ABSTRACT

This fifth annual Cooperative Pole Research Program report outlines our progress in the six project objectives.

Improved Fumigants

Sampling of previously established field tests revealed that Vorlex and Chloropicrin continued to perform well after 15 years, while Vapam was slightly less effective. Solid methylisothiocyanate (MIT) also performed well in the field after 7 years. In additional tests, gelatin encapsulated MIT migrated through Douglas-fir heartwood with addition of moderate quantities of water to degrade the gelatin. However, in the presence of higher quantities of water or no additional water, MIT migration into the wood was slowed. In a previously established test, gelatin encapsulated MIT continues to inhibit reinfestation of poles 3 years after treatment.

Pelletized MIT is a new formulation (65% active ingredient) that appears to have some promise. Preliminary tests indicate that up to 95% of the MIT is release in 24 hours, but a small quantity of MIT remains in the pellets after 63 days aeration and may pose a disposal hazard.

The solid MIT formulations will permit aboveground applications, increasing the risk that MIT will come in contact with pole hardware. Preliminary tests indicate that MIT had little effect on corrosion of hot dipped, galvanized bolts attached to wood. This suggests that treatment in the crossarm zone with MIT or fumigants that produce MIT should not affect the integrity of attached hardware.

In addition to fumigant evaluations, we recently examined an earlier test of groundline treatments with Osmoplastic® and Hollowheart®. After 10 years, these treatments are performing reasonably well, with only a slight rise in the incidence of decay fungi in the past 4 years. We also reevaluated the effectiveness of kerfing for preventing decay and found that this process reduced the depth and width of checks, resulting in a decreased incidence of decay fungi. Kerfing appears to be a valuable method for preventing internal decay at the groundline.

Cedar Sapwood Decay Control

This past year, the second set of five chemicals applied to control sapwood decay were evaluated after 2 years of exposure. As in earlier evaluations using the Aspergillus bioassay, none of the chemicals approach pentachlorophenol in oil for ability to inhibit sporulation of Aspergillus niger; however, several samples from zones deep in the wood produced a slight zone of effect. This may indicate the presence of a reservoir for long-term protection against decay. Several of the chemicals including Fluor Chrome Arsenic Phenol and Ammoniacal Copper Arsenate (ACA) appear to bind to the wood and may be difficult to detect by the bioassay method. We expect to assess the effectiveness of these treatments using a soil block test.

Investigations of the reliability of the Aspergillus bioassay under a variety of conditions indicated that quantity of spores, use of glass or plastic petri dishes, long-term cold storage, and the use of spray inoculum instead of flooding spores had little influence on

the bioassay results with pentachlorophenol, Tributyl-tinoxide, or 3 iodo propynyl butylcarbamate; however, incubation temperature did influence assay results. The Aspergillus bioassay is a simple, effective means for estimating residual preservative levels.

Bolt Holes

Again this year, wood around the unprotected, control bolt holes in pole sections contained such low levels of decay fungi that evaluation of the treated poles will be delayed another year.

In addition to the initial bolt hole treatments, we have begun a test to determine if gelatin encapsulated or pelletized MIT can prevent decay development in field-drilled bolt holes. The pole sections used in these tests had already begun to develop decay prior to treatment and will provide an ideal test material.

Detecting Decay and Estimating Residual Strength of Poles

Fluorescent labeled lectins used in our earlier studies detected decay fungi at low weight losses under laboratory conditions. We are currently evaluating this method for detecting fungi in increment cores removed from poles to reduce the need for culturing.

Last year we identified a peak that was unique to infrared (IR) spectra of warm water extracts from decayed wood. This past year we attempted to identify the chemical responsible for this peak and found that carbonyl compounds, probably from oxidative lignin degradation, were responsible for the peak. Since brown rot fungi apparently do

not completely metabolize lignin breakdown products, they accumulate in the decaying wood and can be readily detected by their IR spectra.

Strength properties of beams cut from Douglas-fir pole sections, air-seasoned for 3 years significantly decreased although decay fungi could not be uniformly isolated from the beams. In addition, there were gradual declines in work to maximum load and modulus of elasticity, as well as increased Pilodyn pin penetration. These results suggest that some strength losses occurred during air-seasoning; however, the losses were not large and should not endanger pole users.

We compared several test methods including the Pilodyn, radial compression tests, longitudinal compression tests, and the pick test for evaluating residual pole strength of the wood surface of Douglas-fir treated with combinations of fumigants or groundline wraps. The results indicate that only the pick test could accurately detect surface damage and illustrate the difficulty of detecting surface damage.

This past year we evaluated several sections cut from ACA treated poles stored for a number of years to determine if they were worth salvaging. Static bending tests of beams cut from the ACA treated zone, the treated/untreated boundary, and the inner heartwood revealed ACA treated sapwood had lower MOR and longitudinal compression strength than the other zones. These results represent only a small sample, but they suggest that some strength loss occurs during ACA

treatments. More importantly, the results suggest that we could have reliably predicted beam MOR by testing small plugs removed from the poles.

Small beams cut from decaying, pentachlorophenol treated Douglas-fir poles were acoustically tested for residual wood strength, then evaluated to failure in static bending. The acoustic test consisted of sending a pulsed sonic wave into the wood and recording this wave after it passed through the beam. As it moved, the wave was altered by the presence of any wood defects or decay, and these alterations create a "fingerprint" specific for that defect. Preliminary results indicated that signal analysis was highly correlated with work to maximum load (r^2=.82) and MOR (r^2 .88), suggesting that this approach to decay detection may prove more reliable than measuring of sound velocity.

Initiation of Decay in Air-Seasoning Douglas-fir

The results of the initial survey to determine the incidence of decay fungi in poles from widely scattered Pacific Northwest seasoning yards indicated that a variety of fungi were colonizing the wood. While most of these fungi do not pose a serious decay problem, two species, Poria carbonica and Poria placenta, became increasingly abundant with length of air-seasoning. These fungi are also the most common decayers of Douglas-fir poles in service.

As expected, the number of fungi and the wood volume they occupied increased with seasoning time; however, this incidence varied considerably between yards, especially in poles air-seasoned for

shorter time periods. In addition to the variation between sites, many of the decay fungi colonizing the wood appear to be monokaryons, indicating that spores landing on the wood are initiating the infestation.

The distribution of fungi within the poles indicated that several of the more abundant decay fungi were present in the outer sapwood where they would be eliminated by conventional pressure treatment. The remaining fungi were most abundant in the heartwood but were more concentrated near the pole end. This suggests that exposed end grain was more readily invaded than lateral grain exposed in checks.

In addition to identifying the fungi colonizing Douglas-fir, we examined the effects these fungi had on wood strength. Toughness tests indicated the presence of wide variation in decay capability of the isolates. Although there was no consistent pattern, most of the isolates did not cause substantial decay and, of those that did, only P. carbonica and P. placenta were sufficiently abundant to have a large influence on wood strength.

Due to the prevalence of P. carbonica and P. placenta in the inner heartwood, where they might not be eliminated in a short heating cycle, we evaluated the temperature tolerance of these two fungi in Douglas-fir heartwood blocks. These tests indicated that both fungi were eliminated by exposure to temperatures above 71°C for over 1 hour or 60°C for 2 hours. The results suggest that careful control of temperature during treatment should eliminate decay fungi and that wood treated at ambient temperatures should be heated to kill fungi that become established during air-seasoning.

This past year was the third and final year of the decay development study. In this study, sterile pole sections have been exposed for 1, 2, or 3 years at widely scattered Pacific Northwest sites, then returned to the laboratory and extensively sampled. We are now in the process of identifying the fungi from the third year poles.

In addition to examining poles prior to preservative treatment, we are also evaluating poles treated with waterborne chemicals (ACA or CCA) for the incidence of surface decay. This past year we examined twenty ACA-treated poles from a line installed in 1946. While a variety of fungi were cultured from the wood, none of the poles had evidence of substantial surface deterioration.

A study was initiated on the fungal flora of fumigant treated wood because of the potential for fungi developing resistance to low levels of fumigant or the ability to actively degrade the chemical. Both of these developments could shorten fumigant retreatment cycles and increase maintenance costs. We have evaluated poles treated 7 and 15 years ago with fumigants and find markedly reduced fungal flora. Tests are continuing on the fungi isolated, and we hope to assess the effects of these isolates on long-term fumigant effectiveness.

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.

COOPERATORS

Electrical Utilities

*Bonneville Power Adm.

*Empire State Electric Energy Research Corp.

New York State Electric and Gas Corp.

*Portland General Electric Co.

*Western Wood Preservers Institute

J. H. Baxter & Co.

Koppers Co., Inc.

McFarland-Cascade Co.

Niedermeyer-Martin Co.

J. A. Taylor Lumber Co.

*Pole Supplier

Crown Zellerbach Corp.

*U.S.D.A. Forest Service, Forest Products Laboratory

*OSMOSE

*NOR-AM Chemical Co.

---

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

PERSONNEL

Advisory Committee

Art Bode, Bode Inspection, Inc. (1982)
Stephen Browning, Bode Inspection, Inc (1984)
Chuck Coombs, McCutchan Inspection (1983)
Bob Dubois, Timber Products Inspection (1981)
Bob James, Portland General Electric Co.
Al Kenderes, New York State Electric & Gas Corp.
Pete Lindgren, Bonneville Power Adm.
Chad Niedermeyer, Niedermeyer-Martin
Bill Pribyl, Crown Zellerbach Corp.

Research

Principal Investigators:
- Jeffrey J. Morrell, Assistant Professor, Forest Products (Wood Preservation)
- Malcolm E. Corden, Professor, Forest Products (Wood Products Pathology)

Co-investigators:
- Robert L. Krahmer, Professor, Forest Products (Wood Anatomy)
- James B. Wilson, Associate Professor, Forest Products (Fracture mechanics)

Research Associate:
- Theordore C. Scheffer, Forest Products (Forest Products Pathology)

Research Assistants:
- Mark A. Newbill, Forest Products
- Susan M. Smith, Forest Products
- Mike Milota, Forest Products
- Camille Sexton, Forest Products

Graduate Students:
- Paul Przybylowicz, Ph.D., Botany and Plant Pathology
- Camille Sexton, M.S., Botany and Plant Pathology
- Andrew Zahora, M.S., Botany and Plant Pathology
- Magdelena Giron, Ph.D., Forest Products

Consultants

Paul Aho, Forestry Sciences Laboratory, U.S. Forest Service (Forest pathologist)
W. E. Eslyn, U.S. Forest Products Laboratory (Forest products pathologist)
Wayne Wilcox, Professor, University of California (Forest products pathologist specializing in microscopy)

TABLE OF CONTENTS

August 1., 1985

OBJECTIVE I

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

A. PREVIOUS ONGOING AND RELATED RESEARCH ON WOOD IN SERVICE

The evaluation of fumigants (Table 1) placed in decaying pressure-treated Douglas-fir transmission poles in 1969 through 1977 is being continued. Results of this ongoing work and related research on Douglas-fir piles are presented as background information for the development of improved fumigant treatments for the future.

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

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).

Fifteen 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 or Vorlex has been reinvaded by decay fungi while five of eight 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 and is detectable as high as 2.4 m above the groundline. Wood removed from Vapam treated poles has only minimal fungistatic effects on the growth of the assay fungus, which correlates well with the high levels of decay fungi cultured from these poles. Wood from Vorlex-treated poles has continued to lose its ability to inhibit P. placenta, but these poles have not been reinvaded to any extent by decay fungi. Residual chlorinated C_3 hydrocarbons may account for some long term protection. Wood from chloropicrin treated poles also continued to lose its fungistatic activity in an unusual pattern. It appears that chloropicrin is moving up and out of the wood, and this has resulted in a cone shaped

pattern of residual protection with complete inhibition at the pole center near the groundline, but little inhibition toward the pole surface at this height. Above the groundline, inhibition increases, indicating that the chemical has moved upward and outward from the pole center. The fungal reinvasion of the groundline zone of these poles as the fumigant concentration declines is also under study (see Objective VI).

