ABSTRACT

This sixth annual report outlines our continued progress in each of six objectives.

Improved Fumigants: Evaluation of previously established field trials indicates that Vorlex and chloropicrin continue to protect Douglas-fir after 16 years, while the Vapam treated poles are gradually being invaded by decay fungi and will be retreated this year. Solid methylisothiocyanate (MIT) also continues to perform well after 8 years and gelatin encapsulated applications of MIT and chloropicrin continue to protect Douglas-fir poles in several tests. Closed tube bioassays for residual fumigant vapors indicate that chloropicrin remains detectable in poles 16 years after treatment, as does MIT after 8 years. Application of fumigants to protect pile tops along the Oregon Coast continues to produce results similar to those experienced with poles, indicating that fumigant treatment is also practical for these structures.

Although all of the fumigants, except allyl alcohol, continue to perform well, we continue to search for improved fumigants. In this effort, we have evaluated the use of various pH's to improve the degradation of Mylone and Tridipam into MIT. These tests indicate that addition of a pH 10 buffer substantially improved the rate of MIT production from Mylone or Tridipam in wood blocks and suggests that fumigant application can be tailored to control specific decay problems.

We continue to use the closed-tube bioassay to measure residual fumigant levels, but there are no reports about the sensitivity of this test. To develop this data, we compared the ability of fumigant treated blocks to inhibit growth of P. placenta in the closed-tube bioassay with the actual level of chemical in the wood. These tests indicate that closed-tube bioassays closely parallel fumigant levels in ponderosa pine, but the tests were more variable with Douglas-fir. This variation may be due to the presence of heartwood extractives.

As mentioned, Vapam continues to perform well in spite of the fact that no fungitoxic vapors are detectable 3 years after treatment. This performance suggests the deposition of non-volatile fungitoxins. We are investigating these breakdown products to develop data on the degradation and to determine how these products provide long term wood protection.

Cedar Sapwood Decay Control: This past year we evaluated 28 additional chemicals in our laboratory screening tests. The results indicate that 9 of these chemicals, including a quaternary ammonium compound, copper-8-quinolinolate, Azaconazole, isothiazolone, Busan 1030, and Busan 1009, provided excellent protection. These chemicals will be included in our field tests.

We also evaluated a number of these chemicals for their sensitivity to the Aspergillus bioassay. These tests indicate that several quaternary ammonium and copper containing compounds were not detected using the bioassay, but all other compounds tested should be detectable with this system.

Bolt Hole Decay Prevention: Again this year, unprotected control bolt holes have yet to develop sufficient levels of decay sufficient to make sampling the treated poles worthwhile. Additional tests to evaluate fumigant treatment to protect bolt holes indicated that MIT migrates well in this zone. Laboratory tests indicate that application of MIT poses no corrosion hazard to galvanized hardware.

Detecting Decay and Estimating Residual Wood Strength: We continue to evaluate the use of fluorescent coupled lectins and IR spectroscopy as methods for detecting incipient decay and these tests show promise under laboratory conditions.

In addition to detecting early decay, we continue to evaluate the effect of colonization by decay fungi during air-seasoning on strength properties of Douglas-fir. These tests indicate that fungi colonizing the wood do not adversely affect strength properties until poles have seasoned for three years. Pole sections air-seasoned for three years exhibited significant declines in modulus of rupture and work to maximum load; however, the strength values of these sections still fell within the ASTM standard distribution for Douglas-fir.

These pole sections have also been used to evaluate the use of small scale mechanical tests as predictors of pole strength. These tests indicate that Longitudinal Compression Strength is a fair predictor of pole bending strength and additional tests are now underway to compare LCS with acoustic tests and full scale bending strength of Lodgepole pine posts.

In addition to evaluation of strength properties of Douglas-fir, we also evaluated the residual strength of recycled western redcedar poles. These tests indicate that poles in service for 20 to 35 years exhibited little loss of residual strength and still fell within the design values for their respective classes.

Initiation of decay in air seasoning Douglas-fir: We continue to evaluate the results of the air seasoning, decay development and decay prevention studies.

We have now completed the identification phase of the decay development studies and find that a variety of fungi colonized Douglas-fir poles sections exposed for one or more years. These tests also indicate that application of ammonium bifluoride at the start of air seasoning delayed colonization on decay fungi and probably results in decreased fungal induced wood changes. Additional tests are planned using application of boron sprays.

Examination of internal temperatures that develop in Douglas-fir poles during preservative treatment indicate that treatment with penta in P-9 Type A oil resulted in temperatures over 68.5 C, the temperature required to sterilize wood, for over six hours. Tests using waterborne ammoniacal copper arsenate were less clear-cut. These results indicate that additional steaming periods might be advisable where ambient temperature treating solutions are used.

Microfungi in Fumigant Treated Wood: Identification of the fungal flora of fumigant-treated wood continues and we are now determining the physiologic needs of these fungi. The results indicate that

several isolates have a substantial tolerance to penta. Additional tests to evaluate effect of prior colonization of fumigant treated wood by microfungi on subsequent decay resistance indicate that exposure to Scytalidium lignicola resulted in decreased weight losses following exposure to Poria carbonica or Poria placenta. These results suggest enhanced protection of fumigant treated wood by S. lignicola. Additional tests to confirm these results are suggested.

ACKNOWLEDGEMENTS

We thank the organizations that are helping fund this research program, the many persons whose assistance and advice makes this truly a cooperative program, and the personnel at Oregon State University all of whom are making this research a very rewarding experience.

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

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OBJECTIVE I

DEVELOP SAFE AND ENVIRONMENTALLY ACCEPTABLE FUMIGANT TREATMENTS TO CONTROL INTERNAL DECAY OF DOUGLAS-FIR POLES

A. PREVIOUS ONGOING AND RELATED RESEARCH ON WOOD IN SERVICE

Douglas-fir poles treated in 1969 with chloropicrin, Vapam or Vorlex

Forty internally decaying pressure-treated poles (18 to 24 m long) located on the Santiam-Toledo line near Corvallis, Oregon were treated with 1 liter of chloropicrin, Vapam or Vorlex distributed among seven holes (four at the groundline and three at 1 m above groundline) or left untreated (controls). Details of the sampling procedures for evaluating treatment effectiveness by culturing and closed tube bioassays have been previously described ('84 Ann. Rept., pages 1-2).

TABLE 1

VOLATILE CHEMICALS TESTED FOR THEIR ABILITY TO CONTROL DECAY FUNGI IN WOOD

COMMON DESIGNATION	SOURCE AND TRADE NAME	ACTIVE INGREDIENT
Allyl alcohol	Eastman Kodak Co. Ek-518	allyl alcohol
Chloropicrin	Dow Chemical Co.	Trichloronitromethane
MIT	NOR-AM Chemical Co. Degussa Corp.	methylisothiocyanate
Vapam	Stauffer Chemical Co.	32% sodium N-methyl dithiocarbamate
Vorlex	NOR-AM Chemical Co.	20% methylisothiocyanate 80% chlorinated C_3 hydrocarbons

Sixteen years after treatment, chloropicrin and Vorlex continue to protect the poles from reinvasion by decay fungi (Table 2, Figure 1). One of five poles treated with chloropicrin and 2 of 5 poles treated with Vorlex have been reinvaded by decay fungi while 5 of 8 poles treated with Vapam have been recolonized. The effectiveness of chloropicrin and Vorlex is illustrated by the continued inhibition of Poria placenta in the closed tube bioassay (Tables 3,4). Chloropicrin remains the most persistent of the fumigants while wood removed from Vapam treated poles has little evidence of residual volatile fungicide. Wood from Vorlex-treated poles continues to lose its ability to inhibit P. placenta in the bioassay, and these poles are gradually being reinvaded by decay fungi. Residual chlorinated C_3 hydrocarbons may account for the long term protection provided by this chemical. The fungal reinvasion of the groundline zone of these poles as the fumigant concentration declines is also under study (see Objective VI).

The closed-tube bioassay continues to be a useful guide for fumigant retreatment of poles, and additional studies are underway to correlate the actual fumigant levels in the wood with the closed-tube bioassay results. Based on our results, retreating cycles of 10 years with Vapam and at least 16 years with the more persistent chloropicrin continue to appear reasonable. The protection provided by Vorlex, which has performed well in this test, appears more variable and a 10 year retreatment cycle also appears advisable with this chemical.

TABLE 2

EFFECTIVENESS OF FUMIGANTS IN DOUGLAS-FIR POLES TREATED WITH 1 LITER OF FUMIGANT AS DETERMINED BY CULTURING INCREMENT CORES REMOVED FROM THE TREATED POLES

	POLES CONTAINING DECAY FUNGI				
	CONTROLS	VAPAM		VORLEX	CP
YEAR	UNTREATED	WRAPPED	UNWRAPPED	WRAPPED	WRAPPED
1968	8	8	8	8	8
1969		POLES TREATED			
1970	8	4	4	0	1
1971	8	1	1	0	0
1972	8	0	1	0	0
1973	8	0	0	0	0
1974	7	4^{7}	4^{7}	0^{7}	1^{6}
1975	7	1	0	1	0
1976	5	2	3	0	0
1977	5	2	1	0	0
1978	5	3	2	0	0
1979	5	3	2	2	1
1980	5	1	3	1	0
1981	3	2	2^{6}	1	0
1982	2	2	2	1	0
1983	2	2	2	1	0
1984	2^{2}	4^{6}	1^{2}	1^{5}	1^{5}
1985	1^{1}	3	2	2	1

[a]All poles contained decay fungi before the fumigants were applied. The superscripts denote the number of poles remaining in test; the missing poles were inadvertently removed from service.

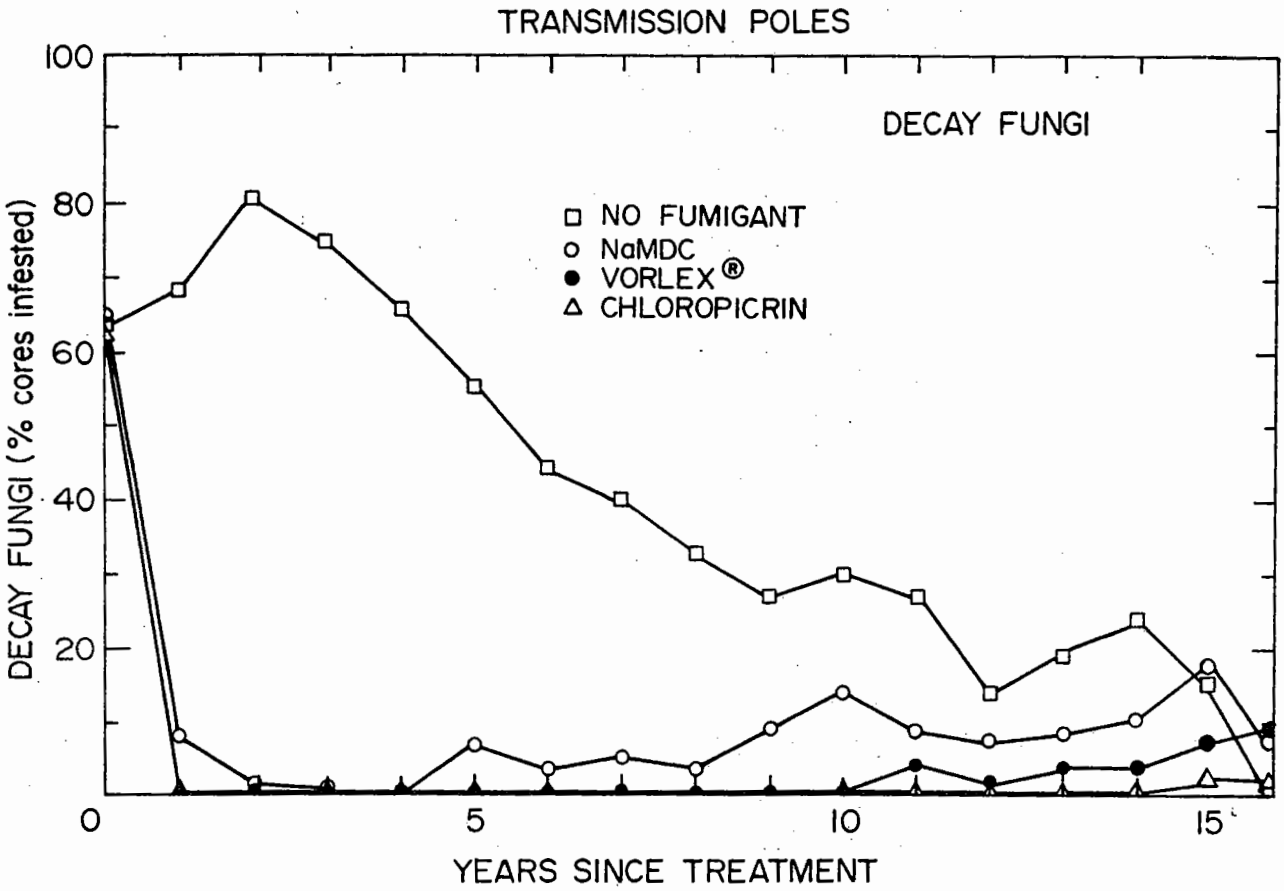


Figure 1 Population of decay fungi isolated from internally decaying pressure-treated Douglas-fir poles treated with Vapam, Vorlex or chloropicrin. Values represent the average of 12 cores removed annually from selected heights above and below groundline.

TABLE 3

RESIDUAL FUMIGANT VAPORS IN PRESSURE-TREATED DOUGLAS-FIR POLES 16 YEARS AFTER FUMIGANT APPLICATION AS MEASURED USING THE CLOSED TUBE BIOASSAY

METERS ABOVE GROUND	SEGMENT LOCATION FROM SURFACE (cm)	GROWTH OF THE ASSAY FUNGUS AS A % OF THE CONTROL[a]			
		NO FUMIGANT	VAPAM	VORLEX	CHLOROPICRIN
2.4	0-2.5	38	34	83	38
	5.1-7.6	138	62	83	1
	12.5-15	141	69	86	14
1.8	0-2.5	100	45	45	7
	5.1-7.6	114	93	117	24
	12.5-15	100	86	106	38
1.2	0-2.5	138	58	59	10
	5.1-7.6	134	41	69	34
	12.5-15	--	55	86	34
0	0-2.5	38	24	55	31
	5.1-7.6	138	31	72	62
	12.5-15	117	58	86	59
CONTROL	(NO WOOD)	29 mm[b]			

[a] For the closed-tube bioassay, a core was removed at each height from eight poles. A 2.5-cm long segment of the core was sealed in a test tube below the agar slant which had been inoculated with Poria placenta. Suppressed growth of P. placenta compared to growth of the fungus where no wood was present (control) indicates the presence of fungitoxic vapors. The lower the percentage, the higher the concentration of fumigant vapors in the wood.

[b] Average growth of the test fungus in 8 tubes.

TABLE 4

DECLINE IN RESIDUAL FUMIGANT VAPORS IN DOUGLAS-FIR TRANSMISSION POLES AT SELECTED POINTS AFTER APPLICATION OF CHLOROPICRIN, VAPAM, OR VORLEX AS MEASURED BY THE CLOSED-TUBE BIOASSAY.[a]

METERS ABOVE GROUND	GROWTH OF THE ASSAY FUNGUS (AS % OF CONTROL) IN THE PRESENCE OF WOOD FROM POLES AT VARIOUS TIMES (YEARS) AFTER FUMIGANT TREATMENT[b]															
	Control (no fumigant)			Vapam				Vorlex				Chloropicrin				
	10	13	16	5	7	15	16	10	13	15	16	10	13	15	16	
2	91	96	72	53	100	80	55	48	68	69	84	4	36	11	21	
1.8	96	100	104	60	78	73	75	35	68	61	89	0	28	5	23	
1.2	96	80	136	60	78	72	51	39	64	74	71	4	40	38	26	
0	100	100	98	60	100	52	38	52	72	81	71	17	60	51	51	

a Each pole was treated with 1 liter of the selected chemical applied to three holes 1 m above the groundline and four holes at the groundline.

b For the closed-tube bioassay, a core was removed at each height from eight poles. A 2.5-cm long segment of the core was sealed in a test tube below the agar slant which had been inoculated with Poria placenta. Suppressed growth of P. placenta compared to growth of the fungus where no wood was present (control) indicates the presence of fungitoxic vapors. The lower the percentage, the higher the concentration of fumigant vapors in the wood.

Douglas-fir poles treated in 1977 with allyl alcohol, methyl-isothiocyanate or Vorlex.

In 1977, methylisothiocyanate (MIT) and allyl alcohol were compared with Vorlex for their ability to control decay in poles in service. For this test, internally decaying Douglas-fir poles pressure-treated with pentachlorophenol in heavy oil were evaluated for decay by removing three cores from equally spaced locations around the poles at -0.3, 0, 0.6, and 1.2 m from the groundline and culturing the cores for the presence of decay fungi. Because of the prevalence of decay fungi at 1.2 m, cores also were removed 1.8 and 2.4 m above the groundline for culturing.

This past year decay fungi have been isolated from one pole treated with Vorlex (Table 5). The continued presence of decay fungi associated with this treatment is of some concern and we intend to follow these results more closely; however, the performance of Vorlex may have been affected by wood condition at time of treatment since severely decayed wood holds less fumigant than sound wood.

The number of poles treated with 20% MIT in diesel oil or 100% MIT from which decay fungi were cultured decreased. The 20% MIT treatment should be comparable to Vorlex (which also contains 20% MIT) but the diesel component has little effect on decay fungi, while the chlorinated C_3 hydrocarbons in Vorlex should enhance the effectiveness of MIT. The allyl alcohol continues to perform poorly, and, although this chemical performed well in laboratory tests, it

TABLE 5

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.[a]

	NUMBER OF POLES CONTAINING DECAY FUNGI				
		ALLYL		METHYLISOTHIOCYANATE	
YEAR	UNTREATED	ALCOHOL	VORLEX	20%[b]	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

[a] 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.

[b] Diluted in diesel oil.

appears that the formulation used was ineffective as a fumigant. These poles will be retreated this summer to prevent further decay.

While the percentage of cores infested with decay fungi was slightly lower than the percentage of poles infested (Figure 2), the results followed a similar pattern, with levels of infestation being highest in allyl alcohol treated poles and lowest with the 100% MIT treatment.

Closed-tube bioassays of wood from these same poles indicated that poles treated with Vorlex or 20% MIT had declining levels of inhibition (Table 6), while wood from poles treated with 100% MIT continued to inhibit fungal growth. As expected, wood removed from the allyl alcohol treated poles had little effect on growth of P. placenta. These results correlate with the cultural results and suggest that treatments of 20% MIT will provide control for a shorter period than that achieved with pure MIT or Vorlex. The decreased performance of Vorlex compared to previous results on the Santiam to Toledo line indicates that pole condition at time of treatment is an important aspect of fumigant longevity. Thus, the current 10 year retreatment cycle employed by many utilities may be a safe figure that insures minimal loss.

Evaluation of fumigants for pile top decay control: Bulkhead piles, Florence, Oregon

Eleven years after treatment with soil fumigants, Vorlex or Chloropicrin have virtually eliminated decay fungi from the top 6 ft. of creosote-treated bulkhead piling that contained extensive advanced

TABLE 6

RESIDUAL FUMIGANT VAPORS IN DOUGLAS-FIR POLES 8 YEARS AFTER APPLICATION AS MEASURED USING THE CLOSED TUBE BIOASSAY[a]

METERS ABOVE GROUND	SEGMENT LOCATION FROM SURFACE (cm)	GROWTH OF ASSAY FUNGUS AS % OF CONTROL				
		NO FUMIGANT	ALLYL ALCOHOL	VORLEX	METHYLISOTHIOCYANATE 20%[b]	100%
2.4	0-2.5	33	55	30	15	33
	12.5-15	96	--	70	55	55
1.8	0-2.5	81	67	44	63	37
	12.5-15	63	59	63	104	67
1.2	0-2.5	92	37	07	52	15
	12.5-5-15	59	111	59	111	48
0.6	0-2.5	41	59	04	22	0
	12.5-15	100	81	33	59	59
CONTROL	(NO WOOD)	27 mm[d]				

[a] For the closed-tube bioassay a core was removed at each height from four to six poles (Table 5). A 2.5-cm long core segment was sealed in a test tube below an agar slant inoculated with Poria 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.

[b] In diesel oil.

[c] A slash mark (-), indicates that no solid wood was available for the assay due to the presence of advanced decay.

[d] Average growth in 11 tubes.

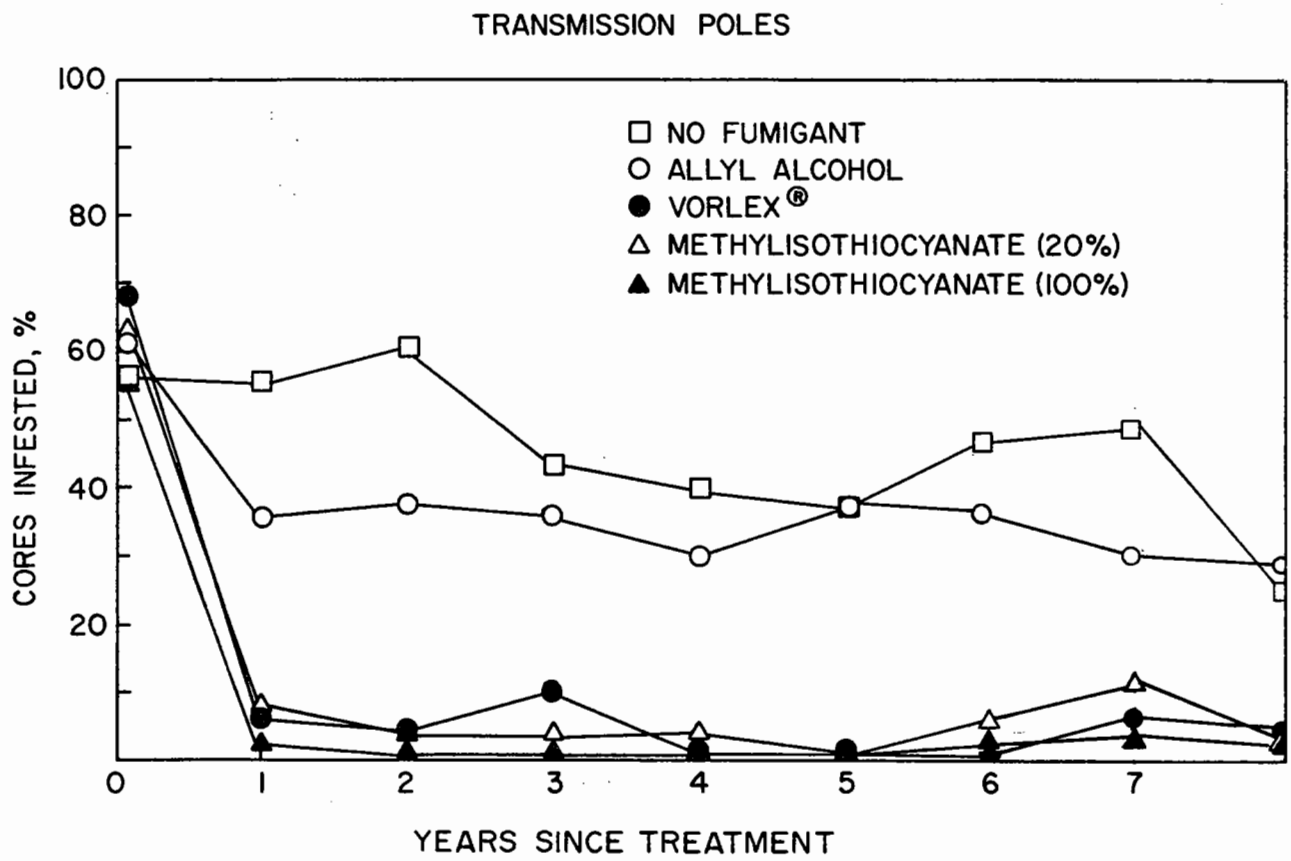


Figure 2. Changes in the population of decay fungi isolated from internally decaying pressure-treated Douglas-fir poles treated with fumigants. Each value is based on 15 cores removed at -0.3 to 2.4 m from the groundline from the poles listed in Table 5.

decay (Table 7). Piles treated with Vapam experienced a fairly strong reinfestation of decay fungi between 6 and 8 years after treatment. This reinfestation has been previously noted in similar studies on land-based electric transmission poles; however, the level of reinfestation has been slow, and periodic inspections of piling should detect early decay before it becomes a problem. The long term ability of Vapam and Vorlex to prevent recolonization of decay fungi in wood is questionable and marina owners should schedule retreating cycles every 10 years for this chemical while retreatment cycles of 15 or more years appear feasible for Chloropicrin.

