experiencing lower levels of colonization than the penta treatment. These treatments are simple to apply and, in the case of boron compounds, are readily available in the United States. Earlier examination of hardware from the treatment holes indicated that none of the treatments were corrosive. The only treatment which continues to perform poorly is the Patox washer. This treatment apparently cannot move from the washer into the wood in sufficient quantities to provide protection against fungal attack.

The water soluble chemicals continue to exhibit promise for supplemental protection of field damage. Their combination of low toxicity to humans and their ability to migrate into the wood with moisture make them highly attractive for field application.

Table II-6. Basidiomycetes and other fungi found in preservative-treated Douglas-fir poles 6 to 9 years after bolt holes were drilled and treated in the field, as shown by cultures from increment cores.

Field treatment	Percentage of cores containing -- Basidiomycetes				Other fungi			
	6 yr	7 yr	8 yr	9 yr	6 yr	7 yr	8 yr	9 yr
Ammonium bifluoride (n-32)	0	2	0	2	5	2	16	42
Boracol[R] 40 (n=32)	0	2	0	0	18	27	33	66
Patox[R] washer (n = 32)	5	5	8	14	12	22	31	66
Pentachlorophenol (n = 32)	2	2	8	5	25	17	25	51
Timbor[R] (n = 32)	0	0	0	2	11	25	25	37
Control (n = 64)	3	9	17	9	30	26	46	70

OBJECTIVE III

DETECT EARLY DECAY AND ESTIMATE RESIDUAL STRENGTH OF POLES IN SERVICE

A. ESTIMATING RESIDUAL STRENGTH OF UTILITY POLES USING SMALL SCALE TESTS

In previous reports, we have described two small scale tests for estimating the residual strength of Douglas-fir poles. Longitudinal compression and radial compression of small plugs removed from the wood surface have both been explored using small clear beams and Lodgepole pine posts; however, the results have been less than satisfactory. A better relationship was found between LCS and bending strength in full scale tests on western redcedar. In the next few months, Dr. J.B. Wilson, in an ESEERCO sponsored project, will be evaluating an acoustic strength assessment device on Douglas-fir poles which will then be tested to failure. We will evaluate the RCS and LCS of samples removed from these poles in a further effort to develop a small scale field strength test.

B. EFFECT OF DRILLING PATTERN ON TREATMENT OF GLU-LAMINATED TIMBERS

The treatment of refractory wood species results in a well treated sapwood shell surrounding an untreated heartwood core. This core will be protected as long as the treated shell remains intact, but any damage to the surface renders the core susceptible to internal decay. The problem is potentially greater when Douglas-fir boards are laminated to produce utility poles since heartwood boards will be exposed on the surface and may receive only a shallow treatment. Conversely, glu-lam is dry at the time of treatment and will be less likely to develop deep checks in service. Because of these characteristic, there is currently an effort within the American Wood Preserver's Association to develop a separate specification for laminated poles. As a part of this effort, we have

examined various methods for improving the depth of preservative treatment in a glu-laminated Douglas-fir transmission pole.

One 24 m long laminated pole was fabricated from boards which had been incised on all four sides to a depth of 1.9 cm. The pole was marked in alternating 0.6 m and 0.9 m long sections. The 0.9 m long sections received various drilling patterns to enhance preservative treatment, while the 0.6 m long sections served as controls.

One set of sections received a through boring pattern in which 1.09 cm diameter holes were drilled at a 5 degree downward sloping angle so that holes were 5 cm apart vertically or horizontally. A series of holes were drilled so that each hole was 7.5 cm from another either vertically or horizontally (through bore A). As an alternative, a series of 3 rows of holes each 5.0 cm apart horizontally and vertically were drilled, followed by a 15 cm gap and a second series of 3 rows of holes (Through bore B).

A second series of sections were radial drilled in one of two patterns. In the first (Radial A), 6.25 cm deep by 0.6 cm diameter holes were drilled in a diamond pattern so that holes on the same horizontal plane were 5.0 cm apart and those in the same vertical plane were 10 cm apart. Rows of holes were then offset by 3.75 cm so that the drilling pattern resembled a diamond. A second series of sections (Radial B) were radially drilled in the same manner, but the holes were 7.5 cm apart horizontally and 15 cm vertically.

The pole was treated with pentachlorophenol in light solvent to achieve the proposed depth of penetration in both the incised (2.5 cm), radial drilled (6.25 cm) and through bored (complete) zones. The pole was then evaluated for depth of penetration by removing increment cores from selected laminations. Six cores were removed from each section. Two 6.25 cm long cores were taken on the narrow face of a lamination, while an additional four 22.5 cm long cores were removed

from sites 6.25 cm in from the edge of the wide face of the lamination. Cores removed from the wide faces extended to the center of the beam. This drilling pattern resulted in a core which sampled the 2.5 cm zone in from the edge of each lamination in the timber. This pattern was developed as an alternative to the AWPA specified sampling pattern and would normally be employed when less than 90% of the cores in the specified sample met the penetration requirement. The depth of preservative penetration was measured for each core.

The beam was exceptionally well treated, with an average depth of penetration in the incised control (non-drilled) zones ranging from 3.1 to 6.25 cm (Table III-1). The proposed standard requires that poles be treated to a depth of 1.9 cm in the incised zone. The exceptional treatment makes it difficult to make distinctions between drilling patterns although there do appear to be some differences between the two through boring patterns.

Seventy one percent of the laminates in non-drilled sections had preservative penetration 5.0 cm from the wood surface. In general, sections which experienced penetration problems as determined using the standard method of removing a limited number of cores from the face also had incompletely penetrated laminations when the more intensive coring pattern was employed. These variations suggest that the percentage of non-conforming samples detected is unlikely to be reduced by enhanced sampling; however, the enhanced sampling will be more likely to detect non-conforming members.

Radial drilling or through boring both markedly enhanced the already excellent treatment in the test sample. Radial drilled sections had 2.5 to 6.1 percent non-coforming laminations, depending on the radial drilling pattern. As expected, the denser radial drilling pattern had fewer non-conforming laminations, although the differences were slight. Through boring also improved penetration with the percentage of non-conforming laminations ranging from 0 to

2.6 %. One again, the tighter boring pattern resulted in fewer non-conforming laminates.

Although the excellent treatment of the entire member makes it difficult to detect more subtle differences between the various treatments, it is readily apparent that any of boring patterns markedly improved the uniformity of treatment. The results also demonstrate that coring along the face of a laminated timber at the depth of penetration required on the perpendicular face may provide a more representative sample for assessing preservative penetration.

Table III-1. Preservative penetration in glue-laminated Douglas-fir timber sections receiving radial drilling, through-boring and incising prior to preservative treatment with pentachlorophenol.

		Depth of treatment (cm)		
Pole Treatment[1]		Side Laminate Sample[2]	Wide face sample[3]	Failing laminations
Control (22.5 cm)	1-a	6.25		
	b	-	0 to 10.6, 15.0 to 17.50	3
	c	-	0 to 22.5	-
	d	-	0 to 0.6, 3.8 to 7.5, 11.3 to 15	4
	e	-	0 to 22.5	-
				7/24
(22.5 cm)	2-a	3.13		
	b		0 to 17.5, 20 to 22.5	1
	c		0 to 11.3, 17.5 to 18.8	3
	d		0 to 5.6, 10.0 to 20.0	3
	e		0 to 9.4, 14.4 to 15.6	4
				11/24
(21.3 cm)	3-a	3.75		
	b		0 to 7.5, 8.7 to 13.8, 17.5 to 21.3	1
	c		0 to 6.9, 7.5 to 10.6, 12.5 to 21.3	2
	d		0 to 7.5, 8.7 to 21.3	-
	e		0 to 17.5	1
				4/24
(20.0 cm)	4-a	6.25		
	b		0 to 14.4	2
	c		0 to 10.0, 13.8 to 20.0	1
	d		0 to 20.0	-
	e		0 to 10, 12.5 to 17.5	2
				5/24
(19.4 cm)	5-a	6.25		
	b		0 to 7.5, 11.3 to 15.0	2
	c		0 to 19.4	-
	d		0 to 8.8, 11.3 to 17.5	2
	e		0 to 8.8, 11.9 to 17.5	2
				6/20
(18.8 cm)	6-a	6.25		
	b		0 to 15.0	1
	c		0 to 14.4	1
	d		0 to 13.8	2
	e		0 to 5.6, 10 to 13.1, 13.8 to 18.8	1
				5/20
(17.5 cm)	7-a	6.25		
	b		0 to 10, 11.3 to 17.5	1
	c		0 to 17.5	-
	d		0 to 17.5	-
	e		0 to 17.5	-
				1/20
(16.3 cm)	8-a	6.25		
	b		0 to 12.5	1
	c		0 to 16.3	-
	d		0 to 8.8	2
	e		0 to 6.9, 9.4 to 16.3	1
				4/16
(15.0 cm)	9-a	5.00		
	b		0 to 15	-
	c		0 to 10, 13.3 to 15.0	1
	d		0 to 15.0	-
	e		0 to 3.8, 7.5 to 15.0	1
				2/16
Control (17.5 cm)	7-a	6.25		
	b		0 to 10, 11.3 to 17.5	1
	c		0 to 17.5	-
	d		0 to 17.5	-
	e		0 to 17.5	-
				1/20
(16.3 cm)	8-a	6.25		
	b		0 to 12.5	1
	c		0 to 16.3	-
	d		0 to 8.8	2
	e		0 to 6.9, 9.4 to 16.3	1
				4/16
(15.0 cm)	9-a	5.00		
	b		0 to 15	-
	c		0 to 10, 13.3 to 15.0	1
	d		0 to 15.0	-
	e		0 to 3.8, 7.5 to 15.0	1
				2/16

		Depth of treatment (cm)		
Pole treatment[1]		Side Laminate Sample[2]	Wide face sample[3]	Failing laminations
(12.5 cm)	10-a	6.25		
			0 to 3.8	3
			0 to 11.3	1
			0 to 5.0, 11.3 to 12.5	2
			0 to 1.9	3
				9/12
(12.5 cm)	11-a	6.25		
	b		0 to 12.5	-
	c		0 to 3.8, 7.5 to 12.5	2
	d		0 to 5.6, 9.4 to 12.5	1
	e		0 to 1.9, 8.8 to 10.0	3
				6/12
(11.9)	12-a	6.25		
			0 to 11.9	-
			0 to 7.5	1
			0 to 11.9	-
			0 to 5.6, 6.2 to 11.9	1
				2/12
(11.3 cm)	13-a	6.25		
	b		0 to 11.3	-
	c		0 to 11.3	-
	d		0 to 6.9	2
	e		0 to 4.4, 56 to 7.5, 8.16 to 10.6	1
				3/12
(10.0 cm)	14-a	5.00		
	b		0 to 10.0	-
	c		0 to 10.0	-
	d		0 to 10.0	-
	e		0 to 3.1	3
				3/12
(10.0 cm)	15-a	3.10		
	b		0 to 2.5	3
	c		0 to 6.9, 8.9 to 10.0	-
	d		0 to 3.8, 6.25 to 10.0	1
	e		0 to 3.8	2
				6/12
Radial drill	1-a	5.00		
	b	6.25		
(22.5 cm)	c		22.5	-
	d		22.5	-
	e		22.5	-
	f		22.5	-
				0/24
(20.0 cm)	2-a	6.25		
	b	2.25		
	c		0 to 20.0	-
	d		0 to 3.8, 9.4 to 20.0	2
	e		0 to 20.0	-
	f		0 to 20.0	-
				2/24
(15.0 cm)	3-a	6.25		
	b	6.25		
	c		0 to 15	-
	d		0 to 15	-
	e		0 to 15	-
	f		0 to 15	-
				0/16
(11.9 cm)	4-a	6.25		
	b	6.25		
	c		0 to 11.9	-
	d		0 to 11.9	-
	e		0 to 10.0	-
	f		0 to 11.9	-
				0/16
Radial	1-a	5.00		
	b	6.25		
(21.3 cm)	c		21.3	-
	d		0 to 11.9, 13.8 to 15.6, 17.5 to 21.3	2
	e		21.3	-
	f		21.3	-
				2/24
(17.5 cm)	2-a	6.25		
	b	6.25		
	c		17.5	-
	d		17.5	-
	e		17.5	-
	f		17.5	-
				0/18

Pole Treatment[1]		Depth of Treatment (cm)		
		Side Laminate Sample[2]	Wide face sample[3]	Failing laminations
(12.5 cm)	3-a	6.25		
	b	6.25		
	c		12.5	1
	d		12.5	1
	e		12.5	1
	f		12.5	1
				1/12
(10.0 cm)	4-a	6.25		
	b	6.25		
	c		0 to 8.8	1
	d		10.0	-
	e		10.0	-
	f		10.0	-
				1/12
Through bore (A) (22.5 cm)	1-a	3.10, 4.4 to 6.25		
	b	6.25		
	c		22.5	-
	d		21.9	-
	e		22.5	-
	f		22.5	-
				1/24
(18.8 cm)	2-a	6.25		
	b	6.25		
	c		18.8	-
	d		18.8	-
	e		18.8	-
	f		18.8	-
				0/24
(14.4 cm)	3-a	6.25		
	b	6.25		
	c		14.4	-
	d		14.4	-
	e		14.4	-
	f		0 to 3.8, 7.5 to 10.0, 11.3 to 14.4	2
				2/16
(11.3 cm)	4-a	6.25		
	b	6.25		
	c		11.3	
	d		11.3	
	e		11.3	
	f		11.3	
				0/12
Through bore (B) (20.6 cm)	1-a	6.25		
	b	6.25		
	c		20.6	-
	d		20.6	-
	e		20.6	-
	f		20.6	-
				0/24
(16.9 cm)	2-a	6.25		
	b	6.25		
	c		16.9	-
	d		16.9	-
	e		16.9	-
	f		16.9	-
				0/16
(12.5 cm)	3-a	6.25		
	b	6.25		
	c		12.5	-
	d		12.5	-
	e		12.5	-
	f		12.5	-
				0/12

[1]Values in parentheses represent depth of increment core used for the face sample.

[2]One or two increment cores (6.25 cm long) were removed from the side (narrow face) of a laminate.

[3]Increment cores were removed 6.25 cm in from each edge of the wide faces of a test section in a given vertical plane of the pole.

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

Studies to evaluate the risk of air-seasoning on quality of Douglas-fir poles have been underway for over 10 years. These studies originated as a result of the high incidence of decay fungi in Douglas-fir utility poles in service. The presence of these fungi suggested that colonization occurred during air-seasoning and that these fungi survived the treatment process. At present, most of the effort involves evaluating the wealth of field data collected over the first 5 years of the research. In this report, we will describe analyses of the results of short air-seasoning exposures and discuss future plans for sterilization research.

A. EVALUATE THE POTENTIAL FOR INFECTION AND DECAY DEVELOPMENT IN AIR-SEASONING DOUGLAS-FIR POLES

The air-seasoning research was originally established as 3 separate studies. The incidence of decay fungi in air-seasoning Douglas-fir poles was evaluated in air-seasoning yards through the Pacific Northwest, the sequence of fungal colonization of Douglas-fir pole sections was monitored at four sites over a 3 year period, and finally, the seasonal rates of colonization were examined by exposing pole sections for relatively short periods of time at each of the four selected sites.

The final results from the first two portions of this study have been reported in previous annual reports. In this section, we will discuss the results of the short-term field exposures. The objective of this study was to determine at what time of year poles are most likely to be infected with decay fungi and how temperature and rainfall affect fungal infection.