TABLE 2

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

	NUMBER OF POLES WITH DECAY FUNGI[a]				
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}

[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.

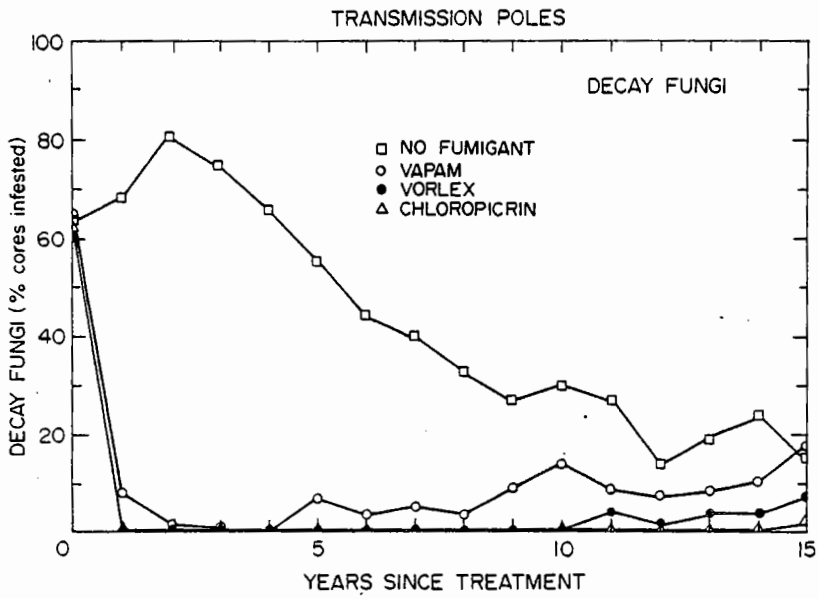


TABLE 3

RESIDUAL FUMIGANT VAPORS IN PRESSURE-TREATED DOUGLAS-FIR POLES 15 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	9	44	59	34
	5.1-7.6	84	100	87	0
	12.5-15	--	97	62	0
1.8	0-2.5	44	72	69	6
	5.1-7.6	75	91	59	9
	12.5-15	--	56	56	0
1.2	0-2.5	31	69	81	37
	5.1-7.6	94	87	78	25
	12.5-15	78	59	62	53
0	0-2.5	44	94	69	78
	5.1-7.6	91	47	75	75
	12.5-15	--	16	100	0
CONTROL	(NO WOOD)	32 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 in 15 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	12	13	15	5	7	13	15	10	11	13	15	10	12	13	15
4	91	88	96	46	53	100	84	80	48	57	68	69	4	32	36	11
1.8	96	96	100	59	60	78	80	73	35	57	68	61	0	12	28	5
1.2	96	80	80	68	60	78	80	72	39	57	64	74	4	8	40	38
0	100	96	100	67	60	100	88	52	52	48	72	81	17	28	60	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.

The closed-tube bioassay continues to be a useful guide for fumigant retreatment of poles, but additional studies are needed 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 15 years with the more persistent chloropicrin and Vorlex continue to appear reasonable.

Douglas-fir poles treated in 1977 with allyl alcohol, methylisothiocyanate 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.

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

[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] In diesel oil.

Selected poles were treated with 1 pint of MIT, Vorlex or allyl alcohol equally distributed between four holes in each pole. MIT was melted and poured into the holes; however, not all of the chemical could be applied because it solidified too rapidly in the wood. Thus, the amount of MIT applied may be as low as 0.5 pint per pole. The poles have been evaluated annually by removing three cores from equally spaced locations around each pole at five levels and culturing these cores to detect the presence of decay fungi. Additional cores were examined for residual fumigant vapor using the closed-tube bioassay with Poria placenta as the test fungus. Three years after fumigant treatment, three to four poles per group were deleted from the test when they were inadvertently treated with Vapam by a commercial applicator.

This past year we isolated decay fungi from two poles treated with Vorlex (Table 5). The sudden appearance of decay fungi associated with this treatment is of some concern and we intend to follow these results more closely. The performance of Vorlex in these poles may have been affected by wood condition at time of treatment since severely decayed wood holds less fumigant than sound wood.

Once again the number of poles treated with 20% MIT in diesel oil from which decay fungi were cultured increased, while the number of fungi isolated from poles treated with 100% MIT remained constant. The 20% MIT treatment may be proving less effective than Vorlex (which also contains 20% MIT) probably because the diesel component has little effect on decay fungi, while the chlorinated C_3 hydrocarbons in Vorlex may enhance the effectiveness of MIT. The allyl

alcohol continues to perform poorly, and, although this chemical performed well in laboratory tests, it appears that the formulation used was ineffective as a fumigant.

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 in 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.

Effectiveness of externally applied pastes and internally applied chemicals for controlling internal decay of Douglas-fir.

Externally applied treatments were, at one time, the only treatments available for controlling decay of utility poles, while internally applied chemicals were mostly used for insect control.

TABLE 6

RESIDUAL FUMIGANT VAPORS IN DOUGLAS-FIR POLES 6 YEARS AFTER APPLICATION AS MEASURED USING THE CLOSED TUBE BIOASSAY[a]

METERS ABOVE GROUND	SEGMENT LOCATION FROM SURFACE	GROWTH OF ASSAY FUNGUS AS % OF CONTROL				
		NO FUMIGANT	ALLYL ALCOHOL	VORLEX	METHYLISOTHIOCYANATE 20%[b]	100%
	(cm)					
2.4	0-2.5	68	50	50	61	28
	5.1-7.6	100	71	43	46	32
	12.5-15	--	68	57	100	0
1.8	0.2.5	57	86	43	39	4
	5.1-7.6	94	57	71	64	11
	12.5-15	--[c]	100	75	86	18
1.2	0.2.5	50	54	36	71	07
	5.1-7.6	71	71	36	82	18
	12.5-5-15	--	--	57	100	18
0.6	0.2.5	82	46	32	50	18
	5.1-7.6	96	71	71	75	32
	12.5-15	86	79	43	100	57
CONTROL	(NO WOOD)	28 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 decreased 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 18 tubes.

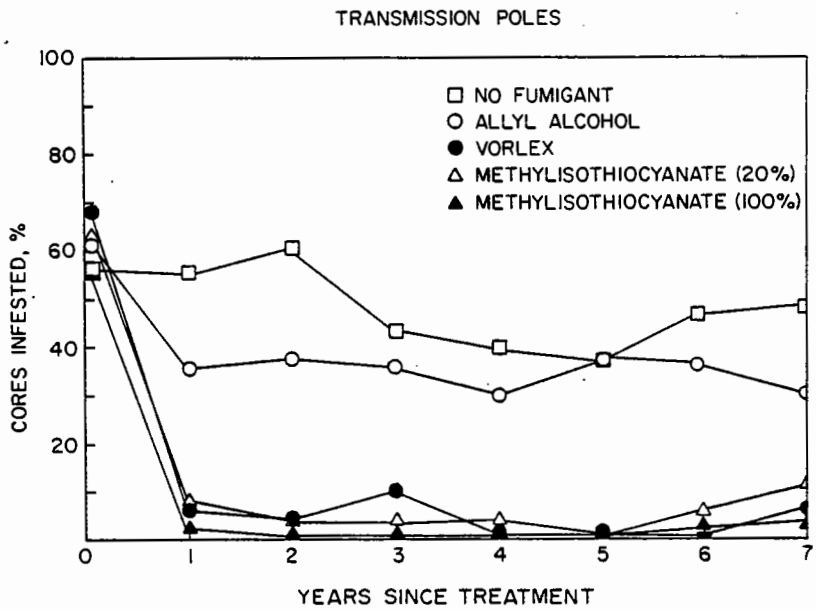


Figure 2. Changes in the population of decay fungi in internally decaying pressure-treated Douglas-fir poles treated with fumigants. Each value is based on 15 cores removed at -0.3 to 2.4 m from the groundline from the poles listed in Table 5.

Shortly after the first application of fumigants to the Santiam to Toledo line, the Forest Research Lab began a cooperative project to evaluate the performance of externally applied Osmoplastic® and internally applied Hollowheart® on a line near Oregon City, Oregon. These poles were evaluated annually be removing three equally spaced increment cores from -0.3; 0.0.6, 1.2 and 1.8 meters above the groundline and culturing for the presence of decay fungi.

These poles were sampled for the first 5 years after treatment but had not been sampled for the past 6 years. This spring we were notified that the cooperator planned to retreat these poles as part of their routine maintenance program. Because the results at the time the poles were last sampled suggested that these treatments were affecting the incidence of decay fungi, we decided to reevaluate these poles 11 years after treatment, before they were retreated.

Cores were removed near the previous sampling sites, visually assessed for evidence of decay and then cultured for the presence of decay fungi. Previous results indicated that the percentage of cores with decay fungi had declined in both treatments over a 4 year period (Table 7). The current sampling indicates that poles treated with Osmoplastic® or Hollowheart® both experienced only slight increases in the levels of decay fungi during the past 6 years. These results are somewhat unexpected since Osmoplastic has been reported as capable of penetrating only the sapwood zone. In this instance, the wrap may have prevented reinfestation by other decay fungi, however, the cause of decline in the presence of established decay fungi is less clear.

These poles do have fungal infestations above the wrapped zones, indicating that the fungitoxic paste did not migrate upward (Table 8). Similarly, the low levels of decay fungi present in Hollowheart treated poles is difficult to explain. However, this material contains a number of water soluble salts including ammonium bifluoride, a highly effective chemical that acts as a fumigant by releasing toxic hydrogen fluoride gas that moves through the wood to control decay fungi. The apparent declines in incidence of decay fungi in these test poles, especially the Osmoplastic treatments, suggests that preventing reinvasion may be as important as eliminating the initial infestations. Although we have little information on this topic, it is one that will ultimately determine the long term effectiveness of fumigant treatment programs.

TABLE 7

EFFECTIVENESS OF COMMERCIAL APPLICATIONS OF CHEMICALS FOR CONTROLLING INTERNAL DECAY OF DOUGLAS-FIR POLES[a]

TREATMENT	POLES TREATED	CORES WITH DECAY FUNGI (%) YEAR SAMPLED		
		1975	1979	1985
Osmoplastic[b]	5	23	3	10
Hollow Heart	7	38	4	9

[a] Three cores, equally spaced around the poles, were removed at -0.3,0,0.6, 1.2 and 1.8 meters from the groundline.

[b] The Osmoplastic® is an external groundline treatment while the Hollowheart® is an internal chemical treatment.

TABLE 8
EFFECTIVE OSMOPLASTIC® GROUNDLINE WRAP AND HOLLOWHEART® INTERNAL TREATMENTS ON DECAY OF DOUGLAS-FIR POLES AT SELECTED HEIGHTS FROM THE GROUNDLINE.

Treatment	SAMPLING HEIGHT FROM GROUNDLINE	NUMBER OF POLES SAMPLED	% CORES CONTAINING DECAY FUNGI 1975	1979	1985
Osmoplastic	-0.3	5	7	0	0
	0		27	0	13
	0.6		40	7	13
	1.2		27	7	20
	1.8		13	0	0
Hollowheart	-0.3	6	7	7	0
	0		27	0	6
	0.6		40	0	6
	1.2		27	7	17
	1.8		13	13	17

Douglas-fir marine piles treated with fumigants. In addition to the field tests of electric transmission poles, we are evaluating fumigants in creosoted Douglas-fir piling. The results are presented here because many of the problems and solutions are similar. Creosoted Douglas-fir piles with sloping, unprotected tops in a 90 m long bulkhead at Florence, OR, were inspected after 4 years' service by culturing cores from the piles. All were found to be decaying internally below the sound appearing tops. In 1974 the tops were cut off flat, 0.5 liters (1 pt) of Vapam, Vorlex or chloropicrin were distributed among four holes within 1 m of the top, and coaltar cement-fiberglass mesh caps were applied to keep the piles dry and contain the fumigant.

