ABSTRACT

Fumigants. Chloropicrin, Vapam and Vorlex continue to control internal decay of Douglas-fir poles 11 years after application.

Methylisothiocyanate (MIT), which was melted and poured into holes in Douglas-fir poles 3-years ago and goes directly from a solid to a gas in the wood, appears promising in controlling decay fungi. Now encapsulated MIT also appears promising in laboratory tests.

Varying quantities of encapsulated MIT will be placed in decaying CCA-treated Douglas-fir poles 90 to 100 feet long and in service near Buffalo, NY. A high percentage of the 81 poles inspected contained decay fungi; 29 contained decay pockets or carpenter ants.

Cedar sapwood. Twenty 10-foot long pole sections of well weathered cedar were installed at an OSU test site. Six chemicals, including 10% penta-chlorophenol in diesel oil will be tested for their ability to control sapwood decay. Other chemicals have been selected for laboratory evaluation.

Bolt-hole protection. Twenty-eight Douglas-fir poles 18 feet long were Boulton dried in a pentachlorophenol-heavy petroleun solution. Eight bolt holes will be drilled in each pole and the poles will be installed at the OSU test site. Bolt holes will be protected with preservative powders, liquids and preservative-containing washers before installation of the hardware.

Detection of Decay. Chemical color tests, a needle scratch (fracture) test and radial compression tests were applied to Douglas-fir cores decayed to weight losses up to 20%. The radial compression test was the most promising for detecting early decay (weight losses up to 10 percent). A small

compression testing device for field use has been developed and will be evaluated.

Extent of decay. In attempts to quantify the extent of early decay in Douglas-fir and southern pine, small beams and wafers were decayed to weight losses up to 13%. Large reductions in moduli of elasticity and rupture occurred at small weight losses. A staining technique was developed that colors undecayed portions of cell walls green and decayed portions orange when viewed by fluorescent microscopy. Neither computer image analysis nor alkali solu-bility were satisfactory measures of early decay.

Decay of Douglas-fir Poles Prior to Pressure Treatment. Fourteen 6-inch long cores were removed from about 100 poles at each of 13 air seasoning yards and the cores were cultured for fungi. Included were unpeeled poles, freshly peeled poles and poles in various stages of air-seasoning. Cultures are being examined microscopically for Basidiomycetes which are being isolated, identified, and their ability to decay wood is being studied.

Research is in progress to deterine how fungi are spread (soil or air) and how infection of poles occurs.

To determine how and when poles are infected and to follow decay development, pole sections were placed upright or horizontally at four air seasoning yards from northern Washington to northern California. Sections will be removed or replaced periodically during the next 3 years, and the sections will be extensively sampled by removing cores to determine the presence of decay fungi.

A 32% water solution of ammonium bifluoride was applied to some horizontal sections in an attempt to prevent or slow infection of poles.

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Others

*OSMOSE

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Objective I

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

The evaluation of fumigants placed in Douglas-fir poles in 1969 and 1977 is being continued and will be presented as background information for the development of improved fumigant treatments.

DOUGLAS-FIR POLES FUMIGANT-TREATED IN 1969

Forty pressure-treated poles from 18 to 24 m long with internal decay and located in a pole line near Corvallis, Oregon, were randomly assigned to five test groups. No fumigants were applied to one control group. Poles in the other groups were treated with 1 liter of chemical distributed among four holes near the groundline and three holes 1 m above the ground. The 2-cm diameter holes were plugged with treated dowels. A laminated paper-polyethylene film wrap was applied to poles treated with chloropicrin, Vapam, and Vorlex. A group of Vapam-treated poles and the controls were not wrapped.

To evaluate effectiveness of the treatments, three cores equally spaced around each pole starting near the widest check were removed at -0.3, 0, 0.6, and 1.2 m from the groundline and bioassayed for decay fungi. Three additional cores were removed at 0, 1.2, 1.8, 2.4, and 3.7 m above the groundline to determine distribution of residual fumigant by the closed-tube bioassay.

Changes in Fungal Population

Chloropicrin and Vorlex provided excellent control by eliminating decay fungi within 1 year and by preventing them from becoming

reestablished for 11 years (Figure 1). Vapam was less effective and decay fungi were isolated from 5 of 14 tested poles (Table 1). The temporary paper wrap that, for the most part, deteriorated within 1 year had no influence on the effectiveness of Vapam or, very likely, of Vorlex or chloropicrin.

Table 1

UNTREATED AND FUMIGANT-TREATED DOUGLAS-FIR POLES WITH DECAY FUNGI[1]

	NUMBER OF POLES				
		VAPAM		VORLEX	CHLOROPICRIN
YEAR	UNTREATED	WRAPPED	UNWRAPPED	WRAPPED	WRAPPED
1968	8	8	8	8	8
1969		POLES TREATED WITH FUMIGANT			
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[1]	7	4	4	0	1
1975[2]	7	1	0	0	0
1976[3]	5	2	3	1	0
1977[3]	5	2	1	0	0
1978[3]	5	3	2	0	0
1979[3]	5	3	2	0	1
1980[3]	5	2	3	2	0

[1]Seven untreated poles remain in test.
[2]Poles remaining in test: untreated, 7; vapam wrapped, 7; vapam unwrapped, 7; vorlex wrapped, 7; chloropicrin wrapped, 6. Fumigant-treated poles were inadvertently removed from service.
[3]Five untreated poles remain in test but not in service.

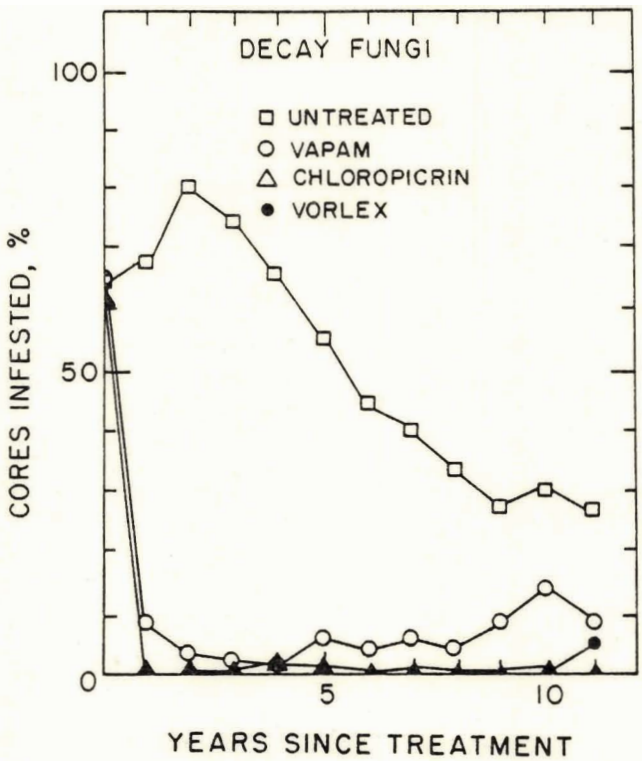


Figure 1. Change in fungal population of pressure-treated Douglas-fir poles with internal decay that were treated with fumigants. Each value is based on 12 cores removed each year times the number of poles in the test (Table 1).

Distribution of Residual Fumigant

After 11 years, closed-tube bioassays of cores removed as far as 2.4 m above the groundline showed that chloropicrin was present in fungitoxic concentrations (Table 2). Vapors of Vorlex also were present at many sites but, apparently, in lower concentrations. The virtual absence of fungitoxic vapors from Vapam may explain the reinvasion by decay fungi of poles treated with this fumigant.

Table 2

CLOSED-TUBE BIOASSAY FOR RESIDUAL FUMIGANT VAPORS IN PRESSURE-PENTACHLOROPHENOL-TREATED DOUGLAS-FIR POLES ELEVEN YEARS AFTER APPLICATION[1]

METERS ABOVE GROUND	SEGMENT LOCATION FROM SURFACE	AVERAGE GROWTH OF ASSAY FUNGUS, MM			
		NO FUMIGANT	VAPAM	VORLEX	CHLOROPICRIN
	CM.				
2.4	2.5-5	17	10	6	0
	9-11.5	20	19	12	0
	12.5-15	21	18	10	0
1.8	2.5-5	16	11	7	0
	9-11.5	17	19	12	0
	12.5-15	21	17	10	0
1.2	2.5-5	11	13	4	1
	9-11.5	17	15	10	0
	12.5-15	18	12	11	0
0	2.5-5	8	10	6	3
	9-11.5	13	15	10	5
	12.5-15	18	15	10	9

[1]Suppressed growth of the assay fungus at each location from the surface compared to poles with no fumigant indicates that fungitoxic vapors are present. Lower values in the outer 2.5-5 cm zone reflect the presence of pentachlorophenol.

DOUGLAS-FIR POLES FUMIGANT-TREATED IN 1977

New fumigants found effective for controlling decay fungi in our wood-block bioassay (methylisothiocyanate and allyl alcohol) were compared with Vorlex in poles in service. Internally decaying poles pressure-treated with pentachlorophenol in heavy oil were selected for treatment by removing three cores equally spaced around the poles at -0.3, 0, 0.6, and 1.2 m from the groundline and culturing them for fungi. The poles were randomly assigned to groups for fumigant treatment. Because of the prevalence of decay fungi at 1.2 m, cores also were removed at 1.8 and 2.4 m and cultured for fungi. Annually thereafter cores were removed from each pole at four heights above ground, cultured for fungi, and assayed for residual fumigant vapor by the closed-tube bioassay.