Douglas-fir poles were obtained from four air-seasoning yards located in Oroville, CA, Eugene, OR, Scappoose, OR, and Arlington, WA. Increment cores were removed from the ends of these poles and cultured on malt extract agar (MEA). The results indicated that most of the pole sections contained existing fungal colonies. The presence of these colonies made it difficult to determine if fungi isolated following air-seasoning exposure were new invasions or expansions of existing colonies. As a result of these problems, the first 3 and 6 month exposure data was eliminated.

To overcome the problem of existing fungal attack, 2.59 m long pole sections were obtained from a single source. These sections were end-coated with an elastomeric paint (Gaco A5400) to retard end-drying and heated in a kiln for 48 hours at 93.3 C. Moisture measurements made before and after heating indicated minimal moisture change, reflecting the relatively narrow wet bulb/dry bulb depression under which the wood was heated. Increment cores removed from these poles following heating were cultured on MEA for the presence of decay fungi. Although some fungi grew from the cores, microscopic examination revealed that none of these were basidiomycetes, a class of fungi containing many important wood decayers.

Four sterilized pole sections were taken to each of the four air-seasoning yards. Increment cores were removed at 7.5 to 10 cm intervals around the pole 0.6 m from each end of the pole. These cores were placed into drinking straws which were sealed and returned to the laboratory where they were cultured on MEA amended with benomyl to retard the growth of non-basidiomycetes. Any decay fungi isolated from the cores were identified to species using previously published keys.

A chainsaw was used to cut the pole section through the zone from which the increment cores were removed. This process created two 0.6 m long sections and one 1.2 m long section.

The 0.6 m long sections were placed vertically with their sealed end downward. One end of each 1.2 m long section was coated with elastomeric paint and the section was exposed horizontally on treated lumber skids to simulate an air-seasoning pole. Fresh stubs were exposed at 3 and 6 month intervals and previously exposed stubs were returned to Corvallis where they were extensively sampled to determine the patterns of fungal colonization.

Wood moisture content was measured 1.25, 2.5 and 5.0 cm from the surface at 2 locations 180 degrees apart 2.5, 15, and 30 cm from the top of two 0.6 m long stubs from each yard using an electrical resistance type moisture meter. Moisture content in the 1.2 m foot sections was assessed at the same depths, but at 2.5, 22.5, 45, 60, 97.5, and 117.5 cm from the coated end along the top and bottom face.

Increment cores were removed at 7.5 cm intervals around the stub 7.5 and 30 cm from the top of the 0.6 m long sections. Increment cores were removed at 7.5 cm intervals around the stub 5 to 7.5 cm from each end of the 1.2 m long sections. An additional 10 increment cores were removed along the upper surface of the 1.2 m long sections. These cores were cultured on benomyl amended MEA and any basidiomycetes growing from the wood were identified to species using previously published keys.

Six month exposures occurred from November 1981 to April 1982, while 3 month exposures occurred from May 1981 until January 1984. Six month exposures were dropped because sufficient colonization was found to occur over the 3 month period.

Colonization over the respective periods was compared with weather data to determine whether this information could reliably predict the risk of fungal infection at a given site. Weather data was collected from the nearest U.S. Climatological Service weather station. Data from Seattle, WA was used for Arlington, WA. This site is 45 miles north of Seattle. Data

from Portland airport was used for the Scappoose site, located 30 miles to the west. Data for Eugene was collected from the airport, located 4 miles north of the test site. Oroville climate data was obtained from Red Bluff, CA, some 60 miles from the test site. The data was used to develop a climate index for each site using a formula proposed by T.C. Scheffer to provide a relative index of the potential for decay in above ground exposures. The formula used to develop this index was:

$$\text{Climate Index} = (T-35)(D)/N$$

Where T=mean temperature for the exposure period, D= the number of days with 0.01 inches or more of rain, and N= the number of days in the exposure period. Within this formula, the rate of spore germination and decay development is presumed to be proportional to the number of degrees F by which the temperature exceeds 35, or T-35. The resulting climate index was then compared with the corresponding fungal isolation data for a given site.

Of the 9,990 cores removed from pole sections exposed for 3 months, 8.4 % contained a decay fungus (Table IV-1). While this may appear to be a relatively low rate of colonization, these pole sections were only exposed for short periods, indicating that the risk of infection at air-seasoning yards is relatively high. Although 23 basidiomycetes species were identified, the majority were isolates of 5 species. Postia placenta was present in 1.93 % of the cores samples, followed by Peniophora spp. (0.92 %), Stereum hirsutum (0.84 %), Phanerochaete sordida (0.67 %), and Sistotrema brinkmanii (0.60 %). Of these fungi, two later become prevalent in pole sections which are air-seasoned for periods ranging from 1 to 3 years.

Table IV-1. FREQUENCY OF BASIDIOMYCETES ISOLATED FROM STERILIZED DOUGLAS-FIR POLE SECTIONS EXPOSED FOR 3- OR 6-MONTH INTERVALS AT FOUR SITES IN THE PACIFIC NORTHWEST.[1]

	Arlington				Scappoose				Eugene				Oroville				Total			
	3 months		6 months		3 months		6 months		3 months		6 months		3 months		6 months		3 months		6 months	
	#	%	#	%	#	%	#	%	#	%	#	%	#	%	#	%	#	%	#	%
Unidentified basidiomycete	12	0.5	14	4.9	12	0.5	31	11.2	37	1.5	22	7.9	15	0.6	8	2.8	76	0.8	75	6.6
Unidentified w/o clamps	25	1.0	8	2.8	24	0.9	13	4.7	51	2.0	5	1.8	61	2.5	26	9.1	161	1.6	52	4.6
Androdia serialis	-	-	-	-	-	-	1	0.1	-	-	-	-	-	-	-	-	-	-	1	0.1
Trametes versicolor	-	-	-	-	1	0.04	-	-	4	0.2	2	0.7	1	0.04	1	0.3	6	0.1	3	0.3
Trametes versicolor monokaryon	3	0.1	1	0.3	2	0.1	-	-	6	0.2	-	-	8	0.3	1	0.3	19	0.2	2	0.2
Epicoccum nigra	3	0.1	-	-	3	0.1	-	-	8	0.3	-	-	6	0.2	4	1.4	20	0.2	4	0.4
Fomitopsis cajanderi monokaryon	-	-	-	-	-	-	-	-	2	0.1	-	-	2	0.1	-	-	4	0.4	-	-
Fomitopsis pinicola	-	-			-	-			-	-	1	0.4	-	-	-	-	-	-	1	0.1
Fomitopsis pinicola monokaryon	-	-	-	-	-	-	-	-	1	0.04	-	-	-	-	-	-	1	0.1	-	-
Stereum sanguinolentum	5	0.2	9	3.1	4	0.2	-	-	9	0.4	1	0.4	-	-	-	-	18	0.2	10	0.9
Peniophora spp.	17	0.7	3	1.0	23	0.9	4	1.4	24	1.0	2	0.7	32	1.3	11	3.8	96	1.0	20	1.8
Phlebia A	-	-	-	-	1	0.04	-	-	-	-	-	-	1	0.04	-	-	2	0.02	-	-
Phlebia albida	2	0.1	1	0.3	-		-	-	-	-	-	-	-	-	-	-	2	0.02	1	0.1
Phlebia radiata	1	0.04	1	0.3	1	0.04	3	1.1	-	-	-	-	-	-	-	-	2	0.02	4	0.4
Phlebia radiata monokaryon	1	0.04	3	1.0	1	0.04	3	1.1	1	0.04	-	-	2	0.1	-	-	5	0.1	6	0.5
Antrodia carbonica	2	0.1	-	-	-	-	-	-	-	-	1	0.4	-	-	-	-	2	0.02	1	0.1
Antrodia carbonica monokaryon	1	0.04	-	-	-	-	-	-	1	0.04	-	-	-	-	-	-	2	0.02	-	-
Postia placenta	8	0.3	2	0.7	6	0.2	77	27.8	76	3.0	53	18.9	13	0.5	13	4.5	103	1.0	145	12.8
Postia placenta monokaryon	7	0.3	9	3.1	20	0.8	38	13.7	42	1.7	19	6.8	20	0.8	28	9.8	89	0.9	94	8.3
Poria xantha	12	0.5	-	-	-	-	9	3.2	-	-	-	-	3	0.1	1	0.3	15	0.2	10	0.9
Poria xantha monokaryon	2	0.1	-	-	4	0.2	2	0.7	1	0.05	1	0.4	-	-	2	0.7	7	0.1	5	0.4
Schizophyllum commune monokaryon	-	-	-	-	-	-	-	-	-	-	-	-	1	0.04	-	-	1	0.01	-	-
Sistotrema brinkmanii	14	0.6	6	2.1	2	0.1	1	0.4	38	1.5	11	3.9	5	0.2	-	-	59	0.6	18	1.6
Stereum hirsutum	3	0.1	2	0.7	3	0.15	8	2.9	19	0.8	10	3.6	57	2.3	30	10.5	82	0.8	50	4.4
Poria cinerascens	-	-	-	-	-	-	-	-	-	-	-	-	1	0.04	-	-	1	0.01	-	-
Poria cinerascens monokaryon	1	0.04	-	-	3	0.15	-	-	1	0.04	-	-	1	0.04	-	-	6	0.1	-	-
Phanerochaete sordida	15	0.6	1	0.3	24	0.9	-	-	1	0.04	-	-	26	1.1	5	1.7	66	0.7	6	0.5
Pleuroflammula puberula monokaryon	-	-	-	-	-	-	-	-	-	-	-	-	1	0.04	-	-	1	0.01	-	-
Crustoderma dryinum	-	-	2	0.7	2	0.1	5	1.8	15	0.6	7	2.5	1	0.04	2	0.7	18	0.2	16	1.4
Crustoderma dryinum monokaryon	-	-	1	0.3	1	0.04	-	-	1	0.04	1	0.4	-	-	-	-	2	0.04	2	0.2
Phlebia A monokaryon	1	0.04	-	-	1	0.04	2	0.7	3	0.10	-	-	8	0.3	-	-	13	0.1	2	0.2
Phlebia gigantea	1	0.04	-	-	1	0.04	1	0.4	-	-	-	-	-	-	-	-	2	0.02	1	0.1
Heterobasidion annosum	-	-	-	-	3	0.15	-	-	-	-	-	-	-	-	-	-	3	0.03	-	-
Phlebia C monokaryon	-	-	1	0.3	4	0.2	1	0.4	4	0.2	-	-	2	0.1	-	-	10	0.1	2	0.2
Phlebia C	-	-	-	-	3	0.15	1	0.4	1	0.04	-	-	-	-	-	-	4	0.4	1	0.1
Number of cores with basidiomycetes	128		59		139		165		317		132		251		120		835		476	
Total Cores	2498		288		2542		277		2501		280		2449		287		9990		1132	
% cores with basidiomycetes	5.1		20.5		5.5		59.6		12.7		47.1		10.21		41.8		8.4		42.0	

[1]Where # equals number of increment cores from which a fungus was identified and % represents percentage of all cores from that exposure site which contained the fungus.

Exposure of pole sections for an additional 3 months resulted in substantial increases in the incidence of basidiomycetes. Of the 1132 cores examined, 42 % contained at least one basidiomycete (Table IV-1). Once again, P. placenta was most commonly isolated, followed by S. hirsutum.

Postia placenta, the most commonly isolated decay fungus in this study, is a brown rot fungus which is an important decayer of Douglas-fir heartwood in service. This fungus appeared at all yards, primarily during the winter months (Table IV-2,3). After 3 months exposure, P. placenta was most prevalent in heartwood of stub ends and horizontal surfaces, except at Eugene, where it was isolated from both sapwood and heartwood but was most prevalent in the sapwood. The incidence of P. placenta at Eugene was 4 times the rate at other yards, suggesting a continuous inoculum source of this fungus with many spores germinating on stub surfaces and in sapwood checks. The Eugene air-seasoning site is surrounded by many other wood processing industries with woody debris that may provide a potent source of inoculum. Longer exposure of pole sections resulted in a higher incidence of colonization by this fungus near the stub ends, suggesting that end grain was important for colonization. The presence of this fungus in air-seasoning pole sections is not a major concern provided a sterilization procedure is incorporated during the treatment process; however, this fungus will eventually produce significant strength losses.

Peniophora spp. are white rot fungi which are important decayers of sapwood. These fungi are difficult to taxonomically separate and, for the purposes of this study, were lumped under a single species complex. These fungi were isolated from stubs in all yards, primarily from November through March (Tables IV-2,3,5).

Table IV-2a. FREQUENCY OF BASIDIOMYCETES ISOLATED FROM STERILIZED POLE SECTIONS FOLLOWING 3-MONTH EXPOSURES AT ARLINGTON, WA.

		NUMBER OF CORES CONTAINING BASIDIOMYCETES										
FUNGI	Begin	8/81	11/81	02/82	05/82	08/82	11/82	02/83	05/83	12/83		
	End	11/81	02/82	05/82	08/82	11/82	02/83	05/83	08/83	03/84	Total	%
Unidentified basidiomycete		2		2	2					6	12	0.5
Unidentified without clamps		1	4	3	11	1			4	1	25	1.0
Trametes versicolor monokaryon			1			1	1				3	0.1
Epicoccum nigra					1				2		3	0.1
Stereum sanguinolentum			1							4	5	0.2
Peniophora spp.		2	3							12	17	0.7
Phlebia albida			1							1	2	0.1
Phlebia radiata		1									1	0.0
Phlebia radiata monokaryon								1			1	0.0
Antrodia carbonica		1			1						2	0.1
Antrodia carbonica monokaryon		1									1	0.0
Postia placenta		3			5						8	0.3
Postia placenta monokaryon			2		2	2			1		7	0.3
Poria xantha						1			11		12	0.5
Poria xantha monokaryon					1				1		2	0.1
Sistotrema brinkmanii			1							13	14	0.6
Stereum hirsutum			2							1	3	0.1
Poria cinerascens monokaryon							1				1	0.0
Phanerochaete sordida		1			5	4			5		15	0.6
Phlebia A monokaryon						1					1	0.0
Phlebia gigantea							1				1	0.0
Number of cores with basidiomycetes[1]		12	14	5	26	10	3	1	24	33	128	
Total number of cores taken		204	303	286	267	317	253	261	325	282	2498	
Percent cores with basidiomycetes		5.9	4.6	1.7	9.7	3.2	1.2	0.4	7.4	11.7	5.1	

[1]Does not equal the sum of the column because a core may contain more than one fungus.

Table IV-2b. FREQUENCY OF BASIDIOMYCETES ISOLATED FROM STERILIZED POLE SECTIONS EXPOSED FOR THREE MONTH INTERVALS AT SCAPPOOSE, OR.