Within 1 year, fumigants virtually eliminated decay fungi from the piles (Fig. 3). While chloropicrin and Vorlex have continued to control reinfestation by decay fungi for 10 years, the population of decay fungi gradually increased in Vapam-treated piles after the fourth year but appears to be leveling off. Fungitoxic vapors, especially of chloropicrin and Vorlex, are still present in the wood from 0.3 and 1.8 m below the pile tops.

Conclusions on the use of fumigants on wood in service

- Chloropicrin, methylisothiocyanate, Vapam and Vorlex effectively control internal decay of pressure-treated transmission poles and piles.
- Estimated retreating schedules with these fumigants are: Vapam - 10 years; chloropicrin and Vorlex - 15 years or longer.
- The closed-tube bioassay continues to be an effective method for determining the fumigant persistence in wood and may be a useful guide for determining when fumigant-retreatment is necessary.

Effectiveness of Kerfing for Limiting the Development of Internal Decay

In addition to our continued evaluations of fumigants for controlling internal decay, this past year we re-evaluated kerfing as a non-chemical means for limiting decay development. The technique of using deep saw kerfs from the butt to about the groundline to limit the development of deep checks that expose untreated wood was advocated in the late 1960's by R. D. Graham and E. Estep (1966. Proceedings AWPA 62:155-158). With some exceptions, these

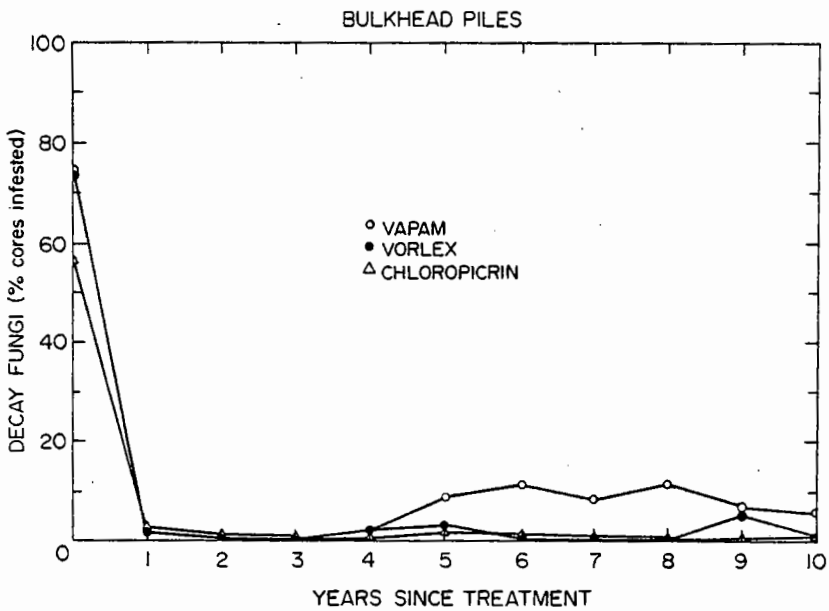


Figure 3. Change in population of decay fungi isolated from creosoted Douglas-fir piles treated with fumigants. Each value represents cultural results of 60 cores from 12 piles.

recommendations were widely ignored and few users of large round wood products use kerfing. In 1976, Graham and Helsing evaluated the effects kerfing on check development and incidence of decay fungi in Douglas-fir poles. This year a number of these poles were scheduled for routine inspection and fumigation by the cooperator. Because the poles represented a substantial body of data, we re-evaluated the condition and incidence of decay fungi one last time.

The poles were visually inspected for evidence of decay and the width of the widest check was measured. Cores were removed from poles at three equally spaced locations at groundline and examined for evidence of advanced decay. Additional cores were removed from locations above the kerfed zone or 6 feet above the groundline of non-kerfed poles to detect the presence of decay away from the kerfed zone. All cores were cultured for the presence of decay fungi.

The results indicated that kerfed poles continue to out perform non-kerfed poles (Table 9). Check width on kerfed poles was only one half that of non-kerfed structures, indicating that kerfing limited the development of additional deep checks. One non-kerfed line also had minimal check development; however, previous examination of treating records had revealed no anomalies that would explain the limited checking in these poles.

Examination of cores from the poles for evidence of advanced decay again indicated that kerfed poles had lower levels of advanced decay. Cultural results from these cores collaborated the visual inspections and indicated that the non-kerfed poles with minimal check development

contained substantial numbers of decay fungi. This indicates that while check development was low in these poles, it was sufficient to expose untreated wood to colonization by decay fungi.

Examination of poles above the kerfed zone (2.4 m above the groundline) indicated 10% of the kerfed poles contained decay fungi while no decay fungi were isolated from the non-kerfed poles. Since the decay fungus in question was isolated form a decay pocket that developed within the kerfed zone, the significance of these results is

TABLE 9

A COMPARISON OF KERFED AND NON-KERFED PRESSURE-TREATED DOUGLAS-FIR POLES IN WESTERN OREGON.

LOCATION	TREATMENT	NUMBER INSPECTED	YEARS IN SERVICE	INSPECTION LOCATION	WIDTH OF WIDEST CHECK[b] (cm)	POLES WITH ADVANCED DECAY(%)	POLES WITH FUNGI[d] BASIDIOMYCETES (%)	POLES WITH FUNGI[d] NON-BASIDIOMYCETES (%)
Philomath, OR	kerfed[a]	41	19	GL[c]	0.6	2	3	93
		10	19	2.4m		10	10	77
		41	12	GL	0.6	0	0	90
Kings Valley,OR	kerfed	40	18	GL	0.6	2	2	95
		40	11	GL	0.6	.0	2	92
Corvallis, OR	non-kerfed	29	24	GL	0.6	.3	21	90
		10	24	2.4m		.0	0	27
			17	GL	0.5	.0	0	76
Cottage Grove, OR	non-kerfed	16	17	GL	2.9	19	37	62

a Kerfed to the pole center from the butt to about 1.5 m above groundline.
b Within 1.5 m of groundline.
c GL=groundline
d Fungi were detected by culturing 15 cm long increment cores on malt agar and observing for evidence of fungal growth.

questionable. However, the results of culturing in the groundline zone clearly indicate that, after 18-19 years of service, kerfing has decreased the probability that decay fungi will become established. Thus, kerfing appears to be a viable alternative for maintaining wood at its highest strength by preventing decay development.

B. EVALUATE NEW FUMIGANTS

Preparation and Evaluation of Methylisothiocyanate Formulations

Gelatin capsules filled with NOR-AM MIT nearly 3 years ago continue to effectively contain the chemical, with no noticeable leakage. Last summer we attempted to encapsulate pure MIT from the Degussa Corp. Although the encapsulation went well, the anticipated project using the capsules was delayed and we were forced to store the capsules. After 4 months of storage we reexamined the capsules and found that many had extensive leakage. The leaking capsules had a liquid component that appeared to affect gelatin integrity. Gas chromatographic comparisons between Degussa and Nor-Am MIT formulations revealed some subtle differences (Figure 4), and suggest that the presence of a relatively minor component could substantially alter gelatin properties.

The findings emphasize the importance of evaluating individual formulations to insure that properties do not vary greatly. Gelatin

encapsulation, although extremely useful for one MIT formulation, has proven ineffective for the second.

Evaluate Laboratory Characteristics of Pelletized MIT

We continue to evaluate the effectiveness and treating characteristics of the silica-pelletized MIT developed by Degussa Corp. This formulation physically entraps MIT in a silica pellet which readily releases the MIT once placed in open air. Because of the silica, the maximum amount of MIT in this formulation is 65%, but this is still considerably greater than the theoretical MIT yield from Vapam (19% wt./wt. basis). We tested MIT release from the pellets by placing weighed pellet samples in a fume hood, aerating for selected periods, and reweighing the pellets. These tests revealed that about 85% of the pelletized MIT was released after 24 hours of aeration. While this volatility, is a beneficial characteristic in wood, we are concerned about the levels of MIT that may remain in the pellets after extended periods in wood. Since the pellets will have to be removed when the poles are retreated, the presence of MIT in the silica might cause this waste to be classified as hazardous, and thus pose a disposal problem.

To determine MIT retention by silica, weighed samples of pellets were placed in open glass jars and left in a fume hood. The pellets were removed after 24, 48, 96, 192, 364 and 4864 hours of aeration, and placed in 5 ml of ethyl acetate to extract any MIT remaining in the pellets. The extracts were examined using gas chromatographic techniques.

Although the majority of the MIT was rapidly lost during the first 24 hours, a small amount remained in the pellets even after 36 days aeration (Figure 5). Although this level gradually declined, it is apparent that some MIT remains entrapped within the pellets. We will continue to sample the pellets, but at this time it appears that used pellets must be treated as a potentially hazardous waste.

Effect of MIT on corrosion of galvanized hardware in wood

One of the advantages of solid or pelletized MIT is the ability to safely apply the chemical in decay hazard zones above the groundline. Since this application will increase the likelihood that the fumigant will contact the pole hardware, we evaluated the effects of MIT on galvanized hardware in a wood system. Since there is no standard for measuring wood-metal corrosion, we developed a method based upon our standard fumigant test.

Small wood blocks (1 x 1 x 4" long), normally used in our fumigant evaluation studies were drilled at one end to hold a 3/8" diameter galvanized (hot dipped) bolt, which was screwed into the block. A second, 3/4" deep hole was drilled at the opposite end of each block to hold the chemical and a serum cap was used to seal this hole. The holes were filled with solid MIT, pelletized MIT, ammonium bifluoride, or left untreated. Ammonium bifluoride is extremely corrosive and was included to provide a standard for evaluating the effect of MIT.

The blocks were stored in closed chambers above a pool of water to create high humidity conditions. The bolts were visually examined at weekly intervals for evidence of corrosion. Once visible corrosion

Figure 4 Gas chromatograph output from Degussa and Noram MIT formulations.

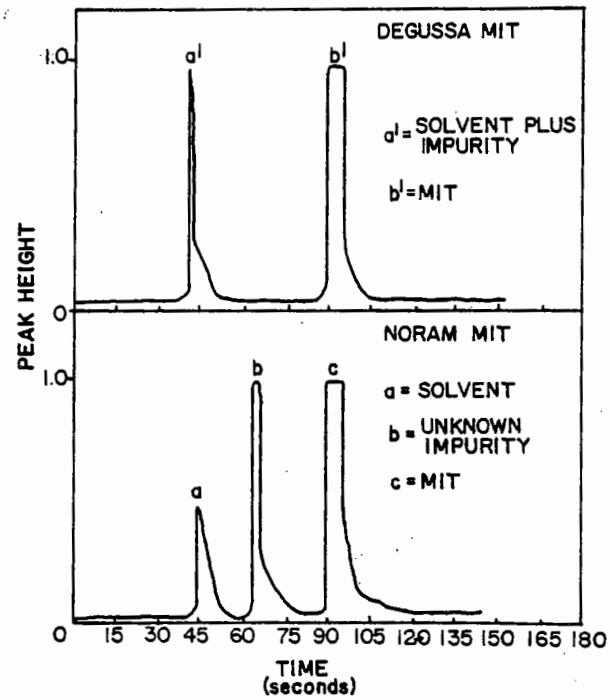
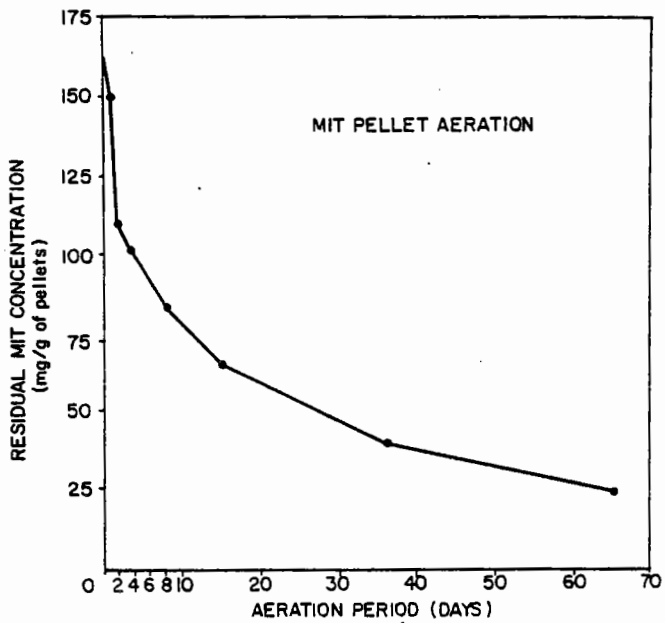


Figure 5. Residual MIT in Degussa pellets aerated for varying time periods as determined by gas chromatographic techniques.



was evident, blocks from each treatment group were cut in half around the bolt hole and examined for evidence of wood degradation.