Fumigant treatment of untreated marina piling: Florence, Oregon

Ten years after treatment with Vapam, Vorlex or Chloropicrin, fumigants continue to prevent decay fungi from recolonizing nonpressure-treated Douglas-fir pile tops (Table 8). These results indicate that where marine borer hazards are absent or low, fumigant treatment can prolong wood service life above the water line.

In addition to culturing, a closed-tube bioassay was used to measure residual fumigant vapors present in the wood. This test continues to indicate the presence of toxic levels of chloropicrin remain in the wood after 10 years, while wood removed from Vapam and Vorlex treated piling had no detectable vapors (Table 9). This suggests that decay fungi will begin to gradually recolonize the Vorlex treated wood as they have in the Vapam treated piles.

TABLE 7

FUNGAL POPULATION IN DOUGLAS-FIR BULKHEAD PILES TREATED WITH FUMIGANTS IN 1974 AS DETERMINED BY CULTURING INCREMENT CORES REMOVED FROM SELECTED LOCATION ON EACH PILE.

CHEMICAL TREATMENT	CORES WITH DECAY FUNGI, (%) [a]											
	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985
Vapam	73	2	0	0	2	8	12	8	12	7	6	5
Vorlex	72	2	0	0	2	4	0	1	0	5	1	0
Chloropicrin	59	4	0	0	0	3	0	1	0	0	0	0

[a] Give cores were removed from each pile, one at 1, 2, 3, 4 and 6 ft. below pile tops.

TABLE 8

PRESENCE OF DECAY FUNGI IN UNTREATED DOUGLAS-FIR MARINA PILES TREATED WITH FUMIGANTS IN 1975 AS DETERMINED BY CULTURING INCREMENT CORES REMOVED FROM SELECTED LOCATIONS ON EACH PILE.

CHEMICAL TREATMENT	NUMBER OF PILES AND % OF CORES WITH DECAY FUNGI[a]										
	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985
Piles											
Vapam	6	2	1	3	4	4	3	2	3	1	3
Vorlex	6	4	5	4	3	6	1	2	2	2	1
Chloropicrin	6	3	0	3	2	3	1	0	4	0	0
Cores											
Vapam	32	4	7	6	13	15	8	7	12	2	6
Vorlex	37	6	3	5	11	12	1	3	6	5	2
Chloropicrin	55	3	0	6	3	5	1	0	6	0	0

[a] Seven cores were removed from each pile, one at 1, 2, 4, 6, 8, 10, and 12 ft. below pile tops.

TABLE 9

PRESENCE OF FUNGITOXIC FUMIGANT VAPORS IN UNTREATED DOUGLAS-FIR MARINA PILES AS DETERMINED USING THE CLOSED-TUBE BIOASSAY

CHEMICAL TREATMENT	CORE LOCATION FROM PILE SURFACE (CM.)[a]	GROWTH OF THE ASSAY FUNGUS PORIA PLACENTA (AS A % OF CONTROL)						
		1979	1980	1981	1982	1983	1984	1985
Vapam	0-2.5	82	57	82	100	79	64	89
	6.25-8.75	71	50	89	86	89	75	93
	12.5-15	68	39	75	89	89	82	89
Vorlex	0-2.5	61	50	82	93	82	64	89
	6.25-8.75	25	18	32	68	82	68	75
	12.5-15	21	11	36	64	57	61	71
Chloropicrin	0-2.5	43	39	50	46	79	50	43
	6.25-8.75	14	7	11	39	18	11	7
	12.5-15	11	7	11	25	18	18	14
Controls(no wood)		28	25	30	34	27	29	31

[a]Cores were removed at 0.3, 1.0, 2.0 and 3.0 m levels from pile tops.

South beach marina pile top test site, Newport, Oregon

The pile top treatment test in cooperation with the South Beach Marina was designed to demonstrate the ability of various internal treatments in combination with pile caps to prevent decay in the tops of Douglas-fir piling (Table 10).

Our pile top farm near Corvallis has provided us with several promising treatments to be tested in the harsher marine environment. Fumigants were added to this list based on success in other coastal studies. Additional wood preservatives were added to the test based on cost, safety and ease of application, toxicity, and commercial availability.

In addition to the wide array of chemical treatments used, five different types of water-shedding pile capping devices are also being evaluated.

One year after treatment, gelatin encapsulated MIT, Vorlex, or Chloropicrin have completely eliminated decay fungi that were previously detected in the wood. Semi-permeable bags containing one pound of Ammonium bifluoride, (ABF), Sodium fluoride, (NaF), or a compound with fluoride-chrome-arsenic-phenol (FCAP) nailed to pile tops have also eliminated decay fungi. These chemicals do not diffuse through the wood as far as more volatile fumigants and will not protect the wood for as long, but appear to be extremely cost effective and reapplication at shorter intervals may be feasible.

Boron glass rods (boric oxide, boric oxide/Cu Timbor, or Timbor Cu/oxide) have not yet eliminated the decay fungi present, while liquid application of Penta (5% active ingredient) and Pole topper (10% penta) had little effect on the presence of decay fungi.

TABLE 10

FUNGAL POPULATION OF PILES 1 YEAR AFTER TREATMENT WITH COMBINATIONS OF WOOD PRESERVATIVES, FUMIGANTS OR CAPPING DEVICES

CHEMICAL TREATMENT	% OF CORES CONTAINING DECAY FUNGI[a] INITIAL	1 YEAR
	CAPPED PILES	
MIT	60 (60)	0 (1)
Vorlex	60 (60)	0 (13)
Chloropicrin	60 (80)	0 (7)
Boric Oxide	40 (100)	26 (67)
Boric Oxide/Cu.	40 (80)	67 (47)
Timbor	40 (80)	13 (78)
Timbor/Cu.Oxide	20 (100)	8 (53)
Penta	40 (100)	33 (47)
Pole Topper	60 (80)	47 (47)
Tie-Gard rods	25 (75)	0 (0)
Patox Discs	25 (80)	7 (33)
None*	0 (80)	0 (47)
	NONCAPPED PILES	
MIT	20 (100)	0 (0)
Vorlex	0 (50)	0 (0)
Chloropicrin	20 (80)	0 (13)
Boric Oxide	20 (100)	13 (67)
Boric Oxide/Cu.	20 (100)	7 (33)
Timbor	40 (80)	7 (46)
Timbor/Cu. Oxide	20 (80)	7 (40)
Tie-Gard rods	33 (80)	0 (27)
Patox Discs	10 (100)	7 (60)
	SEMI-PERMEABLE BAGS	
ABF	80 (100)	0 (0)
NaF	60 (100)	0 (7)
FCAP	60 (100)	0 (33)

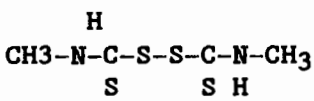
[a]The figures represent the % of cores with decay fungi, while the number in parenthesis denotes the % of nondecay fungi.

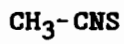
In the control group (no treatment, but capped) piles remain as before with no further evidence of decay fungi, while the controls (no treatment, no cap) were vulnerable to colonization by decay fungi and showed signs of increased fungal activity.

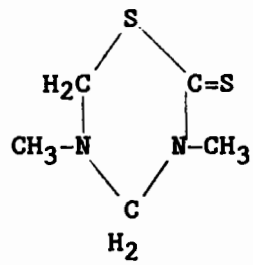
B. EVALUATE NEW FUMIGANTS

Preliminary evaluation of Tridipam and Mylone as wood fumigants

Although solid MIT, either encapsulated or pelletized continues to perform well in the field, our search for safer chemicals has led us to evaluate two additional solid chemicals, Mylone and Tridipam. The structure of these chemicals is:







Mylone is a crystalline solid at room temperature that slowly decomposes in wood or soil to produce a number of toxic gases, including MIT. Tridipam is also a solid compound that is formed by bridging two n-methyldithiocarbamates (Vapams) together. Both of these compounds degrade at very slow rates when applied to dry wood, but this rate accelerates slightly when moisture is present. Previous reports suggest that decomposition can be accelerated using high pH buffers (>7)('85 Annual Report pg. 20-21). This approach might permit

more controlled fumigant treatment tailored to fit the decay encountered. The prospect for such treatments was investigated using 2 small-scale laboratory procedures in a series of tests that are in progress.

In the first test, the effect of pH on the decomposition of Mylone and Tridipam to volatile MIT was investigated by placing weighed samples of the respective chemicals in 20 x 100 mm glass tubes containing combinations of Douglas-fir sawdust and buffer solutions at pH's of 4, 7, or 10. In addition, small inoculum plugs of P. placenta or P. carbonica or pieces of wood infested with these fungi were placed at the top of each tube to determine the effect of volatiles on fungal survival. The tubes were sealed with tight fitting serum caps and incubated for 7 days at room temperature. At that point, air samples were withdrawn from each tube and injected into the gas-chromatograph to determine the air concentration of MIT. These values were then quantified on a dosage basis to determine the ability of each environment to affect decomposition. After GC analysis the tubes were opened and the agar plugs were plated onto fresh malt agar plates. These plates were observed for evidence of fungal growth, which was used as a measure of fumigant effectiveness.

The results (Table 11) indicated that pH strongly influenced both the rate of decomposition and the nature of products produced. Acid buffer generally slowed decomposition to MIT, although some methylamine, an additional decomposition product, was noted. At neutral pH's the rate of decomposition increased slightly, but it was at higher pHs that decomposition increased markedly.

TABLE 11

EFFECT OF PH ON EVOLUTION OF MIT FROM TRIDIPAM AND SURVIVAL OF PORIA CARBONICA OR PORIA PLACENTA AS MEASURED USING GAS CHROMATOGRAPHY AND CULTURING, RESPECTIVELY.

CHEMICAL	DOSAGE (MG)	pH	FUNGAL SURVIVAL IN WOOD %	FUNGAL SURVIVAL IN AGAR %	MIT LEVEL (µg/cc AIR)	METHYL AMINE PRESENT (+) OR ABSENT (-)
Control	-	dry	100	100	--	--
		4	100	100	--	--
		7	100	100	--	--
		10	100	100	--	--
Tridipam	20	dry	78	90	15	--
		4	78	0	10	+
		7	100	0	10	+
		10	0	0	90	+
Tridipam	50	dry	100	100	15	-
		4	100	33	7	+
		7	89	0	15	+
		10	0	11	150	+
Vapam	50	dry	0	56	10	-
		4	0	0	15	+
		7	0	0	15	-
		10	34	11	20	-

Based upon the results from these tests, the ability of buffers to influence Mylone and Tridipam decomposition was investigated using our small scale wood block test method. In this method, Douglas-fir blocks thoroughly colonized by the test fungus were treated by adding measured dosages of chemical through a hole drilled in one face. These blocks were incubated for 7 to 28 days, then cut up and cultured to determine if the chemical killed the fungus. This method was used to evaluate the effects of both dosage and pH on fungal survival. Dosages ranging from 10 to 600 mg of chemical/block, and pH,s of 4, 7, 10 and 12 were tested. Following addition of the chemical, 2 ml of the desired buffer was added to the hole in the test block, which was sealed with a tight fitting serum cap. In addition to culturing wood from the blocks to determine fungal survival, sections were extracted with ethyl acetate and the extract was evaluated using the G.C. to determine MIT concentrations in the wood.

The tests are still underway; however, preliminary results (Table 12, 13) indicate that pH has a strong influence on decomposition of both Tridipam and Mylone. Cultural results from these tests indicate incomplete control of the test fungus below 100 mg of either chemical per block. Additional tests of dosages above this level are in progress. This low level of control is not surprising, since decomposition does not produce MIT on an equivalent basis to dosage. GC evaluations reveal that increases in pH dramatically improve the rate of MIT produced by the test chemicals. Generally,

TABLE 12

EFFECT OF pH 4, 7, OR 10 BUFFER ON DECOMPOSITION OF MYLONE AND CONTROL OF PORIA PLACENTA IN SMALL WOOD BLOCKS ONE WEEK AFTER APPLICATION

MYLONE DOSAGE MG	BUFFER PH	# REPS	FUNGAL SURVIVAL (%)	MG MIT/G ODW WOOD
25	10	8	73[a]	86.6
25	7	8	95	44.9
25	4	8	94	7.2
75	10	8	78[a]	114.1
75	7	8	94	43.5
75	4	8	92	17.1
100	10	8	92	109.5
100	7	8	63	42.1
100	4	4	94	13.7
Control		4	100	0

[a] low survival is due to contamination

TABLE 13

EFFECT OF BUFFER SOLUTION pH ON RELEASE OF MIT AND SURVIVAL OF PORIA CARBONICA IN DOUGLAS-FIR BLOCKS TREATED WITH SELECTED DOSAGES OF TRIDIPAM.

CHEMICAL DOSAGE (MG)	BUFFER PH	#REPS	FUNGAL SURVIVAL (%)	MG MIT/G ODW WOOD
10	10	4	75	83.1
10	7	4	91	89.3
25	10	4	34	133.6
25	7	4	84	49.3
50	10	4	19	268.7
50	7	4	75	73.1
75	10	4	9	209.9
75	7	4	81	52.9
100	10	4	0	218.6
100	7	4	50	161.3
150	10	4	16	240.5
150	7	4	66	166.2
300	10	4	50	434.0
300	7	4	47	144.5
300	4	2	44	546.0
450	10	4	34	435.8
450	7	4	78	106.2
CONTROL	10	4	100	0
CONTROL	4	2	100	0

MIT production at a given pH did not seem to vary, suggesting that the amount of buffer added, not chemical dosage, was the limiting factor in decomposition (Figure 3). This theory is supported by the presence of residual crystalline chemical in the treatment holes and suggests that additional buffer should be added; however, our buffer dosage was limited by the size of the treatment hole.

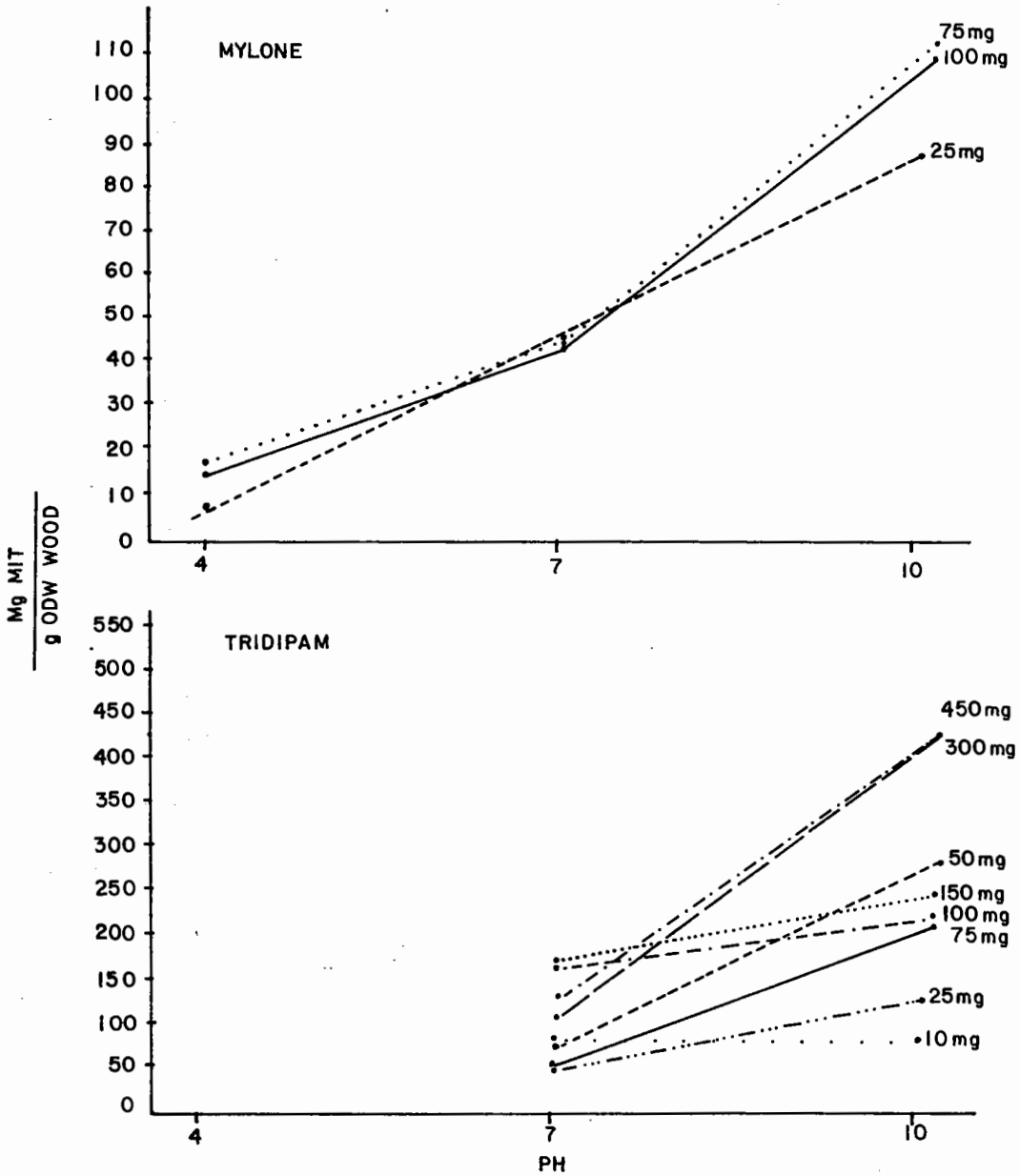


Figure 3. Effect of pH or decomposition rate to MIT in small wood blocks of (A) Mylone or (B) Tridipam.

These preliminary tests indicate that both Mylone and Tridipam have potential as wood fumigants. Furthermore, the pH effect indicates the potential for controlling the rate of MIT production to suit a given decay problem. For instance, in sound wood, where long term protection is desired, a low pH buffer that delayed chemical release might be useful, while the use of a high pH buffer would be advisable to quickly arrest decay in an endangered structure. These tests are only prelimnary, but they offer the potential of more precise decay control.

Effect of MIT on corrosion of galvanized hardware in wood

As discussed previously, one of the advantages of using solid fumigants will be the ability to control decay above the groundline; however, MIT is more likely to come in contact with galvanized metal hardware in this zone. To insure that MIT does not pose a corrosion hazard, we set up a small scale laboratory test and a large field trial to test the corrosiveness of MIT. In the small scale test, 2.5 X 2.5 X 10 cm blocks were treated at one end with MIT, ammonium bifluoride, or water and a galvanized bolt was attached to the wood through a hole drilled to the other end. The blocks were incubated at 25°C in a humidified chamber and observed for evidence of corrosion.

These small scale test indicated that MIT caused no more corrosion than water controls after five months ('85 Annual Report pg. 22-23). An additional 8 months of exposure (13 months total) in the humidified atmosphere indicates that MIT treated blocks experienced slightly more

corrosion and discoloration than the water controls although neither water or MIT treated blocks experienced the degree of corrosion found in the ammonium bifluoride treated blocks. It is important to remember that the chemical levels were quite high in this test and the dosage was applied less than 7.5 cm from the hardware. It is likely that the levels of MIT that develop in a large pole will never approach those experienced in these blocks.

In the field tests, galvanized hardware was attached 0.6, 1.2 or 4.3 m from the bottom several Douglas-fir and western redcedar pole stubs. The poles were treated by adding pelletized or gelatin encapsulated MIT to a point 1 foot below the location of the lowest galvanized hardware. These poles were examined one year after treatment by removing each piece of hardware and comparing the degree of corrosion to that found in untreated controls. None of the MIT treated poles exhibited increased corrosion of the hardware and it appears that fumigation near pole attachments will not pose a hazard to galvanized hardware.

C. EVALUATION OF THE MOST PROMISING FUMIGANTS IN POLES

New York field test with encapsulated MIT

Twenty-four chromated-copper-arsenate (CCA)-treated Douglas-fir poles placed in service near Hamburg, New York in 1972 had a high incidence of decay fungi and were used to compare the effectiveness of gelatin encapsulated MIT with a standard Vapam treatment. In October 1981, groups of 8 poles were treated with 473 ml of encapsulated MIT plus 1 liter of water, 950 ml of encapsulated MIT plus 900 ml of water, or 950 ml of Vapam or were left untreated as controls. The water was added with encapsulated MIT treatments to aid in fumigant

release from the capsules. Experimental and sampling procedures details were previously described ('82 Ann. Rept., pages 21-31 '83 Ann. Rept., pages 31-33).

Inspection of these poles 45 months after treatment indicates that decay fungi continue to be isolated from the MIT and Vapam treated poles although the levels remain low (Table 14). Incomplete control in these poles may pose future problems, leading to shorter reinspection cycles. The control poles in these evaluations continue to contain high levels of decay fungi and were treated with gelatin encapsulated Vorlex last summer. Some of these poles had carpenter ant infestations and it is our intent to evaluate the insecticidal effectiveness of Vorlex. We believe the presence of insecticidal chlorinated C_3 hydrocarbon compounds may increase the ability of this MIT formulation to control insect infestations.

Closed-tube bioassays continue to indicate the presence of fungitoxic vapors in the MIT treated poles, with both dosages producing complete inhibition (Table 15). Wood from Vapam treated poles had little effect on the growth of P. placenta, indicating that the volatile fungistatic ability of this treatment is beginning to decline after nearly 3 years. This is somewhat earlier than previously found, but the large diameter of these poles may have allowed the treatment to dissipate more rapidly. The results indicate that both levels of MIT will inhibit entry of decay fungi for a longer period than Vapam.

TABLE 14

INCIDENCE OF DECAY FUNGI IN DOUGLAS-FIR POLES IN NEW YORK STATE PRIOR TO AND AFTER TREATMENT WITH VAPAM OR GELATIN ENCAPSULATED METHYLISOTHIOCYANATE (MIT).[a]

SAMPLING DATE	METERS ABOVE GROUNDLINE	CORES WITH DECAY FUNGI(%) NO FUMIGANT	VAPAM 950 ML	ENCAPSULATED MIT[b] 475 ML	ENCAPSULATED MIT[b] 950 ML
June 1981	0	83	61	78	78
	0.6	61	72	61	56
Oct. 1981		Poles treated with fumigants			
July 1982	0	94	22	22	6
	0.6	67	17	0	6
	1.2	22	6	6	6
July 1983	0	44	6	0	0
	0.6	61	11	0	6
	1.2	33	0	0	0
July 1984	0	67	0	0	0
	0.6	78	0	0	0
	1.2	33	6	0	0
July 1985	0	39	0	0	6
	0.6	61	0	11	0
	1.2	28	17	6	0

[a] A total of 18 cores (three per height) were removed from six poles for each sampling date.