Results

Methylisothiocyanate (MIT) was the most effective fumigant tested followed by MIT in diesel oil and Vorlex (Table 3). Allyl alcohol was least effective. The culture results which take about 4 weeks to obtain were predicted within 7 days by the closed-tube assay (Table 4). Vapors of MIT and Vorlex were detected at all heights including 2.4 m above the groundline, but vapor concentrations decreased with height above ground.

Because of these encouraging results and the solid nature of MIT which should increase the safety and ease with which it could be stored, handled and applied to poles in service, MIT along with ammonium bifluoride were selected as the first candidates for encapsulation.

Table 3

POPULATION OF DECAY FUNGI IN DOUGLAS-FIR POLES PRIOR TO AND AFTER TREATMENT WITH FUMIGANTS IN 1977[1]

CHEMICAL AND METERS ABOVE GROUNDLINE	POLES	POLES WITH DECAY FUNGI				CORES WITH DECAY FUNGI, PERCENT			
		1977	1978	1979	1980	1977	1978	1979	1980
METHYL ISOTHIOCYANATE (SOLID, 100%)	8								
1.8 to 2.4		5	1	0	0	40	2	0	0
-0.3 to 1.2		8	1	0	0	61	1	0	0
METHYL ISOTHIOCYANATE (20%) IN DIESEL OIL	9								
1.8 to 2.4		8	6	4	2	54	24	15	2
-0.3 to 1.2		9	1	0	1	65	1	0	1
VORLEX	7								
1.8 to 2.4		7	3	3	2	55	17	12	8
-0.3 to 1.2		7	0	1	2	73	0	1	12
ALLYL ALCOHOL	9								
1.8 to 2.4		8	8	7	8	51	54	52	16
-0.3 to 1.2		9	9	9	9	67	25	30	20
NO FUMIGANT	9								
1.8 to 2.4		8	7	8	9	61	59	68	15
-0.3 to 1.2		9	9	9	9	56	55	55	22

[1]Each pole was treated with 500 cc of chemical. Three cores equally spaced around each pole were removed at -0.3, 0, 0.6 and 1.2 m as well as 1.8 and 2.4 m from the groundline.

Table 4

CLOSED-TUBE BIOASSAY FOR RESIDUAL FUMIGANT VAPORS IN DOUGLAS-FIR POLES 3 YEARS AFTER APPLICATIONS[1]

METERS ABOVE GROUND	SEGMENT LOCATION FROM SURFACE	AVERAGE GROWTH OF ASSAY FUNGUS-IN MM				
		METHYL ISO-THIOCYANATE (MIT)	MIT IN DIESEL OIL	VORLEX	ALLYL ALCOHOL	NO FUMIGANT
	CM.					
2.4	0-2.5	9	10	11	13	8
	5.1-7.6	5	11	11	15	22
	12.7-15.2	2	9	13	17	20
1.8	0-2.5	5	9	8	13	10
	5.1-7.6	1	4	7	14	22
	12.7-15.2	0	7	8	17	22
1.2	0-2.5	3	8	7	12	10
	5.1-7.6	0	8	3	14	21
	12.7-15.2	0	3	8	15	19
0.6	0-2.5	0	2	6	11	9
	5.1-7.6	0	3	3	12	14
	12.7-15.2	0	4	8	12	19
	NO WOOD					27[2]

[1]A core was removed from each height from 7 to 9 test poles. The assay fungus was Poria placenta. Suppression of fungal growth is a measure of fumigant effectiveness and, in the 0-2.5 cm zone, of pentachlorophenol with which the poles were pressure treated.
[2]Average growth in 39 tubes without wood.

A. PREPARE AND EVALUATE ENCAPSULATED FUMIGANTS IN LABORATORY WOOD-BLOCK TESTS.

INFORMATION IN THIS SECTION IS CONFIDENTIAL

In preliminary studies on encapsulation of fumigants for wood treatment, methylisothiocyanate (MIT) was melted by heating and was then poured into capsules. After solidifcation, the capsules were sealed by applying a liquid to the edge of the caps before they were closed. When care was taken with the sealing, the MIT capsules remained virtually vapor tight as judged by their relatively constant weight over a period of weeks when the capsules were aerated in a fume hood (Table 5). Capsules filled with solid ammonium bifluoride (NH_4HF_2) and sealed gained slightly in weight probably due to uptake of moisture from the air.

Table 5

WEIGHT CHANGE IN TIME OF CAPSULES CONTAINING EITHER MIT OR NH_4HF_2

NO. OF DAYS AFTER CAPSULES WERE FILLED	WEIGHT OF REPRESENTATIVE FILLED CAPSULES IN MG.	
	NH_4HF_2	MIT
0	503.0	660.3
1	506.0	659.7
3	509.5	--
5	--	658.3
27	530.0	658.9
35	--	658.4
55	--	658.4

To determine if the capsule might bind and thereby inactivate MIT, various combinations of Douglas-fir sawdust (0.1 g), capsule material (0.05 g), and liquid (0.4 ml) were mixed in microbreakers, MIT (20 µl) was added and the beakers weresealed in flasks with serum caps. Periodically a vapor sample was removed from the flasks and dissolved in ethyl acetate which was injected into a gas chromatograph for MIT detection.

A uniform amount of MIT was detected no matter which substrate mixture the MIT was added to. This suggests that the capsule and the liquid added to free MIT vapors from the capsules would not significantly interfere with the effectiveness of this fumigant.

After our initial success in encapsulating NH_4HF_2 and MIT in capsules, we compared the effectiveness of the fumigants when contained in capsules or applied directly to wood. Test blocks 2.5 by 2.5 by 10 cm long of Douglas-fir heartwood at 30% moisture content were autoclaved and the sides of the blocks were coated with paraffin wax. The ends were inoculated with Poria carbonica and the blocks were incubated for 1 month while the fungus grew into the wood. A 12 mm diameter hole was drilled 22 mm deep at midlength and then capsules cut down in length to fit the hole and containing either MIT or NH_4HF_2 were placed in the wood, 1.0 ml of liquid was added to aid release of the fumigants, and the holes were sealed with serum caps. For comparison, liquid MIT was placed inthe wood and NH_4HF_2 was dry packed into the holes, 1.0 ml of liquid was added and the holes were sealed immediately.

Both MIT and NH_4HF_2 were as effective against P. carbonica when applied in capsules as when applied directly to the wood (Table 6). In fact, at the lower test concentration MIT in the capsules was significantly more effective than in the direct treatment.

Currently, we are determining the minimum amount of liquid necessary to effectively release MIT from the capsules, and we have applied both MIT and NH_4HF_2 in large capsules (1" x 3") to pole sections in which we are monitoring the movement of toxic vapors by gas chromotography and the closed-tube bioassay. If the capsule treatments continue to be promising

in our laboratory studies, we will evaluate the fumigant capsules in poles in service this autumn.

Table 6

THE FUNGITOXICITY OF MIT AND NH_4HF_2 APPLIED IN CAPSULES TO WOOD INFESTED WITH PORIA CARBONICA

FUMIGANT	TREATMENT[2]	PERCENTAGE INHIBITION OF PORIA IN WOOD AT VARIOUS FUMIGANT CONCENTRATIONS PER WOOD BLOCK[1]			
		200 µl	50 µ	100 MG	25 MG
MIT	Injected	94	50		
MIT	In capsules	94	81		
NH_4HF_2	Dry pack			81	22
NH_4HF_2	In capsules			72	25

[1]Each value is based on recovery of Poria from 32 cubes cut from four blocks.
[2]After the fumigants were applied to the wood, 1.0 ml of liquid was added and the holes were immediately sealed with serum caps.

B. EVALUATE NEW FUMIGANTS IN THE LABORATORY

A number of potential wood fumigants were evaluated in our standard laboratory assay with the 2.5 by 2.5 by 10 cm blocks. The fumigants were dissolved and diluted in water for wood treatment except for nitroethane which was dissolved in acetone and Mylone which was dry packed into the wood.

As we knew from previous assays, NH_4HF_2 is a promising fumigant for wood but NH_4F and FCAP are less effective and probably not worthy of continued interest at present while we study NH_4HF_2 as a representative of this type of wood fungicide (Table 7). The increasing effectiveness of

FCAP with time is probably due to its diffusion as a salt through the water-saturated cell walls of the wood.

Table 7

FUNGITOXICITY OF POTENTIAL FUMIGANTS TO *PORIA CARBONICA* IN WOOD

FUMIGANT	CONCENTRATION (MG/BLOCK)	PERCENT INHIBITION OF PORIA IN WOOD AT VARIOUS TIMES AFTER TREATMENT[1]		
		1 WEEK	1 MONTH	3 MONTHS
NH_4HF_2	100	87	100	
	50	64	100	
	25	52	100	
	10	0	100	
NH_4F	100	8	100	
	50	12	100	
	10	0	62	
FCAP[2]	750	0	62	100
	500	0	58	100
	100	0	83	100
Formaldehyde	555	79		
	370	12		
	155	25		
	92	0		
	37	0		
Nitroethane	1422	0		
	711	0		
	142	0		
	71	0		
Mylone[3]	1000	0		100
	500	0		96
	250	0		0

[1]Each value is based on recovery of *Poria* from 32 cubes cut from four blocks.

[2]Flour-chrome-arsenic-phenol.

[3]Tetrahydro-3,5-dimethyl-2H-,1,3,5-thiadiazin-2-thion.