After 2 months, ammonium bifluoride (ABF) had uniformly corroded the galvanized bolts, while both MIT treatments and the controls had minimal corrosion. Internally, the ABF treated blocks were badly discolored and had some evidence of softening around the bolt hole as indicated by probing with a needle. Similar examinations of blocks treated with pelletized and solid MIT revealed minimal discoloration and no evidence of internal softening. These tests are continuing, but, after 5 months, there is little evidence of MIT associated corrosion and it appears that the application of MIT in capsule or pellet form should not pose a hazard to galvanized hardware. These treatments may have some potential for protecting underbuilt lines that are field-drilled and left without bolt hole protection.

Evaluate the effectiveness of Mylone for controlling internal decay and improve its rate of degradation into fungitoxic compounds.

Mylone, a cyclic compound that degrades into MIT, is a solid powder. Earlier tests and several recent studies indicate that this compound may have long-term effectiveness for controlling internal decay. However, the rate of degradation is extremely slow, limiting the ability of Mylone to control established decay fungi.

A preliminary experiment was designed to study conditions that improved release of a volatile fungitoxicant from Mylone. Mylone (100 mg) was incubated in small vials either dry, in distilled water

(1.0 ml) with or without Douglas-fir heartwood sawdust (250 mg), in a phosphate buffer (pH 7.0), or in a borate buffer (pH 9.0). The vials were sealed in wide-mouth jars containing 5 mm disks cut from actively growing Poria carbonica colonies on malt-agar medium. After 24 hrs. incubation, the fungal disks were removed from the sealed jars and placed on fresh malt-agar medium to determine viability of the P. carbonica as an estimate of the volatile fungitoxicant released from Mylone within the jars.

Growth of P. carbonica from the disks, indicated that no volatile fungitoxicant was produced from dry Mylone or Mylone in the presence of water. The presence of sawdust delayed Poria growth from the disks suggesting that a low concentration of a volatile toxicant was released from the Mylone. Disks from the jars containing Mylone in pH 7 and 9 buffers produced no fungal growth indicating the presence of a strong volatile fungitoxicant in these jars.

The influence of neutral and basic pH's on Mylone decomposition to a volatile toxicant was further investigated by incubating Mylone (100 mg) in water or the pH 7 and 9 buffers in sealed tubes. After 24 hrs. incubation, vapor samples were with drawn from the tubes and analyzed by gas-liquid chromatography for the presence of MIT, the primary volatile fungitoxicant from Mylone. Although trace amounts of MIT were detected above water suspensions of Mylone, significantly larger amounts of MIT were present in tubes in which Mylone was buffered at pH 7 or 9.

These preliminary experiments suggest that release of volatile fungitoxicants from Mylone can be enhanced by adjusting the pH of the reaction mixture above pH 7. However, in wood the slow release of volatile toxicants from Mylone may provide effective decay control over a relatively long time period. Our current studies on the fungitoxicity of very low concentrations of MIT over long exposure periods should aid in predicting the potential of Mylone as a wood fumigant.

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 six 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 details were previously described ('82 Ann. Rept., pages 21-31) and sampling procedures and results obtained 9 and 21 months after treatment have been discussed ('83 Ann. Rpt., pages 31-33).

Inspection of the poles 33 months after treatment indicated that decay fungi have been completely eliminated from the MIT-treated poles, while Vapam has almost eliminated all decay fungi (Table 10).

TABLE 10
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

[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.

The control poles in these evaluations continue to have high levels of decay fungi and will be treated with gelatin encapsulated Vorlex this summer. Some of these poles have 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.

One interesting occurrence on these poles was the presence of animal gnawings around the dowels used to plug the treatment holes. These gnawings have been attributed to meadow voles and have become quite severe in some poles. This damage may be caused by accumulation of some salts on the wood surface and has been reported elsewhere. In some cases, this damage has resulted in treating plugs falling out of the poles, exposing the hole to moisture, insects and fungi. Although no work is planned on this problem, it might be advisable to treat the dowels with an animal repellant in areas where the problem is severe.

Closed-tube bioassays continue to indicate the presence of fungitoxic vapors in the MIT treated poles, with the higher dosage producing more complete inhibition (Table 11). Wood from Vapam treated poles had little effect on the growth of P. placenta, indicating that the 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 11

CLOSED-TUBE BIOASSAYS OF CORES REMOVED FROM NEW YORK POLES 3 YEARS AFTER TREATMENT WITH VAPAM OR GELATIN ENCAPSULATED MIT[a]

CHEMICAL	DOSAGE (PINTS)	SAMPLING HEIGHT (FEET)	AVERAGE GROWTH OF P. PLACENTA (AS A % OF CONTROL) CORE ZONE[b] OUTER	INNER
MIT	1	0	13	0
		2	22	0
		4	25	0
MIT	2	0	0	0
		2	9	0
		4	13	0
VAPAM	2	0	63	91
		2	81	63
		4	84	69
CONTROLS		0	66	72
		2	75	84
		4	78	88

Control tubes (no wood): Avg = 32 mm

[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. Cores with lower numbers have higher fumigant levels.

[b] Increment cores were divided into three segments, 0-1", 1-5" and 5-6". The middle segment was discarded and the outer (0-1"0 and inner (5-6") segments were used for closed tube assays.

In our last inspection, we also removed plugs from a number of MIT treated poles and probed for residues of the gelatin capsule. In the previous inspection, empty capsules were all that remained in the holes. The most recent inspection revealed only a few broken pieces of capsule indicating that the gelatin was gradually degrading. This finding implies that residual gelatin should not interfere with later retreatments.

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 12 feet 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. Last year's inspection revealed that the chemicals had begun to become distributed throughout the wood. These poles were not inspected this year, but will be included in our sampling this summer.

Treatment of Douglas-fir poles with encapsulated MIT.

A second field study investigated 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 by 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 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 resulted in a decrease in the number of cores containing decay fungi; although the dry treatments contained higher levels of fungi (Table 12). This indicates that, while there was some moisture present in the wood to release the fumigant, the addition of water at the time of treatment resulted in more rapid control. Since longer exposures to decay fungi translates into increased degradation and strength loss, it is apparent that adding small quantities of water (40 ml) to each treatment hole substantially improves the prospects for rapid decay control. The effect of moisture on MIT release also was evident in the closed tube bioassay (Table 13). These tests indicate that addition of high amounts of moisture or no moisture produced less complete protection of the wood. In these instances, the high moisture level may have interfered with fumigant movement while the low moisture normally in the poles probably was insufficient for complete MIT release from the capsules. Generally, 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.

TABLE 12

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

SAMPLING DATE	METERS ABOVE GROUND-LINE	PERCENT OF 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

[a] The initial decay estimates were based on culturing of shavings collected during treatment hole drilling. The 1 year data is 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) were added to each treatment hole to aid in fumigant release.

TABLE 13

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	6	15	9
	12.5-15	18	0	0
0.9	0-2.5	21	0	0
	12.5-15	0	0	12
1.8	0-2.5	65	0	35
	12.5-5	0	0	0
2.8	0-2.5	35	0	18
	12.5-5	21	0	0
3.7	0-2.5	62	12	32
	12.5-5	21	0	15
4.6	0-2.5	35	26	56
	12.5	35	0	38
5.5	0-2.5	71	56	32
	12.5	6	6	38
Control	(no wood)	34 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 a 1-inch 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. Cores with lower numbers have higher fumigant levels.

OBJECTIVE II

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

A. DECAY RESISTANCE OF SAPWOOD FROM POLES 2 YEARS AFTER SPRAYING WITH CANDIDATE CHEMICALS.

In previous laboratory studies, we evaluated three oil-borne and fourteen waterborne fungicides for their ability to resist weathering and protect cedar sapwood from decay('83 Annual Report pg. 37-38; '82 Annual Report, pg. 25-30). The tests were biased towards water-soluble or water miscible chemicals because of the escalating cost of oil. Of the 17 chemicals evaluated, ten imparted marked decay resistance to small blocks, even after artificial weathering. In October, 1981, seven chemicals were applied to 10 foot long western red cedar stubs at our field test site. The poles were artificially watered from above on a regular basis to increase the severity of exposure and were sampled 2 years after treatment to evaluate fungicide effectiveness. The results of these tests were presented last year (4rd Annual Report, pages 26-34)..

Following application of the first seven fungicides, laboratory evaluations of other potential chemicals continued (3rd Annual Report, pages 37-38) and in July, 1983, five of the more promising chemicals were applied to additional cedar stubs at our test site. As in the

first set, the pole surface was divided into three sections that were oriented N, SE or SW. Generally, two chemicals were applied to each pole (one per side) and the third side was left as an untreated control. When sprayed, the sapwood was dry, well-checked, and had a moisture content of about 14%. The fungicides were applied by placing barriers on each side of the face, and sprayed from top to bottom until chemicals ran off the surface.

Two years after application, we re-evaluated the treatments on these poles by removing increment cores and 3/8" diameter plugs from locations 1, 2 and 4 feet above the groundline. The increment cores were used in our Aspergillus bioassay to detect residual fungicide. In this test each increment core was placed on the surface of a potato dextrose agar plate that was sprayed with a spore suspension of Aspergillus niger. If preservatives were present, they would diffuse from the wood and inhibit growth or sporulation by the fungus. This zone of inhibition (ZOI) can then be used as an estimate of residual protection.

The plugs were cut into 1/8 inch segments that were used to test decay resistance in a modified soil block test using Poria placenta as the test fungus. While we have completed the Aspergillus bioassays, the soil block tests are continuing and the results will be reported next year.

Aspergillus bioassays of whole increment cores indicate that zones 0-6 and 6-13 mm from the pole surface had little effect on inhibition of the assay fungus (Table 14). In addition, we measured the distance

from the pole surface end of each core to the point along the core where the ZOI ceased and found this distance was substantially greater along cores from treated poles. This suggests that the fungicides continue to migrate inward from the pole surface, thereby protecting subsurface wood. This migration protects internal sapwood, but leaves a zone near the wood surface that may be vulnerable to decay. Conversely, this inner zone may also provide a reservoir of toxicant that can subsequently diffuse to the pole surface.

TABLE 14

ASPERGILLUS NIGER BIOASSAY OF INCREMENT CORES REMOVED FROM CEDAR POLES 2 YEARS AFTER SPRAYING WITH SAPWOOD DECAY CONTROL CHEMICALS

CHEMICAL SPRAY	ZONE OF INHIBITION AT TWO SAPWOOD DEPTHS 0-6 mm	6-13 mm	AVERAGE LENGTH OF ZONE OF INHIBITION [a] (mm)
F-CWP 44 (10%) (copperamine formulation)	12	14	46.5
O-Arquad C-50 (5%) (3 trimethyl cocammonium chloride)	12	13	37.5
P-Cunapsol (2% Cu in water)	12	14	38.5
Q-Fluor Chrome Arsenic Phenol (FCAP)	12	14	41.5
S-Ammoniacal Copper Arsenate (Chemonite)	14	15	45.5
X-Control[b]	14	13	26

a Average distance from the pole surface end of the cores to the point along the cores where the zone of inhibition ceased.

b Fungal inhibition from control cores may be due to natural extractives from the cedar wood or residual protection of chemicals applied prior to our tests.