[b] About 1 liter of water per pole was added along with the capsules for the 475 ml MIT treatments, and about 900 ml of water was added with capsules for the 950 ml treatments.

TABLE 15

CLOSED-TUBE BIOASSAYS OF CORES REMOVED FROM NEW YORK POLES 4 YEARS AFTER TREATMENT WITH VAPAM OR GELATIN ENCAPSULATED MIT[a]

CHEMICAL	DOSAGE (ML)	SAMPLING HEIGHT (FEET)	AVERAGE GROWTH OF P. PLACENTA (AS A % OF CONTROL) CORE ZONE[b] OUTER	INNER
MIT	475	0	0	0
		0.6	0	0
		1.2	12	0
MIT	950	0	0	0
		0.6	0	0
		1.2	0	0
VAPAM	950	0	94	91
		0.6	136	62
		1.2	124	116
CONTROLS		0	132	176
		0.6	144	148
		1.2	188	100

Control tubes (no wood): Avg = 8.3 mm[c]

[a] The close tube bioassay uses a 1 inch wood segment removed from the pole. These segments are placed into agar tubes preinoculated with an assay fungus, Poria placenta. Fumigant effectiveness is then evaluated as the ability to inhibit radial growth of the fungus and cores with lower numbers have higher fumigant levels.

[b] Increment cores were divided into three segments, 0-2.5 cm, 2.5 to 12.5 and 12.5-1.5 cm. The middle segment was discarded and the outer (0-2.5 cm) and inner (12.5-15 cm) segments were used for closed tube assays.

[c] Control tubes showed poor growth, ranging from only 5 mm to 20 mm after 7 days growth.

Treatment of through-bored Douglas-fir poles with gelatin encapsulated MIT or chloropicrin

A field test comparing the effectiveness of gelatin encapsulated MIT and chloropicrin was initiated in Bonneville Power Administration poles (Dorena-Tap line) near Cottage Grove OR. Details of the experimental design and initial results were presented earlier ('83 Ann. Rept., pages 33-34). Decay fungi were detected in the poles up to 3.6 m above the groundline, indicating that, while through-boring had effectively prevented decay at the groundline, it did not affect the entry of decay fungi above this zone.

Since these poles could not be safely treated above the groundline by conventional remedial treatments, it was decided to evaluate gelatin encapsulated fumigants which permit handling of the volatile chemicals above the groundline with minimal risk of spillage.

Increment cores removed from 0.6 to 5.1 m above groundline in all 4 quandrants were cultured for decay fungi. The culture results indicate that all decay fungi have been eliminated from these poles (Table 16). Additional cores removed for the closed-tube bioassay from the same location indicated that both MIT or CP vapors inhibited growth in closed tubes in all quadrants and levels inspected. (Table 17); however, wood from four of six poles exhibited less inhibition in the outer zone 0.9 m above the highest treating hole. This trend has also been found in other test poles and occurs because the fumigant must move both up and across the grain to protect this zone.

TABLE 16

FUNGAL POPULATION OF DOUGLAS-FIR TRANSMISSION POLES TREATED WITH ENCAPSULATED MIT OR CHLOROPICRIN[a].

TREATMENT	1981	1983	1985
MIT	35	0	0
CP	64	0	0

[a]Poles were inspected at locations ranging from 0.6 to 5.1 m above the groundline in all 4 quadrants.

Treatment of Douglas-fir poles with encapsulated MIT.

In 1983 a field study was initiated to determine the amount of water needed to effectively release MIT from gelatin capsules and control decay fungi in Douglas-fir utility poles. A group of 17 poles from a Portland General Electric transmission line (Salem to Gresham, OR) were sampled at -0.3, 0, 0.6, 1.2, and 2 meter above groundline in 1982 by removing and culturing three increment cores equally spaced around each pole at each height. These poles had a high incidence of decay fungi, with visible evidence of advanced decay in 20% of the cores, and decay fungi isolated from 67% of the treatment holes prior to fumigation.

Based on the incidence of decay, these poles were divided into three equal groups (five poles each) and treated in September 1983. Treatment holes (2.2 X 43 cm) were drilled at a 45° angle downward in a spiral pattern offset by 90° around each pole at 1 meter intervals from 0 to 5 meter above the groundline. As the holes were drilled, wood shavings were collected and cultured to determine the initial

TABLE 17

EFFECT OF FUMIGANT TREATMENT WITH GELATIN ENCAPSULATED MIT OR CHLOROPICRIN (CP) IN TRANSMISSION POLES FROM DORENA-TAP LINE TWO YEARS AFTER TREATMENT AS MEASURED USING THE CLOSED-TUBE BIOASSAY

	HEIGHT ABOVE GL	AVE. GROWTH OF ASSAYED FUNGUS (MM)[1] AND CORE LOCATION (QUADRANTS)							
		Q1		Q2		Q3		Q4	
TREATMENT	(M)	OUTER	INNER	OUTER	INNER	OUTER	INNER	OUTER	INNER
MIT	5.1	42	0			0	0		
Pole 1	4.2	0	0			0	0		
	3.6			0	0			0	0
	3.0	0	0			-	-	0	0
	2.4			0	0			0	0
	1.8	0	0			0	0		
	1.2			0	0			0	0
	0.6			0	0			0	0
MIT	5.1	9	12						
Pole 2	4.2	13	0			0	0		
	3.3	0	0			0	0		
	2.7			0	0			0	0
	2.1	0	0			0	0		
	1.5			0	0			0	0
	.9			0	0			0	0
MIT	5.1			3	0			0	0
Pole 3	4.2			2	0			0	0
	3.6	0	0			0	0		
	3.0	0	0			0	0		
	2.4		0	0			0	0	
	1.8		0	0			0	0	
	1.20	0			0	0			
CP	3.9	40	7			5	0		
Pole 4	3.0	0	0			0	0		
	2.4			0	0			0	0
	1.8	0	0			0	0		
	1.2			0	0			0	0
	0.6			0	0			0	0
CP	2.7	39	0			0	0		
Pole 5	1.8	0	0			0	0		
	1.2			0	0			0	0
	0.6			0	0			0	0
CP	3.3	0	0			0	0		
Pole 6	2.4	0	0			0	0		
	1.8			0	0			0	0
	1.2			0	0			0	0
	0.6	0	0			0	0		

Growth in unexposed Controls = 33 mm

distribution of decay fungi in the treated zone. Poles were then treated by adding four gelatin capsules containing a total of 88 ml of MIT and either 70, 40, or 0 ml of water to each treatment hole to aid in fumigant release. Treatment holes were then plugged with preservative-treated dowels. These poles were sampled 1 year after treatment to assess the effectiveness of the treatments by removing increment cores from sites opposite the treatment holes and using them for closed tube bioassays and culturing.

The results indicate that all of the MIT treatments have nearly eliminated decay fungi from the test poles (Table 18). After 3 years the effects of the initial introduction of various amounts of water to each treatment appear to have leveled off and the amount of fungitoxic MIT in the poles appears similar, as evidenced by the closed-tube bioassay (Table 19). The closed tube results indicate that the fumigant is becoming well-distributed throughout the pole cross section and should eventually control decay fungi in all treatments.

While the effect of moisture level appears less significant for long term protection, it is apparent that rapid MIT release by the middle moisture level will result in more rapid fungal control, thereby minimizing damage.

Pre-installation fumigation of Douglas-fir transmission poles

It has been our contention that the best time to fumigant treat is when the poles are free of decay. At this point, the sound wood will hold more fumigant and the chemical can prevent fungal colonization, thereby retaining all of the original pole strength. To evaluate this approach twenty-three pentachlorophenol-treated Douglas-fir

TABLE 18

FREQUENCY OF DECAY FUNGI ISOLATED FROM DOUGLAS-FIR POLES TREATED WITH GELATIN ENCAPSULATED METHYLISOTHIOCYANATE (MIT)[a].

SAMPLING DATE	METERS ABOVE GROUND-LINE	CORES WITH DECAY FUNGI (%) [b] 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

[a] The initial decay estimates were based on culturing of shavings collected during treatment hole drilling. The 1 year data was based on culturing increment cores removed from sites opposite from the treatment holes.

[b] Either 0 ml (dry), 40 ml (moist), or 70 ml (wet) of water was added to each treatment hole to aid in fumigant release.

TABLE 19

RESIDUAL FUMIGANT EFFECTIVENESS IN DOUGLAS-FIR UTILITY POLES FOLLOWING APPLICATION OF GELATIN ENCAPSULATED METHYLISOTHIOCYANATE AS MEASURED BY THE CLOSED TUBE BIOASSAY[a].

METERS ABOVE GROUND	CORE LOCATION INSIDE TREATED SHELL (cm)	AVERAGE GROWTH OF ASSAY FUNGUS (as % of control) IN ENCAPSULATED MIT TREATED POLES[b]		
		DRY	MOIST	WET
0	0-2.5	0	0	0
	12.5-15	0	0	0
0.9	0-2.5	0	12	0
	12.5-15	0	0	12
1.8	0-2.5	12	0	4
	12.5-15	0	0	0
2.8	0-2.5	24	0	4
	12.5-15	0	20	0
3.7	0-2.5	4	8	0
	12.5-15	4	4	0
4.6	0-2.5	64	16	16
	12.5-15	32	0	8
5.5	0-2.5	40	20	28
	12.5-15	28	4	8
Control	(no wood)	25 mm		

[a] Four capsules, each containing 22 ml of MIT, were placed in 2.3 cm diameter, treatment holes 44 cm deep. Treatments involved adding either 0 ml (dry), 40 ml (moist), or 70 ml (wet) to each treatment hole to aid in fumigant release from capsules.

[b] The closed tube bioassay uses 2.5 cm wood segments removed from the pole. These segments are placed into agar tubes inoculated with an assay fungus, Poria placenta. Fumigant effectiveness is then evaluated as the ability to inhibit radial growth of the fungus and cores with lower numbers have higher fumigant levels.

transmission poles were field drilled at McFarland-Cascade Pole Yard shortly after conventional treatment and internally treated with gelatin encapsulated MIT. Two drilling patterns were used, both with six treating holes equally spaced in a spiral pattern up the pole to provide for a zone of protection from just below groundline to a point 7.2 m above groundline.

Sixteen poles, ranging from 12-18 m in length, were treated by pattern A (0 to 7.2 m above groundline), while four 27 m, two 24, and one 18 m poles were treated with pattern B (-1.2 to 6.0 m above groundline). The 1.15 cm diameter x 55 cm deep treating holes were drilled at approximately 60° to avoid going through the opposite side of the pole and to maximize the amount of chemical applied to each hole (six capsules or 192 ml of fumigant). Approximately 50 ml of water was added to each hole to degrade the gelatin and release MIT vapors throughout the interior of the pole. All poles were plugged with Penta-treated 1.3 cm diameter plugs. The treated poles were tagged near the belly plug, OSU A or OSU B, to identify them. Although there were some problems with MIT leaking out of checks crossed by the treating holes, these treatments were performed during a driving rainstorm and leaking should be less of a problem under less inclement conditions.

We will follow the progress of these poles by removing increment cores from selected heights on each pole 1, 3 and 5 years after fumigation to insure that the chemical migrates into the wood.

D. SENSITIVITY OF THE CLOSED-TUBE BIOASSAY TO METHYLISOTHIOCYANATE IN WOOD.

The closed-tube bioassay (CTB) was originally developed by Scheffer and Graham and has been extensively used to detect residual fungitoxic vapors in fumigant treated wood. Briefly, test-tube slants of malt agar are edge innoculated with a test fungus, and incubated until the fungus just begins growing from the edge of the onnoculation plug. Pieces of wood to be tested (usually increment core sections) are then sealed in the neck of the test-tubes which are stored at a steep inverted angle to prevent direct wood/agar contact and allow fungitoxic gases to diffuse upward. After an incubation period, the linear growth of the test fungus in the CTB tubes is compared with growth in control (no wood and/or untreated wood) tubes.

The extent of fungal inhibition is used as a relative measure of residual fumigant vapors in the wood. Extensive use of these procedures indicates that the bioassay, using Poria placenta as the test fungus, is sensitive to low levels of MIT in wood, but the exact response range has never been quantified.

We developed the following experiments to relate growth supression of P. placenta in the closed-tube bioassay to the amount of MIT in the wood samples.

Closed tube bioassay tests were conducted using 9 x 100 mm test-tubes with teflon-lined screw caps. Two ml of 2.5% malt extract (1% agar) was slanted in the bottom of each test-tube to form a 5-6 cm long agar surface and the leading edge of the agar was inoculated with a 2 mm diameter plug from an actively growing Poria placenta culture (FP-94267A). Tubes were incubated for 2 to 3 days, until the fungal

growth extended 1 to 4 mm away from the innoculation plugs. The leading margin of the fungus was marked and the test wood blocks were placed into the test-tubes.

After incubating 8 to 12 days, fungal growth in each tube was measured and compared with that of the controls. Growth in tubes containing no wood or non-fumigant exposed wood averaged 30 mm.

Two types of wood blocks were used in these studies. Initial tests used small Douglas-fir (heartwood, 10-20 growth rings/cm) and Ponderosa pine (5-11 growth rings/cm) blocks (1.0 x 1.0 x 0.5 cm grain length). When fumigated blocks were ready for use in the CTB, they were split radially. Half of each block was extracted in ethyl acetate and analyzed for MIT content through gas chromatographic procedures ('83 Annual Report pages 18-22), while the other half was split into a series of small slivers (0.02 to 0.06 g) for use in the closed tube bioassay. A final experiment used 26 mm by 4.8 mm increment cores removed from an 18" diameter Douglas-fir log at a depth of 3 1/2 inches inside the cambium layer (sapwood depth of 2 1/2 to 3 inches) and averaged 2 growth rings per cm.

A number of experiments were conducted to relate specific MIT concentrations in wood with the closed-tube bioassay (CTB) results. Initial experiments used Douglas-fir and pine blocks that were fumigated for over 7 months in a NOR-AM Agricultural Grade MIT (95% pure) saturated atmosphere. These blocks were then removed, aerated in a fume hood and periodically sampled for MIT content and CTB growth response.

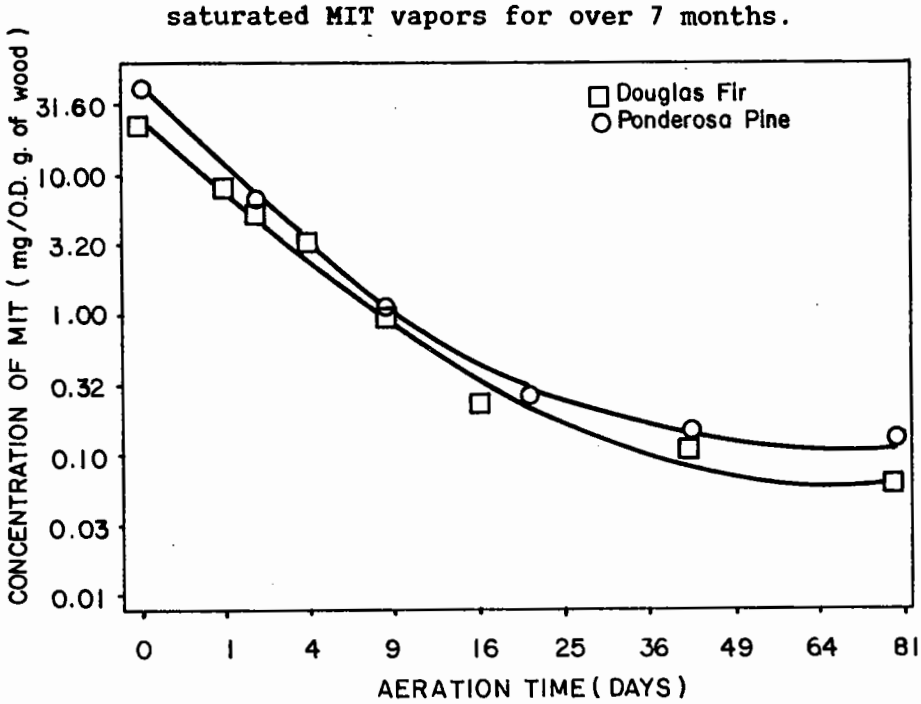
After this long initial fumigant exposure, MIT loss during aeration was very slow (Fig. 4) and 81 days aeration was required before fungal growth was observed in the CTB. Even at this point, growth was only observed when smaller slivers of pine were tested. The CTB showed a linear response of P. placenta growth to the total MIT content in the pine samples (Fig. 5) at a sensitivity range of 1 to 6 ug MIT.

Because of the relatively high MIT concentrations remaining in wood after these long aerations, the experiment was repeated using wood blocks exposed to a MIT saturated atmosphere for 15 minutes. These blocks were then equilibrated in glass jars sealed in the teflon lined lids for 24 days before being removed and aerated for 3 days. Blocks were for 5 to 10 days before being sampled for MIT content and CTB growth.

These tests revealed a linear relationship ($r = 0.82$) between total MIT content in the wood and CTB growth for the fumigated pine (Fig. 6). The CTB response to MIT in the wood initially exposed to MIT for only 15 minutes required higher MIT concentrations than for an equivalent growth response in the wood initially exposed to MIT for 7 months (see Fig. 7), although the assay was still sensitive to about the same MIT range (1 to 7 ug MIT). It is possible that part of the apparent greater response of the CTB to lower MIT concentrations after the long fumigant exposure could be the result of impurities in the NOR-AM MIT, or undetected decomposition products formed during the long fumigant exposure.

While MIT concentration and CTB growth were closely correlated in pine sapwood, there was a very poor correlation ($r = 0.36$) between MIT

Figure 4. Concentration of MIT in Douglas-fir (heartwood) and Ponderosa pine blocks (1.0 x 1.0 x 0.5 cm grain length) during aeration in a fume hood following exposure to saturated MIT vapors for over 7 months.



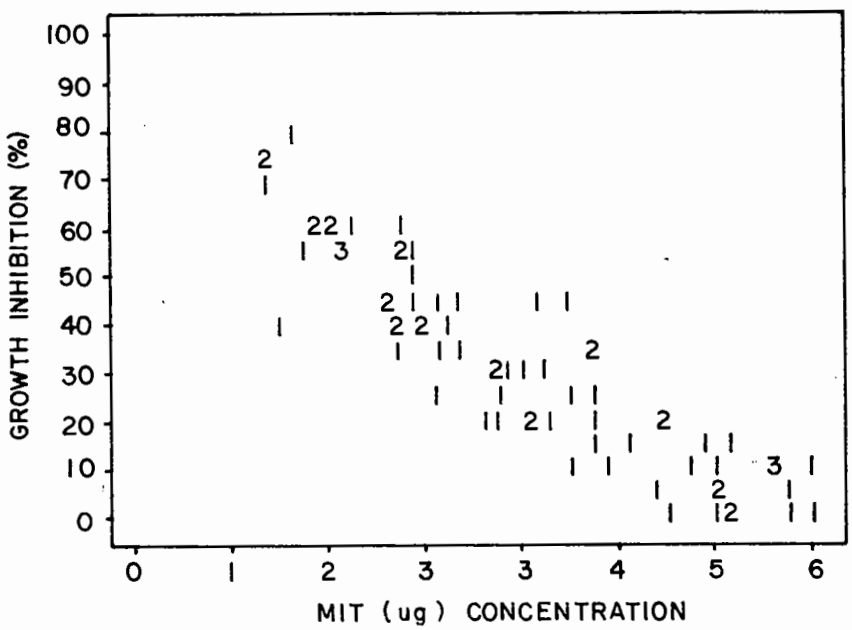
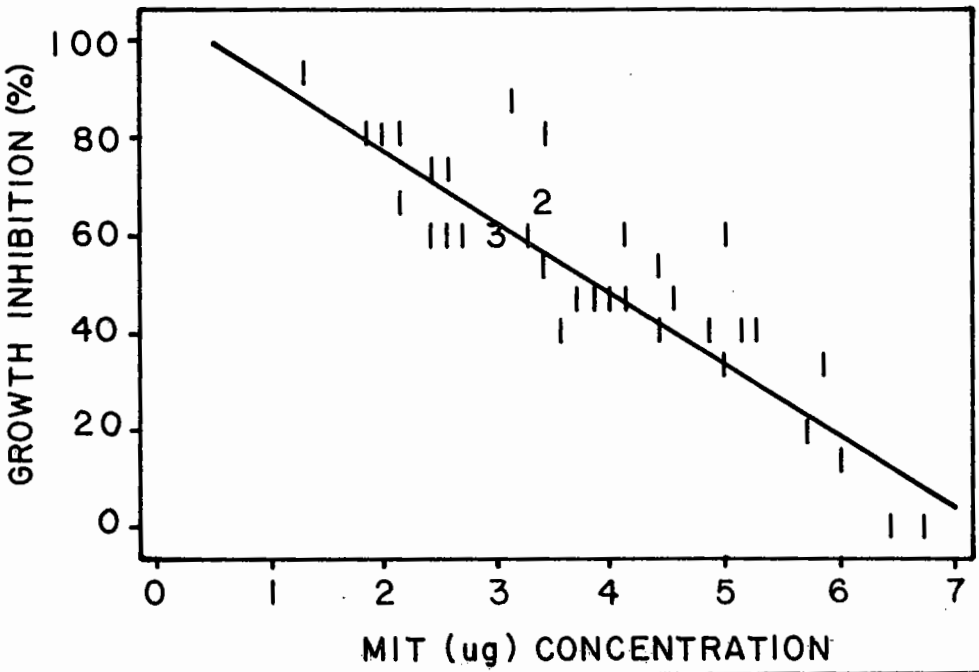


Figure 5. Relationship between concentration of MIT per oven dried (OD) gram of ponderosa pinewood exposed to MIT for over 7 months and percent growth inhibition of P. placenta in the closed tube bioassay.

Figure 6. Relationship between concentration of MIT/OD gram of Ponderosa pine sapwood exposed to MIT for 15 minutes and percent growth inhibition of P. placenta in the closed tube bioassay.



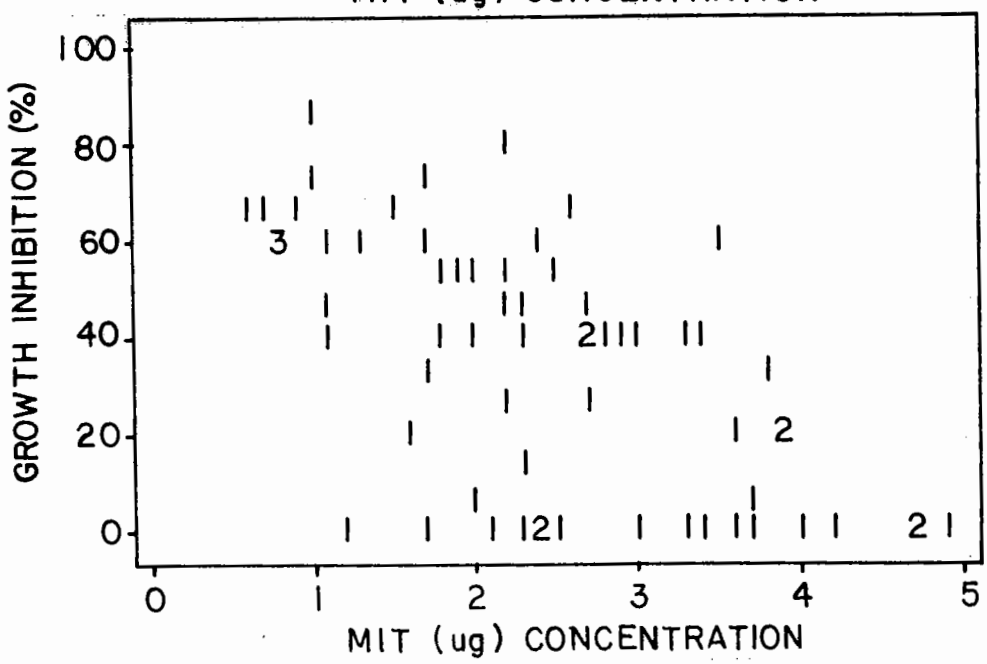


Figure 7. Relationship between concentration of MIT/OD gram of Douglas-fir heartwood exposed to MIT for 15 minutes and percent growth inhibition of P. placenta in the closed tube bioassay.

content and CTB growth in Douglas-fir heartwood (Fig. 7). The CTB was sensitive to lower MIT concentrations in Douglas-fir than for MIT in pine, with complete growth inhibition occurring at 4 ug MIT as compared to 7 ug MIT in the pine. Much of the variation in the relationship between MIT concentration and CTB growth response in the Douglas-fir can be accounted for by the different sizes of wood chips used in the bioassay. When the weight of the wood chip used in the CTB tube was included in the regression model, the correlation improved to 0.65. This suggests that CTB response in Douglas-fir is dependent on both the total MIT added with wood and the amount of wood that the MIT must diffuse through to produce a response.