Formaldehyde, another potential fumigant, was less effective in this assay than the established wood fumigants (e.g., chloropicrin, Vapam) and thus will not be studied further at present.

Nitroethane was tested in the standard assay because it could be halogenated in wood with a bleach solution to form a biocide similar to chloropicrin. The nitroethane alone was ineffective against Poria and in subsequent assays we will determine if a hypochlorite solution will potentiate the nitroethane.

Mylone, a cyclic compound that slowly generates MIT through its decomposition as does Vapam, is ineffective after 1 week in wood but 3 months after treatment is becoming effective. After 3 months the treatment holes still contained residual Mylone that should continue to liberate MIT into the wood. Because Mylone is a solid material that lends itself to encasulation and is readily available, we will continue to evaluate Mylone as a potential wood fumigant.

C. INVESTIGATE THE INFLUENCE OF ENVIRONMENTAL FACTORS ON EFFECTIVENESS AND PERSISTENCE OF FUMIGANTS.

A basic requirement for studying fumigant toxicity in wood and in the influence of environmental parameters on this toxicity is the establishment of accurate concentration-time (C-T) relationships for fungitoxic action. Knowledge of C-T relationships is necessary for accurate quantitative evaluations of the efficacy of fumigant formations and treatment procedures, the determination of minimum application rates, and the evaluation of the expected toxicity of treatments under varying environmental conditions. In our study we are attempting to establish C-T curves for the toxicity of MIT

as a function of the measurable concentration of this fumigant in the vapor phase.

The first step in our study was to establish a wood block size for the fumigation experiments. The wood blocks must be sufficiently large to represent the wood environment in a pole (fiber length of Douglas-fir is about 0.5 cm) and maintain their moisture content during fumnigation, but be small enough to allow rapid fumigant penetration to establish an equilibrium within the blocks. In a preliminary study we used a gas chromatograph to detgermine the rate of penetration of fumigant vapors along the wood grain of wood blocks of different sizes and moisture contents. MIT rapidly traveled thorugh 0.5 cm blocks at all moisture contents but was much slower in 1.0 cm-thick blocks, especially at higher moisture levels. A more detailed study involved "incubating" wood blocks of different end grain lengths in saturated MIT atmospheres and then extracting the blocks with ethyl acetate to remove the MIT.

The time required for equilibrium of MIT sorption in the blocks was investigated. Blocks 1 cm thick failed to reach equilibrium after 4 hours exposure while 0.5 cm-thick blocks reached equilibrium concentrations between the 2nd and 3rd hours. These experiments suggested that 2.5 x 2.5 x 0.5 cm (grain length) wood blocks were most suitable for this type of fumigation study.

A detection system for vapor concentrations of MIT also had to be developed for quantitative analyses of the wood blocks. Because MIT vapors bind to glass, vapor injections into the gas chromatograph gave inconsistent values that were unsuitable for quantative studies. Consequently, a liquid injection system for the gas chromatograph was devised in which MIT vapors were drawn into a syringe containing ethyl acetate, the ethyl

acetate was injected into a vial and the syringe was rinsed with the solvent. This procedure traps the MIT vapors in a known volume of solvent for subsequent analysis and gives consistent results with an 80% recovery rate based on a 13 mm Hg vapor pressure for MIT at 20 C. This recovery rate is similar to rates obtained in agricultural studies involving MIT.

Another prerequisite for the establishment of C-T curves was to produce a constant fumigant concentration in air over time. MIT has a high affinity for glass surfaces (e.g., over 30% of the MIT vapor withdrawn into a 1.0 cc glass syringe remained in the syringe when it is emptied). The adsorbed MIT could later be recovered by subsequent air flushes or an ethyl acetate wash of the syringe. Wood blocks similarly adsorbed relatively large quantities of MIT (e.g., each 2.5 x 2.5 x 0.5 cm block in a trail fumigation run adsorbed an amount equivalent to that contained in about 300 ml of the air surrounding the blocks). Consequently, a single fumigant application to wood blocks in a closed glass vessel would not maintain a constant fumigant vapor concentation over the exposure time. However, these problems have been overcome by using a continuous flow of fumigant vapors over the blocks. An apparatus has been developed using a controlled air flow through a condenser filled with MIT (held at a constant temperature), before the air flows over the treatment blocks. In this apparatus, a constant MIT concentration in air can be maintained over extended time periods. For example, after a 3 to 4 hour "warm up" period, 23.0 mg of MIT/ml per ml of air was maintained for 18 hours with only a 0.5 mg MIT/ml air flow standard deviation in the measured vapor concentrations. Lower MIT vapor concentrations also have been obtained using air dilutions.

A procedure using small wood slivers from both spring- and summerwood bands has also been tested as a measure of fungal viability in the fumigated

wood blocks. This will be used to establish the minimal fumigant doses required for a specified level of fungal control.

Two trial runs with the continuous flow fumigation apparatus indicate that the required data for establishment of accurate C-T curves for fumigant toxicity under various environmental conditions can be obtained.

D. EVALUATE MOST PROMISING FUMIGANTS IN POLES.

New York

To select test poles, cores were removed from 81 CCA-treated Douglas-fir poles 90 to 100 feet long in service near Buffalo, New York, for 8 years. Three equally spaced cores were removed around each pole at the groundline and two were removed at 2 feet. The cores were shipped by overnight express to Oregon State University and cultured for fungi. Twenty-nine poles had carpenter ants or pockets of advanced decay. A very high percentage of the poles contained Basidiomycete fungi and should be suitable for testing fumigants.

Oregon and Washington

Evidence of decay above the perforated and well-treated groundline zone of Douglas-fir poles led to the inspection of perforated BPA test poles near Cottage Grove, Oregon. Cores were removed and cultured for decay fungi. Decay fungi were present. Additional perforated poles in western Oregon and Washington will be sampled above the groundline and poles with high populations of decay fungi will be treated with encapsulated MIT.

E. MICRODISTRIBUTION AND RETENTION OF CHLOROPICRIN IN SOUND AND DECAYED WOOD

Sound Douglas-fir wood, which had a chlorine content of 1 to 3 ppm measured by neutron activation analysis, was treated by allowing chloropicrin to diffuse through blocks for 3 weeks. The chlorine content of the wood, which also is a measure of the amount of chloropicrin (CP) present, ranged from 95 to 603 ppm. After aeration for 3 days, the chlorine content stabilized at 91 to 532 ppm.

Ground wood mixed with chloropicrin (50 µl CP/gram of wood) contained from 7,3000 to 14,800 ppm chlorine. After aeration for 34 days, the chlorine content stabilized at about 30 to 45 ppm. When 0.7 to 0.9 g of this wood was sealed in test tubes below agar inoculated with a decay fungus (closed-tube bioassay), growth of the fungus was inhibited. Apparently the wood is acting as a very slow release matrix for minute amounts of chloropicrin to control decay.

Sound wood and wood decayed to weight losses up to 30% were treated with chloropicrin, analyzed for chlorine and aerated under high vacuum. No strong correlation was found between the amount of chloropicrin retained and the extent of decay, but more complete analyses are pending. Neutron activation analyses indicated that small residues of chloropicrin remained after high vacuum aeration. These residues proved too low to measure by electron dispersive X-ray analysis. Analysis of the wood by infrared spectroscopy has been initiated to determine if weak chemical bonds are present between chloropicrin and wood.

F. APPLYING FUMIGANTS TO POLES AT THE TREATING PLANT

Research on this phase of the work will begin after an encapsulated fumigant has been degeloped. Safety will be of paramont importance to avoid contamination of the environment during application to poles and during the shipment and installation of fumigant-treated poles.

Objective II

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

This study seeks a substitute for the pentachlorophenol-diesel oil solution currently used to control sapwood decay in cedar poles. Because of toxicological and environmental hazards involved during spraying, pentachlorophenol very likely will be prohibited for this application.

Because difficulties in obtaining cedar poles delayed preservative screening tests, ponderosa pine will replace weathered cedar sapwood for the screening substrate and the most promising chemicals will be tested concurrently in the laboratory and the field.

SCREENING TESTS

End-grain ponderosa pine sapwood was selected as the substrate to which preservatives will be applied because of its fine, uniform structure which is easily penetrated by liquids. However, weathered cedar sapwood will be treated with a few selected chemicals to determine if the findings on pine are applicable to cedar.

The following chemicals have been selected for testing including waterborne pentachlorophenol formulations which may be safer to apply than oilborne formulations.

Oilborne

*Pentachlorophenol (10%) in diesel oil (contol).

Pole Spray 675, Copper-8-quinolinolate (0.162% copper) in diesel oil, Chapman Chemical Co.

Tributyltinoxide (5%) in diesel oil

*To be included in initial field tests.

Waterborne

Ammonium copper borate

*Ammonium bifluoride

CWP-44, copper amine formulation, Chapman Chem. Co.

DuraTreet No. 2, water-dispersible pentachlorophenol-7%, Idacon Inc.

*Nylate-10, copper-8-quinolinolate (9%), Seymour Chemicals

*Penta Formula 111380-4, water-dispersible pentachlorophenol-7%, Reichhold Chemical Co.

3-trimethyl cocammonium chloride plus sodium carbonate, Armak Chem. Co.

*Troysan, 40% 3-ido-2 propynyl-butylcarbamate, Troy Chemical Corp.

*Woodtreat WB, 3-iodo-2-propynl butyl carbamate -5.97%, Koppers Co., Inc.