		NUMBER OF CORES CONTAINING BASIDIOMYCETES										
FUNGI	Begin.	07/81	10/81	01/82	05/82	7/82	10/82	01/83	04/83	12/83		
	End	10/81	01/82	05/82	07/82	10/82	01/83	04/83	07/83	03/84	Total	%
Unidentified basidiomycete		1	3					1	7		12	0.5
Unidentified without clamps		2	2	6	2	1		1	8	2	24	0.9
Trametes versicolor				1							1	0.0
Trametes versicolor monokaryon				1	1						2	0.1
Epicoccum nigra								1	2		3	0.1
Stereum sanguinolentum			1	3							4	0.2
Peniophora spp.		1	18						1	3	23	0.9
Phlebia A										1	1	0.0
Phlebia radiata			1								1	0.0
Phlebia radiata monokaryon			1								1	0.0
Postia placenta			3	2					1		6	0.2
Postia placenta monokaryon		5	8	1	1	1			1	3	20	0.8
Poria xantha monokaryon			4								4	0.2
Sistotrema brinkmanii		1	1								2	0.1
Stereum hirsutum		1	1		1						3	0.1
Poria cinerascens monokaryon				1			1	1			3	0.1
Phanerochaete sordida		3			3	2			16		24	0.9
Crustoderma dryinum			1					1			2	0.1
Phlebia A monokaryon											1	0.0
Phlebia gigantea			1				1				1	0.0
Heterobasidion annosum				1			1		1		3	0.1
Phlebia C monokaryon									4		4	0.2
Phlebia C									3		3	0.1
Number of cores with basidiomycetes[1]		14	44	15	8	4	3	7	38	6	139	
Total number of cores taken		211	288	288	257	360	261	260	333	284	2542	
Percent cores with basidiomycetes		6.6	15.3	5.2	3.1	1.1	1.1	2.7	11.4	2.1	5.5	

[1] Does not equal the sum of the column because a core may contain more than one fungus.

The fungus was found primarily in sapwood of stub midsections after both 3- and 6-month exposure intervals. The effects of this fungi on wood strength are variable; however, it is most often present in the sapwood and is eliminated during the treatment process.

Two other fungi, Antrodia carbonica and Stereum sanguinolentum, which were among the most commonly isolated species in the 3 year air-seasoning study, were infrequently cultured from stubs in this study, even after six months of air-seasoning (Table IV-1,2,3). The infrequent isolation of A. carbonica parallels results of a previous study in which this fungus was rarely isolated from poles air-seasoning 0 to 12 months. After one year of air-seasoning, however, this fungus was abundantly isolated from both sapwood and heartwood, with colonization increasing at a faster rate in the heartwood with time.

Stereum sanguinolentum was isolated from only 2% of infected cores in both 3- and 6-month exposure periods (Table IV-1). It appeared during two out of three winters at Arlington, Scappoose, and Eugene (Tables IV-2,3). This fungus colonizes living trees and has been cultured from unpeeled poles in the forest and in air-seasoning yards. The low infection rate by S. sanguinolentum in the pre-sterilized stubs in this study may reflect a subtle change in wood chemistry induced by the heat sterilization. This change may limit nutrient access by the fungus or may stimulate other fungal species which in turn exclude S. sanguinolentum.

The remaining fungi were cultured less frequently and longer term studies suggest that many of these fungi are eventually eliminated from the wood. The eventual loss of these fungi may reflect opportunistic colonization by species which are not well-adapted for the wood substrate or may reflect changing conditions in the wood over the air-seasoning period which lead to the eventual death of the fungus.

Effect of seasoning site on fungal colonization: As expected, there were differences in the incidence of decay fungi among the four seasoning sites (Table IV-1,2), but the results varied from those found with longer term exposures. In the 3 year air-seasoning study, poles exposed at Oroville, CA experienced the lowest levels of fungal colonization, while those in Arlington,

Eugene, and Scappoose experienced similar high levels of colonization. The low levels of colonization at Oroville were believed to reflect the extreme drying conditions present at this site. Conversely, in the current study, the levels of fungal colonization after 3 months of exposure at Oroville approached those found at Eugene (Table IV-2c,d). These results reflect a higher initial rate of colonization at the Oroville site coupled with rapid drying conditions which produce conditions unsuitable for further fungal growth. As a result, the fungus colonizes the wood but can not survive for long periods under the adverse conditions.

Effect of exposure period on fungal colonization: Fungi were infrequently cultured during the July-September exposure period. During the remaining periods there appeared to be no consistent relationship between season of exposure and degree of fungal colonization. For example, the November to January exposure period experienced the highest level of colonization in one year and the lowest in the following year (Table IV-2a-d,3). Variations in isolation frequency reflect a number of variables including inoculum density as well as climatic differences which might limit the amount of moisture available for spore germination.

Effect of log orientation on fungal colonization: Decay fungi were found with about the same frequency in stubs placed vertically and those placed horizontally (Table IV-4,5,6,7) with horizontal surfaces yielding slightly higher decay isolation counts. After 6 months, however, ends of both vertically and horizontally placed stubs had almost double the number of decay isolations as mid-sections. These differences illustrate the importance of end-grain in fungal colonization.

Effect of pole depth on fungal colonization: Decay fungi were usually found in either sapwood or heartwood within a core rather than throughout the entire core, suggesting that the fungi colonized wood primarily in a transverse direction (along the wood grain) from an inoculation point.

Table IV-2c. FREQUENCY OF BASIDIOMYCETES ISOLATED FROM STERILIZED POLE SECTIONS FOLLOWING 3-MONTH EXPOSURES AT EUGENE, OR.

		NUMBER OF CORES CONTAINING BASIDIOMYCETES										
FUNGI	Begin	8/81	11/81	02/82	05/82	08/82	11/82	02/83	05/83	12/83		
	End	11/81	02/82	05/82	08/82	11/82	02/83	05/83	08/83	03/84	Total	%
Unidentified basidiomycete		11	15					6		5	37	1.5
Unidentified without clamps		6	5	1	1		1	8	20	9	51	2.0
Trametes versicolor						3				1	4	0.2
Trametes versicolor monokaryon									6		6	0.2
Epicoccum nigra				2	1			1	4		8	0.3
Fomitopsis cajanderi monokaryon									2		2	0.1
Fomitopsis pinicola monokaryon									1		1	0.0
Stereum sanguinolentum			3							6	9	0.4
Peniophora spp.			16							8	24	1.0
Phlebia radiata monokaryon										1	1	0.0
Antrodia carbonica monokaryon								1			1	0.0
Postia placenta			5	1				70			76	3.0
Postia placenta monokaryon			11	1			2	27	1		42	1.7
Poria xantha monokaryon						1					1	0.0
Sistotrema brinkmanii			29							9	38	1.5
Stereum hirsutum			9	1		1	1		4	3	19	0.8
Poria cinerascens monokaryon									1		1	0.0
Phanerochaete sordida								1			1	0.0
Crustoderma dryinum							1	14			15	0.6
Crustoderma dryinum monokaryon										1	1	0.0
Phlebia A monokaryon									3		3	0.1
Phlebia C monokaryon								4			4	0.2
Phlebia C								1			1	0.0
Number of cores with basidiomycetes[1]		17	91	6	2	5	5	113	38	40	317	
Total number of cores taken		209	288	280	281	269	293	290	294	297	2501	
Percent cores with basidiomycetes		8.1	31.6	2.1	0.7	1.9	1.7	39.0	12.9	13.5	12.7	

[1]Does not equal the sum of the column because a core may contain more than one fungus.

Table IV-2d. FREQUENCY OF BASIDIOMYCETES ISOLATED FROM STERILIZED POLE SECTIONS FOLLOWING 3-MONTH EXPOSURES AT OROVILLE, CA.

		NUMBER OF CORES CONTAINING BASIDIOMYCETES										
FUNGI	Begin	8/81	11/81	02/82	05/82	08/82	11/82	02/83	05/83	12/83		
	End	11/81	02/82	05/82	08/82	11/82	02/83	05/83	08/83	03/84	Total	%
Unidentified basidiomycete		1	7							7	15	0.6
Unidentified without clamps		2	5	6	4	2		3	27	12	61	2.5
Trametes versicolor				1							1	0.0
Trametes versicolor monokaryon		2		1	1				4	1	8	0.3
Epicoccum nigra			1	1				1	3	4	6	0.2
Fomitopsis cajanderi monokaryon		1							1		2	0.1
Peniophora spp.		2	21	1					1	7	32	1.3
Phlebia A									1		1	0.0
Phlebia radiata monokaryon			1			1					2	0.1
Postia placenta			12					1			13	0.5
Postia placenta monokaryon			16					2		2	20	0.8
Poria xantha			3								3	0.1
Schizophyllum commune monokaryon									1		1	0.0
Sistotrema brinkmanii		2	2			1					5	0.2
Stereum hirsutum		1	25	7		2			3	19	57	2.3
Poria cinerascens			1							13	1	0.0
Poria cinerascens monokaryon						1					1	0.0
Phanerochaete sordida			17	2					3	4	26	1.1
Pleuroflammula puberula monokaryon									1		1	0.0
Crustoderma dryinum								1			1	0.0
Phlebia A monokaryon						1		5	2		8	0.3
Phlebia C monokaryon									1	1	2	0.1
Number of cores with basidiomycetes[1]		11	103	17	4	8	0	13	47	48	251	
Total number of cores taken		222	301	288	265	261	275	280	281	276	2449	
Percent cores with basidiomycetes		5.0	34.2	5.9	1.5	3.1	0.0	4.6	16.7	17.4	10.2	

[1]Does not equal the sum of the column because a core may contain more than one fungus.

Table IV-3. FREQUENCY OF BASIDIOMYCETES ISOLATED FROM STERILIZED POLE SECTIONS FOLLOWING 3-MONTH EXPOSURES AT FOUR LOCATIONS IN THE PACIFIC NORTHWEST.

		NUMBER OF CORES CONTAINING BASIDIOMYCETES										
FUNGI	Begin	7/81	10/81	01/82	05/82	07/82	10/82	01/83	05/83	12/83		
	End	10/81	01/82	05/82	07/82	10/82	01/83	04/83	07/83	03/84	Total	%
Unidentified basidiomycete		15	25	2	2	0	0	7	7	18	76	9.10
Unidentified without clamps		11	16	171	181	4	1	12	59	24	161	19.3
Trametes versicolor		0	0	2	0	3	0	0	0	1	6	.72
Trametes versicolor monokaryon		2	1	2	2	1	1	0	10	1	19	2.27
Epicoccum nigra		0	1	3	2	0	0	3	11	0	20	2.39
Fomitopsis cajanderi monokaryon		1	0	0	0	0	0	0	3	0	4	.48
Fomitopsis pinicola monokaryon		0	0	0	0	0	0	0	1	0	1	.12
Stereum sanguinolentum		0	5	3	0	0	0	0	0	10	18	2.15
Peniophora spp.		5	58	1	0	0	0	0	2	30	96	11.50
Phlebia A		0	0	0	0	0	0	0	1	1	2	11.50
Phlebia albida		0	1	0	0	0	0	0	0	1	2	.24
Phlebia radiata		1	1	0	0	0	0	0	0	0	2	.24
Phlebia radiata monokaryon		0	2	0	0	1	0	1	0	1	5	.60
Antrodia carbonica		1	0	0	1	0	0	0	0	0	2	.24
Antrodia carbonica monokaryon		1	0	0	0	0	0	1	0	0	2	.24
Postia placenta		3	20	3	5	0	0	72	0	0	103	12.33
Postia placenta monokaryon		5	37	2	3	3	2	30	5	2	89	10.66
Postia xantha		0	3	0	0	1	0	0	11	0	15	1.80
Poria xantha monokaryon		0	4	0	1	1	0	0	1	0	7	0.84
Schizophyllum commune monokaryon		0	0	0	0	0	0	0	1	0	11	.12
Sistrotrema brinkmanii		3	33	0	0	1	0	0	0	22	59	7.06
Stereum hirsutum		2	37	8	1	3	1	0	7	23	82	9.82
Poria cinerascens		0	1	0	0	0	0	0	0	0	1	.12
Poria cinerascens monokaryon		0	0	1	0	1	2	1	1	0	6	.72
Phanerochaete sordida		4	17	2	8	6	0	1	24	4	66	7.90
Pleuroflammula puberula monokaryon		0	0	0	0	0	0	0	1	0	1	.12
Crustoderma dryinum		0	1	0	0	0	1	16	0	0	18	2.15
Crustoderma dryinum monokaryon		0	1	0	0	0	0	0	0	1	2	.24
Phlebia A monokaryon		0	1	0	0	2	0	5	5	0	13	1.56
Phlebia gigantea		0	0	0	0	0	2	0	0	0	2	.24
Heterobasidion annosum		0	0	1	0	0	1	0	1	0	3	.36
Phlebia C monokaryon		0	0	0	0	0	0	4	5	1	10	1.20
Phlebia C		0	0	0	0	0	0	1	3	0	4	.48
Number of cores with basidiomycetes[1]		54	252	43	40	27	11	134	147	127	835	
Total number of cores taken		846	1180	1142	1070	1207	1082	1091	1233	1139	9990	
Percent cores with basidiomycetes		6.4	21.4	3.8	3.7	2.2	1.0	12.3	11.9	11.2	8.47	

[1]Does not equal the sum of the column because a core may contain more than one fungus.

TABLE IV-4a. FREQUENCY AND DISTRIBUTION OF BASIDIOMYCETES IN STERILIZED DOUGLAS-FIR POLE SECTIONS FOLLOWING 3-MONTH EXPOSURES IN ARLINGTON, WA.

FUNGI	CORES CONTAINING BASIDIOMYCETES											
	0.6 m SECTIONS				1.2 m SECTIONS							
	TOP		MIDDLE		TOP		UPPER		BUTT			
	NO.	%	NO.	%	NO.	%	NO.	%	NO.	%	Total	%
Unidentified basidiomycete	3	0.416	0	0.000	3	0.815	4	0.258	5	1.330	12	0.5
Unidentified without clamps	8	1.108	7	1.087	4	1.087	1	0.258	5	1.330	25	1.0
Trametes versicolor monokaryon	1	0.139	0	0.000	1	0.272	1	0.258	0	0.000	3	0.1
Epicoccum nigra	0	0.000	0	0.000	1	0.272	0	0.000	2	0.532	3	0.1
Stereum sanguinolentum	3	0.416	0	0.000	0	0.000	1	0.258	1	0.266	5	0.2
Peniophora spp.	5	0.693	3	0.466	2	0.543	6	1.546	1	0.266	17	0.7
Phlebia albida	0	0.000	0	0.000	1	0.272	0	0.000	1	0.266	2	0.1
Phlebia radiata	0	0.000	1	0.156	0	0.000	0	0.000	0	0.000	1	0.0
Phlebia radiata monokaryon	0	0.000	0	0.000	0	0.000	1	0.255	0	0.000	1	0.0
Antrodia carbonica	1	0.139	0	0.000	0	0.000	1	0.258	0	0.000	2	0.1
Antrodia carbonica monokaryon	1	0.139	0	0.000	0	0.000	0	0.000	0	0.000	1	0.0
Postia placenta	3	0.416	3	0.466	1	0.272	0	0.000	1	0.266	8	0.3
Postia placenta monokaryon	3	0.416	2	0.311	1	0.272	0	0.000	1	0.266	7	0.3
Poria xanthautum	2	0.277	2	0.311	3	0.815	3	0.773	2	0.532	12	0.5
Poria xantha monokaryon	2	0.277	0	0.000	0	0.000	0	0.000	0	0.000	2	0.1
Sistotrema brinkmanii	8	1.108	0	0.000	2	0.543	2	0.515	2	0.532	14	0.6
Stereum hirsutumnum	1	0.139	1	0.155	0	0.000	0	0.000	1	0.266	3	0.1
Poria cinerascens monokaryonon	1	0.139	0	0.000	0	0.000	0	0.000	0	0.000	1	0.0
Phanerochaete sordida monokaryon	3	0.416	1	0.155	3	0.815	5	1.290	3	0.798	15	0.6
Phlebia A monokaryoni	0	0.000	0	0.000	0	0.000	0	0.000	1	0.266	1	0.0
Phlebia gigantea	0	0.000	1	0.155	0	0.000	0	0.000	0	0.000	1	0.0
Number of cores with fungi	43		19		21		22		23		128	
Total cores taken	722		644		368		388		376		2498	
Percent cores with fungi	5.956		2.950		5.707		5.670		6.117		5.1	

TABLE 4b. FREQUENCY AND DISTRIBUTION OF BASIDIOMYCETES IN STERILIZED DOUGLAS-FIR POLE SECTIONS FOLLOWING 3-MONTH EXPOSURES IN SCAPPOOSE, OR.