Based upon these results, a final experiment was conducted to related MIT content and CTB growth in Douglas-fir heartwood using 26 mm diameter increment cores. Groups of 16 cores were fumigated for 10-60 minutes in a 0.42 liter continuous flow apparatus that maintained fumigant vapor concentration at 0.67 ug MIT/ml air and a flow rate of 15 ml/min.

Groups of cores were then aerated from 0 to 120 minutes to obtain a range of final MIT concentrations. These groups were sealed in small glass vials and equilibrated for 9 days before use. Cores were rapidly removed from the vials and six cores were extracted in ethyl acetate to determine average MIT content, while the 10 remaining cores were tested using the CTB.

Once again the relationship between MIT content and CTB fungal growth varied widely in Douglas-fir (Fig. 8), but a linear relationship was observed when the growth response and MIT content for

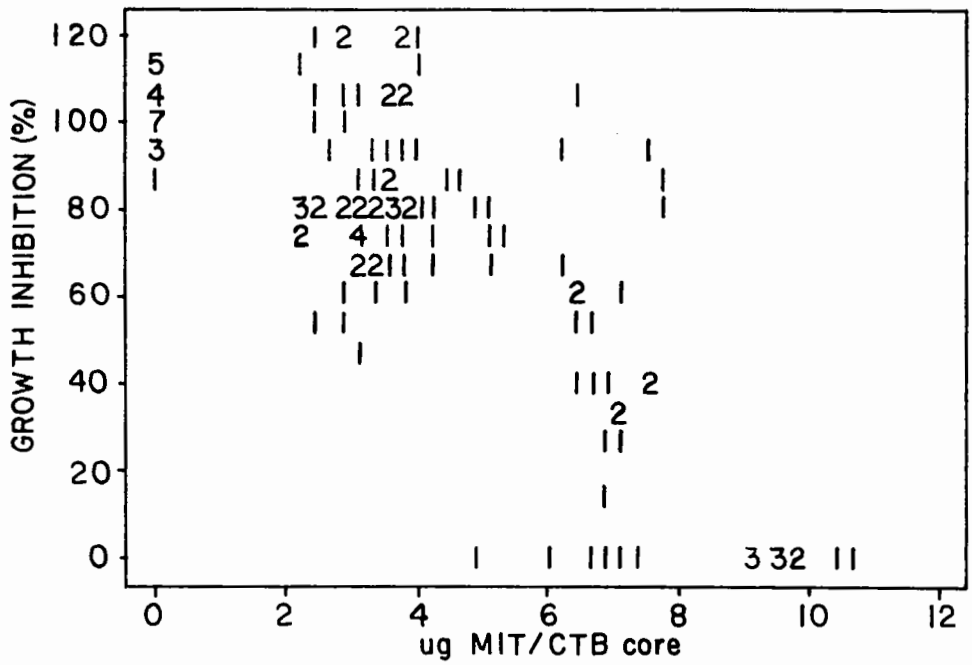
each group of cores was averaged (Fig. 9) ($r = 0.81$). This relationship indicates that the CTB is sensitive to MIT concentrations ranging from 2 ug MIT (no growth inhibition) to 10 ug MIT (complete growth inhibition) per 26 mm by 4.8 mm Douglas-fir heartwood increment core (about 0.20 to 0.23 g wood). The response of the CTB to MIT in Douglas-fir was dependent on both the total MIT added with the wood samples and the amount of wood added. In pine, there was a closer correlation between MIT content and CTB growth which did not appear to be dependent on the amount of wood present.

The differences in bioassay response between Douglas-fir heartwood and pine sapwood probably reflect the presence of heartwood extractives. In some species Western red cedar heartwood extractives, can strongly influence bioassay response and may further complicate results in combination with fumigants. These tests suggest that precise quantification of the closed tube bioassay is not feasible. In spite of this variability, the assay continues to serve as a simple means for assessing long term fumigant performance.

E. EVALUATE THE DEGRADATION OF SODIUM N-METHYLDITHIOCARBAMATE (NaMDC) INTO METHYLISOTHIOCYANATE (MIT) AND RELATED COMPOUNDS

Vapam (32.7% NaMDC) is the most commonly used wood fumigant, but its measurable fungitoxic effect seems short lived (2-3 years). In spite of this, most poles remain relatively free of decay fungi for up to 10 years, suggesting the deposition of more stable fungitoxins or an extremely slow rate of recolonization by decay fungi.

Figure 8. Relationship between concentration of MIT per Douglas-fir heartwood increment core and percent growth inhibition of P. placenta in the closed tube bioassay using individual values.



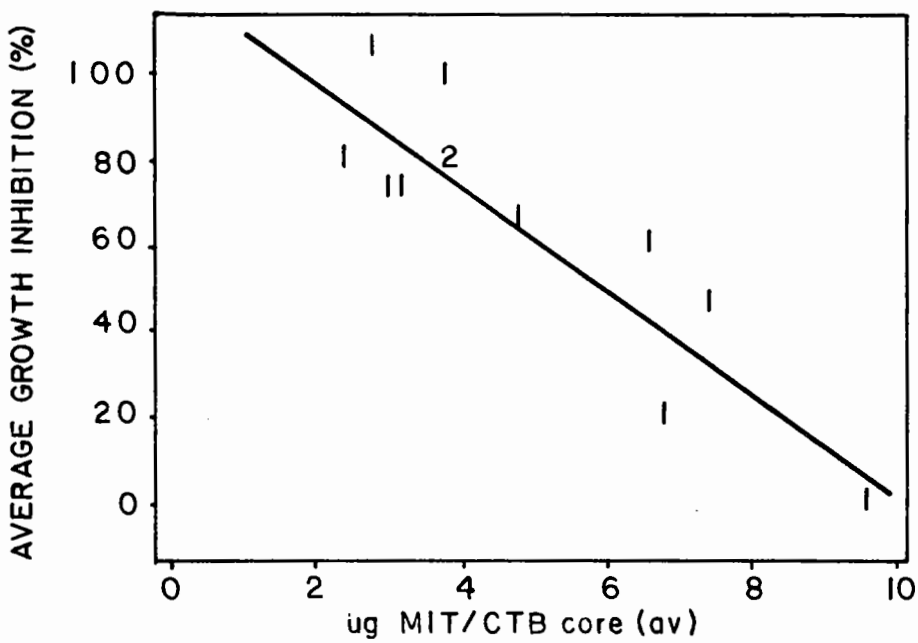


Figure 9. Relationship between MIT concentration per Douglas-fir heartwood increment core and percent growth inhibition of P. placenta in the closed tube bioassay using the average of each 16 increment core group.

Unfortunately little is known about how Vapam reacts in wood and this study has been initiated to determine why Vapam performs so well as a wood fumigant.

The compounds studied in this investigation are interrelated in that they are formed from decomposition of NaMDC and/or they decompose to MIT. Moreover, MIT is formed directly from NaMDC (Table 20). NaMDC is produced by reacting carbon disulfide, methylamine, and sodium hydroxide. At different conditions, the same reactants can give disodium methyldithiocarbamate and are also the reported ingredients used in the commercial production of Mylone.

In the process of identifying the Vapam breakdown products, it has been necessary to develop analytical procedures for quantifying the various products and to synthesize standards of the theorized breakdown products.

At present, the first two steps in this process are now complete and studies to determine how and at what rate Vapam degrades in sawdust are now underway. These controlled studies will then be followed by more practical scale up studies using solid wood blocks.

In a preliminary experiment, aqueous NaMDC (33% active) was mixed with Douglas-fir sawdust at several pH conditions. After 3 weeks the mixtures were extracted with methanol and analyzed by HPLC. The extract contained DMTU, MIT, MMC, DTD, MMTD, sulfur, and some unidentified constituents.

In a parallel experiment, NaMDC treated wood was analyzed after about 2 months, and a material balance of sulfur was attempted. The air space in the container tubes were analyzed by GC, and extracts of

TABLE 20

POTENTIAL DEGRADATION PRODUCTS PRODUCED FROM VAPAM

SHORT ID	CAS NAME	CAS NUMBER	FORMULA	FW	MP
NaMDC	Sodium methycarbamodithioate	137-42-8	$C_2H_4NS_2Na$	129	-
MTU	Methylthiourea	598-52-7	$C_2H_6N_2S$	90	119
DMTU	N,N'-dimethylthiourea	534-13-4	$C_3H_8N_2S$	104	61
MMC	O-methyl-N-methylcarbamothioate	14128-35-9	C_3H_7NOS	107	-
MEMC	O-(1-methylethyl)-N-methylcarbamothioate	20753-31-5	$C_5H_{11}NOS$	135	-
MIT	isocyanato-Methane	556-61-6	C_2H_3NS	73	37
TDTT (Mylone)	Tetrahydro-3,5-dimethyl-2,H,1,3,5-thiadiazine-2-thione	533-74-4	$C_5H_{10}N_2S_2$	162	103
DMTM	N,N^1-dimethyl-thiodicarbono-thioic diamide	5437-22-9	$C_4H_8N_2S_3$	180	75(d)
DMTD	N,N^1 dimethylthioperoxy dicarbonic diamide	2438-90-6	$C_4H_8N_2S_4$	212	96-8(d)
DTD	2,4 dimethyl-1,2,4-thiadiazolidine - 3,5-dithione	6317-20-0	$C_4H_6N_2S_3$	178	120
MMTD	4-methyl-5-(methylimino)-1,2,4-dithiazolidine-3-thione	20042-85-7	$C_4H_6N_2S_3$	178	84
Sulfur	Sulfur	7704-34-9	S8	256	113,119

*Underlined letter determines position in CAS alphabetical list.

the treated wood were analyzed by liquid chromatography. The results indicate that several volatile compounds were produced, but the majority of Vapam degraded to elemental sulfur (Table 21). There were also several unidentified compounds, although no DMTD was found. No MIT was found in the extracts of treated wood, while MIT represented about 1% of the sulfur in controls containing no wood.

As shown by the elemental sulfur results, the quantitative recoveries are not completely reliable. But, it is also clear that elemental sulfur is by far the major product, and that DMTU is the second leading product, in terms of sulfur recovery. Unidentified components probably represent < 10% of the sulfur. Sulfur can inhibit spore germination and its presence may be sufficient to prolong the effectiveness of Vapam treatments

Eventually, we will produce a precise picture of the Vapam breakdown products and how the degradation can be controlled to produce the most fungitoxic breakdown products. In addition, examination of Vapam treated wood will be performed to determine the breakdown products deposited in the wood and the relative levels of each compound. This data may influence how Vapam treated wood can be disposed after it loses its usefulness as a pole.

TABLE 21

COMPOUNDS PRODUCED FOLLOWING EXPOSURE OF VAPAM TO DOUGLAS-FIR SAWDUST

COMPOUNDS	% OF INITIAL DOSAGE
Carbon disulfide	0.1
MIT	0.1
CARBONOXYISULFIDE	0.1
DTD/MMTD	4-6%
DMTU	9-14%
Sulfur	50-100%

OBJECTIVE II

DEVELOP ENVIRONMENTALLY ACCEPTABLE PRESERVATIVE TREATMENTS FOR SAFELY CONTROLLING ABOVE-GROUND SAPWOOD DECAY IN CEDAR POLES.

A. CHECKING FOR RESIDUAL CHEMICAL IN THE SAPWOOD OF POLES SPRAY-TREATED TWO YEARS PREVIOUSLY (1983) WITH FIVE ADDITIONAL FUNGICIDES.

We noted in the annual report of August 1984 (pg 26) that in 1983 Cedar pole stubs in the Peavy Arboretum were sprayed with five additional chemicals in our search for replacements for 10% pentachlorophenol in oil used to control shell rot. Samples of the sprayed sapwood examined this year (2 years later) by means of the Aspergillus bioassay indicated residual chemical, but comparable indications of chemical were found in the untreated, control sapwood. The same result was obtained in tests of decay resistance, using the soil-block technique. Apparently a fungitoxic chemical of some kind had come in contact with the poles while in service, in an amount sufficient to render them unsuitable for our spraying trials. Some of the chemicals, however, will be retested on other untreated poles.

B. EVALUATION OF NEW CHEMICALS AS REPLACEMENTS FOR PENTACHLOROPHENOL.

This past year we again undertook an extensive screening of additional chemicals. This process was begun because of continued uncertainty of the availability of any penta formulations coupled with the development of several promising new fungicides that may have some potential for this application. We initiated laboratory screening tests on 28 additional chemicals, using soak-treated pine sapwood blocks. The chemicals were recommended for trial and supplied by eight manufacturers or distributers (Table 22).

TABLE 22

SUMMARY OF PRODUCTS IN TRIALS OF NEW CHEMICAL CANDIDATES FOR CEDAR-POLE SPRAYS

CHEMICAL TESTED	ABBREVIATION	DISPER-SANT	% PRODUCT IN TREATING MIXTURE	% ACTIVE INGREDIENT
Dodecyl dimethyl benzyl ammonium salt of naphthenic acid (50%)	N 100 WD	Water	16.67 1:1 dil.	8.3 4.2
Copper naphthenate (8% Cu)	NCuN	Diesel	50 1:1 dil	4 (Cu) 2 (Cu)
Copper 8-quinolinolate (1.8% Cu)	QEX	Water	16.67 1:1 dil.	0.3 (Cu) 0.15 (Cu)
Copper 8-quinolinolate (1.8% Cu)	QEB	Diesel	16.67 1:1 dil.	0.3 (Cu) 0.15 (Cu)
Zinc naphthenate (8% Zn)	N Zn	Diesel	50 1:1 dil.	4 (Zn) 2 (Zn)
Dodecyl dimethyl ammonium salt of naphthenic acid (50%)	N 100 SS	Diesel	16 1:1 dil.	8 4
N-(trichloro-methylthio) phthalimide (44%)	FOLPET	Diesel	6.81 1:1 dil.	3 1.5
2-(thiocyanomethylthio) benzothiazole (30%)(TCMTB)	Busan 1030	Water	13.33 1:1 dil.	4 2
Methyl bis (10%) (thiocyanate) (MBT)	Busan 1009	Water	20 1:1 dil.	4 2
(20%)MBT/TCMTB+ (100%) Busperse 47	Busan 1009+ Busperse 47	Water	20 5 1:1 dil.	4 5 2 2.5
TCMTB + Burperse 47	Busan 1030+ Busperse 47	water	13.33 5	4 5

CHEMICAL TESTED	ABBREVIATION	DISPER-SANT	% PRODUCT IN TREATING MIXTURE	% ACTIVE INGREDIENT
				2 1:1 dil. 2.5
Cu-8-10- 10% (1.8% Cu)	M 645	Diesel	100 1:1 dil.	1.8 (Cu) 0.9 (Cu)
Cu-8-10- 10% (1.8% Cu)	M Cu-8	Diesel	16.67 1:2 dil.	0.3 (Cu) 0.15 (Cu)
Cu-8-10 WP 10% (1.8% Cu)	M Cu-8 WP	Diesel	16.67 1:1 dil.	0.3 (Cu) 0.15 (Cu)
Cu-8-10 10% (1.8% Cu)	N WD	Water	16.67 1:1 dil.	0.3 0.15 (Cu)
Zinc Naphthenate (8% Zn)	M-Gard S 552	Diesel	50 1:1 dil.	4 (Zn) 2 (Zn)
Zinc Naphthenate (8% Zn)	M-Gard W 553	Water	50 1:1 dil.	4 (Zn) 2 (Zn)
Zinc Naphthenate (8% Zn)	M-Gard W 550	Water	50 1:1 dil.	4 (Zn) 2 (Zn)
Cu-Naphthenate (8% Cu)	M-Gard S-520	Diesel	50 1:1 dil.	4 (Cu) 2 (Cu)
Cu-Naphthenate (8%)	M-Gard S-522	Diesel	50 1:1 dil.	4 (Cu) 2 (Cu)
Azaconazole (5% ai)	(Rodewood)	Water	6 1:1 dil	0.3 0.15
Technical Penta standard (10%)	Penta	Diesel	100	10

CHEMICAL TESTED	ABBREVIATION	DISPERSANT	% PRODUCT IN TREATING MIXTURE	% ACTIVE INGREDIENT
Trimethyl coccamonium chloride (50%)plus	AC-50+ Polyphase	Diesel	6	3
3-iodopropynyl butyl carbamate (40%)			2.5	1
Isothiazolone (40%)	C-9211	Diesel	2.5	1
Arquad C-50 plus	AC-50 plus	Diesel	6	3
isothiazolone	C-9211		1.25	0.5
Chlorothalonil (96%)	Napcocide	Diesel	4.16	4
			1:1 dil.	2

In these tests, ponderosa pine (P. ponderosa) sapwood blocks (3.18 x 7 x 3.8 cm) were placed, end-grain down, in a solution of the test chemical for 30 minutes, then removed and air-dried. This treatment provide a gradient of chemical into the wood simular to that found in sprayed poles. The test chemicals were tested on six blocks at the concentration recommended by the producer and one half that level.

One set of blocks was left aside, while the remaining blocks were artificially weathered in a "weatherometer" to simulate leaching. The weather cycle consisted of exposure at 1 minute intervals to a water spray and an infra-red heat lamp. The daily cycle included 8 hours of wetting and 16 hours of drying. After weathering, plugs were removed from the weathered end of the blocks and crosscut to provide four circular wafers corresponding to 0 to 3, 3 to 6, 6 to 9, and 9 to 12 mm from the surface.

These wafers were tested using a modified soil block test with Poria placenta as the assay fungus. The chambers were incubated until untreated control blocks experienced 60% weight loss, then all wafers were removed and dried to determine wood weight loss, which was used as a relative measure of preservative protection.

The results (Table 23) indicate that several chemicals protected the wood as well as technical grade penta, while several others were slightly less effective than the standard treatment. Among the better chemicals were N100WD (a quaternary ammonium compound); QEB (copper-8-quinolinolate), Busan 1030, Busan 1009, Azaconazole and isothiazolone. In addition four mixtures, Arquad C-50 plus polyphase, Arquad C-50 plus isothiazolone, Busan 1030 plus Busperse 47 (a

penetrant) and Busan 1009 plus Busperse 47 also exhibited promising decay resistance in the pine sapwood. In several instances, these chemicals provide protection in the third and fourth zones from the surface sampled indicating the potential for long term performance similar to that currently experience with penta.

In addition to those chemicals which provided superior protection, several other chemicals appear to have some potential as penta substitutes including MGARD S 553 and S 550. It is unclear what level of performance is required for protection of weathered western redcedar sapwood and, in some ways, it is unfortunate that potential substitutes must be compared with penta, a highly effective, broad spectrum fungicide. Colonization of cedar sapwood by decay fungi most likely occurs by spores germinating in small checks near the surface. Under these conditions, the spores may be quite sensitive to toxins and less toxic chemicals may be just as effective, provided they are resistant to leaching. This premise should be borne out by field tests. Based on our tests, the 10 formulations deemed effective will be applied to untreated western red cedar sapwood at our Peavy Arboretum test site ('84 Annual Report. Pg. 26).

C. EVALUATION OF THE ASPERGILLUS BIOASSAY FOR ASSESSING THE RELATIVE RETENTION AND DECAY RESISTANCE OF CHEMICALS PROPOSED FOR CEDAR SAPWOOD DECAY CONTROL.

As a part of the process to develop replacements for penta in oil as a cedar decay control, we have examined the ability of the Aspergillus bioassay to detect residual concentrations of each

TABLE 23

WEIGHT LOSS (%) OF PINE SAPWOOD WATERS CUT AT DISTANCES FROM ENDS OF UNWEATHERED AND WEATHERED WOOD BLOCKS TREATED WITH VARIOUS TEST CHEMICALS[a]

CHEMICAL TESTED[b]	CONCENTRATION[c]	WOOD WEIGHT LOSS (%) DEPTH OF WAFER FROM SURFACE[d] 0-3 mm		3-6 mm		6-9 mm		9-12 mm	
		U	W4	U	W4	U	W4	U	W4
N100 WD	1	8	4	2	4	16	4	44	41
	0.5	3.5	3	13	3	27	14	52	44
NCuN	1.0	15	44	35	42	22	39	48	38
	0.5	26	56	51	60	43	52	52	55
QEB	1.5	5	4	4	4	2	7	40	54
	0.5	4	2	3	3	10	36	51	41
NZN	1.0	34	52	54	43	49	41	54	42
	0.5	52	57	56	63	56	57	57	56
N100SS	1.0	10	28	23	33	42	41	36	50
Folpet	1.0	12	41	40	48	42	58	50	48
	0.5	46	59	48	57	46	56	40	56
Busan1030	0.5	5	3	2	2	3	3	51	22
Busan1009	0.5	0	7	1	1	22	28	43	42
M645	1.0	33	41	59	53	58	55	58	63
	0.5	61	65	64	63	60	57	58	64
MCu8	1.0	29	13	48	50	57	56	58	51
	0.5	55	50	61	59	62	60	61	63
MCu8-WP	1.0	13	13	38	45	42	55	58	60
	0.5	58	46	53	55	64	58	60	64
Nytek WD	1.0	6	5	39	50	62	63	60	57
	0.5	36	4	64	59	60	62	59	60
MGARD S-552	1.0	49	41	47	41	48	42	56	45
	0.5	50	44	33	44	42	44	57	51
MGARD S-553	1.0	9	10	8	9	9	20	30	49
	0.5	7	10	8	9	14	10	61	46
MGARD S-550	1.0	10	14	8	9	22	18	53	21
	0.5	11	31	8	16	38	39	56	46
RODEWOOD	1.0	5	5	5	5	5	6	6	17
	0.5	3	5	4	5	7	4	22	15
MGARD S-520	1.0	11	33	59	41	62	66	61	62
	0.5	31	58	61	48	59	60	61	65

CHEMICAL TESTED[b]	CONCENTRATION[c]	WOOD WEIGHT LOSS (%) DEPTH OF WAFER FROM SURFACE 0-3 mm U	0-3 mm W4	3-6 mm U	3-6 mm W4	6-9 mm U	6-9 mm W4	9-12 mm U	9-12 mm W4
MGARD S-522	1.0	25	36	63	62	63	61	65	62
	0.5	38	60	61	65	64	60	56	59
PENTA	1.0	4	9	4	4	6	4	7	5
BUSAN 1009 plus Busperse 47 in oil	1.0	6	54	51	53	50	53	59	52
BUSAN 1030 plus Busperse 47 in oil	1.0	34	41	31	30	32	23	32	24
AC-50 + Polyphase	1.0	8	6	4	5	8	4	7	6
ISOTHIAZOLONE	1.0	6	9	5	10	7	14	6	20
	0.5	8	42	13	21	13	32	34	35
AC-50 +ISOTHIAZOLONE	1.0	5	8	3	10	5	8	5	1
NAPCOCIDE	1.0	53	60	61	57	62	58	60	55
	0.5	54	58	52	60	53	62	54	60
CONTROLS[d]									

[a]U=Unweathered; W4= weathered 4 weeks.
[b]Abbreviations correspond to chemicals in Table 22.
[c]Chemical concentration of first line was full strength while second line was half of initial strength.
[d]At 6 weeks, control (untreated) wafers had a 60% wt. loss.

chemical candidate. Successful use of the Aspergillus bioassay could permit utilities to periodically assay their poles for residual preservative protection in order to identify appropriate retreatment schedules.