The endgrain surface will be flooded twice with a chemical and then the blocks will be air dried for 2 weeks. Treated and untreated specimens will be weathered in a weatherometer for an as yet undetermined time periods. Cores will be removed after various periods of weathering, cut into 5 mm-long sections and residual preservative protection will be determined by one or both zone-of-inhibition tests* currently used by Bonneville Power Administration to determine when sprayed cedar poles should be resprayed.

Field Tests

Eighteen 10-foot long western redcedar poles, scored full-length to a depth of 1-1/2 inch to divide the pole surface equally into three sections,

*Scheffer, T.C. and R. D. Graham. 1973. Bioassay estimation of sapwood protection in spray-treated western redcedar poles. For. Prod. J. 23(9):106-109.
Scheffer, T. C. and L. Gollob. 1978. A bioassay for appraising preservative protetion of wood above ground. Holzforschung 32(5):158-161.

will be set 3 feet in the ground and backfilled with pea gravel with one section facing north. Four 3/8-inch diameter plugs will be cut into the heartwood within each section and cultured for fungi.

Six poles will be selected by a random method for flooding treatment with two of six selected chemicals. One section of each pole will remain untreated and a different chemical will be applied to each of the other two sections. The procedure will be repeated for the four remaining chemicals. The poles will be sprayed with water for 1 hour each day from June 1 through Sept. 30. Annually thereafter, plugs will be cut from the poles and evaluated for residual protection by a zone-of-inhibition bioassay.

Objective III

PREVENT DECAY INITIATED IN FIELD-DRILLED BOLT HOLES IN DOUGLAS-FIR POLES

Twenty-eight poles 18 feet long with top circumferences between 24 and 29 inches will be Boulton-dried for at least 24 hours in a pentachlorophenol-heavy oil solution. The poles will be removed from the retort after drying to obtain a thin treated shell and as large a core of untreated wood as possible.

EXPERIMENTAL DESIGN

	Poles			Holes		Hardware	
Bolt hole protections	Per protection		Total	Per pole	Total	Types	Per type
7	X 4	=	28	x 8	= 224	÷ 2	= 112

Starting 1-1/2 feet below the top, an increment borer core will be removed at eight locations 1-1/2 feet apart in a spiral pattern (45° offset). The cores will be cultured for fungi.

A bolt hole will be drilled at each core location. The holes will be 1/8-inch larger than the bolt to be inserted. Hardware for crossarms and for guys will be fastened at alternate holes in each pole.

The bolt hole protection will include the following:

- Patox pads between poles and attachments.
- Dry chemicals sprayed in holes.
  - Polybor (a mixture of boron compounds)
  - Ammonium bifluoride
- Liquid chemicals sprayed in holes
  - Boracol 40 (Boron in ethyleneglycol)

Pentachlorophenol (10%) in diesel oil

. None - Control poles without protection will be installed to follow the development of decay in bolt holes.

The poles will be set 4 feet in the ground and backfilled with pea gravel. Bolt hole protections will be randomly assigned to poles. The eight holes in each pole will receive the same protection. Four poles will be used per protection except for eight poles with unprotected bolt holes.

Starting next June 1, the poles will be sprinkled with water for 1 hour per day through September.

EVALUATION

Periodically after installation of hardware, cores will be removed to the center of the pole 4 inches below each bolt holes in a group of poles with untreated bolt holes. Results from these cores will be used to determine when cores should be taken to evaluate the protective treatments. The core holes will be plugged with treated dowels and the cores will be cultured for decay fungi.

Objective IV

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

A. DETECTING EARLY DECAY IN DOUGLAS-FIR USING CRUSHING STRENGTH, CHEMICAL INDICATORS AND FRACTURE TESTS

Current inspection methods for estimating the residual strength of decaying poles are based on visible advanced decay. Invisible early decay can cause serious strength losses in wood and may extend well beyond visible decay. As a result, present estimates of residual strength can be overly optimistic. This study evaluated the following methods for detecting early decay in cores or plugs removed during the inspection of poles in service.

- Compression perpendicular to grain in the radial direction.
- Chemical pH indicators and stains that change color in decaying wood.
- A needle wood facture test--a modification of the "pick test" in which a sliver of wood is lifted with a sharp tool. A long, splintering failure indicates sound wood, an abrupt fracture suggests decay.

Procedure

Plugs 3/8-inch in diameter were cut from a decay-free Douglas-fir pole section, machined to a length of 3/4-inch, and decayed by Poria placenta to weight losses between 0 and 20%. The specimens were conditioned to constant weight at 21 C and 68% relative humidity for testing.

Radial Compression. Precisely cut plugs were tested for strength perpendicular to grain in the radial direction in an Instron Universal Testing Machine at a head speed of 0.03 cm/min. Strength values at 5% compression were calculated.

Color indicators. Plugs were split lengthwise to expose their radial faces to which the indicators were applied. Colors were identified by the Inter-Society Color Council-National Bureau of Standards-Color Name Chart.

Fracture tests. Radial faces of split plugs were wet briefly with water and viewed under 30X magnification to determine the nature of the fracture as the surface was scratched with a needle positioned at various angles in a device made to apply a uniform load. Some specimens also were scratched with a hand-held dissecting needle.

Results

The average weight losses of Douglas-fir sapwood and heartwood decayed by Poria placenta for 28 days were 10.4 and 7.2% respectively (Figure 2). Sapwood specific gravity was reduced by 10% and heartwood specific gravity by 5%.

Radial Compression. Compressive strengths of decayed Douglas-fir sapwood and heartwood at 5% compression were reduced a maximum of 62 and 49% respectively (Table 8, Figure 3). Correlation between strength loss and weight loss was very good (Figure 4).

A significant loss in strength of sapwood was detected before weight loss was evident (before 8 days incubation) and of heartwood at 5% weight loss. A small device for testing radial compression in the field was developed and will be evaluated in subsequent research.

Table 8

AVERAGE RADIAL COMPRESSION STRENGTH AND STRENGTH LOSS OF DECAYED DOUGLAS-FIR WOOD

RADIAL COMPRESSION	DAYS INCUBATED	SAPWOOD		HEARTWOOD	
		SOUND	DECAYED	SOUND	DECAYED
STRESS AT	8	599	568	678	676
5% COMPRESSION	20	575	326	713	459
(psi)	24	597	228	765	389
	28	608	276	763	426
STRENGTH LOSS,%	8	-	5	-	0
	20	-	43	-	35
	24	-	62	-	49
	28	-	55	-	37

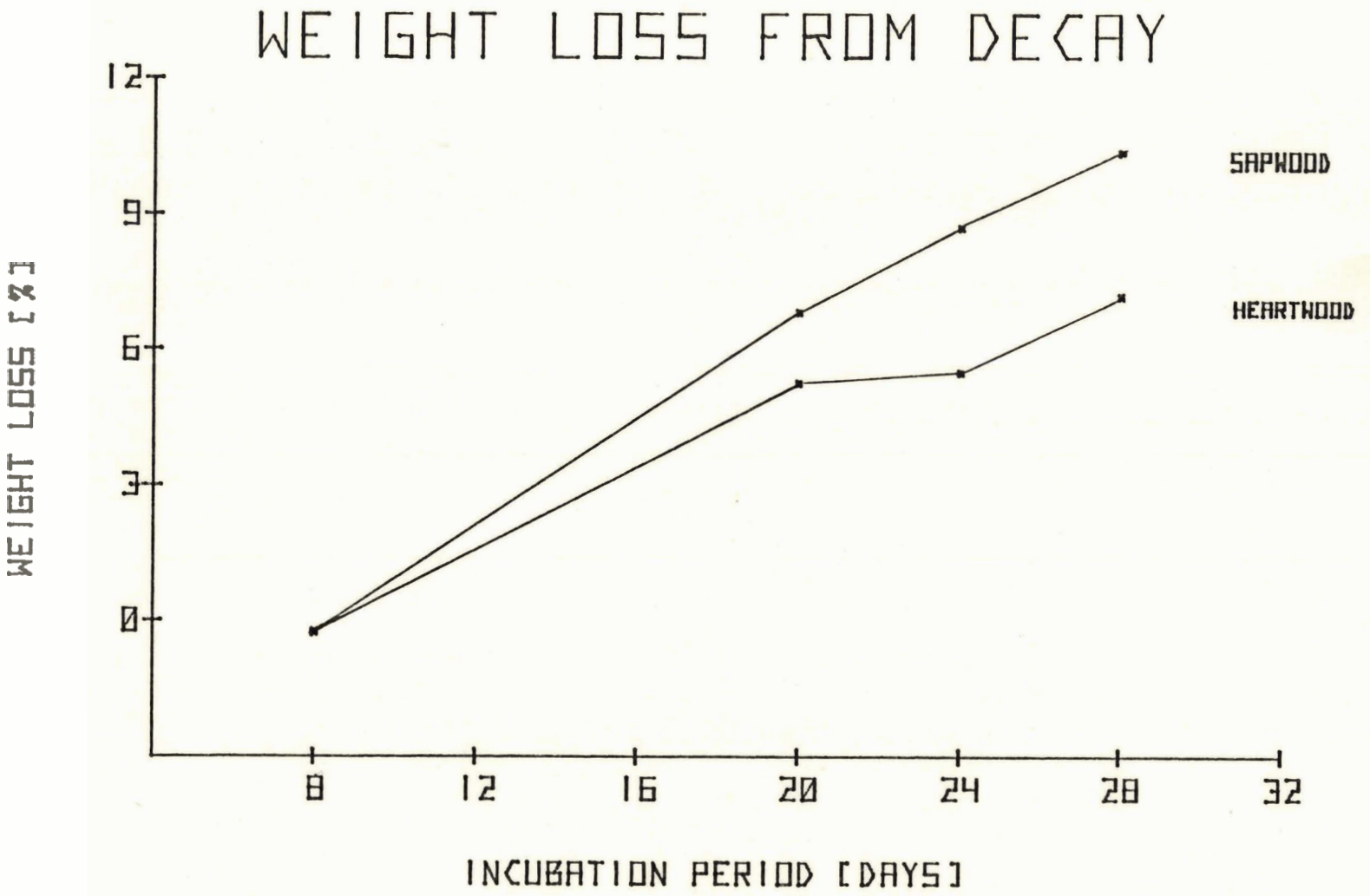


Figure 2. Weight loss of Douglas-fir sapwood and heartwood plugs decayed by Poria placenta, a common cause of internal decay of Douglas-fir poles in service.