FUNGI	CORES CONTAINING BASIDIOMYCETES											
	0.6 m FOOT SECTIONS				1.2 m SECTIONS							
	TOP		MIDDLE		TOP		UPPER		BUTT			
	NO.	%	NO.	%	NO.	%	NO.	%	NO.	%	Total	%
Unidentified basidiomycete	1	0.135	2	0.312	3	0.785	4	1.020	2	0.521	12	0.5
Unidentified without clamps	9	1.213	4	0.623	3	0.785	6	1.531	2	0.521	24	0.9
Trametes versicolor	0	0.000	1	0.156	0	0.000	0	0.000	0	0.000	1	0.0
Trametes versicolor monokaryon	0	0.000	2	0.312	0	0.000	0	0.000	0	0.000	2	0.1
Epicoccum nigra	1	0.135	0	0.000	1	0.262	0	0.000	1	0.260	1	0.1
Stereum sanguinolentum	4	0.539	0	0.000	0	0.000	0	0.000	0	0.000	4	0.2
Peniophora spp.	5	0.674	5	0.779	2	0.524	8	2.041	3	0.781	231	0.9
Phlebia A	0	0.000	0	0.000	1	0.262	0	0.000	0	0.000	1	0.0
Phlebia radiata	0	0.000	1	0.156	0	0.000	0	0.000	0	0.000	1	0.0
Phlebia radiata monokaryon	0	0.000	0	0.000	0	0.000	1	0.255	0	0.000	1	0.0
Postia placenta	2	0.270	0	0.000	0	0.000	1	0.255	3	0.781	6	0.2
Postia placenta monokaryon	9	1.213	1	0.156	3	0.785	5	1.276	2	0.521	20	0.8
Poria xantha monokaryon	0	0.000	0	0.000	2	0.524	1	0.255	1	0.260	4	0.2
Sistotrema brinkmanii	0	0.000	0	0.000	0	0.000	1	0.255	1	0.260	2	0.1
Stereum hirsutum	1	0.135	0	0.000	0	0.000	1	0.255	1	0.260	3	0.1
Poria cinerascens monokaryon	0	0.000	2	0.312	1	0.262	0	0.000	0	0.000	3	0.1
Phanerochaete sordida	5	0.674	2	0.312	7	1.832	6	1.531	4	1.042	24	0.9
Crustoderma dryinum	1	0.135	0	0.000	0	0.000	1	0.255	0	0.000	2	0.1
Crustoderma dryinum monokaryon	1	0.135	0	0.000	0	0.000	0	0.000	0	0.000	1	0.0
Phlebia A monokaryon	0	0.000	0	0.000	0	0.000	1	0.255	0	0.000	1	0.0
Phlebia gigantea	0	0.000	1	0.156	0	0.000	07	0.000	0	0.000	1	0.0
Heterobasidion annosum	0	0.000	1	0.156	0	0.000	0	0.000	2	0.521	3	0.1
Phlebia C monokaryon	3	0.404	0	0.000	1	0.262	0	0.000	0	0.000	4	0.2
Phlebia C	0	0.000	0	0.000	0	0.000	2	0.510	1	0.260	3	0.1
Number of cores with fungi	39		22		21		36		21		139	
Total cores taken	742		641		382		392		384		2542	
Percent cores with fungi	5.256		3.427		5.497		9.184		5.469		5.5	

TABLE IV-4c. FREQUENCY AND DISTRIBUTION OF BASIDIOMYCETES IN STERILIZED DOUGLAS-FIR POLE SECTIONS FOLLOWING 3-MONTH EXPOSURES IN EUGENE, OR.

FUNGI	CORES CONTAINING BASIDIOMYCETES											
	0.6m SECTIONS				1.2 m SECTIONS							
	TOP		MIDDLE		TOP		UPPER		BUTT			
	NO.	%	NO.	%	NO.	%	NO.	%	NO.	%	Total	%
Unidentified basidiomycete	16	2.156	4	0.609	4	1.084	7	1.918	6	1.630	37	1.5
Unidentified without clamps	15	2.022	20	3.044	4	1.084	5	1.370	7	1.902	51	2.0
Trametes versicolor	1	0.135	1	0.152	1	0.271	0	0.000	1	0.272	4	0.2
Trametes versicolor monokaryon	6	0.809	0	0.000	0	0.000	0	0.000	0	0.000	6	0.2
Epicoccum nigra	3	0.404	0	0.000	2	0.542	2	0.548	1	0.272	8	0.3
Fomitopsis cajanderi monokaryon	0	0.000	2	0.304	0	0.000	0	0.000	0	0.000	2	0.1
Fomitopsis pinicola monokaryon	1	0.135	0	0.000	0	0.000	0	0.000	0	0.000	1	0.0
Stereum sanguinolentum	6	0.809	2	0.304	1	0.271	0	0.000	0	0.000	9	0.4
Peniophora spp. monokaryon	1	0.135	6	0.913	3	0.813	12	3.288	2	0.543	24	1.0
Phlebia radiata monokaryon	0	0.000	0	0.000	1	0.271	0	0.000	0	0.000	1	0.0
Antrodia carbonica monokaryon	1	0.135	0	0.000	0	0.0000	0	0.000	0	0.000	1	0.0
Postia placenta	31	4.178	9	1.370	12	3.252	15	4.110	9	2.446	76	3.0
Postia placenta monokaryon	23	3.100	9	1.370	6	1.626	1	0.274	3	0.815	42	1.7
Poria xantha monokaryon	1	0.135	0	0.000	0	0.000	0	0.000	0	0.000	1	0.0
Sistotrema brinkmanii	15	2.022	10	1.522	4	1.084	4	1.096	5	1.359	38	1.5
Stereum hirsutums	6	0.809	9	1.370	2	0.542	0	0.000	2	0.543	19	0.8
Poria cinerascens monokaryon	0	0.000	1	0.152	0	0.000	0	0.000	0	0.000	1	0.0
Phanerochaete sordida	1	0.135	0	0.000	0	0.000	0	0.000	0	0.000	1	0.0
Crustoderma dryinum	5	0.674	0	0.000	4	1.084	4	1.096	2	0.543	15	0.6
Crustoderma dryinum monokaryon	1	0.135	0	0.000	0	0.000	0	0.000	0	0.000	1	0.0
Phlebia A monokaryon	2	0.270	1	0.152	0	0.000	0	0.000	0	0.000	3	0.1
Phlebia C monokaryon	1	0.135	1	0.157	1	0.271	0	0.000	1	0.272	4	0.2
Phlebia C	1	0.135	0	0.000	0	0.000	0	0.000	0	0.000	1	0.0
Number of cores with fungi	126		70		42		45		34		317	
Total cores taken	742		657		369		365		368		2501	
Percent cores with fungi	16.981		10.654		11.382		12.329		9.239		12.7	

TABLE IV-4d FREQUENCY AND DISTRIBUTION OF BASIDIOMYCETES IN STERILIZED DOUGLAS-FIR POLE SECTIONS FOLLOWING 3-MONTH EXPOSURES IN OROVILLE, CA.

FUNGI	CORES CONTAINING BASIDIOMYCETES											
	0.6 m SECTIONS				1.2 m SECTIONS							
	TOP		MIDDLE		TOP		UPPER		BUTT			
	NO.	%	NO.	%	NO.	%	NO.	%	NO.	%	Total	%
Unidentified basidiomycete	4	0.552	1	0.157	3	0.843	6	1.617	1	0.276	15	0.6
Unidentified without clamps	21	2.897	15	2.362	10	2.809	7	1.887	8	2.210	61	2.5
Trametes versicolor	1	0.138	0	0.000	0	0.000	0	0.000	0	0.000	1	0.0
Trametes versicolor monokaryon	5	0.690	1	0.157	2	0.562	0	0.000	0	0.000	8	0.3
Epicoccum nigra	1	0.138	0	0.000	2	0.562	0	0.000	3	0.829	6	0.2
Fomitopsis cajanderi monokaryon	0	0.000	0	0.000	1	0.281	0	0.000	1	0.276	2	0.1
Peniophora spp.	3	0.414	7	1.102	0	0.000	18	4.852	4	1.105	32	1.3
Phlebia	0	0.000	0	0.000	1	0.281	0	0.000	0	0.000	1	0.0
Phlebia radiata monokaryon	0	0.000	2	0.315	0	0.000	0	0.000	0	0.000	2	0.1
Postia placenta	3	0.414	4	0.630	1	0.281	2	0.539	3	0.829	13	0.5
Postia placenta monokaryon	6	0.828	2	0.315	6	1.685	4	1.078	2	0.552	20	0.8
Poria xanthanta	1	0.138	0	0.000	0	0.000	2	0.539	0	0.000	3	0.1
Schizophyllum commune monokaryon	0	0.000	1	0.157	0	0.000	0	0.000	0	0.000	1	0.0
Sistotrema brinkmanii	4	0.552	0	0.000	1	0.281	0	0.000	0	0.000	5	0.2
Stereum hirsutum	23	3.172	10	1.575	9	2.528	6	1.617	9	2.486	57	2.3
Poria cinerascens	1	0.138	0	0.000	2	0.000	0	0.000	0	0.000	1	0.0
Poria cinerascens monokaryon	0	0.000	0	0.000	1	0.281	0	0.000	0	0.000	1	0.0
Phanerochaete sordida	18	2.483	1	0.157	3	0.843	1	0.270	3	0.829	26	1.1
Pleuroflammula puberula monokaryon	0	0.000	0	0.000	0	0.000	0	0.000	1	0.276	1	0.0
Crustoderma dryinum	0	0.000	1	0.157	0	0.000	0	0.000	0	0.000	1	0.0
Phlebia A monokaryon	3	0.414	0	0.000	2	0.562	1	0.270	2	0.552	8	0.3
Phlebia C monokaryon	1	0.138	1	0.157	0	0.000	0	0.000	0	0.000	2	0.1
Number of cores with fungi	87		46		41		43		34		251	
Total cores taken	722		644		368		388		376		2498	
Percent cores with fungi	5.956		2.950		5.707		5.670		6.117		5.1	

TABLE IV-5. FREQUENCY AND DISTRIBUTION OF BASIDIOMYCETES ISOLATED FROM STERILIZED DOUGLAS-FIR POLE SECTIONS EXPOSED FOR THREE-MONTH INTERVALS AT FOUR SITES IN THE PACIFIC NORTHWEST.

FUNGI	CORES CONTAINING BASIDIOMYCETES											
	0.6 m SECTIONS				1.2 m SECTIONS							
	TOP		MIDDLE		TOP		UPPER		BUTT			
	NO.	%	NO.	%	NO.	%	NO.	%	NO.	%	Total	%
Unidentified basidiomycete	24	0.8	7	0.3	13	0.9	18	1.2	14	0.9	76	0.8
Unidentified without clamps	53	1.8	46	1.8	21	1.4	19	1.3	22	1.5	161	1.6
Coriolus versicolor	2	0.1	2	0.1	1	0.1	-	-	1	0.1	6	0.1
Coriolus versicolor monokaryon	12	0.4	3	0.1	3	0.2	1	0.1	-	-	19	0.2
Epicoccum nigra	5	0.2	-	-	6	0.4	2	0.1	7	0.5	20	0.2
Fomitopsis cajanderi monokaryon	-	-	2	0.1	1	0.1	-	-	1	0.1	4	0.0
Fomitopsis pinicola monokaryon	1	0.0	-	-	-	-	-	-	-	-	1	0.0
Stereum sanguinolentum	13	0.4	2	0.1	1	0.1	1	0.1	1	0.1	18	0.2
Peniophora spp.	14	0.5	21	0.8	7	0.5	44	2.9	10	0.7	96	1.0
Phlebia A	-	-	-	-	2	0.1	-	-	-	-	2	0.0
Phlebia albida	-	-	-	-	1	0.1	-	-	1	0.1	2	0.0
Phlebia radiata	-	-	1	0.0	-	-	1	0.1	-	-	2	0.0
Phlebia radiata monokaryon	-	-	2	0.1	1	0.1	2	0.1	-	-	5	0.1
Antrodia carbonica	1	0.0	-	-	-	-	1	0.1	-	-	2	0.0
Antrodia carbonica monocaryon	2	0.1	-	-	-	-	-	-	-	-	2	0.0
Postia placenta	39	1.3	16	0.6	14	0.9	18	1.2	16	1.1	103	1.0
Postia placenta monokaryon	41	1.4	14	0.5	16	1.1	10	0.7	8	0.5	89	0.9
Poria xantha	3	0.1	2	0.1	3	0.2	5	0.3	2	0.1	15	0.2
Poria xantha monokaryon	3	0.1	-	-	2	0.1	1	0.1	1	0.1	7	0.1
Schizophyllum commune monokaryon	-	-	1	0.0	-	-	-	-	-	-	1	0.0
Sistotrema brinkmanii	27	0.9	10	0.4	7	0.5	7	0.5	8	0.5	59	0.6
Stereum hirsutum	31	1.1	20	0.8	11	0.7	7	0.5	13	0.9	82	0.8
Poria cinerascens	1	0.0	-	-	-	-	-	-	-	-	1	0.0
Poria cinerascens monokaryon	1	0.0	3	0.1	2	0.1	-	-	-	-	6	0.1
Phanerochaete sordida	27	0.9	4	0.2	13	0.9	12	0.8	10	0.7	66	0.7
Pleuroflammula puberula monokaryon	-	-	-	-	-	-	0	0.0	1	0.1	1	0.0
Crustoderma dryinum	6	0.2	1	0.0	4	0.3	5	0.3	2	0.1	18	0.2
Crustoderma dryinum monokaryon	2	0.1	-	-	-	-	-	-	-	-	2	0.0
Phlebia A monokaryon	5	0.2	1	0.0	2	0.1	2	0.1	3	0.2	13	0.1
Phlebia gigantea	-	-	2	0.1	-	-	-	-	-	-	2	0.0
Heterobasidion annosum	-	-	1	0.0	-	-	-	-	2	0.1	3	0.0
Phlebia C monokaryon	5	0.2	2	0.1	2	0.1	-	-	1	0.1	10	0.1
Phlebia C	1	0.0	-	-	-	-	2	0.1	1	0.1	4	0.0
Number of cores with fungi	295		157		125		146		112		835	
Total number of cores taken	2931		2578		1475		1516		1490		9990	
Percent cores w/basidiomycetes	10.1		6.1		8.5		9.6		7.5		8.4	

IV-6a. Frequency and distribution of basidiomycetes in sterilized Douglas-fir pole sections following a 6-month exposure in Scappoose, OR.