In this test, we treated small (1.0 x 1.0 x 0.6 cm) Ponderosa pine sapwood blocks with graded solutions ranging in concentration from 0.05 to 3.0 percent active ingredient. Following treatment the blocks were oven-dried and weighed to determine solution uptake. One half of the blocks in each treatment were tested using the Aspergillus bioassay and the remainder were tested for decay resistance to Poria placenta in a modified soil block test as described in Objective IIB.

Comparisons between the Aspergillus zone of effect and the average weight losses produced in the soil block tests indicate that where the Aspergillus bioassays was sensitive to the chemical tested there was a reasonably close negative correlation between zone of effect and weight loss (Table 24, 25). Several chemicals exhibited little sensitivity to the bioassay, suggesting that they were either too strongly bound to the wood cell wall to diffuse into the surrounding agar or were too insoluble in water. Generally, the copper containing compounds and quaternary ammonium formulations (Arquad C-50, N100SS, and N100WD) did not react well in this test. Both of these types of chemicals exhibit strong wood interactions. This bonding should improve the long term performance of these chemicals; however, determining when these chemicals have lost their effectiveness will require the user to perform more time consuming decay resistance tests.

The presence of most of the remaining compounds was readily detected using the Aspergillus bioassay, suggesting that this method should be applicable to in-service determinations of residual preservative protection.

TABLE 24

ABILITY OF CHEMICALS TO MIGRATE FROM PONDEROSA PINE BLOCKS AND INHIBIT FUNGAL SPORULATION AS MEASURED BY THE ASPERGILLUS BIOASSAY

		ASPERGILLUS ZONE OF EFFECT (MM) SOLUTION STRENGTH (%)						
CHEMICAL[a]		0.01	0.05	0.10	0.20	0.50	1.0	3.0
Arquad C-50	(w)	-----	0	0	0	1.6	0.2	2.5
N100SS	(T)	-----	0	0	0	0	0	0
N100WD	(w)	-----	0	0	0	0	0	1.3
IPBC	(w)	11.9	23.4	24.3	26.2	29.9	30.4	35
TCMTB	(w)	3.1	3.1	23.3	35	35	35	35
TCMTB+MTB	(w)	9.5	20.0	30.4	35	35	35	35
Cu Naph	(T)	-----	0	0	0	2.0	2.2	2.7
Zn Naph	(w)	5.5	11.6	11.6	9.8	9.9	10.7	11.7
QEX	(w)	2.1	9.0	11.3	11.0	12.4	13.8	17.8
QEB	(T)	0	10.4	13.1	12.0	11.0	11.0	12.0
M645	(T)	-----	3.9	11.4	9.0	7.0	5.4	7.4
Folpet	(T)	-----	7.3	8.8	10.6	12.4	15.4	12.2
Isothiazolone	(T)	-----	7.1	9.4	10.4	11.8	10.2	11.7
Napocide	(w)	-----	0	0	0	0	0	0
Azaconazole	(w)	-----	0.7	1.6	9.7	28.0	15.9	27.7

[a] For key to chemical identity see Table 1. Chemical formulation diluted in toluene (T) or water (w)

TABLE 25

EFFECT OF CHEMICAL TREATMENT OF PONDEROSA PINE SAPWOOD BLOCKS ON RESISTANCE TO FUNGAL DEGRADATION BY PORIA PLACENTA IN A MODIFIED SOIL BLOCK TEST.

		AVERAGE WOOD WEIGHT LOSS[1] SOLUTION STRENGTH (%)						
CHEMICAL[b]		0.01[c]	0.05	0.10	0.20	0.50	1.0	3.0
QAC AC50	(w)	---	8.31	5.30	1.78	0	0	0
N100SS	(T)	---	34.71	20.35	23.98	21.60	9.30	0
N100WD	(w)	---	29.66	8.69	2.82	2.94	0	0
IPBC	(w)	15.48	31.12	0.79	0	0	0	0
TCMTB	(w)	---	44.30	15.30	1.15	1.4	0	0
TCMTB+MTB	(w)	30.01	1.15	1.2	0	0	0	0
Cu Naph	(T)	---	27.42	23.13	11.32	1.97	0	0
Zn Naph	(w)	58.61	58.96	46.47	13.94	1.94	0	0
QEX	(w)	60.23	49.06	27.41	10.39	1.51	1.0	0
QEB	(T)	56.81	18.84	1.8	1.3	0	0	0
M645	(T)	---	4.12	2.44	0	0	0	0
Folpet	(T)	---	54.92	15.37	3.61	1.71	0	0
Isothiazolone	(T)	---	2.21	0.97	0	0	0	0
Napocide	(w)	---	38.99	27.75	12.91	9.00	0	0
Azaconazole	(w)	---	3.07	3.40	0	0	0	0

[a] Based upon results of 9 blocks per chemical concentration. Weight losses of blocks treated with toluene or water were 56.01 and 58.4% respectively.

[b] Chemicals formulated in toluene (T) or water (w).

[c] Chemicals that produced high ZOES (>30) at the 0.05% concentration were tested at this additional concentration.

OBJECTIVE III

PREVENTING DECAY INITIATION IN FIELD-DRILLED BOLT HOLES IN DOUGLAS-FIR POLES

A. EVALUATION OF TREATMENTS FOR PREVENTING BOLT HOLE ASSOCIATED DECAY.

An experimental field trial was initiated in 1981 to evaluate treatment of field-drilled bolt holes with Polybor, ammonium bifluoride, pentachlorophenol, Patox washers, or Boracol. The details of this test were described in previous reports ('84 Annual Report, Pg. 31-33). The untreated control poles have been sampled on an annual basis by removing increment cores which were cultured for the presence of decay fungi. This process indicated that three out of four of the control poles contained decay fungi; however, the percentage of cores infested remains quite low (9% of cores). This summer (1986) will be the fifth year that these poles have been in test and all of the treatments will be sampled to assess effectiveness.

B. ABOVE GROUND FUMIGANT TREATMENT WITH GELATIN ENCAPSULATED MIT OR PELLETIZED MIT

Fifteen pressure treated Douglas-fir poles were field drilled by line maintenance personnel 0.3 or 0.6 mm below the underbuilt crossarm bolt holes of a 115 KV Douglas-fir transmission line in the zone where internal decay is likely to occur due to inadequate supplemental preservative treatment during construction.

The poles were treated with either 45 or 90 ml of encapsulated MIT (100% ai) or 60 or 120 g of pelletized MIT (65% ai). The 0.6 cm diameter X 27.5 cm deep treating holes were drilled at a 60° angle to

maximize the amount of chemical added to each hole. The wood auger shavings from each hole were collected and cultured to determine if decay fungi were present in the pole. Cultural results indicated that chips from three poles contained decay fungi while six contained nondecay-fungi.

Three MIT capsules were inserted in each hole by linemen wearing protective gloves and the holes were plugged with treated dowels. The MIT pellets were applied at two dosages using a closed-system applicator; however, spillage of pellets occurred when the shut off gate in the application device was left open and vapors from the chemical caused the applicator some discomfort. No further applications will be made with this device until it has been modified into a safer unit.

One year after treatment with fumigants, increment cores were removed 0.3 and 1.2 m below the crossarms in various quadrants around the pole. Cultural results indicated that no decay fungi were present in these cores.

In the future, these poles will be inspected on a reduced basis every 5th year, due to the number of holes already in them (i.e. crossarm, crossarm bracing, treating holes, and increment borings) and the need for a lineman to perform core collection. At present, treatment with encapsulated MIT appears to provide a simple method for assuring protection of untreated, field-drilled bolt holes.

OBJECTIVE IV

DETECT EARLY DECAY IN WOOD AND ESTIMATE THE RESIDUAL STRENGTH OF POLES IN SERVICE

A. USE OF FLUORESCENT LABELED LECTINS FOR DETECTING DECAY FUNGI IN WOOD

We continue to evaluate the use of fluorescent coupled lectins as probes for detecting fungi in wood and recently completed a survey of 35 fungi from our culture collection to assess the variation in lectin reactivity. As previously reported ('85 Annual Rept., pg. 48-49), lectins are plant-derived chemicals that react with great specificity to carbohydrate-containing compounds. One lectin, wheat germ agglutinin (WGA), reacts specifically with chitin, a major component of the fungal cell wall. This reaction can be seen by coupling the lectin to a fluorescent probe and examining the hyphae with a microscope equipped a xenon light source and the appropriate filters.

If lectins are to be useful for studying fungal decay, their reactivity should be uniform among one or more groups of fungi. To investigate this factor, 35 fungi were grown on malt extract agar, asceptically transferred to glass slides, reacted with fluorescent coupled WGA or Concanavalin A (Con A), a second lectin that appears to have some fungal specificity, and examined microscopically.

The results indicated that Basidiomycete hyphae generally reacted with WGA or Con A, although Fomitopsis cajanderi did not react with either lectin while Schizophyllium commune and Phlebia subserialis did not react with Con A (Table 26). These fungi produce chitin containing hyphae; however, the chitin may have been inaccessible to the lectin. The remaining fungi exhibited considerably more variation in their lectin reactivity, although this variation was

TABLE 26

REACTIVITY OF SELECTED FUNGI TO FLUORESCEIN COUPLED WHEAT GERM AGGLUTININ AND RHODAMINE COUPLED CONCANAVALIN A.

	LECTIN REACTIVITY[a]					
	FITC-WGA			TRITC-CON A		
FUNGAL SPECIES	HYPHAE	CONIDIOPHORES	CONIDIA	HYPHAE	CONIDIOPHORES	CONIDIA
Hyalodendron griseus	+	-b	+	+	-	#
Alternaria alternata	-b	-b	-b	-	-	-
Aspergillus niger	-	-b	-b	-	-	-
Aureobasidium pullulans	-	-b	-b	-	-	-
Ceratocystis albida	+	-	-	-	-	-
Chaetomium globosum	++	-b	-b	-	-	-
Cladosporium elatum	++	+b	++	-	-	-
Coriolus versicolor	+	+	+	+	+	+
Crustoderma dryinum	++	++	++	++	++	++
Epicoccum nigrum	-b	+	-b	+	-	-
Fomitopsis cajanderi	-	+	-	-		
Gloeophyllum saepiarum	++	-	-	++		
Gloeophyllum trabeum	++			++		
Haematostereum sanguinolentum	++			-		
Heterobasidion annosum	++			++		
Irpex lacteus	++			++		
Lentinus lepideus	++			++		
Leptodontium elatum	++	-b	+	++	-	+
Oidiodendron griseum	++	-b	++	+	-	-
Paecilomyces variotti	+	-	-	-	-	-
Penicillum italicum	+	-	-	+	-	-
Peniophora gigantea	+			+		
Phellinus weirii	+			+		
Phialocephala dimorphospora	+	-b	+	+	-	+
Phialophora fastigiata	+/-	-b	+	+/-	-	-
Phialophora sp 3	++	-b	+	-	-	-
Phanerochaete sordida	+	-	-	+	-	-
Phlebia radiata	++			++		
Phlebia subserialis	++			-		
Poria carbonica	++			++		
Poria placenta	++			++		
Poria xantha	++			++		
Schizophyllum commune	++			-	-	-
Scytalidium sp.	++	-b	-b	-	-	-
Sistotrema brinkmanii	++			++		

[a] Lectin reactivity based on: (++) strongly reactive, (+) moderately reactive, (+/-) variably reactive, and (-) non-reactive.

[b] Denotes the formation of fungal structures containing dark pigments.

closely related to the presence of dark pigments in the wood. This effect was most pronounced in fungi producing both hyaline and dark (Dematiaceous) structures. For example, the hyaline hyphae of Chaetomium globosum were strongly reactive with WGA, while the dark perithecial fruiting structures produced by this fungus were not.

The effect of pigments may be attributed to interference of the dark pigments with the fluorescent probes, or deposition of dark pigments on the hyphal surface that prevented the lectin from reaching the chitin. While the latter explanation seems plausible, our tests can not confirm this statement.

The results do indicate that fluorescent coupled WGA and Con A will react with most fungal hyphae, except those with dark pigments; however, these darker structures can be easily studied using conventional light microscopy. It does not appear that lectins can be used to determine if decay fungi are present in wood, but these probes can be used to determine if fungi are present. Once fungal infested wood is identified, the appropriate steps (i.e. culturing, mechanical tests) can be performed to determine the effect of these fungi on wood properties.

B. DETECTING INCIPIENT DECAY USING INFRA-RED SPECTROSCOPIC ANALYSIS OF WARM WATER EXTRACTS

Last year ('85 Annual Report, pg. 50-51) we discussed the ability of Infrared (IR) spectroscopy to detect incipient decay in warm water wood extracts. This past year we further investigated the ability of

this method to detect non-decay fungi by exposing Douglas-fir, ponderosa pine, and red alder blocks to selected Basidiomycetes, Ascomycetes, and Fungi Imperfecti. These tests indicated that colonization by only a few Basidiomycetes was detectable using IR spectroscopy. Additional tests are now in progress to more precisely determine which fungal species alter the wood sufficiently to be detectable using IR spectroscopy.

C. INFLUENCE OF AIR SEASONING AND FUNGAL COLONIZATION ON STRENGTH PROPERTIES OF DOUGLAS-FIR

Two brown-rot fungi, Poria carbonica and Poria placenta are frequently isolated from Douglas-fir poles in service and during air seasoning. The prevalence of these fungi in Douglas-fir poles and a suggestion that air seasoning of Douglas-fir poles be limited to 6 months prompted studies to determine: (1) incidence of decay fungi in air seasoning Douglas-fir poles, (2) volume of wood infected by decay fungi, (3) the effect these have on wood strength, and (4) methods for preventing decay in Douglas-fir poles during air seasoning. The first two studies have been discussed in Objective V.

The third study involved twenty-five freshly peeled Douglas-fir poles (Pseudotsuga menziesii (Mirb.) Franco), 9 to 24 m long, which were obtained from several West Coast suppliers. These poles were sampled for decay fungi by removing increment cores from around the pole circumference every 1.8 m (Figure 10).

Core segments were cultured on a nutrient media and fungi growing from the cores were identified. After coring, the poles were cut into

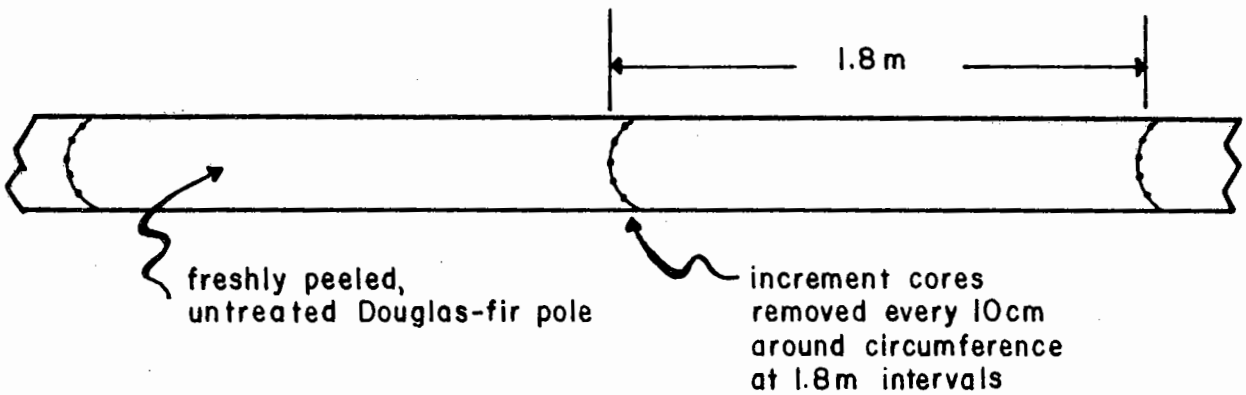


Figure 10. Coring pattern for detecting decay in freshly peeled Douglas-fir poles.

1.8 m long pole sections (polsec's) and one end of each polesec was sealed with an elastomeric compound to retard water loss and minimize end-grain penetration by fungi.

Seventy-two polesecs were placed at seasoning yards located in Arlington, WA, Scappoose, OR, Eugene, OR and Oroville, CA. Climatic conditions at these sites range from very wet at Arlington to very dry at Oroville. The upper faces of one half of the polesecs were sprayed to runoff with a 20% solution of aqueous ammonium bifluoride to evaluate the ability of this chemical to prevent invasion by decay fungi. Previous studies indicate that fungal invasion of southern pine poles treated with ammonium bifluoride in a retort prior to air seasoning was greatly reduced for one year. The polesecs were exposed for 1, 2 or 3 years from the time of installation. At each time-point 3 treated and 3 untreated polesecs were removed from each yard and returned to our laboratory. In each group of three, one 0.6 m bolt was cut from either the sealed end, the middle or the unsealed end of each polesec and the remainder of the polesec was extensively sampled by removing increment cores which were cultured for the presence of decay fungi (Figure 11).

The bolts were cut to produce a series of six small beams (2.5 by 2.5 by 40.6 cm) from the outer 10 cm of the shell (Figure 12), since previous studies indicated that 98% of the load carrying strength of a 35.5 - 38 cm diameter pole lies in this zone. A total of 144 beams were cut at each time point.

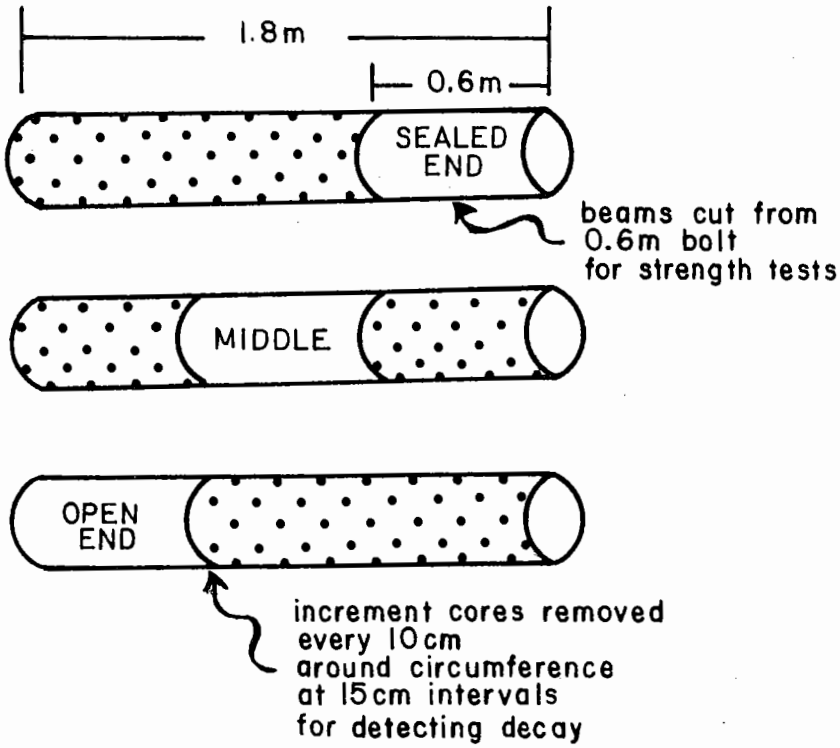


Figure 11. Coring pattern for detecting decay in air seasoned polesecs.

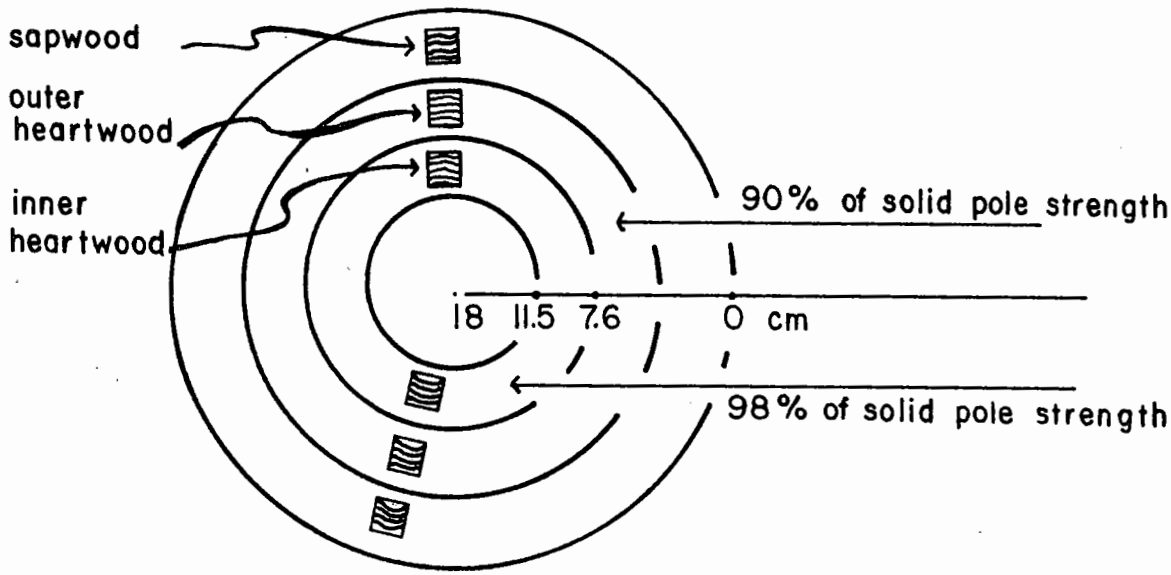


Figure 12. Cross-sectional view of cutting pattern for removing 2.5 by 2.5 by 40.6 cm beams from polesecs air-seasoned for 1, 2, or 3 years.

The beams were tested wet for static bending strength, radial compression and longitudinal compression strength, specific gravity, and Pilodyn penetration using methods previously described ('83 Ann. Rep., pg. 40-41, '84 Ann. Rep., pg. 44-45).

Three percent of the cores removed from freshly peeled poles contained decay fungi (Table 27). After three years of air-seasoning, the percent incidence of decay (the ratio of the number of decay isolates to number of cores examined) increased to 69 percent. Ammonium bifluoride treatment seemed to retard the incidence of decay, especially during the first two years of air-seasoning.

Static bending and other mechanical test results (Table 28) showed that specific gravity, MOE, and RCS did not differ significantly over the three years of air-seasoning. Work to maximum load and Pilodyn measurements of beams declined after two years' of air-seasoning, while MOR of the third year beams was lower than that of one year beams.

The latter finding indicates that the fungi in wood air seasoned for three years begin to exert effects on wood strength. The magnitude of strength changes are illustrated by comparing the MOR and MOE of air-seasoned beams with clear wood beam strength values and variability from ASTM D 2555, [standard methods for establishing clear wood strength values] (Figure 13).

TABLE 27

INCIDENCE OF DECAY FUNGI IN (A) FRESHLY PEELED DOUGLAS-FIR POLES[a] AND (B) AIR-SEASONED POLESECS[b].