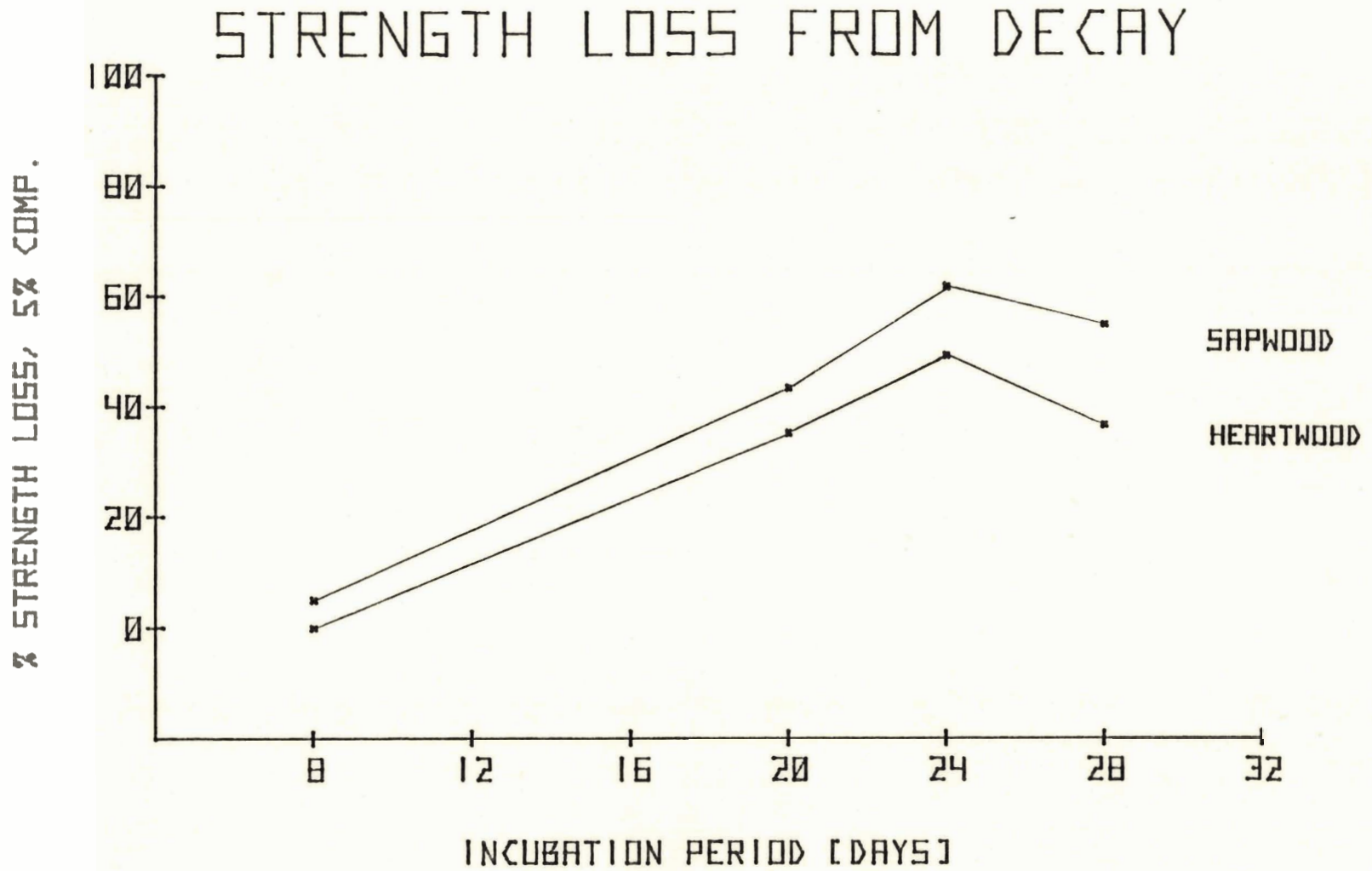


Figure 3. Loss in compressive strength of Douglas-fir sapwood or heartwood decayed by Poria placenta.

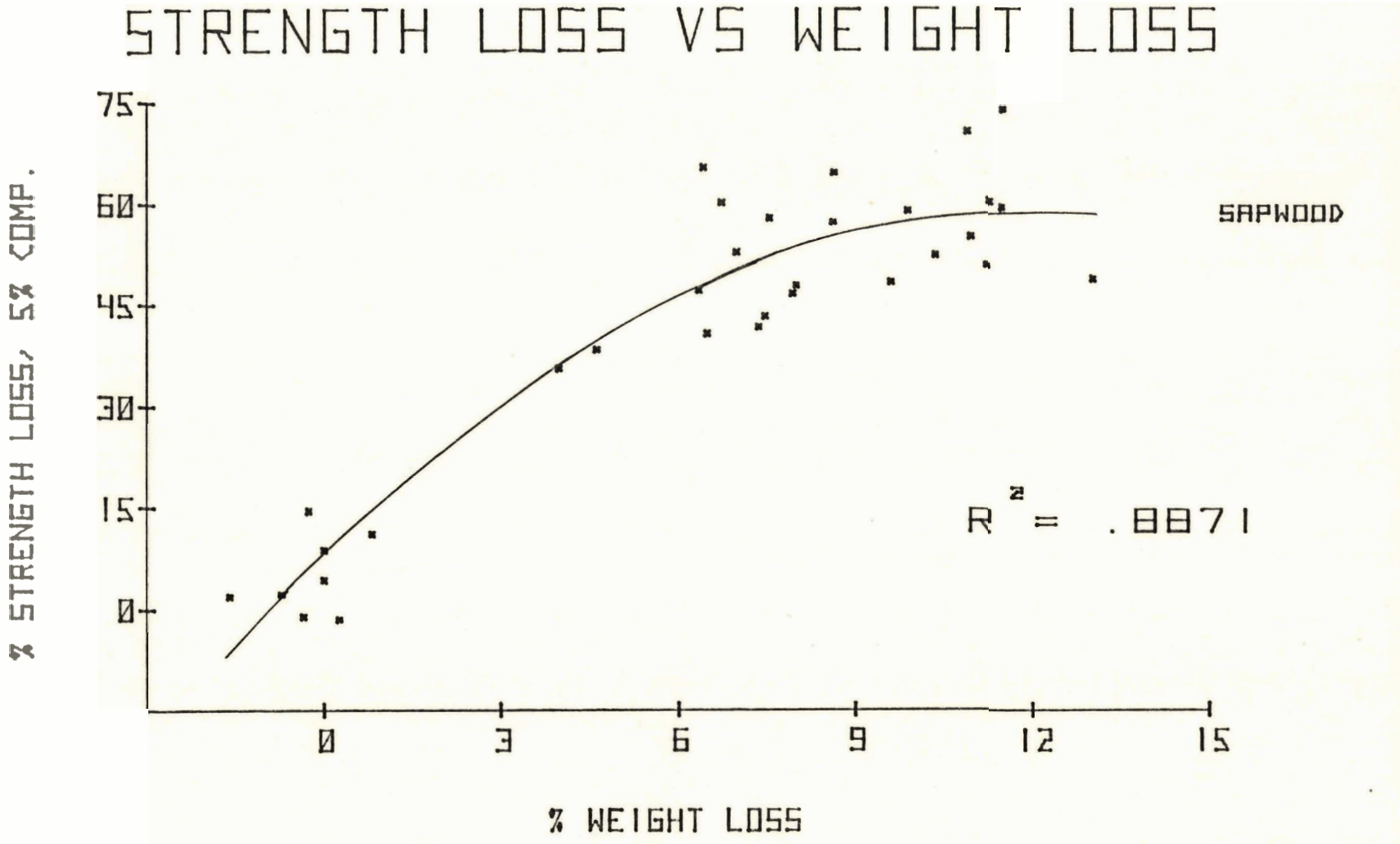


Figure 4. Loss in compressive strength of Douglas-fir sapwood decayed by Poria placenta to increasing weight losses.

Color indicators. Chrome azurol-S + sodium acetate caused the fastest and most obvious color reaction when applied to Douglas-fir. The dye changed from orange-yellow to dark purple on both sapwood and heartwood decayed by Poria placenta for 8 days or longer and weight losses as high as 10%. Methyl orange + indigo carmine, which changed from olive green to a deep violet, was equally as effective on decaying sapwood, but produced a color change on both sound and decayed heartwood. The indicators did not work on Douglas-fir attacked by Gloeophyllum saepiarium, a common decay fungus.