The inability to detect significant fungal inhibition by the test chemicals was disappointing; however, several of these chemicals have a strong interaction with wood and may have been unable to migrate into the culture medium. This was particularly true for the Chemonite, but may also occur with the FCAP, Arquad C-50, and CWP-44. In our laboratory tests, wood treated with Arquad C-50, or CWP-44 was highly decay resistant, while wood treated with the remaining chemicals was only moderately decay resistant. As in last years results, none of the test chemicals approached pentachlorophenol in diesel oil for effectiveness or penetrability. It appears unlikely that we will identify chemicals equally effective as penta, however, in light of the recent decision by Reichhold Chemical Co. to move out of the penta market, and increasing pressure by environmental groups, to discontinue penta use, it is imperative that we continue the search for substitute chemicals.

Since three of our test chemicals are penta formulations, we felt the need to redesign our spray program. This year we will evaluate a variety of new chemicals in our test site at Peavy Arboretum. These chemicals will include a second copper naphthenate formulation, zinc naphthenate and Azaconazole. We will also continue the search for new chemicals to place in this test.

B. THE EFFECTIVENESS OF THE ASPERGILLUS BIOASSAY UNDER VARYING CONDITIONS.

The Aspergillus bioassay is an extremely easy method for measuring residual preservative levels and is useful for detecting trace amounts of fungicides. Nevertheless, the assay is infrequently

used because potential users doubt its reliability or feel it is too complicated to be used in a small laboratory. To allay these concerns and evaluate the reliability of the assay, we examined the influence of some variables that might affect results from this test.

All tests were performed with uniform 6 mm square, Ponderosa pine blocks that were air dried prior to use. The blocks were treated under vacuum in selected concentrations of pentachlorophenol, (PCP) tributyltin oxide (TBTO), or 3 iodo-propynyl butylcarbamate (IPBC) diluted in toluene. Controls were treated with toluene. After treatment, the blocks were air dried for several hours then oven dried for 36 hours at 50°C to eliminate the toluene.

The treated blocks were used in experiments to determine the influence of spore seeding density, length of spore storage before testing, incubation temperature, and the type of culture plate used (glass or plastic). In addition, some culture plates were inoculated by spraying with an A. niger spore suspension instead of the standard practice of adding 1 ml of spore suspension onto the culture medium then pouring off the excess. Three blocks were placed on the culture medium in each plate and three plates were used for each treatment. The plates were incubated for 7 days, then the zone of inhibition (ZOI) surrounding each block was measured to the nearest mm.

The results indicated that the Aspergillus bioassay is a remarkably stable test method. Density of the spore inoculum had a minimal influence on the ZOI for PCP and TBTO, but did influence the results with blocks receiving the lower concentrations of IPBC

(Table 15). Nevertheless, this indicates that significantly large changes in the spore inoculum concentration are necessary to influence the results in the Aspergillus bioassay and, even then, this may not occur with all chemicals. Minor variations in the spore inoculum concentration from test to test should have no influence on the results.

The results obtained by inoculating the culture medium by spraying with a spore suspension were not significantly different from those obtained in plates inoculated by flooding (Table 16). Spray application should permit more rapid inoculation since large numbers of plates can be spread out and sprayed at the same time. When fungal spore suspensions are prepared and sprayed, precautions should be taken to prevent inhalation of the spores and those receiving systemic antibiotics should be particularly cautious in handling fungal cultures.

Cold storage of Aspergillus spore suspensions generally had little influence on ZOI's, although storage for 6 weeks began to a effect the ZOI of PCP-treated blocks (Table 17). This test suggests that spore suspensions could be prepared and stored for up to 1 month before use without seriously affecting assay results.

The use of disposable plastic petri plates instead of glass plates that require washing and sterilization had no influence on bioassay results (Table 18), and consequently plastic plates can be used with a considerable saving in time and expense.

TABLE 15
EFFECT OF SPORE INOCULUM DENSITY ON THE ASPERGILLUS BIOASSAY OF DIFFERENT PRESERVATIVES[a]

	AVERAGE ZONE OF INHIBITION (mm)[b]					
RELATIVE	PRESERVATIVE CONCENTRATION (%)					
SPORE DENSITY[c]	2	0.5	0.1	0.01	.001	0
	Pentachlorophenol					
1	12 (1)	8 (1)	4 (1)	3 (1)	5 (2)	2 (2)
0.5	12 (2)	9 (1)	5 (2)	5 (2)	6 (2)	3 (2)
0.25	11 (2)	9 (2)	5 (2)	5 (1)	6 (1)	3 (2)
0.125	10 (1)	9 (2)	5 (2)	6 (2)	6 (2)	3 (2)
0.062	12 (1)	10 (1)	5 (2)	8 (1)	6 (1)	1 (2)
	Tributyltin oxide					
1	23 (2)	16 (2)	8 (2)	4 (1)	2 (1)	
0.5	22 (1)	14 (1)	4 (1)	3 (2)	2 (1)	
0.25	24 (3)	16 (2)	6 (1)	4 (1)	2 (1)	
0.125	27 (2)	17 (3)	6 (1)	2 (1)	3 (1)	
0.062	25 (2)	17 (3)	8 (2)	4 (2)	3 (1)	
	3-iodo-propynyl-butyl-carbamate					
1	27 (3)	17 (2)	10 (1)	--	5 (1)	
0.5	29 (3)	18 (2)	11 21)	5 (2)	4 (2)	
0.25	28 (2)	15 (2)	6 (1)	6 (1)	4 (2)	
0.125	28 (2)	19 (2)	10 (2)	5 (1)	7 (3)	
0.062	28 (2)	18 (2)	9 (2)	6 (2)	7 (2)	

[a] Assays made in glass dishes at 22°C.
[b] Averages based on 9 measurements. Figures in parentheses are standard deviations.
[c] Maximum spore density, 1 = 3,835,000 per ml; other values represent dilutions of 1.

TABLE 16
BIOASSAY RESPONSE TO SPORE SEEDING BY FLOODING OR SPRAYING, AT VARIOUS SPORE DENSITIES AND PRESERVATIVE CONCENTRATIONS[a]

		AVERAGE ZONE OF EFFECT (mm)[b]					
	RELATIVE	PENTA-		TRIBUTYLTIN		3-IODO-PROPYNYL-	
SEEDING	SPORE	CHLOROPHENOL		OXIDE		BUTYL-CARBAMATE	
METHOD	DENSITY[c]	2%	0.1%	2%	0.1%	1.2%	0.1%
Flooding	1	13 (2)	5 (1)	25 (1)	8 (2)	20 (3)	10 (2)
	0.5	15 (1)	6 (2)	25 (3)	8 (3)	22 (3)	11 (3)
Spraying	1	15 (1)	5 (2)	25 (4)	7 (2)	23 (3)	9 (1)
	0.5	14 (1)	6 (1)	25 (4)	7 (2)		28 (2)
10 (3)							

[a] Assays were made in glass dishes incubated at 22°C.
[b] Averages based on 9 measurements. Figures in parenthesis are standard deviations.
[c] Spore density 1 = 3,835,000 spores per ml.

TABLE 17
EFFECT OF SPORE STORAGE PRIOR TO PLATE SEEDING ON THE BIOASSAY AT SELECTED PRESERVATIVE CONCENTRATIONS.[a]

	AVERAGE ZONE OF EFFECT (mm)[c]					
LENGTH OF SPORE STORAGE[b]	PENTA-CHLOROPHENOL		TRIBUTYLTIN OXIDE		3-IODO-PROPYNYL BUTYL-CARBAMATE	
(weeks)	2%	0.1%	2%	0.1%	2%	0.1%
0	11	5	24	6	28	9
2	13	2	--	--	--	--
3	13	4	--	--	--	--
4	14	3	--	--	--	--
6	16	3	19	4	19	7

[a] Assays made at 22°C in glass dishes seeded by flooding with relative spore density 3,835,000 per ml except for 0 storage time which is represented by all 5 spore densities in Table 15.
[b] Spores stored at 5°C in the same water suspensions that were prepared for the seeding at zero (0) storage time.
[c] Averages at 0 storage time based on 45 observations (9 replications at each of 5 densities of spore seeding); other averages based on 9 replications.

TABLE 18
BIOASSAY RESPONSE IN GLASS AND PLASTIC PETRI DISHES AT SELECTED SPORE DENSITIES AND PRESERVATIVE CONCENTRATIONS [a]

		AVERAGE ZONE OF EFFECT (mm)[b]					
DISH TYPE	SPORE DENSITY[c]	PENTA-CHLOROPHENOL 2%	PENTA-CHLOROPHENOL 0.1%	TRIBUTYLTIN OXIDE 2%	TRIBUTYLTIN OXIDE 0.1%	3-IODO-PROPYNYL-BUTYL-CARBAMATE 1.2%	3-IODO-PROPYNYL-BUTYL-CARBAMATE 0.1%
Glass	1	14 (1)	5 (1)	24 (5)	8 (4)	30 (1)	9 (3)
	0.5	15 (2)	5 (2)	25 (4)	8 (2)	27 (4)	11 (4)
Plastic	1	13 (2)	5 (1)	24 (3)	7 (2)	19 (3)	5 (1)
	0.5	13 (1)	5 (1)	22 (3)	5 (2)	20 (2)	6 (1)

[a] Assays performed at 22°C.
[b] Averages based on 9 measurements. Figures in parentheses are standard deviations.
[c] Spore density 1 = 3,835,000 per ml.

The assay incubation temperature influenced growth and sporulation by A. niger and consequently the bioassay results (Table 19). In general the ZOI's were larger at the lower temperature, indicating a higher sensitivity to the toxicant. At the lower temperature (15°C) ZOI's were indistinct, but when the plates were incubated for 4 hours at room temperature before reading pigmentation enabled easy measurement of the ZOI's. Although incubation temperature will affect the ZOIs, maintaining a uniform temperature and using suitable controls will allow accurate estimates of residual protection.

Our results indicate that the Aspergillus bioassay is an easy to use, readily reproducible method for estimating residual preservative concentrations in wood. The stability of this test suggests that most utilities could perform this assay for residual preservative protection of field sprayed western redcedar sapwood and it might also be of aid in measuring residual protection of Douglas-fir pressure treated with penta in light solvent or liquefied petroleum gas. In these poles, the treated shell is not readily visible and chemical assays for detecting the preservative are quite costly. The Aspergillus bioassay provides a quick method for checking the preservative penetration in these poles.

TABLE 19

EFFECT OF INCUBATION TEMPERATURE ON THE BIOASSAY AT SELECTED PRESERVATIVE CONCENTRATIONS.[a]

	AVERAGE ZONE OF EFFECT (mm)[b]						
TEMPERATURE (°C)	PENTA-CHLOROPHENOL 2%	PENTA-CHLOROPHENOL 0.1%	TRIBUTYLTIN OXIDE 2%	TRIBUTYLTIN OXIDE 0.1%	3-IODO-PROPYNYL-BUTYL-CARBAMATE 2%	3-IODO-PROPYNYL-BUTYL-CARBAMATE 0.1%	CONTROLS[c]
30	14 (1)	8 (1)	19 (1)	6 (2)	23 (1)	8 (2)	0.4
22	14 (1)	5 (1)	30 (1)	6 (2)	28 (3)	10 (1)	2
15	19 (1)	7 (3)	25 (2)	13 (3)	30 (1)	13 (3)	5

[a] Assays made in glass dishes seeded by flooding with spore density #1 (3,835,000 spores per ml).