TEST GROUP	INCIDENCE OF DECAY, %[c] AMMONIUM BIFLUORIDE TREATED	UNTREATED	ALL
A. Poles	--	--	3
B. Polesecs, Years air-seasoned:			
One	13	28	21
Two	34	64	49
Three	50	86	69

[a]3,070 cores from 25 poles.
[b]12 polesecs and approximately 1,000 cores in each year/treatment group.
[c]Percent incidence of decay = the ratio of the number of decay isolates to the number of cores examined.

TABLE 28

MECHANICAL PROPERTIES OF BEAMS CUT FROM DOUGLAS-FIR POLESECS AIR SEASONED AT FOUR PACIFIC NORTHWEST POLE YARDS FOR THREE YEARS.[a]

SEASONING TIME (YEARS)	SPECIFIC GRAVITY	MODULUS OF RUPTURE (PSI)	MODULUS OF ELASTICITY (x1000 PSI)	WORK TO MAXIMUM LOAD (IN-LB)	PILODYN PIN PENETRATION (MM)	COMPRESSION STRENGTH RADIAL (PSI)	COMPRESSION STRENGTH LONGITUDINAL (PSI)
1	0.45 a	7163 a	1539 a	122 a	17.7 a	369 a	--
2	0.44 a	6994 ab	1467 a	106 b	19.6 b	340 a	2045
3	0.44 a	6726 b	1472 a	106 b	19.0 b	348 a	2125

[a] All values are based on green moisture content except for Pilodyn at 12%. Values followed by the same letter are not significantly different at 95% confidence level, according to the Newman-Keuls method.

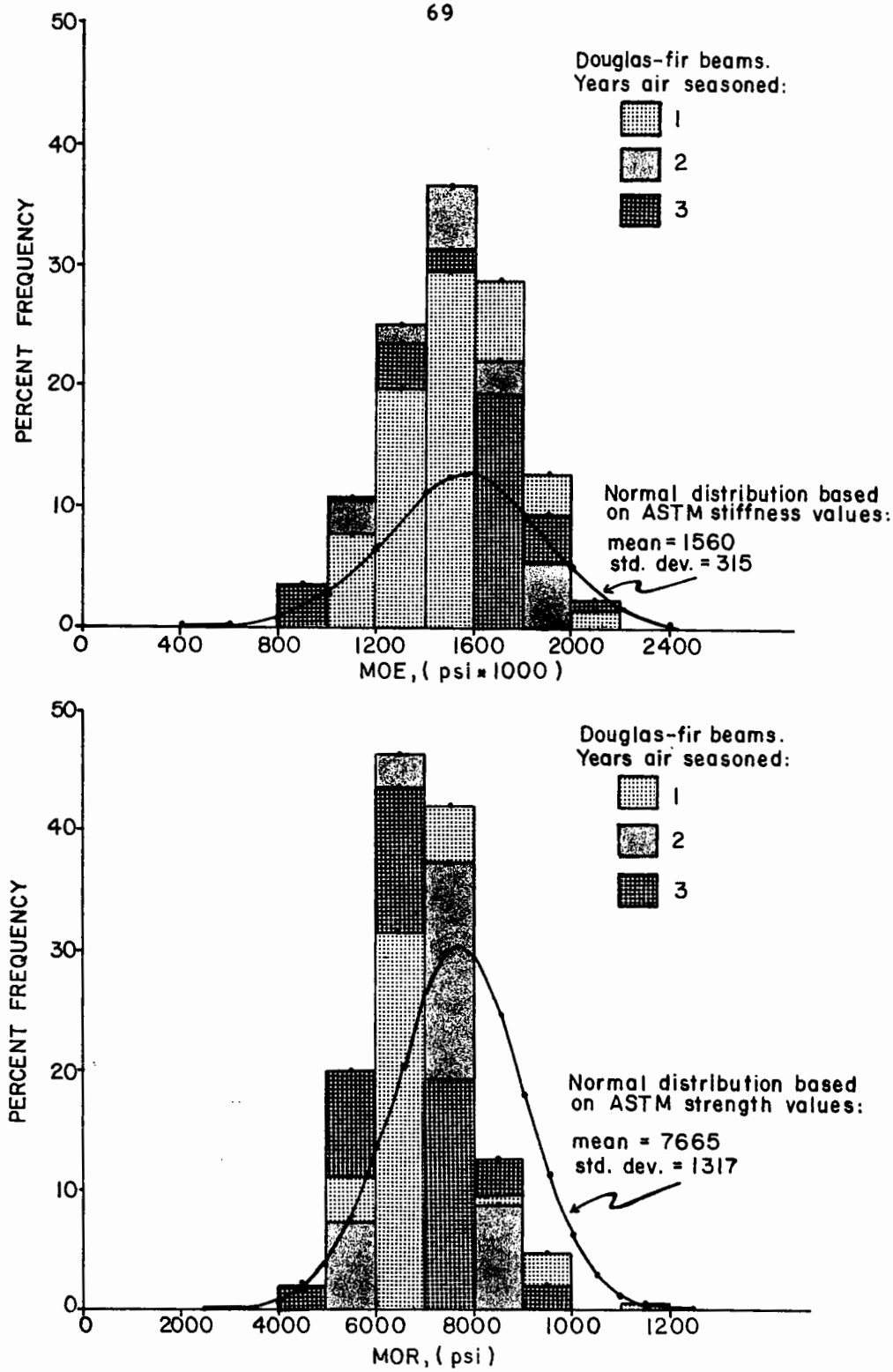


Figure 13. Modulus of rupture (MOR) and elasticity (MOE) of beams cut from air-seasoned polesecs, compared to published wood strength values.

It is evident that strength and stiffness of air-seasoning Douglas-fir is within an acceptable range for the species. While previous reports have suggested that air-seasoning of Douglas-fir be sharply curtailed, our results indicate that poles can be air seasoned at least 2 years and up to 3 years to reduce sapwood moisture content without adversely affecting pole strength; however, care must be taken to insure that the pole is heated for a sufficient period during or after treatment to eliminate fungi that become established during the air-seasoning period.

Ammonium bifluoride (ABF) treatment seemed to retard the incidence of decay, especially during the first two years of air-seasoning. Decay fungi eventually invaded poles treated with these chemicals, suggesting that regular reapplications might have prevented this infestation. This practice will be further evaluated using boron sprays; however, it would appear that the presence of ABF might have a limited colonization for a sufficient time to prevent any fungal damage.

D. STRENGTH OF USED WESTERN REDCEDAR TRANSMISSION POLES.

Reusing western redcedar poles removed from lines that have been redesigned or upgraded is a common method for maximizing a utility's investment in its wood pole plant; however, there have been uncertainties about the residual strength of these poles. This problem has recently surfaced in the Pacific Northwest when older cedar poles with no evidence of decay or other defects failed unexpectedly. The lack of defects led to a suggestion that the wood

became weaker as the poles aged. In a previous study, eleven used cedar poles, in service 22 to 38 years, were full-length tested for bending strength and stiffness and results compared with published strength and stiffness values for new poles. Results showed that the used poles had retained over 80 percent of the strength of new poles without a noticeable loss of stiffness.

The following study was made to determine (1) if there was reduced strength in beams cut from used cedar poles and (2) if strength values from Pilodyn, beam static bending, or plug longitudinal compression (LCS) tests could predict full-length pole bending strength and stiffness.

Eleven pole tops (removed from the poles prior to full-length testing) and eleven pole butts cut at groundline after full-length testing were brought to the Forest Research Lab. Two hundred and seventy-nine beams were removed (Figure 14) from the poles. One hundred and one beams were tested (Figure 15) for static bending strength, Pilodyn pin penetration, specific gravity, and LCS using methods previously described ('83 Ann. Rep., pg. 40-41, '84 Ann. Rep., pg. 44-45). In addition to the previous methods used, LCS load measurements were made at maximum plug compression, the point at which the gap in the LCS test jig (Figure 16) was closed.

One hundred and seventy-eight beams were tested for toughness at 9 percent moisture content on a Forest Products Laboratory Toughness Machine.

Strength and specific gravity of beams cut from used western redcedar poles were not statistically different (95% confidence level)

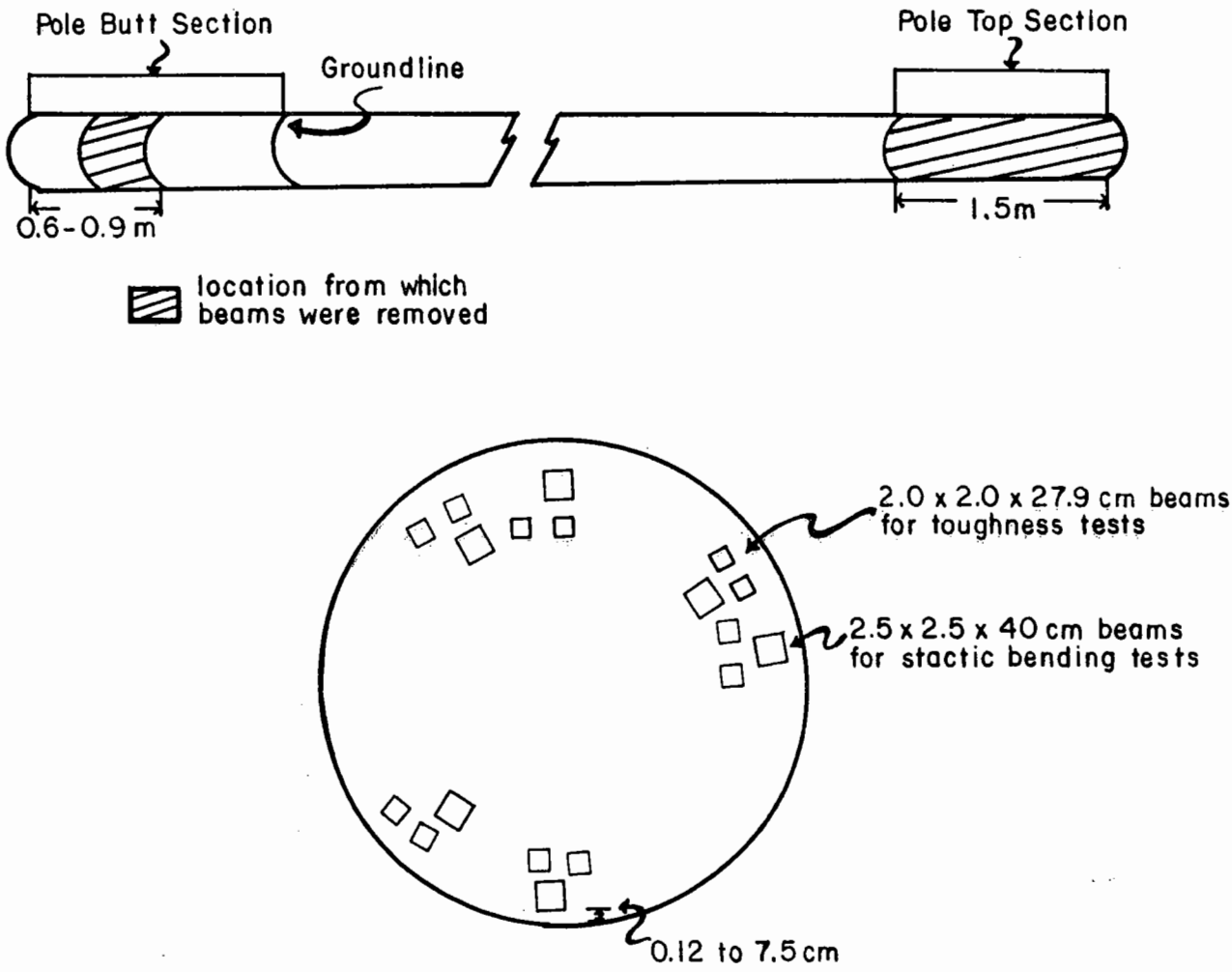
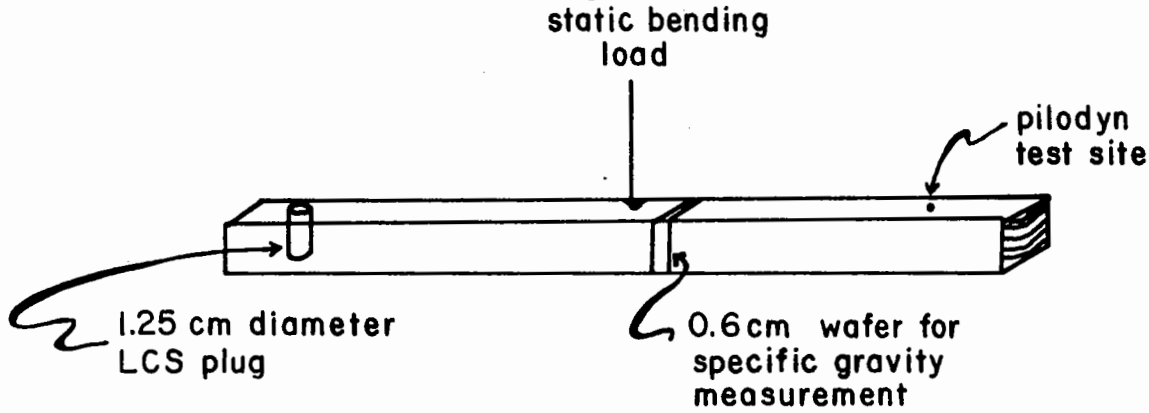


Figure 14. Cutting pattern for pole sections and beams from western redcedar poles.

Figure 15. Location of Pilodyn pin penetration, SG, and LCS test sites in static bending test beams.



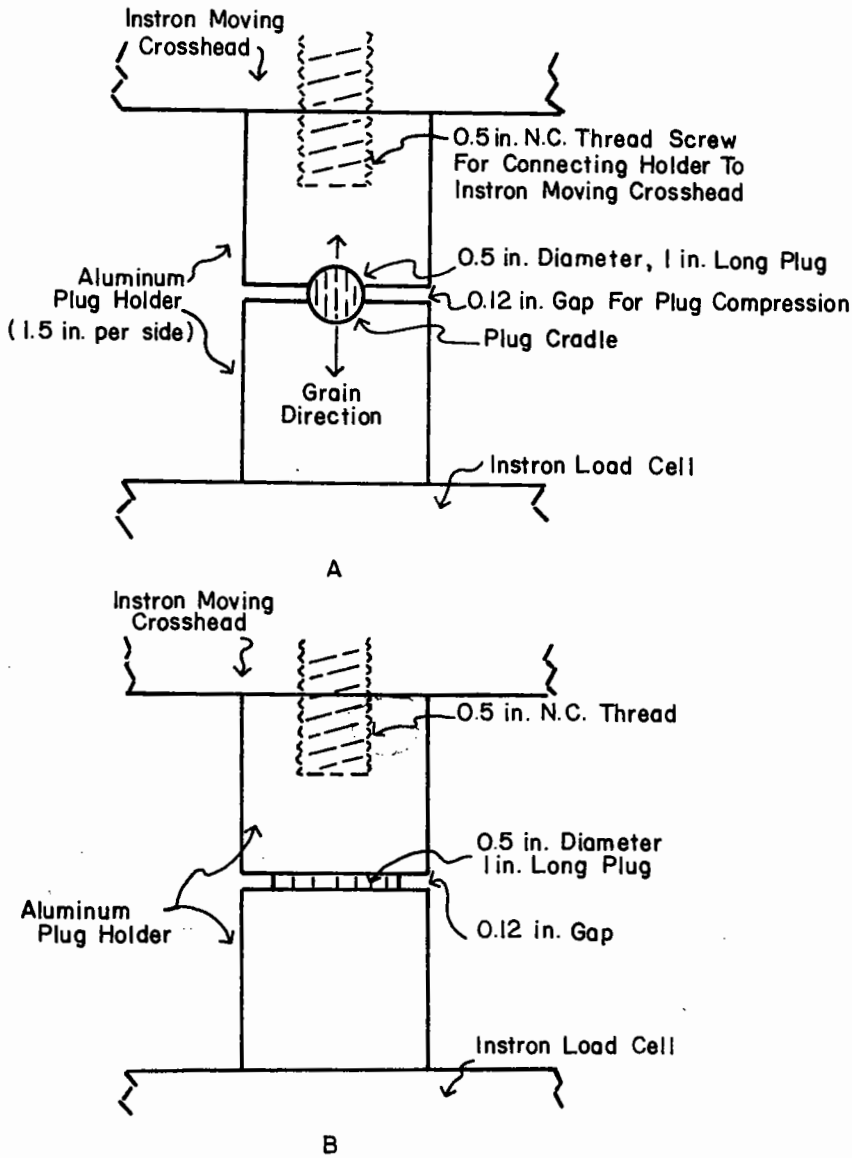


Figure 16. Longitudinal compression strength (LCS) test apparatus.

from published strength values of small, clear, cedar beams (Table 29). Tests on wood removed from the pole butts were better indicators of full-length pole strength than tests on wood from the pole tops.

Comparing the tests applied to the beams, LCS at maximum plug compression had the highest correlation with full-length pole strength (r = 0.58) and a correlation with pole stiffness of r = 0.62 (Table 30). An r value of $\pm$ 1.0 indicates a perfect correlation. The LCS test is a simple, rapid method that can be applied to plugs removed from poles in service. LCS at maximum plug compression adapts well to electronic data collection because manual computation of plug compression is not required.

TABLE 29
STRENGTH OF SMALL BEAMS CUT FROM USED WESTERN REDCEDAR POLES COMPARED TO PUBLISHED STRENGTH VALUES OF SMALL, CLEAR CEDAR BEAMS.

STRENGTH PROPERTY	TEST VALUE	PUBLISHED VALUE[a]
MOR, psi	5284	5200
MOE, psi x 1000	1068	940
WORK, in-lb	79	70
SPECIFIC GRAVITY green volume	.35	.31
LCS, psi at 1.5 mm compression	2184	not avail.
LCS, psi at max. compression	1880	not avail.
LCS, psi at max. load	2315	not avail.
PILODYN PIN PENETRATION[b], mm	23	not avail.
TOUGHNESS[c], in. lb.		
tangential face	148	130
radial face	88	90

a Static bending and specific gravity values are from the USDA Wood Handbook, Table 4-2, for green wood. Toughness values are from Table 4-7.

b 6 Joule Pilodyn; 2.5 mm diameter pin.

c All values are for green wood except toughness which was measured at 9% moisture content.

TABLE 30

CORRELATIONS OF BEAM STRENGTH AND FULL-LENGTH STRENGTH AND STIFFNESS OF USED WESTERN REDCEDAR POLES.[a]

BEAM STRENGTH PROPERTY[b]	CORRELATION (r) POLE STRENGTH MORGL	POLE STIFFNESS EMOE
MOR	.51	.77
MOE	.21	.80
WORK	.49	.62
SPECIFIC GRAVITY	.44	.42
PILODYN PIN PENETRATION[c]	-.53	-.13
LCS at 1.5 mm compression[d]	.40	.38
LCS at max. compression	.58	.62
LCS at max. load	.51	.62
TOUGHNESS, tang. face	-.25	.06
TOUGHNESS, radial face	.37	.25

a A total of 10 poles was tested.
b Beams were cut 1.3 to 2 m below pole groundline after full-length testing.
c 6-Joule Pilodyn equipped with a 2.5 mm diameter pin.
d LCS tests on 1.27 cm diameter plugs removed radially from the beam ends.

Static bending MOR and MOE were correlated with pole strength and stiffness with r values of 0.51 and 0.80, respectively. Pilodyn pin penetration had a correlation (r) with pole strength of -0.53, but was poorly correlated with pole stiffness (r = -.13).

Toughness, a test which is reported to be a good indicator of strength losses caused by early decay and various growth defects, was correlated poorly with pole strength and stiffness, probably because of the high quality of the wood tested.

One pole contained spiral grain and was not included in correlation analysis since this pole had far lower strength and stiffness values than similar straight-grained poles. Another pole, having far lower strength than that predicted by our strength tests or by specific gravity measurements (0.386), was examined for cause of failure. Inspection of the pole below the groundline break zone showed extensive ring shake on the tension side of the pole; however, it was not possible to determine if the ring failures existed prior to testing. The cross-section of the pole was elliptical in shape, measuring 36.8 by 43.2 cm at the smallest and largest diameter at groundline, possibly causing growth stresses and wood defects in the standing tree. The elliptic shape might also have affected the full-length bending test results, making the formula for calculating MORGL inappropriate for this pole. As a result of these deviations, this pole was subsequently omitted from calculations of regressions of beam MOR or plug LCS on pole MORGL . Results showed that MOR and LCS accounted for 77 and 62 percent, respectively, of the variation in MORGL (Figures 17,18) and MOE of beams accounted for 64 percent of pole MOE (Figure 19).

This study provided no evidence to suggest that the strength, stiffness, or toughness of wood in used cedar transmission poles have been reduced by age.

Poles with spiral grain or an elliptic cross-section had strength values far below that which similar straight-grained, round poles would probably have had; poles such as these should not be used for high strength applications.

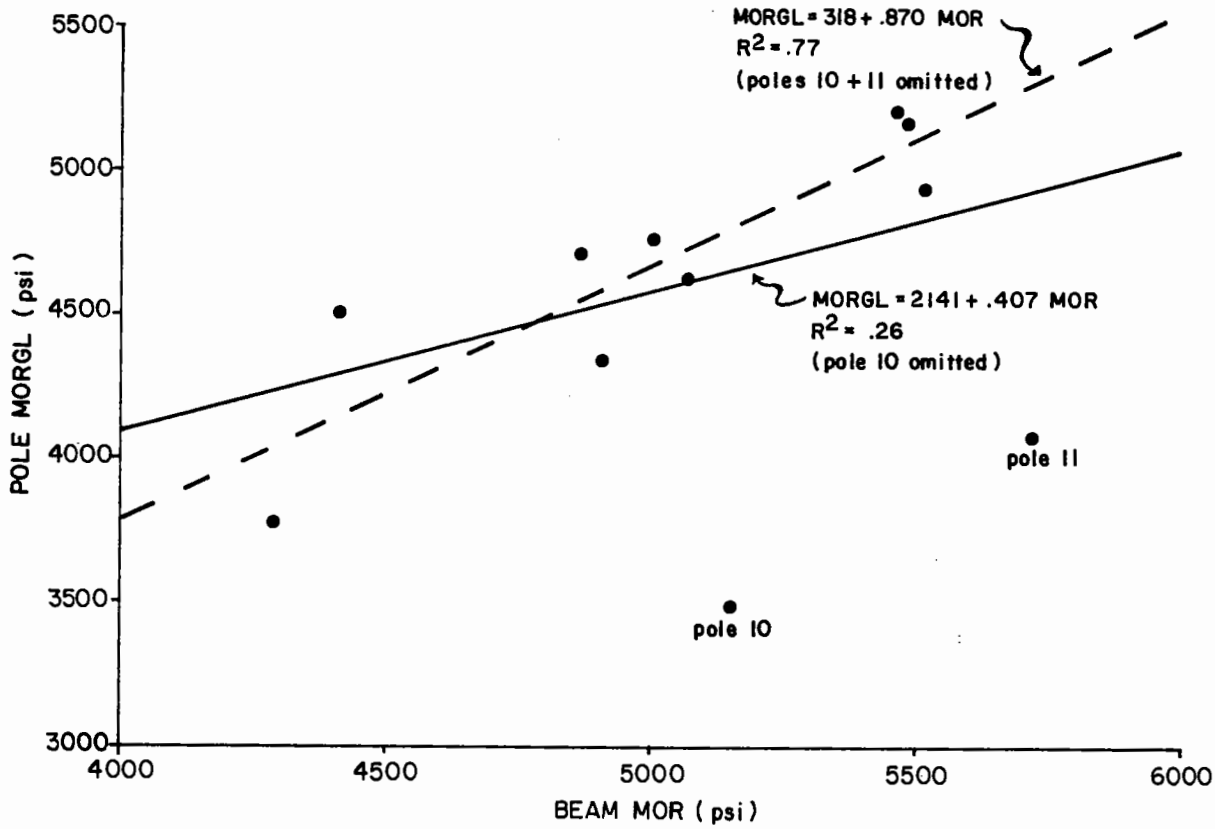


Figure 17. Regression of beam static bending strength (MOR), on pole bending strength at groundline (MORGL).