	CORES CONTAINING BASIDIOMYCETES									
	0.6 m SECTIONS				1.2 m SECTIONS					
	TOP		MIDDLE		TOP		UPPER		BUTT	
FUNGI SPECIES	NO.	%	NO.	%	NO.	%	NO.	%	NO.	%
Unidentified basidiomycete	14	17.95	5	6.41	2	5.27	5	11.36	5	12.82
Unidentified without clamps	3	3.85	5	6.41	3	7.90	2	4.55	0	0.00
Androdia serialis	0	0.00	1	1.28	0	0.00	0	0.00	0	0.00
Peniophora spp.	0	0.00	2	2.56	1 2	2.63	1	2.27	0	0.00
Phlebia radiata	0	0.00	1	1.28	0	0.00	2	4.55	0	0.00
Phlebia radiata monokaryon	0	0.00	3	3.85	0	0.00	0	0.00	0	0.00
Postia placenta	38	48.72	6	7.69	15	39.47	6	13.64	12	30.77
Postia placenta monokaryon	11	14.10	4	5.13	5	13.16	9	20.46	9	23.08
Poria xantha	0	0.00	0	0.00	3	7.9	5	11.36	1	2.56
Poria xantha monokaryon	0	0.00	0	0.00	1	2.63	0	0.00	1	2.56
Sistotrema brinkmanii	0	0.00	1	1.28	0	0.00	0	0.00	0	0.00
Stereum hirsutum	1	1.28	6	7.69	1	2.63	0	0.00	0	0.00
Crustoderma dryinum	3	3.85	2	2.56	0	0.00	0	0.00	0	0.00
Phlebia A monokaryon	1	1.28	0	0.00	0	0.00	0	0.00	0	0.00
Phlebia gigantea	0	0.00	1	1.28	0	0.00	0	0.00	0	0.00
Phlebia C monokaryon	1	1.28	0	0.00	0	0.00	0	0.00	0	0.00
Phlebia C	0	1.28	0	0.00	0	0.00	0	0.00	0	0.00
Number of cores with fungi	58		34		26		23		24	
Total cores taken	78		78		38		44		39	
Percent cores with fungi	74.36		43.59		68.43		52.27		61.54	

IV-6b. Frequency and distribution of basidiomycetes in sterilized Douglas-fir pole sections following a 6-month exposure in Arlington, WA.

	CORES CONTAINING BASIDIOMYCETES									
	0.6 m SECTIONS				1.2 m SECTIONS					
	TOP		MIDDLE		TOP		UPPER		BUTT	
FUNGI SPECIES	NO.	%	NO.	%	NO.	%	NO.	%	NO.	%
Unidentified basidiomycete	10	12.50	2	2.50	2	5.00	0	0.00	0	0.00
Unidentified without clamps	4	5.00	1	1.25	2	5.00	0	0.00	1	2.50
Trametes versicolor monokaryon	0	0.00	0	0.00	0	0.00	1	2.08	0	0.00
Stereum sanguinolentum	3	3.75	4	5.00	0	0.00	1	2.08	1	2.50
Peniophora spp.	0	0.00	2	2.50	0	0.00	1	2.08	0	0.00
Phlebia albida	1	1.25	0	0.00	0	0.00	0	0.00	0	0.00
Phlebia albida monokaryon	1	1.25	0	0.00	0	0.00	0	0.00	0	0.00
Phlebia radiata	0	0.00	0	0.00	0	0.00	0	0.00	1	2.50
Phlebia radiata monokaryon	0	0.00	0	0.00	2	5.00	0	0.00	1	2.50
Postia placenta	1	1.25	0	0.00	1	2.50	0	0.00	0	0.00
Postia placenta monokaryon	4	5.00	2	2.50	1	2.50	1	2.08	1	2.50
Sistotrema brinkmanii	2	2.50	0	0.00	1	2.50	0	0.00	3	7.50
Stereum hirsutum	0	0.00	1	1.25	1	2.50	0	0.00	0	0.00
Phanerochaete sordida	1	1.25	0	0.00	0	0.00	0	0.00	0	0.00
Crustoderma dryinum	2	2.50	0	0.00	0	0.00	0	0.00	0	0.00
Crustoderma dryinum monokaryon	1	1.25	0	0.00	0	0.00	0	0.00	0	0.00
Phlebia C monokaryon	0	0.00	0	0.00	0	0.00	1	2.08	0	0.00
Number of cores with fungi	27		10		10		4		8	
Total cores taken	80		80		40		48		40	
Percent cores with fungi	33.75	12.50	25.00	8.33	20.00		52.27		61.54	

IV-6d. Frequency and distribution of basidiomycetes in sterilized Douglas-fir pole sections following a 6-month exposure in Oroville, CA.

	CORES CONTAINING BASIDIOMYCETES									
	0.6 m SECTIONS				1.2 m SECTIONS					
	TOP		MIDDLE		TOP		UPPER		BUTT	
FUNGI SPECIES	NO.	%	NO.	%	NO.	%	NO.	%	NO.	%
Unidentified basidiomycete	3	3.80	1	1.25	0	0.00	2	4.17	2	5.00
Unidentified without clamps	12	15.19	2	2.50	6	15.00	0	0.00	6	15.00
Trametes versicolor	0	0.00	0	0.00	0	0.00	0	0.00	1	2.50
Trametes versicolor monokaryon	0	0.00	0	0.00	0	0.00	1	2.08	0	0.00
Epicoccum nigra	1	1.27	0	0.00	1	2.50	1	2.08	1	2.50
Peniophora spp.	2	2.53	0	0.00	3	7.50	4	8.33	2	5.00
Postia placenta	6	7.60	3	3.75	1	2.50	1	2.08	2	5.00
Postia placenta monokaryon	3	3.80	12	15.00	5	12.50	5	10.42	3	7.50
Poria xantha	0	0.00	1	1.25	0	0.00	0	0.00	0	0.00
Poria xantha monokaryon	0	0.00	1	1.25	1	2.50	0	0.00	0	0.00
Stereum hirsutum	13	16.46	4	5.00	5	12.50	4	8.33	4	10.00
Phanerochaete sordida	3	3.80	0	0.00	1	2.50	1	2.08	0	0.00
Crustoderma dryinum	1	1.27	1	1.25	0	0.00	0	0.00	0	0.00
Number of cores with fungi	39		25		21		16		19	
Total cores taken	79		80		40		48		40	
Percent cores with fungi	49.37		31.25		52.50		33.33		47.50	

IV-6c. Frequency and distribution of basidiomycetes in sterilized Douglas-fir pole sections following a 6-month exposure in Eugene, OR.

	CORES CONTAINING BASIDIOMYCETES									
	0.6m SECTIONS				1.2 m SECTIONS					
	TOP		MIDDLE		TOP		UPPER		BUTT	
FUNGI SPECIES	NO.	%	NO.	%	NO.	%	NO.	%	NO.	%
Unidentified basidiomycete	12	15.00	4	5.00	3	7.50	3	7.50	0	0.00
Unidentified without clamps	0	0.00	2	2.50	1	2.50	0	0.00	2	5.00
Trametes versicolor	0	0.00	0	0.00	2	5.00	0	0.00	0	0.00
Fomitopsis pinicola	0	0.00	0	0.00	0	0.00	0	0.00	1	2.50
Stereum sanguinolentum	0	0.00	0	0.00	1	2.50	0	0.00	0	0.00
Peniophora spp.	0	0.00	0	0.00	0	0.00	2	5.00	0	0.00
Antrodia carbonica	0	0.00	1	1.25	0	0.00	0	0.00	0	0.00
Postia placenta	39	48.75	7	8.75	4	10.00	1	2.50	2	5.00
Postia placenta monokaryon	5	6.25	5	6.25	6	15.00	1	2.50	2	5.00
Poria xantha monokaryon	0	0.00	0	0.00	0	0.00	1	2.50	0	0.00
Sistotrema brinkmanii	1	1.25	3	3.75	3	7.50	0	0.00	4	10.00
Stereum hirsutum	2	2.50	6	7.50	1	2.50	0	0.00	1	2.50
Crustoderma dryinum	7	8.75	0	0.00	0	0.00	0	0.00	0	0.00
Phlebia A monokaryon	0	0.00	1	1.25	0	0.00	0	0.00	0	0.00
Number of cores with fungi	63		29		20		8		12	
Total cores taken	80		80		40		40		40	
Percent cores with fungi	78.75		36.25		50.00		20.00		30.00	

IV-7. Frequency and distribution of basidiomycetes in sterilized Douglas-fir pole sections following a 6-month exposure at 4 Pacific Northwestsites.

	CORES CONTAINING BASIDIOMYCETES									
	0.6 m SECTIONS				1.2 m SECTIONS					
	TOP		MIDDLE		TOP		UPPER		BUTT	
FUNGI SPECIES	NO.	%	NO.	%	NO.	%	NO.	%	NO.	%
Unidentified basidiomycete	39	12.30	12	3.77	7	4.43	10	5.56	7	4.40
Unidentified without clamps	19	5.99	10	3.15	12	7.60	2	1.11	9	5.66
Androdia serialis	0	0.00	1	0.31	0	0.00	0	0.00	0	0.00
Trametes versicolor	0	0.00	0	0.00	2	1.27	0	0.00	1	0.63
Trametes versicolor monokaryon	0	0.00	0	0.00	0	0.00	2	1.11	0	0.00
Epicoccum nigra	1	0.32	0	0.00	1	0.63	1	0.56	1	0.63
Fomitopsis pinicola	0	0.00	0	0.00	0	0.00	0	0.00	1	0.63
Stereum sanguinolentum	3	0.95	4	1.26	1	0.63	1	0.56	1	0.63
Peniophora spp.	2	0.63	4	1.26	4	2.53	8	4.44	2	1.26
Phlebia albida	1	0.32	0	0.00	0	0.00	0	0.00	0	0.00
Phlebia albida monokaryon	1	0.32	0	0.00	0	0.00	0	0.00	0	0.00
Phlebia radiata	0	0.00	1	0.31	0	0.00	2	1.11	1	0.63
Phlebia radiata monokaryon	0	0.00	3	0.94	2	1.27	0	0.00	1	0.63
Antrodia carbonica	0	0.00	1	0.31	0	0.00	0	0.00	0	0.00
Postia placenta	84	26.50	16	0.03	21	13.29	8	4.44	16	10.06
Postia placenta monokaryon	23	7.26	23	7.23	17	10.76	16	8.89	15	9.43
Poria xantha	0	0.00	1	0.31	3	1.90	5	2.78	1	0.63
Poria xantha monokaryon	0	0.00	1	0.31	2	1.27	1	0.56	1	0.63
Sistotrema brinkmanii	3	0.95	4	1.26	4	2.53	0	0.00	7	4.40
Stereum hirsutum	16	5.05	17	5.35	8	5.06	4	2.22	5	3.15
Phanerochaete sordida	4	1.26	0	0.00	1	0.63	1	0.56	0	0.00
Crustoderma dryinum	13	4.10	3	0.94	0	0.00	0	0.00	0	0.00
Crustoderma dryinum monokaryon	1	0.32	0	0.00	0	0.00	0	0.00	0	0.00
Phlebia A monokaryon	1	0.32	2	0.63	0	0.00	0	0.00	0	0.00
Phlebia gigantea	0	0.00	1	0.31	0	0.00	0	0.00	0	0.00
Phlebia C monokaryon	1	0.32	0	0.00	0	0.00	1	0.56	0	0.00
Phlebia C	1	0.32	0	0.00	0	0.00	0	0.00	0	0.00
Number of cores with fungi	187		98		77		51		63	
Total cores taken	317		318		158		180		159	
Percent cores with fungi	58.99		30.82		48.73		28.33		39.620	

TABLE IV-8. LOCATION (SAPWOOD VS. HEARTWOOD) OF DECAY FUNGI ISOLATED FROM DOULAS-FIR POLES AFTER 3 OR 6 MONTHS OF AIR-SEASONING AT 4 PACIFIC NORTHWEST SITES.

			Cores Containing Basidiomycetes			
Core position	3-month exposure period starting date	# cores removed	No data[1]	Sapwood only	Heartwood only	Entire core
Vertical top	8-81	329	2	4	7	11
	11-81	331	31	11	21	6
	2-82	321	2	6	3	9
	5-82	313	8	2	4	1
	8-82	353	0	2	4	1
	11-82	305	0	1	3	1
	2-83	305	0	16	17	19
	5-83	342	2	14	24	7
	12-83	332	0	42	5	9
	SUM	2931	45	90	88	64
Middle	8-81	--	--	-	--	--
	11-81	330	28	10	17	2
	2-82	319	0	1	3	1
	5-82	316	4	2	1	1
	8-82	347	1	2	3	1
	11-82	298	0	3	1	0
	2-83	304	0	14	5	3
	5-83	339	0	18	12	3
	12-83	325	0	18	1	2
	SUM	2578	33	68	43	13
	SUM FOR VERTICAL	5509	78	166	131	77
Horizontal top	8-81	158	2	3	3	2
	11-81	163	18	7	8	2
	2-82	160	2	3	4	1
	5-82	161	5	3	0	0
	8-82	176	0	1	3	1
	11-82	161	0	0	0	0
	2-83	160	0	13	2	4
	5-83	179	0	14	6	1
	12-83	157	0	12	5	0
	SUM	1475	27	56	31	11
Upper	8-81	190	2	7	3	1
	11-81	193	32	12	14	3
	2-82	182	0	1	1	0
	5-82	118	2	0	1	1
	8-82	156	0	2	0	1
	11-82	158	0	1	0	0
	2-83	160	0	15	1	6
	12-83	197	0	18	7	0
	SUM	162	0	14	0	1
		1516	36	70	27	13
Butt	8-81	169	2	0	5	0
	11-81	163	21	0	0	1
	2-82	160	1	2	2	1
	5-82	162	4	1	0	0
	8-82	175	0	10	5	4
	11-82	160	0	15	5	1
	2-83	162	0	16	0	2
	5-83	176	0	50	25	9
	12-83	163	28	176	83	33
	SUM	1490	91	342	214	110
	SUM FOR HORIZ.	4481	169			
	TOTAL	9990				
	Six-month exposure period					
Vertical top	11-81	317	30	22	77	58
middle		318	14	26	28	30
	SUM FOR VERT.	635	44	48	105	88
Horizontal top		158	12	13	30	22
upper		180	11	3	11	26
butt		159	13	11	14	25
	SUM FOR HORIZ.	497	36	27	55	73
	TOTAL	1132	80	75	160	161

[1] Location of fungus in core could not be determined or was not noted.

TABLE IV-9. Number of decay fungi isolated per increment core removed from Douglas-fir pole sections air-seasoned for 3 or 6 months at four Pacific Northwest sites.

Three-month exposure period starting date	NUMBER OF DECAY FUNGI ISOLATED PER CORE		
	1 fungus per core	2 fungi per core	3 fungi per core
8-81	54	0	0
11-81	253	12	0
2-82	43	3	0
5-82	40	2	0
8-82	27	0	0
11-82	11	0	0
2-83	115	19	0
5-83	147	11	1
12-83	109	17	1
TOTAL	799	64	2
%	92.4	7.4	0.2
Six-month exposure period starting date			
11-81	426	45	5
%	89.5	9.5	1.0

After 3 months, colonization was greater in sapwood than in heartwood, reflecting the fact that sapwood contained more easily available nutrients for fungal growth than heartwood. Also, checks which allow entry and growth of funal spores were relatively shallow at 3 months. After 6 months, however, when checks had deepened and nutrients were probably less abundant in sapwood, fungi were isolated more often from heartwood or from the entire core than from sapwood only (Table IV-8).