[b] Averages based on 9 measurements. Figures in parentheses are standard deviations.

[c] Wood specimens without chemical.

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 various chemical treatments to prevent decay in field-drilled bolt holes in Douglas-fir poles ('82 Ann. Rept., pages 31-33). During the summers of 1982 and 1983, cores were removed from sites near bolt holes in four control poles and the cores were cultured to determine if the incidence of decay fungi in the unprotected bolt holes was high enough to warrant similar assessment of poles with treated bolt holes. Cores were removed from sites directly beneath the gain plate and above the washer on the opposite side on each of the eight bolt holes per pole.

In 1982, decay fungi were cultured from three cores above the bolt holes in two poles. Thus, the incidence of decay fungi at that time was too low to warrant evaluation of the treated poles. Similarly, cores removed during 1983 had a low incidence of decay fungi, and sampling of the test treatments was again delayed.

Resampling of poles this past summer revealed the presence of decay fungi in two of four control poles. In addition, one control pole from which decay fungi were cultured last year failed to yield any decayers in this years sampling. Thus, three out of four poles now contain decay fungi, although only the eight out of sixty-four cores contained these fungi. To insure that sufficient levels of decay have developed in the control poles, we will resample this summer and, if the incidence of decay has increased sufficiently, we will sample the treatment poles.

B. EVALUATING THE USE OF GELATIN ENCAPSULATED AND PELLETIZED MIT FORMULATIONS FOR PREVENTING DECAY DEVELOPMENT IN FIELD DRILLED BOLT HOLES.

The application of fumigants for controlling internal decay has generally been limited to zones near the groundline because of concerns about safety of liquid fumigants; however, the advent of encapsulated and pelletized MIT formulations may permit fumigant treatment of above-ground decay hazards. To evaluate the feasibility of this approach, we treated poles in conjunction with Bonneville Power Administration on a 115 KV Douglas-fir transmission line located north of Eugene, OR. The poles were treated at a height of 30-40 feet, near the point where a distribution line had been underbuilt. It was feared that the unprotected bolt holes for the underbuilt cross-arms would ultimately be points for colonization by decay fungi. The poles were treated by drilling one or two 13/16" diameter 16 inch deep holes at a 45° angle into the pole about 3 feet below the cross-arm. A bucket was attached to the pole below each hole to catch wood chips from the drilling which were collected for later culturing for the presence of decay fungi. The fumigants were applied and the holes were plugged with treated wood dowels. Poles with one treatment hole received 45 ml of encapsulated MIT (100% active ingredient) or 60 grams of pelletized MIT (65% active ingredient) while poles with two treatment holes received 90 ml of encapsulated MIT or 120 g of the pelletized formulation. A small amount of water was added to each hole in poles treated with capsules to accelerate gelatin breakdown and increase the rate of MIT release.

During the treatment process we measured the time required for each treatment and found that encapsulated MIT was applied in a significantly shorter time, primarily because the capsules could be carried up the pole with the drill while the pellet applicator had to be carried up in a separate trip to reduce risk of spillage. In addition, the pellet applicator (Figure 6) was difficult to use. In one case, the linemen mistakenly left the gate-valve open, allowing a quantity of pellets to spill from the applicator. The volatilized MIT caused discomfort and posed some danger to the lineman since he was operating on spikes at a fairly good height above ground. Modifications to the applicator could reduce the risk of such spills.

Culturing of chips collected from the treatment holes revealed that 3 out of 15 poles contained decay fungi and 6 out of 15 contained non-decayers. These results indicate that fungi are already entering the wood exposed by the field drilling and could cause substantial decay in this zone.

We will evaluate these treatments this year to determine fumigant distribution around the point of cross-arm attachment.

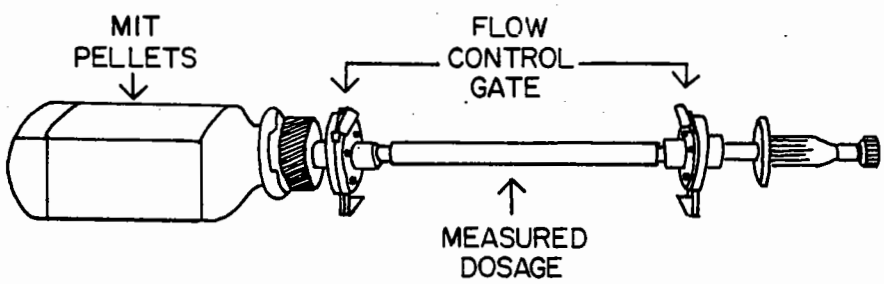


Figure 6. Diagram of Degussa pelletized Mit applicator.

OBJECTIVE IV

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

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

Last year we reported on our preliminary studies using plant proteins that specifically react with portions of the fungal or wood cell walls. These compounds, termed lectins, are used extensively in cell biology for studying protein synthesis and their point of localization can be visualized by coupling the lectin to a fluorescent compound. We have tested a variety of commercially available lectins on prepared fungal cultures and wood sections cut from blocks exposed to decay fungi. The results indicate that wheat germ agglutinin strongly reacts with the chitin containing fungal hyphae, making it far easier to detect early stages of decay (Table 20): In addition, the use of a fluorescence system minimizes the interference by the spiral thickenings present in Douglas-fir. These characteristics have improved our ability to study the deterioration process at the early stages, when visual evidence of decay is sparse, but substantial changes in wood properties can occur. We are also evaluating the feasibility of staining whole pieces of wood with the lectin and directly observing for evidence of fungal hyphae. This system does not distinguish between active and inactive fungi, but will permit rapid screening of cores prior to culturing. This screening could reduce the number of cores that had to be cultured. Although our

block tests indicate that this method may be useful, we intend to test this system on split cores taken from our field tests to determine the practicality of our approach.

We are also evaluating other lectins for their ability to react with various portions of the wood cell wall. At present we are experiencing some interference problems with normal wood autofluorescence, but are working to overcome this effect and hope to try dual stain systems using lectins specific for fungal cell walls and other lectins specific for wood components to simultaneously study wood colonization and degradation.

TABLE 20. SPECIFICITY OF FLUORESCENT-LABELED LECTINS TESTED ON HYPHAL FRAGMENTS AND ON WOOD SECTIONS EXPOSED TO DECAY FUNGI

LECTIN	CARBOHYDRATE SPECIFICITY	LECTIN REACTIVITY[a]			
		HYPHAE[b]		WOOD SECTION[c]	
		ND	D	HYPHAE	WOOD CELL WALL
Concanvalin A	α-D-mannosyl, α-D-glucosyl	++	+	++	+++
Soybean agglutinin	N-acetylgalactosaminyl	0	0	0	0
Wheat germ agglutinin	(ß-N-acetylglucosaminyl)n sialic acid	+++	+++	+++	0
Dolichos biflorus agglutinin	N-acetylgalactosaminyl-Blood group A	0	0	0	++
Ulex europaeus agglutinin I	L-fucosyl, Blood group 0	0	0	0	0
Peanut agglutinin	ß-D-gal(1-3)D-galNac ß-D-galactosyl	+	+	0	++

a Based upon visual assessment where +++= strongly reactive, ++=moderately reactive,+= weakly reactive, 0 = nonreactive.

b Hyphae were collected from cultures grown in 1.25% malt extract for 7 days, rinsed to remove media, and frozen before use. Dilute lectin solutions (1:1000 in phosphate-buffered saline) were reacted on slides and examined directly after rinsing. ND=a nonwood decaying fungus, Hyalodendron griseus; and D = wood decay fungi, Sistotrema brinkmanii and Poria placenta.

c Wood sections were cut from Douglas-fir and southern pine blocks exposed to P. placenta and examined following reaction with dilute lectin solution (1:500 in phosphate-buffered saline).

B. DETECTING INCIPIENT DECAY BY ANALYSIS OF WARM WATER EXTRACTS USING INFRARED SPECTROSCOPY.

In previous work ('84 Ann. Rept. Pg. 41-42), the infrared (IR) spectra of warm water extracts of blocks decayed to a range of weight losses up to 5% by six brown and white rot fungi were compared to extracts of non-decayed blocks. These results were compared with tests of similarly treated, end-matched beams for static bend and modulus of rupture (MOR). An absorption peak at 1720 cm^{-1} was identified in decayed samples that was not present in sound wood, with a correlation between the peak ratio and MOR of .72 in brown rotted beams.

Based upon these results, the nature of the 1720 cm^{-1} absorption peak was examined with the goal of identifying the chemical component and developing simpler detection methods.

Soxhlet extraction using ethanol appeared to be the most practical method for removing soluble decay compounds from wood. This method also yielded a larger portion of the carbonyl containing compounds that produced an absorbance peak of 1720 cm^{-1} in the infrared range.

The carbonyl-containing compounds detected probably derived from the enzymatic oxidative degradation of lignin. The spectra of these compounds, or the bands containing them, closely resembled the spectrum produced by milled wood lignin that has been oxidatively degraded by hydrogen peroxide at high temperatures or that produced by heavily degraded lignin extracted from wood using a dioxane and water mixture.

In addition to degradation of lignin, fungal decay of Douglas-fir appeared to destroy soluble sugars originally present in the extractable portion of wood. This destruction of soluble sugars was evidenced by the lack of detectable compounds on chromatograms using aniline hydrogen naphthalate sprays specific for sugars.

The results suggest that IR analysis of hot water extracts of decayed wood detects a peak caused by the enzymatic oxidation of lignin into carbonyl containing fragments. Brown rot fungi leave most of the lignin in a modified state making this fraction more easily detectable, while the white rot fungi can more thoroughly degrade these components making detection more difficult. Thus, IR spectra appears to be more practical for brown-rotten wood but should also work on white rotted material.

C. ESTIMATING RRESIDUAL STRENGTH OF DOUGLAS-FIR POLES

In conjunction with Objective V, we have been evaluating the residual strength of wood cut from Douglas-fir poles air-seasoned at four Pacific Northwest locations for 1, 2, or 3 years. These tests have been performed on small beams (1x1x16 inches) cut from 24 pole sections per year. Each beam was tested for static bending, radial compression, and longitudinal compression strength, specific gravity, and Pilodyn pin penetration using methods previously described ('83 Ann. Rep., pg. 40-41, '84 Ann. Report, pg. 44-45). Following mechanical testing, wood was removed at mid-span, cultured on malt agar, and observed for the presence of decay fungi.

Previous testing after 1 and 2 years air-seasoning indicated that there was no significant difference in specific gravity, MOR, and MOE of the 1 and 2 year air-seasoned poles. Significant differences were found for work to maximum load, Pilodyn pin penetration and RCS of the same materials. Comparisons between 2 year air seasoned material from which decay fungi were isolated and noncolonized material indicated that there were no significant differences between any of the measured properties. These results suggest that the presence of decay fungi in the pole sections had not adversely affected strength properties.

This past year we examined beams cut from 24 pole sections air-seasoned from 3 years. Freshly cut beams from 15 of these sections had a reddish discoloration suggesting the presence of incipient decay. Decay fungi were isolated from 11 of these sections while 5 of the remaining 9 non-discolored sections contained decay fungi. A total of 27 of the 141 beams contained decay fungi.