Fracture tests. Scratching earlywood of sound and decayed (less than 5% weight loss) Douglas-fir with a needle produced a rasping sound and a slight pressure was needed to fracture the fibers. At 5% weight loss and higher, there was no rasping sound and the earlywood fibers fractured at the least pressure.

The fiber fracturing device worked best at a needle angle of 75°, but an angle of 45° permitted the fracturing to be viewed under magnification. The wood fibers broke either abruptly, remaining parallel with the wood grain, or in a sweeping pattern following the needle direction. The incidence of abrupt failure was very high in earlywood bands of both sapwood and heartwood of decayed Douglas-fir but was low in sound wood (Table 9). In latewood of both sound and decayed Douglas-fir, the incidence of abrupt failure was low. The needle fracture test was very tedious.

Conclusions

. Earlywood of Douglas-fir, which was more susceptible to decay than latewood, provides the best material for detection of early decay.

. Radial compression offers the most encouraging approach to the field detection of early decay.

Table 9

INCIDENCE OF ABRUPT FAILURE CAUSED BY SCRATCHING THE WOOD SURFACE OF SOUND AND DECAYED DOUGLAS-FIR WOOD WITH A NEEDLE

CONDITION OF WOOD	WEIGHT LOSS, %	INCIDENCE OF ABRUPT FAILURE, %	
		LATEWOOD	EARLYWOOD
		SAPWOOD	
SOUND	0	14	33
	0	0	8
	0	0	33
	0	0	30
Decayed	-2.1	14	71
	3.8	43	100
	4.4	20	50
	5.5	0	100
	6.4	0	100
	7.9	25	100
	8.9	0	100
	10.4	50	100
		HEARTWOOD	
SOUND	0	0	50
	0	0	0
	0	0	0
	0	0	25
DECAYED	-1.7	0	100
	2.3	0	100
	3.7	0	100
	4.9	0	100
	6.5	0	100
	7.2	0	100
	8.6	25	100
	8.9	0	100
	9.9	0	100

B. FLUORESCENT MICROSCOPY FOR DETECTING INCIPIENT DECAY AND ESTIMATING RESIDUAL STRENGTH OF WOOD

Fluorescent microscopy may offer a relatively rapid laboratory method for distinguishing between sound and decayed wood and for quantitatively assessing the amount of decay present. The amount of decay should provide a basis for estimating the residual strength of wood. The purpose of this research was the development of a suitable technique for staining the wood to permit color differentiation of the various stages of decay by fluorescenT microscopy. This technique was applied to Douglas-fir and Southern yellow pine specimens.

Procedure

Small end-grain wafers (2.57 cm square and 0.32 cm thick) for microscopy and miniature beams (1.27 cm wide, 0.48 cm thick and 11.43 cm long) for bending tests were decayed by Gloeophyllum trabeum to weight losses up to about 13% at the U.S. Forest Products Laboratory.

The wafers were cut with a microtome into very thin sections (5 to 30 micrometers) and stained with the fluorochrome stain acridine orange using solutions with pH levels from 4.0 to 8.0. The stained sections were mounted on glass slides, observed under an incident light Lietz fluorescence system through a Ploemopak filter module H_2 using a xenon light source, and photomicrographs were taken. Selected slides were subjected to computer image analysis to determine the percentage of decayed wood which was stained orange in contrast to the bright green of undecayed wood. Differences in contrast (brightness) were measured as gray levels.

End-matched decayed and undecayed beams were conditioned to an equilibrium moisture content of about 7.5% and center loaded over an 8.9 cm

span at a head speed of .05 cm/min. to failure. Small pieces of wood from the break areas were removed for microscopic evaluation and for alkali solubility tests.

Results

Fluorescent microscopy. The most distinguishable color patterns, green for sound wood and orange for decayed wood, were imparted to wood sections by acridine orange stain at pH 6.0 in southern yellow pine and pH 8.0 in Douglas-fir. Washing sections for 24 hours was necessary to remove residual orange stain.

In general, the brightness level decreased as the weight loss increased (Figure 5). However, problems encountered in using the image analyzer suggest that a new approach, analyzing color wave lengths for example, may provide better correlation with weight loss as a measure of the extent of incipient decay.

Strength. Loss in moduli of elasticity (MOE) and rupture (MOR) increased with increasing weight loss in both pine and Douglas-fir (Table 10). Maximum losses in MOE and MOR respectively were 39 and 77% for pine and 37 and 53 for Douglas-fir.

Alkali solubility. Alkali solubility correlations with strength and strength losses were poorer than those obtained with weight loss.

Conclusions

. An acridine orange stain permitted adequate differentiation between undecayed wood and wood decayed to small weight losses when observed by fluorescent microscopy.

. Although image analysis does detect the green color of undecayed wood and orange color of decayed wood, the mixture of these colors at low

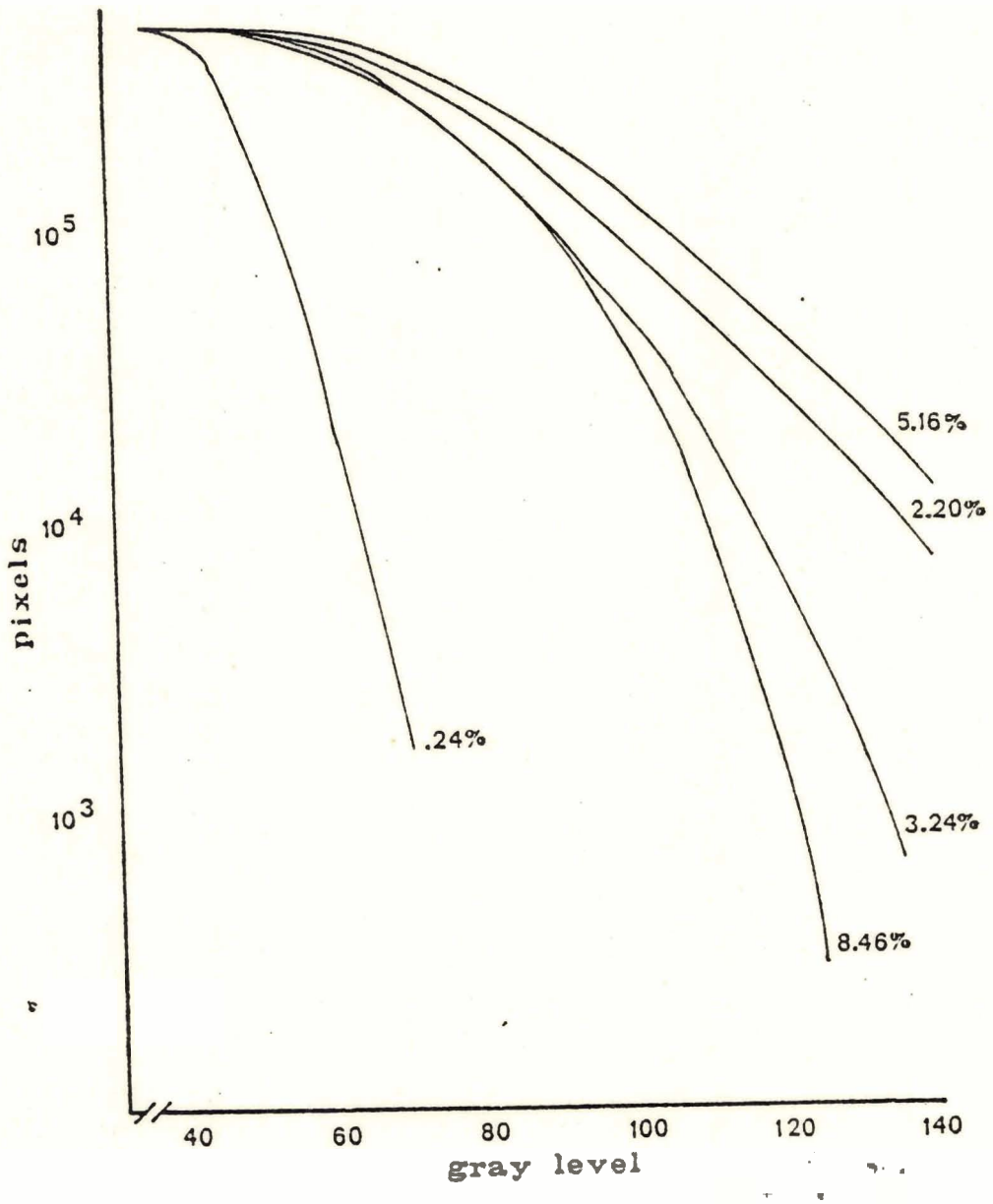


Figure 5. Brightness generally decreased (increasing gray levels) with the amount of decay (weight loss) when Southern pine beams were subjected to computer image analysis.

decay levels and anatomical features pose problems in quantifying the amount of decay.

. Large reductions in modulus of elasticity and even larger reductions in modulus of rupture of southern pine and Douglas-fir occur during the early stages of decay characterized by small weight losses.

. Alkali solubility is a poor indicator of the extent of decay at small weight losses.

Table 10

EFFECT OF INCREASING WEIGHT LOSS FROM DECAY ON STRENGTH OF SMALL SOUTHERN PINE AND DOUGLAS-FIR BEAM*

WEIGHT LOSS,%	AVERAGE STRENGTH LOSS, PERCENT			
	MODULUS OF ELASTICITY		MODULUS OF RUPTURE	
	PINE	DOUGLAS-FIR	PINE	DOUGLAS-FIR
2	9	5	54	16
5	14	15	58	28
8	18	23	61	40
11	23	--	66	--
14	29	--	70	--

*Values from linear regression lines.