Most of the colonized cores yielded only on basidiomycete, even after 6 months of air-seasoning when individual decay colonies would have grown extensively through the wood (Table IV-9). This suggests competition among various fungal species for wood substrate.

Effect of wood moisture content on colonization: Wood moisture content (MC) (should have a significant influence on the degree of fungal colonization. In general, wood moisture contents below 30 % should limit fungal colonization, although preexisting infestations might still survive in the wood. While wood moisture content can vary widely, selected examination of MC at various depths in the wood can provide a guide to the risk of fungal attack and many utilities specify a pretreatment moisture level to ensure that poles are dry prior to treatment and that checks have formed.

There appeared to be little difference in average moisture content in the 2 or 4 foot long sections, despite their different orientations (Table IV-10,11). Average moisture content at the end of the 3 month exposure periods ranged from 8 % in Oroville, CA to 42 % at Arlington, WA. With the exceptions of the Nov. to Jan. exposure periods in Scappoose, Arlington and Eugene, moisture levels at 5 cm were generally below 25 %, the level most often specified by utilities as a pretreatment MC. Thus, most air-seasoning for the purpose of drying the zone

TABLE IV-10. MOISTURE CONTENT OF STERILIZED 0.6 m LONG POLE SECTIONS FOLLOWING 3- OR 6-MONTH EXPOSURES AT FOUR PACIFIC NORTHWEST SITES

Seasoning Interval Beginning		MOISTURE CONTENT (%)									
	cm from top:	2.5			15.0			30.0			AVG.
	cm from surface:	1.25	2.5	5.0	1.25	2.5	5.0	1.25	2.5	5.0	
SCAPPOOSE											
07-81		26	29	31	21	20	23	22	22	24	24
10-81		37	43	51	36	38	37	41	43	38	40
10-81 (6 mo)		12	12	12	12	12	12	11	12	12	12
01-82		12	14	17	14	17	23	15	18	24	17
05-82		16	17	16	15	18	24	15	19	25	18
07-82		18	21	26	16	18	22	16	18	21	20
10-82		30	38	40	28	28	26	27	29	26	30
01-83		13	15	17	17	22	27	17	21	26	19
04-83		12	13	14	14	18	22	15	17	21	16
12-83		28	29	37	32	33	36	34	34	37	33
ARLINGTON											
08-81		29	28	32	27	24	26	30	26	26	28
11-81		36	38	46	41	40	38	49	47	43	42
11-81(6 mo.)		15	16	19	15	19	25	17	20	26	19
02-82		17	17	21	17	19	24	17	19	24	19
05-82		7	7	8	14	18	24	15	19	25	15
08-82		13	15	19	14	16	20	14	17	20	16
11-82		22	30	33	20	28	26	22	28	26	26
02-83		20	22	27	20	22	25	20	22	25	23
05-83		10	12	12	14	17	20	14	17	20	15
12-83		25	29	30	27	28	31	28	30	30	29
OROVILLE, CA.											
08-81		30	24	30	24	19	18	20	16	19	22
11-81		34	33	32	32	33	34	34	33	40	22
11-81 (6 mo)		7	7	8	10	10	11	10	11	11	9
02-82		9	9	10	10	11	11	10	11	11	10
05-82		6	6	7	7	8	10	8	10	8	8
08-82		9	11	14	10	12	14	10	11	14	12
11-82		16	19	22	18	22	24	18	21	23	20
02-83		9	13	14	11	15	19	11	15	19	14
05-83		9	10	9	9	9	11	9	10	13	10
12-83		13	15	18	17	21	27	17	21	27	20
EUGENE, OR.											
08-81		28	28	35	24	22	25	23	21	24	26
11-81		29	34	40	35	42	38	42	52	38	39
11-81		13	15	20	13	16	22	12	15	23	17
02-82		13	13	14	14	16	20	14	16	22	16
05-82		7	7	8	12	13	18	13	16	22	13
08-82		10	12	17	11	15	21	11	14	20	15
11-82		25	29	35	27	30	31	26	26	28	29
02-83		10	12	14	15	19	26	16	21	27	18
05-83		8	9	9	11	14	17	12	14	18	12
12-83		27	28	33	26	27	31	27	28	31	29

which will be treated with chemical can be readily accomplished over a three month period. Further seasoning, however, will decrease internal moisture content and enhance the development of checks. Checks which develop prior to treatment will be more likely to be preservative treated, potentially reducing the risk of internal decay development in service.

Moisture levels at the same seasoning site appeared to vary widely with exposure period, reflecting seasonal variations in temperature and rainfall. Except for some winter exposure periods, moisture levels 5 cm from the surface were approaching or below 25 to 30 %, the fiber saturation point and the point below which most fungal growth ceases. Although it was not possible to measure, moisture levels deeper in the wood should be correspondlingly higher than those found near the surface. The only exception in these results occurred at Oroville, CA where a combination of very hot dry conditions produced fairly rapid drying over nearly every exposure period. In longer term studies, fungal colonization was consistently lower at Oroville, reflecting the rapid drying conditions which limited subsequent growth of those fungi which managed to colonize the wood.

Relationship between climate and fungal colonization: The amount of rainfall and average temperature should play critical roles in the colonization of air-seasoning logs. Moisture is critical for spore germination, while increased temperatures should, to an extent, increase the rate of mycelial growth once the fungus colonizes the wood. Conversely, drier conditions decrease spore germination and result in more rapid drying which may limit fungal growth through the wood.

Examination of plots of rainfall and temperature data for each of the air-seasoning sites and exposure periods produced a confusing array with only a minimal relationship between moisture, temperature and fungal colonization (Figure IV-1). One difficulty in dealing with

temperature data was the need to choose average temperature as the bench mark for a given site. Average temperature may ignore the difference between sites with widely divergent highs and lows and those where the daily high and low temperatures are more moderate. While both sites may have the same average temperature, the conditions for germination and growth of fungal spores differ dramatically. In addition, each site may have microclimatic differences from the site where weather measurements were made. While it was difficult to make accurate comparisons between climate and fungal colonization, there are an array of other factors which affect spore germination which are not reflected in the data. While there appeared to be relationships between the various parameters, these were often contradicted at other sites or at the same site during a different period.

As an alternative to simple comparisons between rainfall, temperature and colonization, Climate Index (CI) can provide a relative measure of the risk of decay above ground.

Climate Indices were developed by T.C. Scheffer on a broader basis to describe decay hazard across the United States. The index provides a relative measure of the relationship between temperature and rainfall, and is especially useful for wood exposed out of ground contact. We modified the climate index to account for different exposure durations. The result was a number indicative of the relative hazard of fungal colonization which ranged from 0 to 12 (low to high decay hazard) (Table IV-12). Climate index should be strongly correlated with colonization; however, there was no consistent pattern between climate index and fungal colonization for the same period. CI vs % cores with decay fungi had an R^2 of 0.012 for all yards combined and R^2 ranging from 0.023 to 0.088 for individual yards (where a value of 1.00 is a perfect correlation). The absence of relationships between moisture and colonization may reflect the wide array of variables which might influence colonization. Inoculum density and

TABLE IV-11. MOISTURE CONTENT OF STERILIZED 1.2 m POLE SECTIONS FOLLOWING THREE- OR SIX-MONTH EXPOSURES AT FOUR PACIFIC NORTHWEST SITES.

	MOISTURE CONTENT (%)												
Cm from end:	2.5			22.5			45			60			
Cm from surface:	1.25	2.5	5.0	1.25	2.5	5.0	1.25	2.5	5.0	1.25	2.5	5.0	Avg.
Seasoning interval beginning	**SCAPPOOSE**												
07-81	26	27	28	22	21	23	22	21	24	23	22	25	24
10-81	35	37	40	45	44	37	47	49	37	49	50	37	42
10-81 (6 mo.)	13	14	15	13	20	29	15	21	29	15	19	29	19
01-82	8	10	11	13	17	23	13	16	21	13	17	21	15
05-82	13	13	14	15	18	25	17	18	26	16	18	25	18
07-82	17	21	25	15	18	20	16	19	21	16	18	21	19
10-82	32	37	38	32	30	26	28	27	25	29	27	25	30
01-83	16	19	21	16	22	25	16	22	26	17	22	27	21
04-83	12	14	16	15	21	24	16	22	27	18	24	29	20
12-83	30	34	33	33	39	36	35	39	36	35	40	37	36
	ARLINGTON												
08-81	31	31	36	29	26	28	29	26	28	26	24	28	29
11-81	35	37	42	41	42	37	44	45	38	46	43	38	41
11-81 (6 mo.)	14	14	15	19	21	24	19	21	25	19	22	25	20
02-82	14	14	14	15	18	23	16	19	23	18	20	24	18
05-82	10	11	11	16	20	25	15	20	25	15	20	27	18
08-82	13	16	22	15	18	24	15	19	24	15	18	24	19
11-82	24	30	30	21	25	28	23	27	27	23	26	27	26
02-83	24	27	30	20	23	27	21	24	27	21	24	27	25
05-83	11	14	15	13	18	22	13	18	22	13	18	21	17
12-83	27	32	33	29	34	35	30	36	35	30	35	35	33
	OROVILLE, CA												
08-81	30	26	27	26	22	24	29	26	25	28	24	23	26
11-81	40	39	37	40	39	38	45	42	40	41	41	39	40
11-81 (6 mo.)	7	8	9	11	11	12	11	11	12	11	11	12	11
02-82	8	8	9	11	12	12	11	12	12	11	12	12	11
05-82	6	6	7	8	9	12	9	11	14	9	11	14	10
08-82	9	12	13	10	12	14	10	12	14	10	12	15	12
11-82	20	22	25	21	23	24	21	24	25	22	24	25	23
02-83	11	11	12	11	14	20	11	15	21	12	16	22	15
05-83	8	9	9	9	9	11	9	10	13	9	11	13	10
12-83	14	16	17	18	22	26	18	22	26	18	23	27	21
	EUGENE, OR												
08-81	34	32	35	34	30	27	33	31	28	32	28	30	31
11-81	30	35	36	35	46	36	41	53	39	39	51	39	40
11-81 (6 mo.)	16	17	17	14	16	23	14	17	23	14	16	23	18
02-82	12	14	15	14	17	23	15	18	24	15	17	24	17
05-82	7	8	9	11	14	21	12	15	22	11	14	21	14
08-82	11	13	18	12	15	20	12	15	21	12	15	21	15
11-82	28	34	37	28	34	35	30	36	35	34	38	36	34
02-83	12	14	16	15	23	31	14	22	32	14	20	30	20
05-83	9	10	11	12	15	19	13	16	20	13	16	20	15
12-83	27	29	32	30	30	33	30	31	33	30	30	33	31

Table IV-12. Comparison between number of days with precipitation, average daily temperature, climate index (CI) and percentage of increment cores containing decay fungi in Douglas-fir poles seasoned for 3 month periods at four Pacific Northwest sites.

SITE	EXPOSURE PERIOD	TOTAL DAYS	NO. DAYS WITH PERCIP. = >0.01	AVG. TEMP.	C.I.	% CORES WITH DECAY	CI vs. % Fungal Colonization (R^2)[1]
Scappoose	07-27-81 10-30-81	95	23	64	7.02	6.6	
	10-30-81 01-28-82	90	65	44	6.50	15.3	
	01-28-82 05-19-82	111	53	48	6.21	5.2	
	05-19-82 07-30-82	72	16	66	6.89	3.1	
	07-30-82 10-27-82	89	32	63	10.07	1.1	
	10-27-82 01-24-83	89	50	43	4.49	1.1	
	01-24-83 04-26-83	92	59	50	9.62	2.7	
	04-26-83 07-26-83	91	39	59	12.00	11.4	
	12-01-83 03-02-84	92	48	39	3.13	2.1	0.068
Arlington	08-03-81 11-03-81	92	30	60	8.15	5.9	
	11-03-81 02-03-82	92	60	44	5.87	4.6	
	02-03-82 05-04-82	90	41	48	5.92	1.7	
	05-04-82 08-03-82	91	18	62	5.34	9.7	
	08-03-82 11-04-82	93	35	57	8.28	3.2	
	11-03-82 02-03-83	92	48	44	4.70	1.2	
	02-04-83 05-04-83	89	47	51	8.45	0.4	
	05-04-83 08-02-83	90	31	62	9.30	7.4	
	12-05-83 03-08-84	94	46	43	3.91	11.7	0.088
Oroville	08-10-81 11-10-81	92	10	70	3.80	5	
	11-10-81 02-10-82	92	37	49	5.63	34.2	
	02-10-82 05-11-82	90	28	56	6.53	5.9	
	05-11-82 08-07-82	88	8	75	3.64	1.5	
	08-07-82 11-11-82	96	17	67	5.67	3.1	
	11-11-82 02-17-83	98	46	49	6.57	0	
	02-17-83 05-26-83	98	45	58	10.56	4.6	
	05-26-83 08-23-83	89	5	77	2.36	16.7	
	12-20-83 03-21-84	92	25	50	4.08	17.4	0.051
Eugene	08-07-81 11-16-81	101	31	57	6.75	8.1	
	11-16-81 02-18-82	94	54	40	2.87	31.6	
	02-18-82 05-20-82	92	42	47	5.48	2.1	
	05-20-82 08-26-82	90	17	64	5.03	0.7	
	08-26-82 11-16-82	82	31	53	6.80	1.9	
	11-16-82 02-11-83	87	50	41	3.45	1.7	
	02-11-83 05-23-83	101	56	50	8.32	39.0	
	05-23-83 08-19-83	88	21	63	6.68	12.9	
	12-09-83 03-19-84	101	51	42	3.53	13.5	0.023
TOTAL							0.012

[1] where R = 1.00 represents a perfect correlation and 0 represents no relationship between the variables.

species makeup should change seasonally. For example, species sporulate at different times in the year and spores produced at certain time periods are more likely to find conditions suitable for growth. Furthermore, small changes in climate prior to the exposure period may alter sporulation patterns in subsequent periods. Drought, for example, might sharply decrease subsequent sporulation, decreasing the inoculum potential many months after the climatic change. Alternatively, many basidiomycetes take several years to produce fruiting bodies. Thus, earlier unfavorable conditions at a given site may decrease the frequency of a given fungus thereby reducing the inoculum load. As a result, moisture and temperature during the actual exposure period may have a less noticeable effect on colonization of wet wood. To explore this possibility, the climate indices for the 3-month period immediately prior to wood exposure as well as the 3-month period 6 months prior to wood exposure were regressed against % colonization. The results of these analyses were also poor ($r^2 = 0.026$ and 0.021).

The other factor which could not be controlled in this study was site. Inoculum density should be correlated with the amount of woody debris in the zone around the air-seasoning site. While the sites used for exposure were relatively clean, the zones around the sites were not under the direct control of the operator. The best example of this situation was at Eugene, which had several wood processing operations within two miles of the plant. Each of these other operations had collections of woody debris which could act as a potent inoculum source. This site had higher levels of colonization by P. placenta than any other site and longer exposures indicated that this had a substantial effect on the colonization of the air-seasoning poles. Although it would be impossible to completely control infestation by this fungus, the presence of high inoculum levels might alter pole handling characteristics to minimize the length of exposure to potential colonization. Since moisture levels in the zone to be treated decline to pretreatment requirements within 3 months after peeling, shorter air-seasoning cycles may be prudent in sites where the risk of infection is high.

The results of our observations indicate the air-seasoning Douglas-fir poles are rapidly colonized by a wide array of basidiomycetes. While these fungi are not likely to have caused significant strength effects over the relatively short exposure period, their presence emphasizes the importance of incorporating an adequate sterilization process at some point in the treatment cycle.