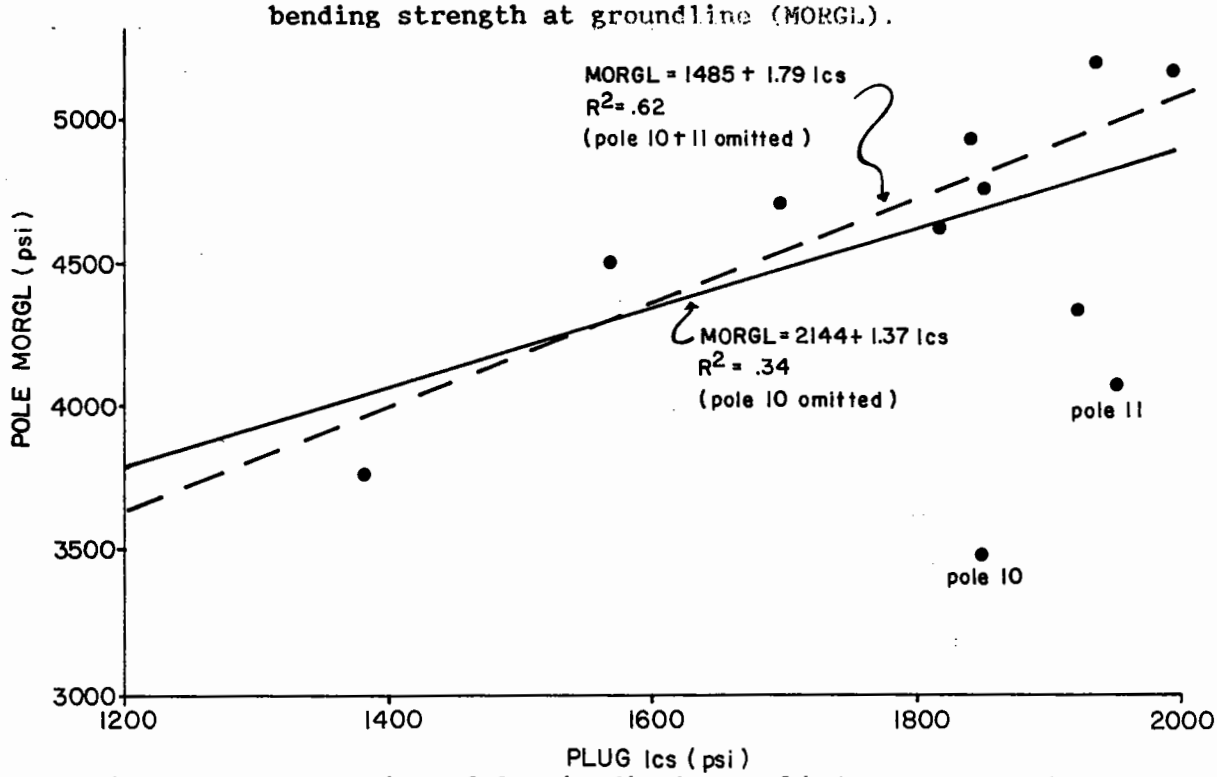


Figure 18. Regression of longitudinal compression strength (LCS) of plugs, on pole bending strength at groundline (MORGL).

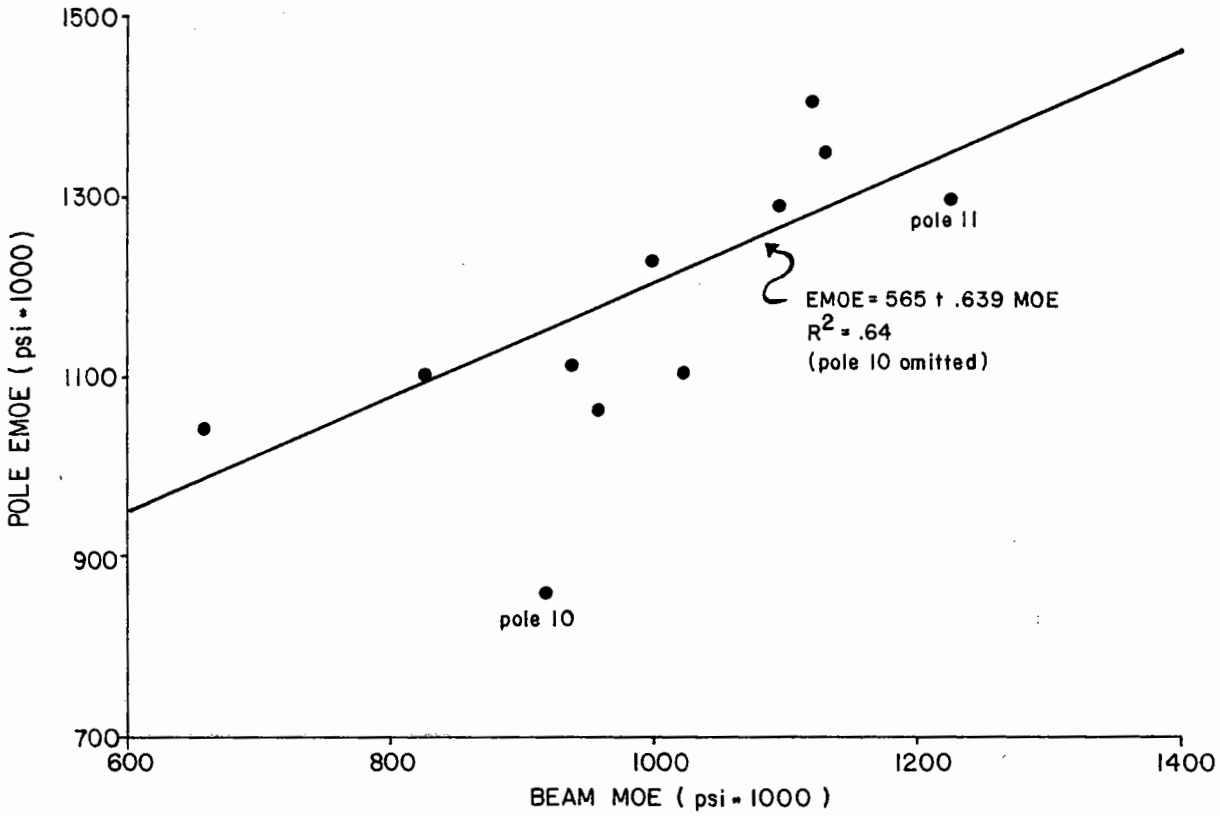


Figure 19 Regression of beam stiffness (MOE), on pole stiffness (EMOE).

The bending strength and stiffness of beams cut from the pole butts were good predictors of pole strength, accounting for 77 and 64 percent of pole strength and stiffness.

LCS of plugs cut from the beam ends predicted 0.62 percent of pole strength. The LCS test is much easier and faster than beam bending tests, therefore, the LCS test might be recommended for future tests of wood strength.

E. THE USE OF LONGITUDINAL COMPRESSION AS A MEASURE OF RESIDUAL WOOD STRENGTH

Full-length pole testing is the most accurate measure of pole strength; however, the test obviously destroys the usefulness of the pole. We have been investigating the possibility of microtesting poles using Pilodyn pin measurements of wood penetration or longitudinal compression strength (LCS) measurements of plugs to estimate the strength of the large structures. These tests would eliminate the need to "prove" pole strength by destructively testing the whole pole.

Tests were made at groundline of previously full-length tested western redcedar transmission poles, to simulate evaluation of poles in service. Pilodyn pin penetration of the pole surface was measured. Plugs for LCS tests were removed at three sites, equally spaced around the pole circumference, from wood just inside the treated pole shell. The plugs were water saturated prior to compression tests. LCS and Pilodyn pin penetration were correlated with full-length pole strength (MORGL) and stiffness (EMOE) and a prediction equation was computed for the best pole strength predictor variable.

LCS of plugs removed from the poles at groundline and tested at 1.5 mm compression and maximum load correlated well with MORGL (Table 31) with r values of 0.80 and 0.78, respectively.

TABLE 31

CORRELATION BETWEEN FULL-LENGTH POLE STRENGTH AND SMALL-SCALE STRENGTH-TEST AT POLE GROUNDLINE.[a]

SMALL SCALE TESTS AT GROUNDLINE	CORRELATION (r) POLE STRENGTH MORGL	POLE STIFFNESS EMOE
LCS[b] at 1.5 mm compression	.80	.17
LCS at max. load	.78	.11
PILODYN[c] PIN PENETRATION	-.49	-.07

[a] n = 8. Poles with spiral grain and elliptic cross-section were eliminated from calculations.

[b] LCS tests made on 1.27 cm diameter plugs removed from pole groundline just inside the treated pole shell.

[c] A 6-Joule Pilodyn equipped with a 2.5 mm diameter pin was used at three sites per pole.

Pilodyn pin penetration at pole groundline was not as good a predictor of pole strength (r = -0.49) as LCS; however, more measurements per pole might have increased the value of this test. Neither the Pilodyn nor LCS was a good predictor of pole EMOE.

A regression of LCS at 1.5 cm plug compression on MORGL showed that LCS accounted for 64 percent of the variation of full-length pole bending strength (Figure 20).

LCS of plugs removed from pole groundline was an excellent predictor of pole strength. More tests need to be performed to confirm these results since only 8 poles were evaluated; however, it seems likely that LCS, possibly in conjunction with additional tests such as acoustic evaluation, could be used to accurately predict pole strength.

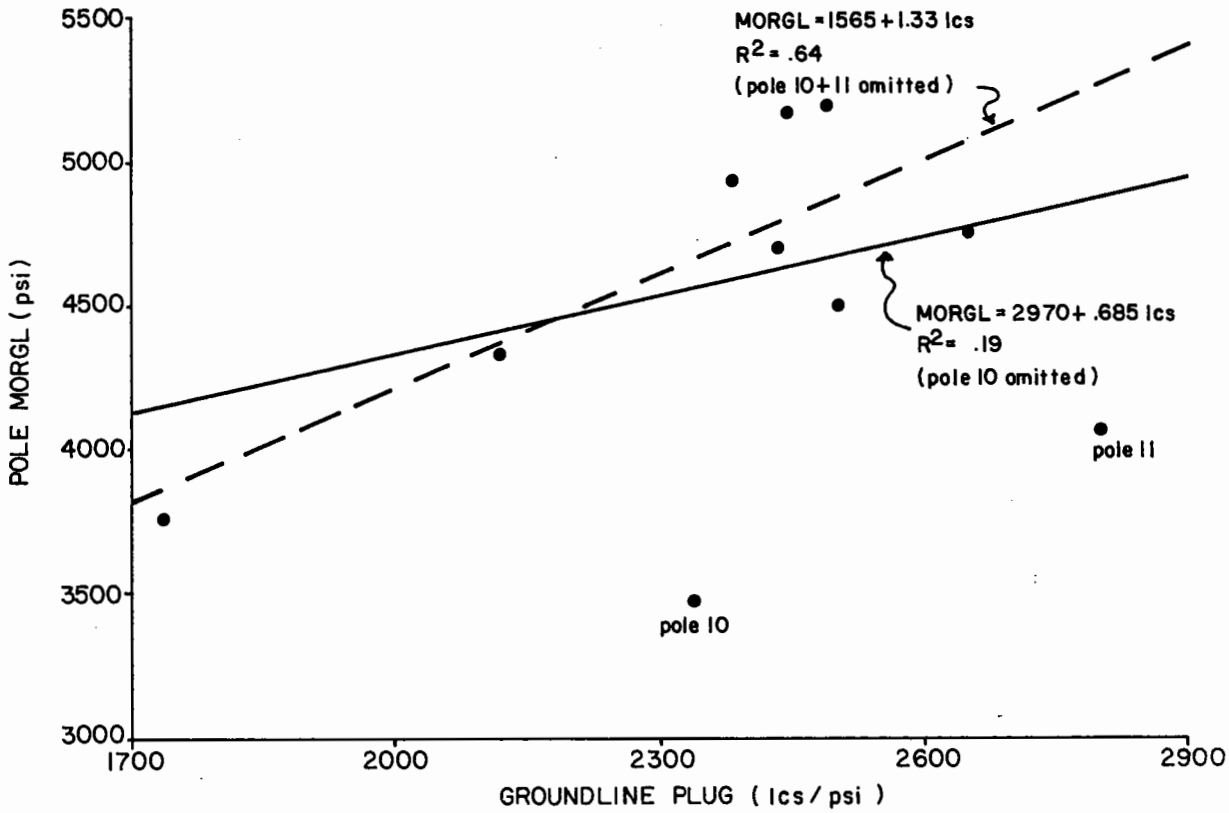


Figure 20. Regression of longitudinal compression strength (LCS) of plugs removed at pole groundline, on pole bending strength at groundline (MORGL). Each point represents the average of three plugs.

The next step in the development of these tests into practical field devices that predict pole strength will be small scale tests and acoustic analysis of the strength of fifty 2.4 m long Lodgepole pine posts. Small scale tests will include Pilodyn pin penetration of the posts and compression tests of plugs and cores removed from the posts. The posts will then be loaded till failure and the predicted strength values will be compared to the actual measured strength.

OBJECTIVE V

EVALUATE THE POTENTIAL FOR INFECTION AND DECAY DEVELOPMENT IN AIR-SEASONING DOUGLAS-FIR POLES PRIOR TO PRESERVATIVE TREATMENT

A. INTERNAL TEMPERATURE DEVELOPMENT IN DOUGLAS-FIR POLES DURING PRESERVATIVE TREATMENT.

Over the course of the air-seasoning study it has become apparent that virtually all poles are colonized by Basidiomycetes after one year. While long treatment cycles at sufficient temperatures can sterilize the wood, thereby eliminating the risk that fungi will survive to continue decaying, there is continuing pressure to reduce heating periods to decrease strength effects. The most vivid example of this practice was ambient temperature CCA treatment of large diameter, air-seasoned Douglas-fir. These poles have experienced extensive early decay and failure.

Generally, wood must be heated to 68.25 C for 75 minutes to insure sterilization; however, there are no reports which insure that this temperature is adequate to eliminate decay fungi commonly isolated from Douglas-fir nor is there data to substantiate whether these temperatures are currently being attained in commercial cycles. Last year ('85 Annual Report, pg. 96-100) we reported our results on laboratory tests of the sensitivity of Poria carbonica and Poria placenta to elevated temperature. These tests indicated that temperatures below 61 C reduced survival of these two fungi, but only at temperatures above 65 C were these fungi completely eliminated from the wood.

Based upon these results, we have undertaken a series of tests to evaluate internal temperature development in Douglas-fir during treatment with oilborne Pentachlorophenol or waterborne Ammoniacal Copper Arsenate. In these tests Teflon® coated, copper constantine thermocouples have been embedded at points 5, 10, 15 or 20 cm into

1.8 m long, end-coated Douglas-fir pole sections. These thermocouples are run through a specially designed pressure plate on the top of the cylinder and connected to a continuously recording data logger. At present, we have completed 3 test runs and hope to complete an additional five.

The results of the first 3 tests indicate that the logs were heated for a sufficient period to adequately sterilize the wood in 2 out of three runs. In the first test, a typical Boulton Drying/Empty Cell cycle using penta in oil, the internal temperatures measured closely paralleled those previously reported and the internal core of the poles reached at least 68.25 C for nearly 6 hours (Fig. 21). This is a more than adequate time period to insure sterilization. The second and third tests were performed using ammoniacal copper arsenate, a treatment that uses an initial steam period to condition and heat the poles. This steaming period is followed by addition of treatment solution at 24 C. There has been concern by many utilities that this process would result in incomplete sterilization, since the exposure time to high temperatures is fairly short. Our results indicate that the initial steam period resulted in rapid internal heating of the wood (Fig. 22). Although the subsequent solution was considerably cooler, heat continued to conduct to the pole center, resulting in continued internal temperature development even in cooler solution. Our results indicate that internal temperature in only one charge reached the level required to eliminate established decay fungi, while the other charge resulted in internal temperatures of about 60°C, suggesting that further steaming would be advisable. We intend to complete the remaining trials this summer as schedules at the

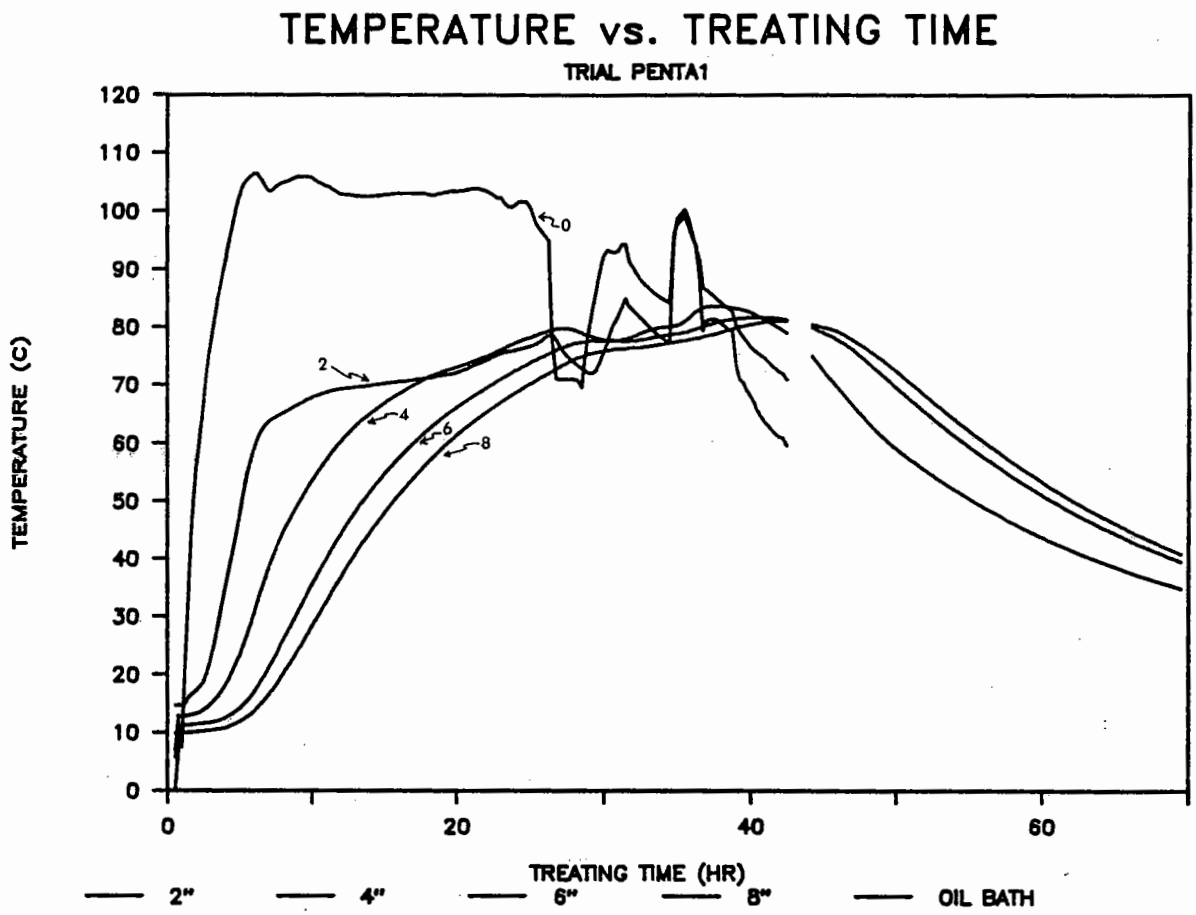


Figure 21. Internal temperature development in Douglas-fir logs during preservative treatment with pentachlorophenol in P-9 type A oil.

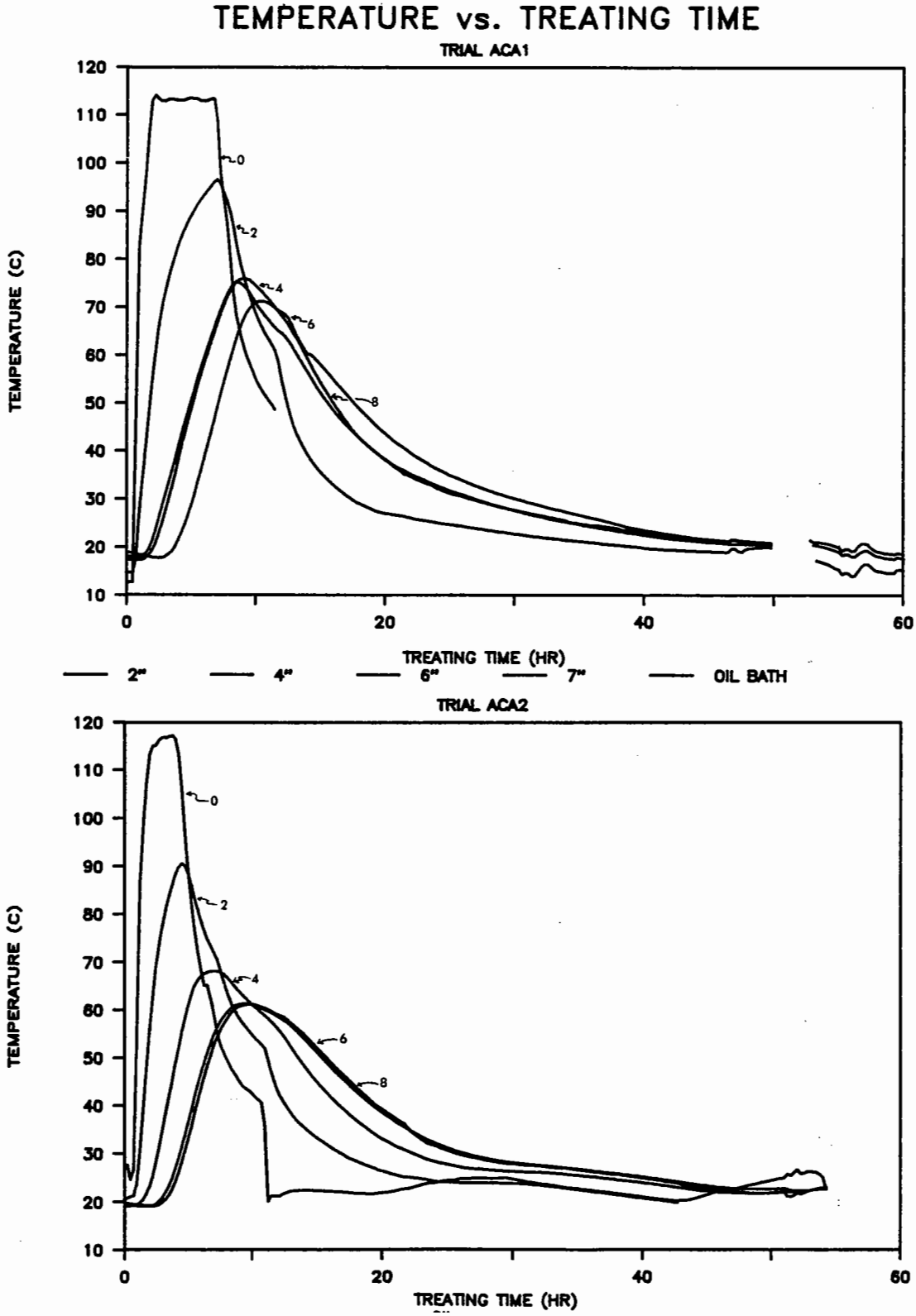


Figure 22. Internal temperature development in Douglas-fir logs during preservative treatment with waterborne Ammoniacal Copper Arsenate.

cooperating treater permit. It is important to note that the cooperating treater differs from other ACA treaters in using solution at ambient temperatures (others heat solution to 60 C for treatment). Thus, internal temperature development should be correspondingly greater in other plants.