Mechanical tests indicated that while specific gravity, MOE, and RCS declined slightly over the 3 years of seasoning, none of the changes were significant (Table 21). Work and Pilodyn measurements have shown slight strength reductions after 1 year air-seasoning, while MOR of the third year sections was lower than the 1 year sections. The latter finding indicates that the fungi colonizing wood exposed for this length of time are beginning to have some effect on wood strength. The results for MOR measurements of sapwood, outer heartwood, and inner heartwood all illustrated a gradual decline in

TABLE 21

COMPARISON OF MECHANICAL PROPERTIES OF BEAMS CUT FROM UNTREATED COAST DOUGLAS-FIR POLE SECTIONS

SAMPLES COMPARED	SPECIFIC GRAVITY (GREEN)	STATIC BENDING TESTS: MODULUS OF RUPTURE (GREEN)	STATIC BENDING TESTS: MODULUS OF ELASTICITY (GREEN)	STATIC BENDING TESTS: WORK TO MAXIMUM LOAD (GREEN)	NONDESTRUCTIVE TESTS: PILODYN[a] PENETRATION (12%)	NONDESTRUCTIVE TESTS: RCS[b] (GREEN)	NONDESTRUCTIVE TESTS: LCS[c] (GREEN)
		PSI	x1000	in-lb	MM	PSI	PSI
One-year Air-seasoned:	.45[d]	7163a[e]	1539a	122a	17.7a	369a	--
	(.04)	(980)	(220)	(39)	(3.1)	(77)	
	143	143	142	142	137	138	
Two-year air-seasoned:	.44a	6994ab	1467a	106b	19.6b	340a	2045a
	(.03)	(772)	(206)	(29)	(2.7)	(63)	(100)
	135	134	131	127	128	102	94
Three-year air-seasoned:	.44a	6726b	1472a	106b	19.0b	348a	2125b
	(.04)	(1038)	(261)	(32)	(2.7)	(74)	(63)
	140	140	140	140	98	136	137
Three-year air-seasoned, no decay fungi: 110	.44	6696	1459	108	19.0	346	2120
	(.04)	(1097)	(264)	(32)	(2.7)	(76)	(65)
		113	113	113	113	98	110
vs.							
Three-year air-seasoned, decay fungi: present:	.44[ns][f]	6852[ns]	1528	97[ns]	18.9[ns]	359[ns]	2146
	(.03)	(750)	(246)	(27)	(2.6)	(63)	(48)
	27	27	27	27	27	26	27

a As measured with 1.8 mkp model using 3mm diameter pin, 70 mm long.

b Radial compression strength of 0.5 in diameter plugs, 0.75 in long.

c Longitudinal compression strength of 0.5 in diameter plugs, 1.0 in long.

d In each set of numbers the first value is the mean, the value in parentheses is the standard deviation and the value beneath is the sample size.

e Numbers followed by the same letter are not significantly different (p = 0.05) according to the Newman-Keuls method.

f ns = No significant difference (p = 0.01).

MOR with length of seasoning (Figure 7). This effect was more noticeable for the inner heartwood and might reflect the lower decay resistance of older heartwood.

Comparisons between beams from which decay fungi were isolated and those free of decay fungi indicated that there was no significant difference between these two groups. This suggests that the fungi have no effect on wood strength; however, the handling procedures used prior to culturing probably reduced the survival rate of decay fungi in the beam, making comparison difficult. The cultural results in Objective V indicate that fungal colonization was considerably higher than the culturing from the beams might indicate. Our results indicate that air seasoned poles become colonized by a variety of decay and non-decay fungi; however, these fungi have only minimal effects on strength properties of Douglas-fir pole sections. Nevertheless, air-seasoning of wood in the Pacific Northwest should be limited to 2 years to insure maximum strength retention. It is also important to realize that even after 3 years of air seasoning, the magnitude of strength losses are not great and should not result in catastrophic pole failure.

Comparing test methods for measuring residual wood strength

In addition to our studies on the effects of air-seasoning on wood strength, we continue to search for simple, reliable tests that can be performed on poles in the field to produce residual wood strength estimates. These tests permit a utility to accurately assess the condition of its poles and concentrate remedial efforts on poles

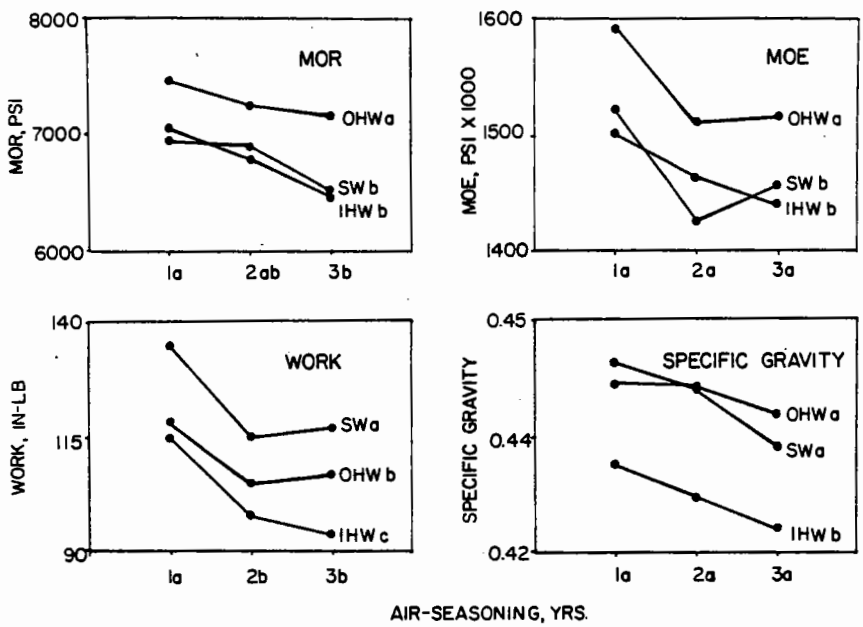


Figure 7. Strength properties of beams cut from the sapwood, outer heartwood, and inner heartwood of pole sections seasoned for 1, 2 or 3 years.

most worthy of saving. In addition, such tests could be used at the pole processing stage to select high strength material or weed out substandard wood. This application would permit more accurate line design while reducing the amount of low strength material rejected by the buyer.

Our previous tests on beams cut from 2-year air-seasoned Douglas-fir have shown that longitudinal compression strength (LCS) tests of plugs removed from the beams and Pilodyn pin penetration of beams provided good estimates of bending strength ('84 Ann. Report, pages 44-50). Because more tests were needed to determine which measurements were related to beam strength as it was reduced by decay, we tested 2 additional Douglas-fir sample groups using similar procedures. Fifty-four heartwood beams, ranging from sound to visibly decayed, were cut from 3 pentachlorophenol pressure-treated poles removed from service after 27 years and 45 beams were cut from Chemonite® (ACA)-treated poles stored for 5 years. The former group was also used for our sonic tests while the latter group of poles were the subject of a previous investigation to assess the effects of storage ('83 Annual Report, pg 46-47) on pole condition.

The various strength tests indicated a wide variation in strength properties (Table 22) and provided a good sample for evaluating the use of LCS and the Pilodyn as MOR predictors.

The tests indicated that LCS was highly correlated with MOR with r values for LCS ranging from .73 to .81 (a perfect correlation has an r-value of 1.0), while r values for the Pilodyn ranged from .45- .71 (Table 23). The low r-value obtained for Pilodyn pin penetration of

TABLE 22

SUMMARY OF DATA FOR MODULUS OF RUPTURE (MOR), LONGITUDINAL COMPRESSION STRENGTH (LCS), AND PILODYN PIN PENETRATION (P) OF DOUGLAS-FIR BEAMS.

SOURCE OF BEAMS[a]	SAMPLE SIZE	VARIABLE[b]	MEAN[c]	STANDARD DEVIATION	COEFFICIENT OF VARIATION
2-year AIR-SEASONED UNTREATED POLES	88	MOR,psi	6965 (5164-8923)	777	.11
		LCS,psi	2048 (1782-2170)	91	.04
		P, mm	20 (14-26)	2.4	.12
27-YEAR-OLD POLES CONTAINING A RANGE OF DECAY[d]	43	MOR,psi	7640 (1395-12455)	3479	.46
		LCS,psi	1776 (690-2278)	382	.22
		P, mm	21 (13.5-40.0)	7.4	.35
5-YEAR-OLD ACA-TREATED POLES	45	MOR,psi	6688 (4195-8969)	1363	.20
		LCS,psi	2054 (1648-2225)	157	.08
		P,mm	15 (9.5-21.0)	3.1	.21

[a] Beams are 1 x 1 x 16 inches long.

[b] Longitudinal compression strength was measured on (LCS) 0.5 in diameter plugs, 1.0-in long, removed from end of beams while Pilodyn tests were 6-Joule Pilodyn, 2.0 mm diameter pin.

[c] Figures in parentheses represent range.

[d] Heartwood only was tested.

TABLE 23

CORRELATION OF MODULUS OF RUPTURE (MOR) OF DOUGLAS-FIR BEAMS WITH LONGITUDINAL COMPRESSION STRENGTH (LCS) OR PILODYN PIN PENETRATION (P).[a]

SOURCE OF BEAMS	SAMPLE SIZE	CORRELATION COEFFICIENT (r) OF PREDICTOR VARIABLE VS MOR OF BEAMS	
		LCS, psi	P,mm
2-YEAR AIR-SEASONED UNTREATED POLES	88	0.73	0.63
27-YEAR-OLD POLES CONTAINING A RANGE OF DECAY[b]	43	0.75	0.45
5-YEAR-OLD ACE-TREATED POLES	45	0.81	0.71

[a] All beams tested were 1 x 1 x 16 inches long. LCS of 0.5 in diameter plugs, 1.0 -in long, removed from end of beams. Pilodyn pin penetration as measured using a 6-Joule Pilodyn; a 2.0 mm diameter pin was used to test 2-year, air-seasoned beams; and a 2.5 mm diameter pin used to test remaining beams.

[b] Heartwood only was tested.

the decayed beams suggests that the damage was less uniform and may have been missed by the Pilodyn.

Comparisons between LCS and MOR, measured as a percentage of the average strength value for coast Douglas-fir (USDA Wood Handbook, 1974), illustrates the strong relationship between these two properties over a range of wood conditions (Figure 8). These results indicate that LCS may be a useful method for measuring residual wood strength.

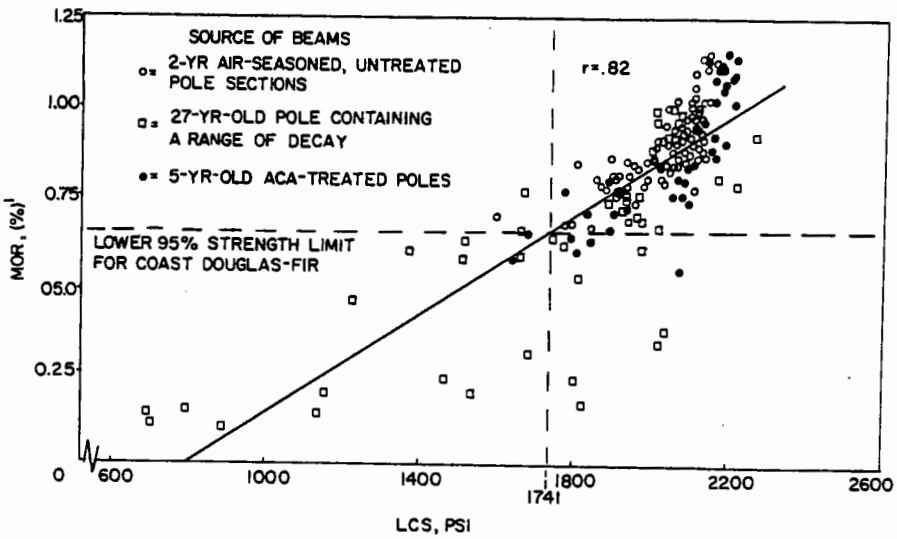


Figure 8 MOR vs LCS of preservative-treated and untreated Douglas-fir beams cut from poles removed from service or pole sections exposed in air-seasoning yards for varying periods.

Although we performed these tests on our laboratory Instron, we feel this method can be performed using a field adapted apparatus. This apparatus would permit an inspector to use small plugs removed from the pole to develop realistic values of residual wood strength and reduce the risk of overlooking badly decayed poles during inspection.