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

The studies to identify methods for preventing fungal colonization using borate or ammonium bifluoride treatments are now complete. Both treatments proved effective at limiting the frequency of fungal colonization although neither could completely prevent colonization. The current regulations regarding the release of chemicals in the treating plant are likely to limit the potential application of regular spraying of air-seasoning poles to prevent fungalcolonization, although dipping in a concentrated solution of boron may still be practical.

Alternatively, poles must be adequately heated during the pressure treatment cycle to eliminated decay fungi which become established during the air-seasoning period. Previously, we have developed heating curves for different depths in Douglas-fir poles during treatment with pentachlorophenol in heavy oil, penta in liquified petroleum gas, and ammoniacal copper arsenate. The results of the latter treatment were used to develop curves for predicting steaming times to achieve sterilization for poles of various diameters.

We plan to collect additional data on pentachlorophenol in heavy oil charges in the coming year to develop similar heating curves for this treatment. In addition, we plan to collect temperature profiles for poles during kiln drying to assess the effect of this process on

elimination of fungi established in Douglas-fir poles. Kiln drying is increasingly employed to reduce inventory needs and speed drying, but its effect on sterilization remains poorly understood.

OBJECTIVE V
PERFORMANCE OF MODIFIED GROUNDLINE PRESERVATIVE SYSTEMS

A. EFFICACY OF MODIFIED GROUNDLINE WRAPS ON UNTREATED DOUGLAS-FIR POLE SECTIONS

While Douglas-fir treated with creosote, CCA, ACZA or pentachlorophenol in heavy oil does not normally experience extensive groundline decay, many utilites incorporate wraps into their maintenance programs where this species is set in concrete or when an existing pole is moved to a new location.

Until recently, these preservative systems were composed of mixtures which included virtually all of the commonly used wood preservatives; however, increasing environmental regulations have stimulated the elimination of many of these formulations and the substitution of systems containing copper naphthenate and either sodium fluoride or borates. While these chemicals have been available for many years, their efficacy in groundline wrap systems remains untested.

In 1989, a test to evaluate the effectiveness of a variety of reformualted groundline preservative systems was installed. Freshly peeled Douglas-fir pole sections (25 to 30 cm in diameter by 1.8 m long) were obtained from a local cooperator. These poles were stored for 6 months undercover to permit some drying to occur. Five pole sections each were treated with one of the following preservative formulations:

CUNAP WRAP (Tenino Wood Preservatives, Inc) containing 2 % copper naphthenate on an absorbant pad with a plastic barrier.

Cu-RAP 20 (Chapman Chemical Co.) a paste containing 18.16 % amine based copper naphthenate and 40 % sodium tetraborate decahydrate.

POL-NU 15-15 (Chapman Chemical Co.) a grease containng 12.9 % pentachlorophenol, 15.5 % creosote, and 1.5 % chlorinated phenols to serve as an accepted standard.

Pol-Nu (Chapman Chemical Co.) a grease containing 10.2 % pentachlorophenol

COP-R-RAP (Osmose Wood Preserving Co.) a grease containing 19.25 % copper naphthenate.

CRP-82631 (Osmose Wood Preserving Co.) a paste containing 19.25 % copper naphthenate and 45 % sodium fluoride.

The pastes were applied according to the manufacturer's guidelines and polyethylene wrap was applied to those which were not self-contained. The pole sections were set to a depth of 45 cm in the ground. Poles were capped with roofing felt to prevent water absorption and minimize the risk of above ground decay.

After 18 months of exposure, the pole sections were sampled by removing 1 cm diameter plugs at 3 points around the pole 15 cm below the groundline. The plugs were divided into segments corresponding to 0 to 3, 4 to 9, 10 to 15, and 16 to 25 mm from the wood surface. Segments from the same zone were combined for a given treatment group. The wood was ground to pass a 20 mesh screen and analyzed for residual chemical content. Copper or pentachlorophenol were determined using an ASOMA 8620 x-ray fluorescence analyzer. Previous laboratory studies has shown a high correlation between copper level as determined by x-ray and that determined using atomic absorption spectroscopy.

Borate analysis as performed by ashing the samples, adding 3 drops of 6 N HCl to the residue and washing the acidified residue into a beaker with hot water. The residue was stirred for 5 minutes, then filtered through Whatman # 4 filter paper. The filter paper was washed 3 times with 10 ml of hot water and the resulting solution was diluted to 250 ml in a volumetric flask. One ml of this solution was pipetted into a 1 cm cuvette along with 1 ml of ammonium acetate buffer (250 g ammonium acetate, 15 g disodium EDTA, 125 ml acetic acid, and 400 ml distilled water). One ml of Azomethine-H-reagent (1.0 g ascorbic acid

and 0.45 g Azomethine-H per 100 ml distilled water) was added and the absorbance of the resulting solution at 420 nm was measured 30 to 40 minutes after addition of the Azomethine-H. Boron concentration was calculated by comparison with absorbances obtained with standard boron solutions. Although this technique has been reported to be reliable for wood analysis, questions have been raised about the validity of the ashing procedure. Therefore, the boron analysis should be used to compare relative levels and not be compared with results with other chemicals. Fluoride analysis was performed by ashing the wood samples in sodium carbonate and analyzing the distillate for fluoride using a specific ion electrode (fluoride analyses were performed on a blind basis by R. Ziobro, Osmose Wood Preserving).

Untreated control poles have already begun to experience noticeable surface decay 18 months after installation, while all of the chemically treated poles were sound below the groundline. In many instances, preservative had migrated upward for short distances from the gorundline in the treated poles.

Chemical analysis revealed that all of the chemicals tested were detected 2.5 cm below the wood surface, indicating that each was capable of moving for some distance into the wood (Table V-1).

As expected, levels of all chemicals declined rapidly from the surface inward, reflecting depletion from the higher surface loadings. Levels of both copper and pentachlorophenol declined most rapidly, reflecting their lower water solubility. Copper naphthenate levels ranged from 0.16 to .239 pcf of copper in in outer zone (0 to 3 mm), far exceeding the requirements of the American Wood Preservers' Association. Copper levels further into the wood remained highest with the Cunap wrap, perhaps reflecting the less viscous nature of this formulation. Penta levels followed a trend similar to that found with copper naphthenate. Interestingly, penta levels were higher in the formulation

TABLE V-1. CHEMICAL CONTENT OF DOUGLAS-FIR POSTS 18 MONTHS AFTER TREATMENT WITH SELECTED GROUNDLINE BANDAGE SYSTEMS.

Average Chemical Level[a]																
	COPPER				PENTA				BORON				SODIUM FLUORIDE			
Chemical Treatment	a	b	c	d	a	b	c	d	a	b	c	d	a	b	c	d
	(pcf)				(pcf)				(% BAE)				(% wt/wt)			
Cunap wrap	0.160	0.100	0.045	0.015	-	-	-	-	-	-	-	-	-	-	-	-
CuRap 20	0.210	0.046	0.007	0.001	-	-	-	-	0.170	0.136	0.085	0.049	-	-	-	-
Pol-Nu 15-15	-	-	-	-	0.214	0.085	0.032	0.007	-	-	-	-	-	-	-	-
Pol-Nu	-	-	-	-	0.392	0.161	0.053	0.012	-	-	-	-	-	-	-	-
Cop-R-Rap	0.169	0.043	0.015	0.004	-	-	-	-	-	-	-	-	-	-	-	-
CRP-82631	0.239	0.067	0.025	0.007	-	-	-	-	-	-	-	-	2.38	1.21	0.55	0.35

a) Zones correspond to 0 to 3mm (a), 4 to 9mm (b), 10 to 15mm (c), and (d), 16-25mm from the wood surface.

containing a slightly small percentage of penta. This should not pose a problem, since other components present in the less concentrated penta formulation should provide additional protection. The results do, however, illustrate the potential for substantial differences in chemical movement with minor changes in formulation and highlight the need to verify field performance when such changes are made.

Fluoride levels were far higher than those for boron. Fluoride levels detected were considerably greater than those found by previous researchers using a sodium fluoride/coal-tar creosote paste with similar levels of sodium fluoride. The reasons for these differences are unclear, but may again reflect the effects of the co-biocide in these formulations.

Laboratory studies indicate that boron moves rapidly through Douglas-fir heartwood and remains at elevated levels near the surface, even 6 months after treatment. Previous studies on southern pine also suggest that boron should be present at high levels near the surface, while our field data suggest that the surface loadings will continue to decrease to levels below those required to prevent renewed fungal attack. However, the presence of copper naphthenate should minimize the risk of decay in these posts.

All of the groundline chemical treatments appear to be capable of moving through Douglas-fir sapwood to the depth sampled. While there are noticeable differences in the degree of chemical movement into the wood, the short exposure period prevents separation of individual formulations on the basis of performance against biological attack.

These pole sections will be further evaluated this year to determine if chemical levels are continuing to rise within the wood and to begin monitoring the incidence of fungal colonization of the wood.

B. PERFORMANCE OF GROUNDLINE PRESERVATIVE SYSTEMS IN DOUGLAS-FIR, WESTERN REDCEDAR AND PONDEROSA PINE UTILITY POLES

While the field trial described in the first section of this Objective will provide valuable data on the movement of the various preservative systems into Douglas-fir sapwood, the test site receives a moderate amount of moisture and does not reflect conditions in many other regions of the western United States. Additional data on the performance of groundline preservatives will be developed by establishing a test site in California.

Douglas-fir, western redcedar and ponderosa pine poles which had been in service for 10 or more years were selected for study. Three 5 cm long cores (9 mm in diameter) were removed from sites 15 cm below the groundline zone of each test pole. The cores from a given pole were combined and the wood was ground for analysis of chemical content using an x-ray fluorescence analyzer. These results were used to segregate the poles into treatment groups containing equal numbers of poles treated to similar retentions (Table V-2).

Each treatment group of 9 poles per species was then treated with one of three groundline preservatives: CUNAP Wrap (Tenino Wood Preserveratives Inc.), CURAP 20 (Chapman Chemical Co.), or Patox II (Osmose Wood Preserving Co.). The composition of these formulations was discussed in the first section of this objective. Wraps were applied from a zone extending 8 cm above the groundline to 45 cm below the groundline. Soil was then replaced around the pole, taking care not to disturb the wrap.

The poles will be sampled 1, 3, 5, 7, and 10 years after installation by removing plugs from sites adjacent to the original assay sites. These plugs will be segmented into zones corresponding to 0 to 3, 4 to 9, 10 to 15, and 16 to 25 mm from the wood surface and analyzed for the appropriate chemical components as described in the first section of this objective. In addition to chemical evaluations, the condition of the wood at the time of inspection will be visually assessed to provide a gross comparison between chemical level and degree of protection.

C. DIFFUSION OF A COPPER NAPHTHENATE/BORON PASTE THROUGH DOUGLAS-FIR HEARTWOOD

Pressure treatment with preservatives dramatically enhances the service life of wood; however, some wood species remain susceptible to surface decay caused by a combination of depletion of preservative and the development of a preservative tolerant microflora in the surrounding soil. To limit this damage, supplemental preservative pastes are applied to the wood surface and are covered with plastic or paper wraps. Until recently, these pastes were composed of various mixtures of creosote, pentachlorophenol, arsenic pentoxide, sodium fluoride, sodium dinitrophenol, and sodium dichromate; however, increasing environmental regulations and concerns have resulted in a shift to formulations containing copper naphthenate, sodium fluoride, or boron. While the biocidal efficacy of each of these chemicals is well documented, the ability of each chemical to move into and protect the wood has only been studied in southern pine poles. In this report, we describe studies of the movement of a copper naphthenate/boron paste through Douglas-fir heartwood maintained at two moisture levels.

Treatment and Exposure: Douglas-fir heartwood cubes (10 X 10 X 10 cm) were pressure-soaked with water and air-equilibrated to either 30 or 60 % moisture content (MC). The equilibrated blocks were triple-coated with paraffin to retard further moisture loss. A flat-bottomed treatment hole (2.5 cm in diameter by 3 mm deep) was drilled into the center of either the transverse or tangential face of each block and 5 g of a paste composed of 18.16 % copper naphthenate and 40 % sodium tetraborate decahydrate (POL-NU CuRAP 20, Chapman Chemical Company, Memphis, TN) was placed into the hole. The hole was covered with heavy duty tape and resealed with molten paraffin. The blocks were maintained at room temperature (22 to 25 C) and oriented with the grain running vertically, providing for perpendicular radial diffusion and parallel longitudinal diffusion with respect to gravitational forces. Selected blocks were destructively sampled 1, 2, 3, or 6 months after treatment.

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

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

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

2. Sampling and Chemical Assays: Following each exposure time, 5 blocks per treatment were destructively sampled by removing a core directly beneath and parallel to the treatment hole of each block. The core was divided into five assay zones: 0-6 mm, 6-13 mm, 13-25 mm, 25-38 mm, and 38-64 mm. An additional zone (64-89 mm) was removed after 6 months. The samples were oven-dried overnight, ground in a Wiley mill through a 20-mesh screen, and analyzed for copper and boron content.

Copper content (% copper per weight of wood) was determined using an ASOMA 8620 X-ray fluorescence analyzer (Asoma, Inc. Austin, Texas) configured for chromated copper arsenate analysis. Selected samples were later digested in boiling nitric acid and analyzed by atomic absorption spectroscopy to confirm ASOMA results. A standard regression line (R^2=0.997) was used for final copper calculations (Figure V-1).

Boron content (% boric acid equivalent (BAE) per weight of wood) was determined by ashing 1 g (nearest 0.0001 g) of each sample at 500 C for 16 hours and the residue was analyzed as described in Section A.

Chemical analyses indicated that both components of the paste were capable of moving into the wood in both the radial and longitudinal directions (Figures V-2, V-3) at both MC's. Chemical gradients were generally steep at first and gradually leveled as the reservoir of chemical on the surface was depleted.

3. Effect of moisture content: Both boron and copper were more mobile in the wet (60 % MC) than the dry samples (30 % MC). Low MC samples were characterized by high surface loadings and a steep decline in chemical concentration further into the wood. The wet samples were characterized by more shallow chemical gradients which flattened with time. This was particularly evident in the 60% MC longitudinally oriented blocks. Although the wet samples permitted more effective diffusion, drier samples still allowed some chemical migration (e.g., 30% MC radial diffusion).