B. DECAY DEVELOPMENT STUDY

The decay development study was begun in 1982 to determine the volume of wood occupied by decay fungi during air seasoning and to relate this to the level of wood damage caused by these fungi. Pole sections were left untreated or flooded with a 20% solution of ammonium bifluoride and exposed for 1, 2, or 3 years at four Pacific Northwest Pole yards. Five pole sections from each site were returned to Corvallis at each time point and sampled extensively for the presence of decay fungi.

These tests are now complete and last year we presented the first summaries of the results ('85 Annual Rept., pg. 100-107). At that time, the mating studies to identify monokaryotic isolates were in progress and their presence was not denoted in the tables. The presence of monokaryons would suggest that airborne spores constituted a major source of infection while dikaryons suggest that hyphal fragments carried by air, water or soil were the source of colonization. The updated tables reflect the completion of the mating studies, as well as further identification of previously unknown isolates. The results indicate that monokaryons play an important role in colonization of Douglas-fir during the air-seasoning process.

The data from these tests are now being further analyzed to determine the frequency of specific fungi at various depths in the wood, the volume of wood occupied by the various fungi isolated, and the sequences of colonization in various zones with the pole. These results will be used to provide a more precise picture of the impact these fungi have on air-seasoning Douglas-fir poles.

Preventing Colonization of Douglas-Fir

While it is important to determine the risk of fungal colonization during the air-seasoning process, it is equally important that methods be developed for preventing this invasion especially in poles treated using ambient temperature processes.

The use of ammonium bifluoride, a crystalline solid that breaks down in the presence of water to release toxic hydrogen fluoride, offers one approach to prevention. Fluoride is fairly mobile in water and should be able to migrate with any moisture entering the wood. In addition, previous tests indicate that this chemical provides at least 5 years of protection to exposed marine piling.

Exposure of pole sections sprayed with a 20% ammonium bifluoride at the four PNW tests sites generally limited the degree of colonization by decay fungi, especially in the first two years of air seasoning (Table 36). After three years the chemical protection appeared to decline in the more northern sites and there was little difference between treated and untreated poles exposed at Arlington, WA. Conversely, ABF sprayed pole sections exposed at Oroville, CA had extremely low levels of fungal colonization. Over-all colonization levels were low in untreated sections exposed at this site, but ABF

TABLE 32

PRELIMINARY FREQUENCIES OF DECAY FUNGI ISOLATED BY LOCATION TREATMENT, AND FUNGAL SPECIES AFTER 1, 2 OR 3 YEARS AIR-SEASONING AT OROVILLE, CA.[a]

	LENGTH OF AIR SEASONING								
	ONE YEAR		ONE YEAR		TWO YEARS			THREE YEARS	
	CHEMICAL TREATMENT								
FUNGAL SPECIES	NONE	ABF	NONE	ABF	NONE	ABF	NONE[b]	NONE	ABF
Unidentified Basidiomycetes	41	5	47	0	36	13	79	94	15
Unidentified suspect fungi	21	18	33	0	27	11	20	19	25
Androdia serialis	0	0	0	0	1	0	0	0	0
Coriolus versicolor	0	0	0	0	1	0	0	2	1
Coriolus versicolor monokaryon	0	0	0	0	0	0	1	0	3
Epicoccum nigrum	11	1	7	0	2	0	11	0	5
Fomitopsis cajanderi	0	0	0	0	0	1	0	0	0
Gloeophyllum saeparium	0	0	1	0	1	0	2	1	0
Heterobasidion annosum	0	0	1	0	0	0	0	0	0
Peniophora spp.	0	0	100	0	61	0	89	76	1
Phanerochaete sordida	0	0	1	0	0	0	0	0	0
Phlebia A monokaryon	0	0	0	0	0	0	0	0	1
Phlebia radiata monokaryon	0	0	0	0	0	0	0	0	1
Phlebia subserialis monokaryon	0	0	0	0	0	0	0	1	0
Poria carbonica	2	3	3	0	4	5	0	1	0
Poria carbonica monokaryon	0	0	3	0	0	3	1	0	0
Poria placenta	10	12	9	0	15	3	10	0	0
Poria placenta monokaryon	0	0	0	0	0	0	1	1	2
Poria xantha	0	0	2	0	0	0	1	0	1
Poria xantha monokaryon	0	0	0	0	0	0	0	0	2
Sistotrema brinkmanii	0	0	1	0	1	0	1	1	0
Stereum hirsutum	0	1	15	0	13	1	6	7	1
No. of cores with decay fungi	84	38	221	0	151	35	211	194	46
No. of decay isolates	85	40	225	0	162	37	197	210	57
Total number of cores taken	530	484	559	0	408	332	515	523	383

a. ABF = ammonium bifluoride, which was flooded onto poles prior to air-seasoning.

b. Untreated sections exposed one year later than first 2 year sections.

TABLE 33

PRELIMINARY FREQUENCIES OF DECAY FUNGI ISOLATED BY LOCATION, TREATMENT, AND FUNGAL SPECIES AFTER 1, 2 or 3 YEARS AIR-SEASONING AT EUGENE, OR.[a]

	LENGTH OF AIR SEASONING								
	ONE YEAR		ONE YEAR		TWO YEARS			THREE YEARS	
	CHEMICAL TREATMENT								
FUNGAL SPECIES	NONE	ABF	NONE	ABF	NONE	ABF	NONE[b]	NONE	ABF
Unidentified Basidiomycetes	26	2	6	0	31	7	31	59	40
Unidentified suspect fungi	66	27	14	0	26	34	6	19	10
Coriolus versicolor	0	0	1	0	0	0	0	1	2
Crustoderma dryinum	0	0	0	0	0	0	0	2	0
Epicoccum nigra	3	4	9	0	4	1	7	6	8
Fomitopsis cajanderi	0	0	0	0	3	0	0	1	0
Gloeophyllum saeparium	10	0	11	0	6	0	13	23	5
Haematostereum sanguinolentum	1	0	2	0	7	0	0	0	0
Heterobasidion annosum	0	0	0	0	0	1	0	0	0
Peniophora spp	0	0	46	0	51	1	53	28	2
Phanerochaete sordida	0	0	1	0	5	0	0	0	0
Phlebia radiata	0	0	0	0	1	0	0	0	0
Poria carbonica	60	15	51	0	74	38	79	259	80
Poria carbonica monokaryon	0	0	5	0	0	1	2	2	1
Poria placenta	56	15	16	0	53	42	30	138	29
Poria placenta monokaryon	0	0	0	0	0	0	16	13	12
Poria xantha	0	0	1	0	2	0	0	1	1
Poria xantha monokaryon	0	0	0	0	0	0	0	1	0
Schizophyllum commune	0	0	1	0	0	0	0	0	0
Sistotrema brinkmanii	1	1	0	0	9	1	1	12	3
Stereum hirsutum	4	0	21	0	9	0	19	12	5
Type 16	0	0	0	0	0	0	0	0	0
Type 16 monokaryon	0	0	0	0	0	0	1	4	0
No. of cores with decay fungi	205	61	165	0	228	110	222	375	167
No. of decay isolates	227	65	184	0	281	126	266	572	194
Total number of cores taken	576	530	456	0	427	574	443	523	481

a. ABF = ammonium bifluoride, which was flooded onto poles prior to air-seasoning.

b. Untreated sections exposed one year later than first 2 year sections.

TABLE 34

PRELIMINARY FREQUENCIES OF DECAY FUNGI ISOLATED BY LOCATION, TREATMENT, AND FUNGAL SPECIES AFTER 1, 2 or 3 YEARS AIR-SEASONING AT SCAPPOOSE, OR.[a]

	LENGTH OF AIR SEASONING								
	ONE YEAR		ONE YEAR		TWO YEARS			THREE YEARS	
	CHEMICAL TREATMENT								
FUNGAL SPECIES	NONE	ABF	NONE	ABF	NONE	ABF	NONE[b]	NONE	ABF
Unidentified Basidiomycetes	22	12	35	0	90	31	69	109	31
Unidentified suspect fungi	9	14	14	0	15	30	18	31	20
Coriolus versicolor	4	2	3	0	23	1	11	18	2
Coriolus versicolor monokaryon	0	0	0	0	0	0	0	0	0
Crustoderma dryinum	1	4	0	0	0	0	0	1	0
Epicoccum nigrum	2	0	2	0	0	0	2	0	0
Fomitopsis cajanderi	0	0	0	0	0	0	3	0	0
Fomitopsis cajanderi mono.	1	0	0	0	0	0	0	1	0
Gloeophyllum saeparium	11	5	8	0	41	29	41	56	10
Haematostereum sanguinolentum	15	3	1	0	38	10	4	28	2
Peniophora spp	16	3	39	0	19	0	61	44	0
Phanerochaete sordida	0	0	5	0	6	5	1	0	0
Phlebia "A" monokaryon	0	0	0	0	1	0	0	0	0
Poria carbonica	34	30	21	0	131	121	65	250	186
Poria carbonica monokaryon	4	3	6	0	4	0	–	–	2
Poria placenta	22	7	10	0	17	17	14	73	30
Poria placenta monokaryon	11	15	0	0	31	0	18	10	8
Poria xantha	0	0	0	0	0	0	0	0	0
Schizophyllum commune	3	0	7	0	2	0	6	2	0
Schizophyllum commune mono.	3	1	0	0	0	0	0	0	0
Sistotrema brinkmanii	1	2	0	0	19	0	12	23	0
Stereum hirsutum	4	1	3	0	3	6	15	12	3
Type 16 monokaryon	0	0	0	0	0	0	0	0	2
No. of cores with decay fungi	144	96	138	0	329	198	265	401	259
No. of decay isolates	163	102	154	0	440	250	345	671	297
Total number of cores taken	551	696	476	0	604	541	457	528	576

a. ABF = ammonium bifluoride, which was flooded onto poles prior to air-seasoning.

b. Untreated sections exposed one year later than first 2 year sections.

TABLE 35

PRELIMINARY FREQUENCIES OF DECAY FUNGI ISOLATED BY LOCATION, TREATMENT, AND FUNGAL SPECIES AFTER 1, 2 or 3 YEARS OF AIR-SEASONING AT ARLINGTON, WA[a]

	LENGTH OF AIR SEASONING								
	ONE YEAR		ONE YEAR		TWO YEARS			THREE YEARS	
	CHEMICAL TREATMENT								
FUNGAL SPECIES	NONE	ABF	NONE	ABF	NONE	ABF	NONE[b]	NONE	ABF
Unidentified Basidiomycetes	7	3	30	0	16	24	156	63	78
Unidentified suspect fungi	16	9	67	0	39	29	105	61	32
Androdia serialis	0	1	0	0	0	0	0	0	0
Coriolus versicolor	2	0	49	0	0	0	47	2	0
Coriolus versicolor monokaryon	2	0	0	0	0	0	3	0	0
Crustoderma dryinum	0	0	0	0	0	0	1	0	1
Epicoccum nigrum	7	2	3	0	1	0	1	0	0
Fomitopsis cajanderi	0	0	0	0	0	0	0	1	1
Gloeophyllum saeparium	6	0	6	0	2	12	8	23	9
Haematostereum sanguinolentum	54	6	129	0	60	8	102	88	2
Peniophora spp.	0	0	22	0	8	0	31	28	0
Phanerochaete sordida	0	0	18	0	0	0	1	2	0
Phlebia albida	0	0	1	0	0	1	0	0	0
Phlebia gigantea	0	0	0	0	0	0	1	0	0
Phlebia subserialis monokaryon	0	0	0	0	0	0	1	0	0
Poria carbonica	18	22	36	0	73	115	299	217	194
Poria carbonica monokaryon	7	2	6	0	0	1	0	0	0
Poria placenta	1	9	3	0	9	23	76	27	40
Poria placenta monokaryon	4	12	0	0	0	1	8	5	17
Poria xantha	0	0	0	0	0	0	3	0	15
Schizophyllum commune	0	0	3	0	0	0	0	0	0
Sistotrema brinkmanii	2	1	4	0	6	0	19	8	1
Stereum hirsutum	2	1	8	0	1	2	68	7	9
Type 16 monokaryon	0	0	0	0	0	0	1	0	0
No. of cores with decay fungi	126	66	308	0	184	182	551	326	317
No. of decay isolates	128	68	385	0	215	217	1036	514	399
Total number of cores taken	486	467	636	0	349	484	648	459	460

a. ABF = ammonium bifluoride, which was flooded onto poles prior to air-seasoning.

b. Untreated sections exposed one year later than first 2 year sections.

sprayed sections experienced less than one third of the colonization found in the untreated group. Both rain-fall and temperature differ widely between the four sites and it would appear the ABF is able to migrate into the wood to a sufficient degree to limit fungal colonization in drier climates, but under higher moisture regimes the ABF may be too soluble to adequately protect the surface from invasion. Since spores must land on the surface to begin colonization, it is apparent that chemicals with a strong affinity for wood may be more useful in this application.

In addition to slowing colonization, chemical treatments also decreased the number of fungi isolated from each core; for example, the fungus containing cores from treated sections exposed for 3 years at Scappoose, OR contained 1.15 fungi/core, while similar untreated sections contained 1.67 fungi per core. This decreased fungal colonization should reduce the impact on strength properties and the delay in colonization associated with the chemical treatment should reduce the impact that decay fungi will have on wood properties during the air-seasoning process. Thus, initial chemical treatment to limit fungal colonization appears both practical and recommendable for Douglas-fir air-seasoned for more than one year. Additional tests are now underway to test the use of low-toxicity boron compounds for this application.

TABLE 36

PERCENTAGE OF CORES REMOVED FROM DOUGLAS-FIR POLE SECTIONS TREATED WITH AMMONIUM BIFLUORIDE OR LEFT UNTREATED AND AIR-SEASONED FOR 1, 2 OR 3 YEARS THAT CONTAINED BASIDIOMYCETES.[a]

EXPOSURE SITE	LENGTH OF AIR SEASONING							
	ONE YEAR			TWO YEARS			THREE YEARS	
	UNTREATED		ABF	UNTREATED		ABF	UNTREATED	ABF
	A	B		A	B			
Arlington WA	26	48	14	53	85	37	71	68
Scappoose OR	26	29	13	54	58	36	75	45
Eugene OR	35	36	11	53	50	19	71	34
Oroville CA	15	39	7	37	41	10	37	12

a 20% ammonium bifluoride solution was sprayed on treated poles at the start of air seasoning. Pole sections were exposed at 2 time periods (A or B).

OBJECTIVE VI

DETERMINE THE ROLE OF NON-DECAY FUNGI IN INTERNAL AND EXTERNAL DECAY OF PRESERVATIVE TREATED DOUGLAS-FIR IN GROUND CONTACT.

A. FUNGAL FLORA OF PRESERVATIVE-TREATED DOUGLAS-FIR POLES BEFORE AND AFTER FUMIGANT.

Fumigant treated wood generally contains lower levels of microorganisms; however, there are few reports of the effect these organisms may have on fumigant effectiveness. To fill this void, we have sampled all of our fumigant treated lines for the presence of "non-decay" fungi. The results indicate that few fungi are capable of surviving in the presence of fumigant; however, a total of 18 species were isolated from our test poles ('85 Annual Report, pg. 114).

We are now in the process of determining the role these fungi play in wood by determining their physiologic capabilities.

Tolerance of microfungi to wood preservatives

The tolerance of microfungi to creosote and pentachlorophenol may help explain how they moved from the surrounding soil into the treated wood. To test for the presence of preservative tolerance, the microfungi were grown in various concentrations of fungicide containing malt-agar. Creosote was tested at 0.05, 1.0, 1.5, 2.5 and 5.0 percent, while pentachlorophenol was tested at 1.0, 2.0, 5.0, 10, 25 and 50 ppm.

Fungal inoculum was planted on each medium and the plates were incubated at room temperature. The resulting fungal growth was

easured every 2 days for a two week period. Cultures were kept for 2 months and were observed to determine whether growth resumed on plates that did not originally support growth within the two week period.

Average radial growth of the microfungi on varying concentrations of creosote and pentachlorophenol indicate that most fungi were sensitive to creosote, but more tolerant of penta (Tables 37, 38).

Creosote prevented the growth of Scytalidium aurantiacum, Graphium, Penicillium, Fusarium and Cladosporium at .05 percent; however, minimal growth of Aureobasidium and Cladosporium was observed after 3 or 4 weeks. Growth of Phialophora sp at .05 percent was initially confined to the edge of the inocula, while growth on the media was observed at 1.0 and 1.5 percent concentrations after 4 weeks. Scytalidium lignicola, Scytalidium sp A., Trichoderma viride, and two other species of Trichoderma were completely inhibited at 1.0 percent creosote. Oidiodendron sp, on the other hand, was able to grow at 5.0 percent creosote, although it did not sporulate.

Subsequent transfers of inocula from the plates without growth to fresh agar indicated that the creosote was fungitoxic not fungistatic.

Pentachlorophenol at 10 ppm prevented the growth of Graphium sp A, and Oidiodendron. Growth of the remaining fungi was arrested with increasing concentration of pentachlorophenol up to 50 ppm, except for Scytalidium sp A. and S. lignicola which were able to grow at this concentration. These results indicate that these fungi have the ability to adapt to increasing penta levels.

Degradation of fumigants and interactions between decay and microfungi.

The interaction between decay and micro-fungi is an important aspect of understanding the degradation of fumigant treated wood. This study was designed to determine the effect of prior infestation of fumigant-treated wood by decay or microfungi.

Douglas-fir blocks (2.5 x 10 x 20 mm) were prepared, labeled and conditioned to constant weight over salt solutions. Moisture content of the test samples was determined and 40 samples were exposed to selected fumigant levels.

The fumigant-treated blocks were aseptically inoculated on actively growing cultures of P. carbonica, P. placenta, or S. lignicola using the following sequences:

1. Wood samples exposed to S. lignicola for 4 weeks.
2. Wood samples exposed to each of P. carbonica and P. placenta for 4 weeks.
3. Wood samples exposed to S. lignicola for 4 weeks and then exposed to a decay fungus for 4 weeks.
4. Wood samples exposed to a decay fungus for 4 weeks then transferred to an actively growing culture of S. lignicola for 4 weeks.

At the end of each exposure, the average weight losses of the exposed test blocks were determined to identify the effect of each fungus on the treated wood.

Generally, the average percent weight losses of chloropicrin treated blocks were lower than that of those treated with Vapam (Table 38); however, results varied depending on the exposure sequence.

Fumigant-treated test blocks infected with actively growing cultures of S. lignicola and subsequently transferred to chambers containing P. carbonica showed slightly lower average percent weight losses than those which were exposed first to P. carbonica then transferred to S. lignicola. Similarly, tests with P. placenta showed that prior exposure to S. lignicola resulted in a lower weight losses. The two decay fungi generally failed to grow on the surface of the S. lignicola exposed blocks.

These results suggest that S. lignicola, which is commonly isolated from fumigant-treated Douglas-fir, may act to improve the long term performance of these chemicals; however, further tests need to be performed to confirm these results.

TABLE 37

GROWTH OF SELECTED MICROFUNGI ON VARIOUS CONCENTRATIONS OF CREOSOTE DILUTED IN MALT AGAR AFTER 14 DAYS

FUNGAL SPECIES	AVERAGE RADIAL GROWTH (cm) CREOSOTE CONCENTRATION (%) 0	.05	1.0	1.5	2.0	2.5	5.0
Aureobasidium sp	2.5	0[a]	0	0	0	0	0
Cladosporium sp	0.8	0[b]	0	0	0	0	0
Fusarium sp	1.3	0	0	0	0	0	0
Graphium sp A	3.0	0.6	0	0	0	0	0
Graphium sp B	0.9	0	0	0	0	0	0
Oidiodendron sp	1.3	1.3	1.3	1.2	1.2	1.1	0.8
Penicillium sp	1.2	0	0	0	0	0	0
Phialophora sp	1.4	0[c]	0[a]	0[a]	0	0	0
Scytalidium sp A	1.6	0.4	0	0	0	0	0
Scytalidium aurantiacum	3.0	0	0	0	0	0	0
Scytalidium lignicola	3.0	1.68	0	0	0	0	0
Trichoderma sp A	3.0	0.2	0	0	0	0	0
Trichoderma sp B	3.0	1.2	0	0	0	0	0
Trichoderma viride	3.0	1.7	0	0	0	0	0

a Growth was observed on the 21st day of test
b Growth on the 28th day of test
c Growth only from edge of inoculum plug

TABLE 38

GROWTH OF SELECTED MICROFUNGI ON VARIOUS CONCENTRATIONS OF PENTACHLOROPHENOL DILUTED IN MALT AGAR AFTER 14 DAYS.

FUNGAL SPECIES	AVERAGE RADIAL GROWTH (cm) PENTACHLOROPHENOL CONCENTRATION (PPM) 0	.05	1.0	1.5	2.0	2.5	5.0
Aureobasidium sp	3.0	3.0	3.0	2.0	2.6	0	0
Cladosporium sp	0.8	0.7	0.6	0.5	0.5	0.1	0
Fusarium sp	1.3	1.1	1.0	0.8	0.9	0	0
Graphium sp A		0.2	0.3	.1	0	0	0
Graphium sp B		1.0	0.8	0.7	0.6	0[b]	0
Oidiodendron sp	3.0	0.3	.5	0.03	0	0	0
Penicillium sp	3.0	1.0	0.8	0.9	0.2	0	0
Phialophora sp	1.2	1.3	1.3	1.1	1.0	0.2	0
Scytalidium sp A	3.0	0.8	0.8	0.4	0.1	0	0
Scytalidium aurantiacum	3.0	3.0	3.0	2.6	2.5	0.8[a]	1.4[a]
Scytalidium lignicola	3.0	2.7	2.7	2.6	1.5	0.1	[b]
Trichoderma sp A	3.0	3.0	3.0	3.0	1.5	0.1	0
Trichoderma sp B	3.0	2.2	2.0	1.2	0.5	0	0
Trichoderma viride	3.0	2.4	2.2	1.2	0.5	0	0
Unknown sp A	0.4	0.4	0.3	0[b]	0	0	0

a Growth was observed on the 21st day of exposure.
b Growth was only observed from the edge of the original inoculum plug.

TABLE 39

AVERAGE WEIGHT LOSSES OF FUMIGANT-TREATED TEST BLOCKS EXPOSED TO COMBINATIONS OF BASIDIOMYCETES AND MICROFUNGI

FUNGAL EXPOSURE		AVERAGE WEIGHT LOSS (%)				
INITIAL FUNGUS	SECOND FUNGUS	CHLOROPICRIN 10 mg	CHLOROPICRIN 25 mg	VAPAM 100 mg	VAPAM 250mg	CONTROL
P. Carbonica	S. lignicola	0.85	0.74	2.71	2.69	
S. lignicola	P. carbonica	0.64	0.0	2.06	1.78	
P. placenta	S. lignicola	3.88	1.92	6.62	6.45	
S. lignicola	P. placenta	2.08	0.74	4.33	2.09	
P. carbonica	--	3.33	0.89	3.56	3.29	13.86
P. placenta	--	6.60	5.08	5.94	4.13	24.42
S. lignicola	--	2.91	1.10	2.0	1.75	4.66