Objective V

CONSERVE ENERGY BY PROCURING DOUGLAS-FIR POLES THAT HAVE BEEN SEASONED BY THE MOST EFFICIENT METHODS AND THAT ARE AND WILL REMAIN FREE OF VIABLE DECAY IN SERVICE

A. DETERMINE THE INCIDENCE AND SPECIES OF DECAY FUNGI IN FRESHLY CUT POLES AND IN POLES STORED IN WIDELY SCATTERED AIR-SEASONING YARDS FOR ONE, TWO OR MORE SUMMERS.

Studies under this objective were initiated by a trip to the Crown Zellerbach Corporation pole yard in Scappoose, Oregon in October 1980 where our tentative research plan for examining poles during their production was evaluated to determine its feasibility. At that time cores were taken from one set of poles air seasoned for about 1.5 years, and decay fungi were detected in the tops or butts of all poles samples. Subsequently, a detailed research plan was developed, and poles in about 13 air seasoning yards in Washington, Oregon and California will have been sampled this summer.

Fourteen 6-inch long cores distributed along the length of each of about 100 poles per week are being removed and placed in plastic straws. The holes are flooded with alcohol and plugged with treated dowels. The cores are stored in a refrigerator at the end of the day.

At OSU, the cores are flamed briefly to kill surface contaminates, plated on nutrient media and incubated at 21 C for 30 days. The plates are examined after 1 week to detect rapid-growing air-borne contaminates which are marked on the bottom of the plate. After 30 days, fungal growth on the plates is examined microscopically. Fungi having characteristics indicative of wood decayers are transferred to other plates for isolation and identificaiton. Fungi that appear to be wood destroyers are incubated with

small sticks that later are bent around mandrells of decreasing radii until the specimen breaks.* The smaller the radius at failure, the less likelyhood that the wood is decayed. Eventually, representative wood-destroying fungi will be sent to Dr. Eslyn, U.S. Forest Products Laboratory, for verificaiton.

To date, 10 pole yards have been sampled with about 1100 cores per yard. Some of the Basidiomycetes isolated were easily identified (e.g., Fomatopsis cajanderi, Gloeophyllum saepiarium, Poria carbonica), but the majority are still to be identified. The ability of these fungi to decay wood is being studied.

B. DETERMINE THE ABILITY OF VARIOUS FUNGAL STRUCTURES TO INITIATE DECAY AND DETERMINE HOW AND WHEN POLES IN SERVICE ARE INFECTED WITH DECAY FUNGI.

Poria carbonica is the major decay fungus in Douglas-fir poles in the Northwest, but relatively little is known about its means of spread and infection of poles. Although infection can occur from soil-borne inoculum, air-borne inoculum in the form of basidiospores (from fruit bodies) and small soil particles carrying hyphal fragments and chlamydospores (spores formed from hyphal cells) may be important. To assess the probability of these various fungal structures (propagules) acting as decay inoculum, the fungal units first must be isolated, their viability determined, and their ability to initiate decay studied.

Most of the work in this area centered on isolatuion of the fungal spores and understanding the conditions necessary for the production of these spores.

*Safo-Sampah, S. and R. D. Graham. 1976. A rapid agar-stick breaking-radius test to determine the ability of fungi to degrade wood. Wood Science 9(2):65-69.

Chlamydospores are produced abundantly in cultures on malt agar at room temperature under diffuse daylight, but to investigate their ability to initiate decay they must be separated from the fungal hyphae. Cultures of P. carbonica were grown on malt agar that was covered by a sheet of porous cellophane which allowed nutrients from the medium to pass and fungal mycelium to grow on top of the sheet. Mycelium could be scraped from the sheet without picking up the culture media. The mycelium was homogenized with broken glass and the suspension was then sonicated for 1 minute to suspend and separate the chlamydospores. The fungal suspension was then filtered through four layers of cheesecloth followed by Whatman No. 4 filter paper. The filtrate with suspended chlamydospores was centrifuged and the pelleted spores were resuspended in 3 ml of sterile distilled water. Spores separated in this manner are fairly free of other fungal structures. About 60% of these spores germinated on nutrient agar.

Individual chlamydospores were placed on the end grain of wood blocks. After a 1-month incubation, isolations from the blocks will determine the success of infection. Results of this experiment will establish if single chlamydospores are capable of establishing an infection leading to decay of wood.

To determine if soil particles small enough to be wind-borne could contain viable fungal inoculum, P. carbonica was grown in a Jory-series soil, typical of Douglas-fir stands in the Coast Range of Oregon. Soil was brought to field moisture capacity, autoclaved, and inoculated with spores and mycelium of the decay fungus. The inoculated soil was incubated for 1 month, then allowed to dry by circulating air around the culture flasks. The dry soil was sieved through a range of sieve sizes from 14 to 400 mesh/inch.

To determine the viability of the decay fungus in soil particles of various sizes, a small amount of soil of each particle size was sprinkled onto plates of malt agar medium and subsequent colony growth was noted. Particles smaller than 170 mesh (90 μm) contained no viable decay fungus, while particles that passed through the 120 mesh (125 μm) generally contain viable propagules. This experiment shows that soil particles small enough to be wind-borne for short distances can contain viable decay fungus propagules. Further experimentation will deal with establishment of decay fungi in wood using infested air-borne-size particles as inoculum.

Basidiospores are another important air-borne propagule of decay fungi, and our initial investigations in this area have centered around inducing P. carbonica to sporulate in culture by variations in light and temperature.

To study the influence of light on sporulation, malt agar plate cultures of P. carbonica were incubated in the dark at 30 C until colony diameters reached about 3 cm. The plates were divided into three gorups of 12 plates each. One group was maintained in the dark, a second group was exposed to the normal diurnal light cycle in a greenhouse, and the third group received 12 hours of near-ultravolet light. The treatments were continued for 2 months before the cultures were examined for the presence of fruiting bodies. None of the treatments induced fruiting body production, but under both light treatments small, yellowish patches on the mycelial mats contained fruiting initials with some basidia. The cultures in the dark had uniformly sparse mycelial mats with no fruiting initials. This suggested that light is necessary for fruiting, but other factors probably limited sporulation in this experiment.

Cold induction of sporulation by placing plate cultures of P. carbonica at low temperatures for various periods was investigated. The cultures were incubated at 30 C until colony diameters had reached 4 cm and then the cultures were transferred to 5 C. Six plates were removed and placed in the light at room temperature at intervals of 1, 2, 4 and 6 weeks. Cultures removed after 1 and 2 weeks in the cold resumed normal growth with no fruiting body production, but those removed after 4 and 6 weeks generally produced fruiting bodies around most of the colony margins. The fruiting bodies were atypical, consisting of stalks of sterile tissue covered with basidia. Sterigmata and basidiospores were also observed microscopically. A cold period may be a necessary part of the fruiting cycle of P. carbonica or it may be overcoming an unknown inhibiting factor. Further studies are planned to investigate the influence of light and temperature on fruiting after the cultures have undergone a 4-week cold period.

In addition to light and temperature, nutrients in the culture medium are known to influence growth and sporulation by fungi. Consequently, an experiment was designed to determine the influence of various malt extract concentrations and Douglas-fir wood on sporulation by P. carbonia. Cultures growing on media with various levels of malt extract were exposed to either near-ultraviolet (NUV) or diffuse daylight for 4 days, after which they were inverted and incubated in daylight at about 20 C.

The rsults of this experiment show that the addition of Douglas-fir wood to the culture media stimulates sporulation (Table 11). However, under daylight with 6.2 g malt extract/500 ml media significant sporulation was obtained without wood present. The basidiocarps that discharged spores

from the Douglas-fir amended media were not formed on the wood blocks themselves, but occurred near the edges of the cultures. This suggests a diffusible substance that stimulates sporulation. The basidiospores obtained from this experiment are currently being used to determine the concentration of spores necessary to establish P. carbonica in wood.

Table 11

THE INFLUENCE OF MALT EXTRACT ON SPORULATION BY PORIA CARBONICA GROWING UNDER NEAR-ULTRAVIOLET LIGHT (NUV) AND DAYLIGHT

MALT EXTRACT CONC. (g/500 ML)	NUMBER OF CULTURES OUT OF 9 GROWING UNDER NUV AND DAYLIGHT WITH VARIOUS STAGES OF SPORULATION					
	NUV			DAYLIGHT		
	NO DIFFEREN-TIATION	FRUITING INITIALS ONLY	ACTIVE SPORU-LATION	NO DIFFEREN-TIATION	FRUITING INITIALS ONLY	ACTIVE SPORU-LATION
12.5 + wood[1]	0	0	8	0	0	8
12.5	0	7	0	0	7	0
6.2	3	4	0	1	4	4
3.1	7	1	0	7	1	0
1.5	8	0	0	7	1	0
0	8	0	0	8	0	0

[1]Three small blocks of Douglas-fir heartwood were added to the culture media while the media was still molten.

Basidiospores from the cold-induced fruiting bodies were collected and spread onto malt agar medium where a relatively high percentage of the spores germinated. Small isolated colonies, probably arising from single spores, were transferred to separate plates and these cultures were examined periodically for the presence of clamp connections, a specialized structure of many Basidiomycetes. Colonies producing clamps were discarded but those without clamps were maintained and assumed to be monokaryon isolates of P. carbonica. Thirty-two of these single spore

isolates have been collected and verification of their identity is currently underway utilizing dikaryon/monokaryon mating techniques.