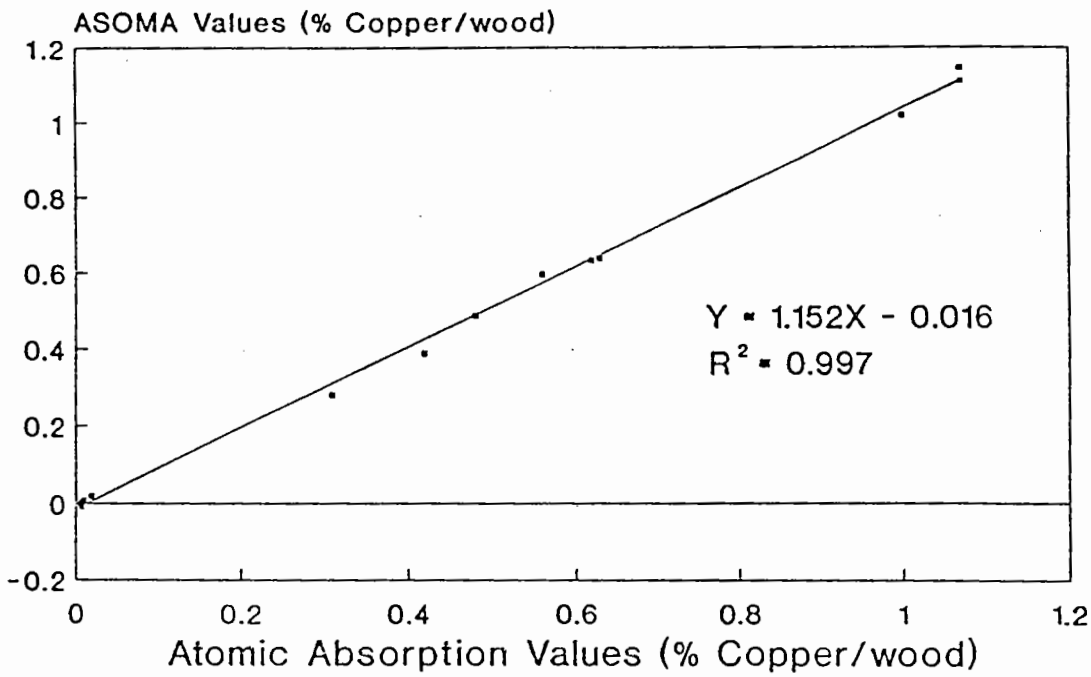


Figure V-1. Comparison of copper naphthenate levels (as % copper) in Douglas-fir heartwood as determined by x-ray fluorescence spectroscopy and atomic absorption spectroscopy of the same samples.

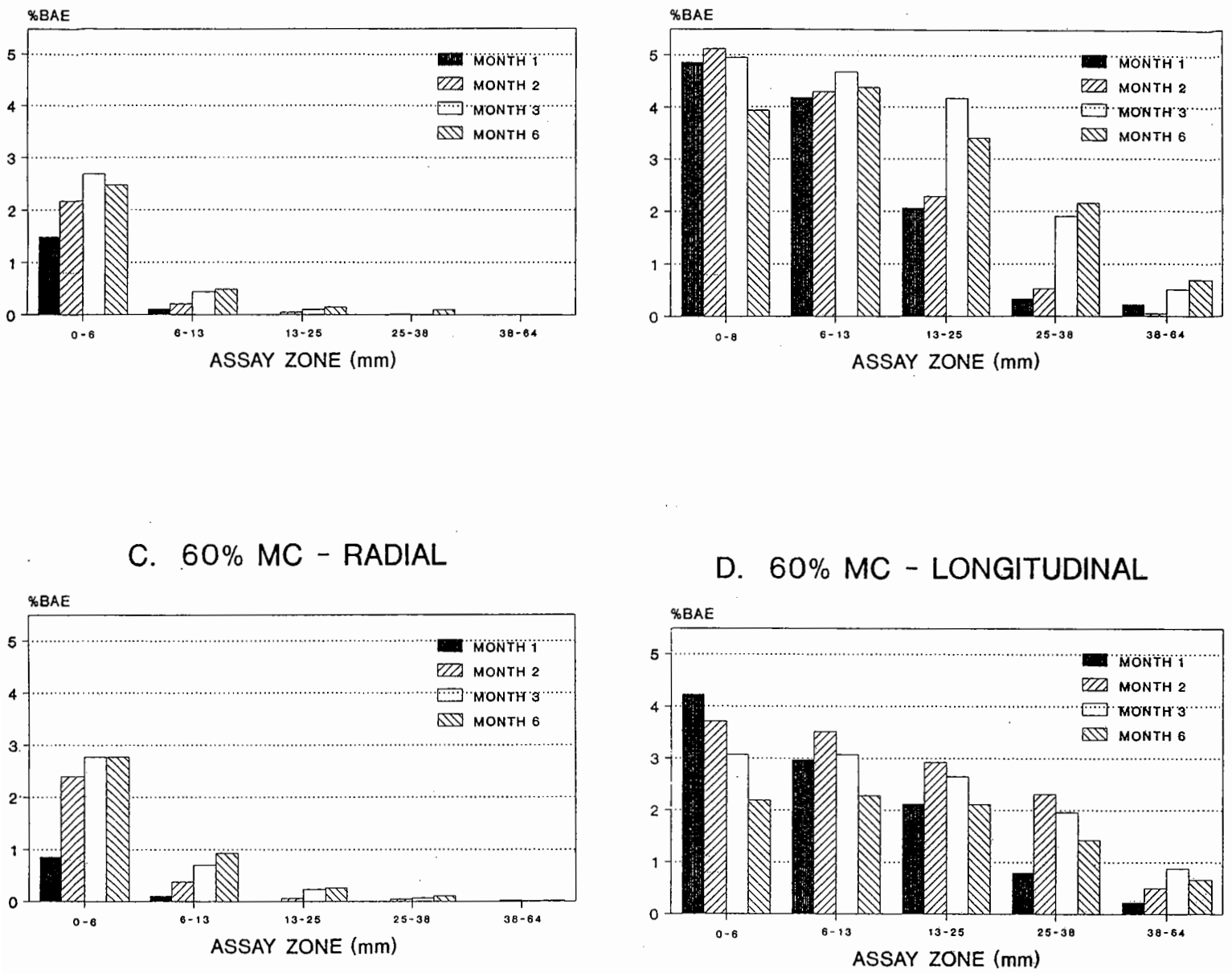


Figure V-2. Concentration of boron (as % BAE) at selected radial (A,C) or longitudinal (B,D) depths in Douglas-fir heartwood blocks at 30 or 60 % MC one to six months after treatment with 5 g of a copper naphthenate/borate paste.

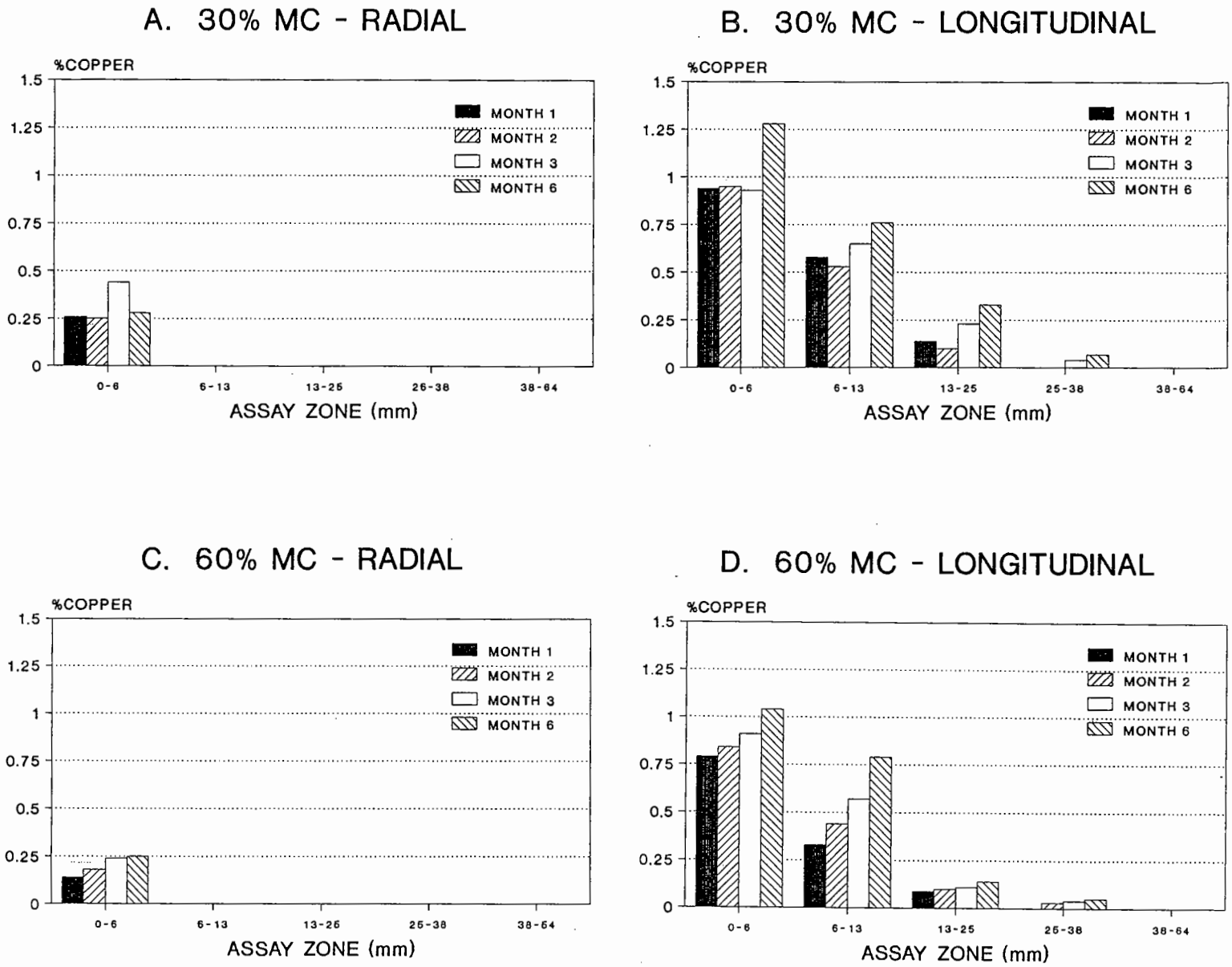


Figure V-3. Concentration of copper at selected radial (A,C) or longitudinal (B,D) depths in Douglas-fir heartwood blocks at 30 or 60 % MC one to six months after treatment with 5 g of a copper naphthenate/borate paste.

4. Effect of orientation: As expected, chemical movement was greatest in the longitudinal direction. Complete longitudinal boron penetration was acheived in all samples within one month. Chemical levels declined in the outer zones and increased further within the blocks as diffusion proceeded. Orientation actually affected diffusion more than did MC.

5. Copper vs. Boron movement: Boron is considered to be a highly diffusible chemical capable of moving along moisture gradients; however, the formulation evaluated contained an amine based copper naphthenate which was also water soluble. Thus, both chemicals were expected to move into the wood. Boron diffusion always exceeded that of copper. Complete boron penetration was achieved in 1 month while complete copper penetration never occurred. Slower movement may reflect the dependence of copper on amine for water solubility. Evaporation of the amine component renders the copper naphthenate insoluble and may have reduced diffusion. Alternatively, copper has been shown to react with cellulose and may be selectively adsorbed, causing copper depletion as this formulation progressed further from the application site. Boron has minimal reactivity with wood, minimizing the effects of selective depletion with this chemical.

The results indicate that the copper naphthenate/boron paste was capable of moving in both the longitudinal and radial directions at 30 and 60% MC. As expected, movement was greatest in the longitudinal direction and at the higher MC. Direction of movement seems to play a greater role than MC in diffusion. The diffusion of both components through Douglas-fir heartwood suggests that these pastes should be capable of diffusion through most refractory woods to provide some level of internal, as well as surface decay protection; however, the levels required for effective protection remain to be determined.

OBJECTIVE VI
PERFORMANCE OF COPPER NAPHTHENATE IN WESTERN WOOD SPECIES

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

The fungicidal capabilities of copper naphthenate have been known for many years, but only in the past few years has this chemical been incorporated in the Standards of the American Wood Preserver's Association. These efforts have been based on the performance of the chemical in southern pine stakes treated with selected retentions. There is little data on the effectiveness of this chemical in western wood species including western redcedar.

Although western redcedar contains a high percentage of naturally decay resistant heartwood, the sapwood has no natural durability and must be chemically protected. Most western redcedar poles are butt or full-length treated with oilborne preservative. Copper naphthenate represents a potential substitute for penta and creosote in these applications, but their is no data on the performance of this chemical in western redcedar sapwood.

Performance data was developed by exposing copper naphthenate treated sapwood 1.25 by 2.5 by 15 cm long) stakes in a fungus cellar. One set of stakes was obtained from freshly sawn lumber, while a second set was obtained from the untreated, above ground section of a western redcedar pole which had been in service for approximately 15 years. These stakes were conditioned to constant weight under controlled temperature and humidity, then weighed to the nearest 0.01 g. The stakes were then treated with copper naphthenate diluted in diesel oil to produce retentions of 0.05, 0.10, 0.15, 0.20, and 0.25 pounds per cubic foot (as copper). Ten stakes were treated to each target retention. During treatment the stakes were immersed in treating solution, a vacuum (22 inches Hg) was drawn over the solution for 30 minutes and then the pressure was slowly

raised to 125 psi. Pressure was held for 4 to 6 hours and then released. The samples were then weighed and the weight gain from treatment was used to calculate chemical retention. The stakes were then air-dried to eliminate excess solvent. Selected samples were then ground to pass a 20 mesh screen and analyzed for copper content by x-ray fluorescence spectroscopy (XRF). Previous tests had indicated that XRF results were closely correlated with those obtained via atomic absorption spectroscopy.

The stakes were then exposed in a soil bed maintained at 85 F and 80 % relative humidity. The soil was a forest loam which was maintained in a moist condition, but was allowed to cycle between wetting and drying. The stakes were rated for the presence of fungal attack 6 and 14 months after treatment on a scale from 0 to 10 where 0 represents complete destruction and 10 represents no evidence of attack.

Untreated Western redcedar sapwood stakes exhibited little resistance to decay. Weathered stakes were virtually failed after 14 months of exposure, while untreated stakes from freshly sawn wood were slightly more durable. The presence of diesel provided a reasonable degree of protection to both weathered and new stakes, although weathered stakes were again less resistant to attack. The lowest retention of copper naphthenate was beginning to experience some decay in the weathered samples, while the newly sawn samples treated to this retention were slightly stained after 14 months of exposure. Samples cut from freshly sawn wood were consistently in better condition than those cut from weathered wood, despite having lower initial levels of treatment. The poorer performance of weathered stakes may reflect a more open structure which encourages increased leaching of chemical. Weathered stakes were included because of a desire to retreat sound western redcedar poles removed from service. These poles often retain adequate strength and are removed for other reasons such as line upgrades

or road widening. Our results suggest that care should be taken in the exposure of retreated western redcedar in ground contact; however, these poles will also contain chemical from the initial treatment which should provide supplemental protection. Care should be taken when untreated cedar is retreated or when previously butt-treated poles are retreated and then set deeper than the original groundline. In these instances, the application of a supplemental preservative bandage at the time of installation would be prudent.

Table VI-1. Condition of western redcedar sapwood stakes treated to selected retentions with copper naphthenate in diesel oil and exposed in a soil bed for 6 and 14 months.

	WEATHERED SAMPLES			NEW SAMPLES		
TARGET RETENTION[1] (LB/FT^3)	ACTUAL RETENTION (LB/FT^3)	AVERAGE DECAY RATING[2] 6 MTHS	14 MTHS	ACTUAL RETENTION (LB/FT^3)	AVERAGE DECAY RATING[2] 6 MTHS	14 MTHS
control	-	4.7	0.9	-	6.6	3.2
Diesel	-	8.5	6.8	-	9.9	8.4
0.05	0.10	9.0	8.0	0.04	10.0	9.6
0.10	0.09	9.5	8.9	0.08	10.0	9.4
0.15	0.13	9.6	9.2	0.12	10.0	9.4
0.20	0.17	9.6	9.1	0.16	10.0	9.2
0.25	0.25	9.9	9.2	0.19	10.0	9.5

1. Retentions measured as pounds per cubic foot (as copper).

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