These monokaryon isolates are currently being used to determine the mating system of P. carbonica. Each monokaryon was crossed with four other monokaryons, incubated for 2 weeks, and examined for clamp connections. The presence of clamps indicates that the two isolates mated and are sexually compatible. Out of 72 crossings made, two pairs of sexually compatible isolates were found. In a second series of crossings, all of the monokaryon isolates were crossed with each isolate of the two sexually compatible pairs. The results of these crossings are currently being examined. The preliminary results indicate that P. carbonica is heterothallic and has at least two mating types. Since all of the monokaryon isolates originated from a single dikaryon, single spore isolates must be collected from other dikaryon isolates of P. carbonica before the mating system can be completedly worked out.

If wind-borne basidiospores are to be capable of initiating infection of wood, then the monokaryotic hyphae resulting from these spores must be capable of decaying wood. To investigate the ability of monokaryons to decay wood, decay chambers containing 2% malt agar were inoculated with four monokaryotic isolates and four dikaryotic isolates of P. placenta. All the isolates used in this experiment were obtained from the Forest Mycology Research Center, Madison, Wisconsin. Douglas-fir blocks were incubated in the chambers for 4 months after which they were dried, weighed, and weight loss was calculated.

In general, more decay was obtained form the dikaryon cultures, but the monokaryons produced a significant amount of weight loss. This

experiment demonstrated that monokaryons can invade wood and consequently that basidiospores are capable of initiating invasion of wood.

Initation and development of decay

To determine how and when poles in service are infected with decay fungi, poles sections placed upright and horizontally are being exposed at Arlington, Washington (J. H. Baxter & Co.), Scappoose, Oregon (Crown Zellerback Corp.), Eugene, Oregon (McFarland-Cascade Co.), and Oroville, California (Koppers Co., Inc.).

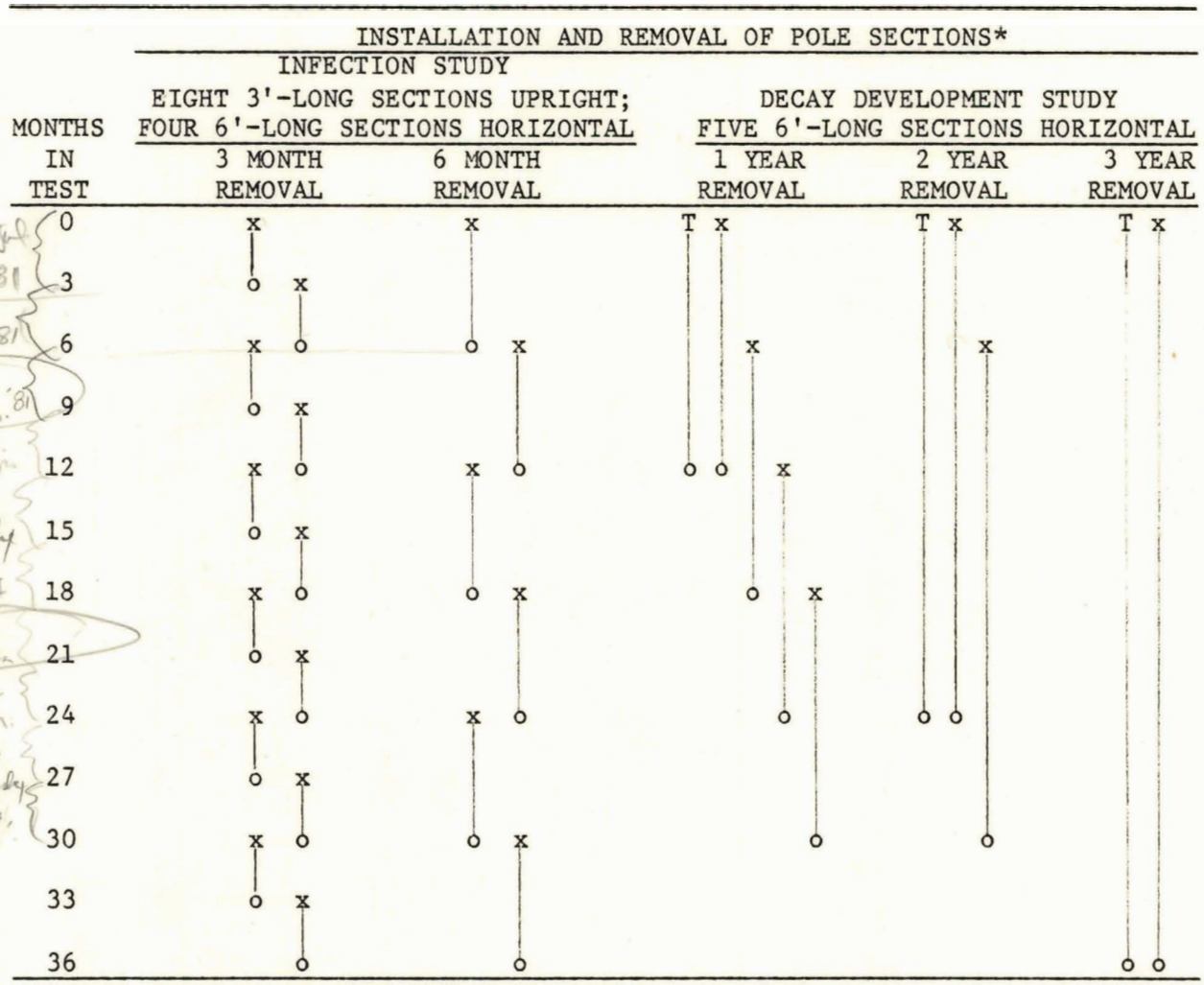
Poles supplied at each yard were marked into 6-foot long sections. At the end of each section, cores were removed at 4-inch intervals around the pole. The average number of cores removed per pole was about 150. The poles were cut in the plane of the holes and the cores were cultured for fungi.

Infection Study

Pole sections are being removed at 3- and 6-month intervals (Table 12) and extensively cored to determine the infection potential at various times of the year. At the 3-month and subsequent exposure intervals, 8.5-foot long pole sections, which were end coated with two coats of Gaco A5400 white end coating to reduce moisture loss and heated in a kiln to kill all fungi, were taken to each storage yard. The poles were then cut into two 2-foot long sections, one from each end, leaving a 4-foot long section from the middle. The 2 foot sections are being exposed vertically and the 4 foot sections were laid horizontal on treated skids. One end of each 4 foot section was coated.

Table 12

EXPERIMENTAL DESIGN TO STUDY INVASION BY DECAY FUNGI, DECAY DEVELOPMENT AND ITS PREVENTION IN DOUGLAS-FIR POLES



* = One pole section was added to each study group as a replacement if needed.

x = Untreated sections at start of seasoning.

o = End of seasoning.

T = Treated sections.

The moisture distribution in the sections was determined, and the sections will be returned to Corvallis and extensively sampled for decay fungi. The sections will be retained until the cores are processed.

In the 2-foot sections, moisture content will be measured at depth of 0.5, 1 and 2 inches at 1, 6 and 12 inches below the top on two sides 180° apart. Cores will be removed 3 inches below the top at 3-inch intervals around the circumference with every core taken to the depth of 6 inches.

In the 4-foot sections, moisture content will be measured at depths of 0.5, 1 and 2 inches at 1, 9, 18 and 36-inch intervals from the ends along the top in two rows 2-3 inches from the top.

Decay Development Study

Rate of invasion of decay fungi. Fifteen 6-foot long pole sections, sealed on one end with three coats of Gaco A5400 to slow drying, will be placed horizontally on treated skids. Groups of five pole sections will be added at 6-month intervals and other groups of five sections will be removed after 1, 2 and 3 years (Table 12). Moisture content at time of removal will be measured at depths of 0.5, 1 and 2 inches at 1, 18 and 36-inch intervals from the ends along the top and bottom. Cores will be removed to the center at 6-inch intervals around the circumference 1 inch from each end and at 6-inch intervals form the ends. The cores will be staggered to obtain even distribution.

After culturing, additional cores may be taken where decay fungi are detected and the pole sections will be dissected with a chain saw. This information will provide a three-dimensional view of decay distribution and an estimate of the volume of wood infested.

Variation in Susceptibility of Douglas-fir to Invasion by Fungi

decay. To determine the relative susceptibility to invation by decay fungi of Douglas-fir from the different sources used in this experiment, eight 3-foot long sections from each wood source will be exposed vertically at the Northwest Forest Genetics Nursery, Corvallis, for 6 months. Cores will be removed at 3-inch intervals around the circumference 1 inch from both ends of the pole sections.

C. INVESTIGATE METHODS FOR PREVENTING INFECTION OF POLES BY DECAY FUNGI DURING AIR SEASONING AND FOR ELIMINATING THE DECAY FUNGI PRIOR TO AND DURING PROCESSING

During Air Seasoning

Fifteen 6-foot long pole sections, sealed on one end with three coats of Gaco A5400 to slow drying, will be placed horizontally on treated skids. The tops will be flooded with a 32-percent solution of ammonium bifluoride known to prevent invasion of southern pine poles by decay fungi. Groups of five pole sections will be removed after 1, 2 and 3 years and distribution of moisture and decay fungi will be determined as described under Rate of Invasion.

During Processing

Plans for this portion of the study will be developed for implementation next spring.