Detecting surface decay of poles - a comparison of several test methods

As a part of our studies on the preservation of historic Fort Vancouver in Washington, we have been evaluating the effectiveness of remedial treatments including MIT, chloropicrin, and an Osmoplastic wrap on untreated Douglas-fir,. In addition, bark was left on some poles and polyvinyl-chloride was wrapped around others. These poles have been sampled annually by removing increment cores for culturing. This past year we also evaluated pole condition using the Pilodyn, radial compression tests, the pick test, and microscopic ratings to compare the efficiency of these techniques for detecting surface deterioration.

Except for the pick test, none of the tests employed produced statistically significant differences between the treatments, although decay fungi were commonly isolated from many of the poles (Table 24). Each test seemed to have limitations that minimized its usefulness for detecting surface decay. The failure of the Pilodyn to detect surface decay was surprising since this instrument is commonly used for that purpose; however, we feel the number of tests performed per pole (6) may have been insufficient to accurately assess wood condition. We

TABLE 24

SURFACE CONDITION OF DOUGLAS-FIR POLES AS MEASURED BY SEVERAL MECHANICAL AND VISUAL TESTS.[a]

TREATMENT NO.	WRAP	FUMIGANT	PICK[b]	RADIAL COMPRESSION STRENGTH[c]	Pilodyn[d] AT GROUNDLINE	Pilodyn[d] BELOW GROUNDLINE	MICROSCOPE[e]
1	None	None	1.6 ab	166 a	18 bc	19 a	5.4 a
2	POLY	None	1.4 a	184 ab	29 a	18 a	4.7 a
3	POLY	CP	3.3 c	214 ab	18 bc	18 a	7.2 a
4	POLY	MIT	4.0 cd	283 bc	15 c	16 a	7.2 a
5	OSMO	None	4.0 cd	259 bc	16 c	17 a	6.8 a
6	OSMO	CP	4.0 cd	262 bc	15 c	16 a	6.9 a
7	Bark	None	2.1 ab	239 abc	23 b	19 a	6.3 a
8	Bark	MIT	4.0 cd	297 c	15 c	16 a	7.1 a

a Based upon three readings from five poles per treatment. Within a column, numbers followed by the same letter are not significantly different at the 5 percent level by the Newman-Keuls method.

b Poles subjected to the pick test were rates as: 1, soft and punky; 2, brash; 3, mixed brash and fibrous; and 4, tough and splintery.

c As measured on a .5 inch diameter, 0.75 inches long plug. Sound sapwood has a radial compression strength ranging from 204 to 478 psi at the 95 percent confidence level.

d Pin penetration measured with a 6-joule Pilodyn equipped with a 2.5-mm-diameter pin.

e As a result of microscope examination, wood sections were rated from 0 (badly decayed) to 10 (sound).

also experienced difficulties with radial compression tests since plugs cut from decayed poles often fell apart and could not be tested. Since plugs sometimes broke up for other reasons (small checks, dull plug cutter), we could not always accurately determine if the defect was decay related.

Although the pick test was surprisingly accurate, the need to remove a relatively large sliver for each test minimized the usefulness of this approach for detecting surface decay. Thus our results suggested that no single test was sufficiently accurate to detect decay in all poles.

The chemicals evaluated in these tests appear to be performing well (Figure 9). At present, application of MIT to poles with bark left on appears to be slightly more effective than chloropicrin for preventing internal decay. With the exception of bark/MIT, all of the treatments appear to have higher levels of basidiomycete colonization than would be found in pressure-treated Douglas-fir remedially treated with fumigants. It appears that the presence of a preservative-treated shell makes significant contributions to fumigant effectiveness.

The use of Osmoplastic alone also failed to completely protect the wood, although the number of basidiomycetes isolated from these poles has declined. In this case the presence of a barrier may have a strong impact on colonization. Our results suggest that combinations of external preservative wraps and internal fumigation should provide the most effective protection.

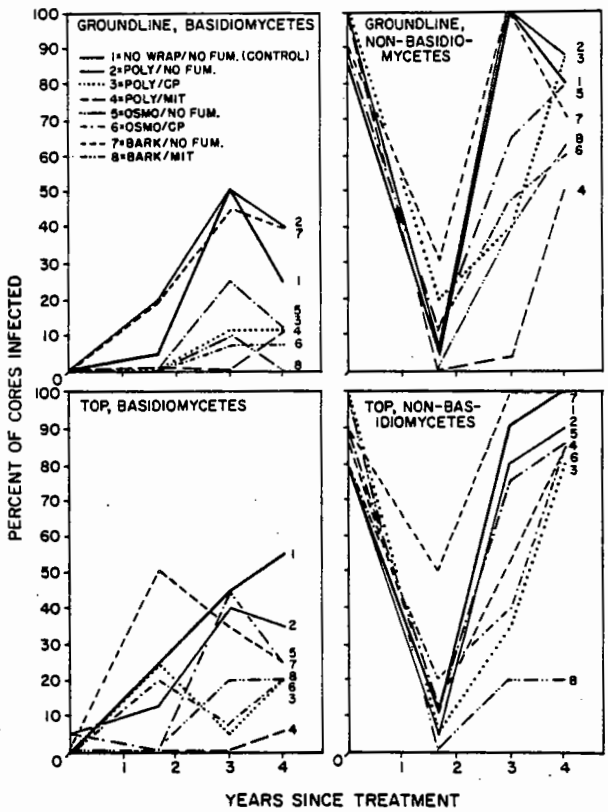


Figure 9. Percentage of colonization by basidiomycetous and non-basidiomycetous fungi in the top and groundline of Douglas-fir poles subjected to eight remedial treatments.

We will continue to monitor these poles to determine the ultimate effectiveness of these chemicals.

Significance of discolored wood in ammoniacal copper arsenate (ACA) treated Douglas-fir poles

In 1983, our New York cooperator had several large Chemonite® (ACA) treated Douglas-fir transmission poles that had been in storage for 4 years. Red-discoloration of wood on the inside edge of the treated zone of poles along with isolation of bacteria and imperfect fungi from the treated zone caused concern that the wood was deteriorating in storage. Previous tests ('83 Ann. Rept. page 46) indicated that red-discolored wood was not decayed but probably ammonia-stained heartwood; however, RCS values of plugs removed from the ACA-treated sapwood were low and suggested reduced pole strength. In the fall of 1984, 45 beams were cut from 3 sections of the ACA-treated poles and tested for strength. Equal numbers of beams were cut from treated sapwood, the treated/untreated discolored zone, and untreated heartwood. Preparation of beams and test procedures were identical to those previously described (Section IV-C).

In general, beams cut from the ACA-treated sapwood had significantly lower MOR (Table 25) and LCS (Table 26) values than beams from the other two wood zones although Pilodyn pin penetration and specific gravity were not significantly different. The reddish discolored zone, which we have tentatively attributed to the effect of ammonia from the treatment, had MOR and LCS values that were similar to the untreated heartwood, suggesting that the discoloration had little or no effect on wood strength.

TABLE 25.
MODULUS OF RUPTURE (MOR) OF BEAMS CUT FROM ACA-TREATED DOUGLAS-FIR POLES.[a]

POLE	ACA-TREATED SAPWOOD MOR,psi	RED-DISCOLORED, TREATED-UNTREATED BOUNDARY MOR,psi	UNTREATED HEARTWOOD MOR,psi	
				Totals:
1	4858 a	5402 ab	5996 bd	5418
2	5676 b	7430 e	7752 ef	6953
3	6492 d	8273 f	8317 f	7694
Totals	5675	7035	7355	

[a] Each value represents the average of 5 beams, while totals represent the average of 15 beams. Numbers followed by the same letter are not significantly different (P=0.05) according to the Newman-Keul's method.

TABLE 26.

LONGITUDINAL COMPRESSION STRENGTH (LCS), SPECIFIC GRAVITY (SG), AND PILODYN PIN PENETRATION OF WOOD FROM ACA-TREATED DOUGLAS-FIR POLES.[a]

STRENGTH PREDICTOR VARIABLE	ACA-TREATED SAPWOOD	RED-DISCOLORED, TREATED-UNTREATED BOUNDARY	UNTREATED HEARTWOOD
LCS,psi	1998 a	2081 b	2084 b
SG	.44 a	.44 a	.44 a
Pilodyn, mm	15 a	15 a	15 a

a. Each value represents the average of 15 tests. Numbers followed by the same letter are not significantly different by Newman-Keul's method at P = 0.05.

While these results suggest that ACA treatment may influence sapwood strength, the small number of samples tested limits the value of this data. However, the high correlation between MOR and LCS suggests that residual strength of beams could have been estimated using LCS.

D. ACOUSTIC TESTING OF BEAMS REMOVED FROM DOUGLAS-FIR POLES

We continue to evaluate nondestructive methods for determining utility pole strength based on the transmission of acoustical waves through the pole. To develop this method we have established the basic acoustical properties of wood and the relationship of these properties to wood strength.

Earlier sonic tests on a limited number of small wood beams showed that we could predict beam strength by analyzing the "fingerprint" of an acoustic wave transmitted through the wood ('84 Ann. Rept. pg. 52-57). Introducing a burst of sound to the wood results in the soundwaves becoming modulated as they travel, taking on the characteristics that reflect the material through which they pass. This modulated wave or "fingerprint", represents a coded data base of the material's properties, (Figure 10). We have attempted to decode and translate the information contained in the fingerprint to develop meaningful predictions of material strength.

The earlier study was expanded by testing an additional 54 small beams (1 x 1 x 16 inches long), cut from pentachlorophenol treated Douglas-fir poles that had been removed from service due to the presence of extensive decay.

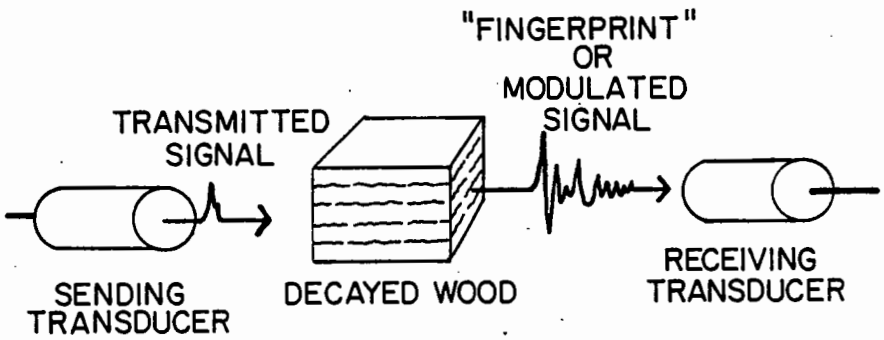


Figure 10. Diagramatic representation of acoustic testing of decayed wood to predict strength.

The beams were acoustically tested in three orientations (radial, tangential, and longitudinal) to record information about the acoustical wave such as velocity and acoustic analysis factor (a simple interpretation of the wave fingerprint). Each fingerprint was photographed to provide a permanent record for additional processing when we acquire more sophisticated equipment. Wave velocity, which is the technique in most currently available sonic pole testers, was used as a bench mark for the improved test methods that we hope to develop.

After acoustical testing, the beams were destructively tested in three-point loading to determine their bending strength calculated as modulus of rupture, (MOR) and work-to-maximum load. Statistical correlations were made between the acoustical parameters measured and MOR and work-to-maximum load.

Predictive models for MOR and work-to-maximum load, and their respective correlation coefficients (where r = 1.0 for a perfect prediction) were:

$$MOR = -6120 + 1.6a + 335b - 2.9c \quad \text{(psi)}$$

$$(r = .88)$$

$$Work = -287 - 4.7A + 0.02B + 5.1C \quad \text{(in-lb)}$$

$$(r = .82)$$

where the coefficients a, b, c, A, B, and C represent various values of wave velocity and acoustic analysis factors.

There values suggest that acoustic analysis produces a reasonable predictor for beam MOR or Work. Work-to-maximum load is an important

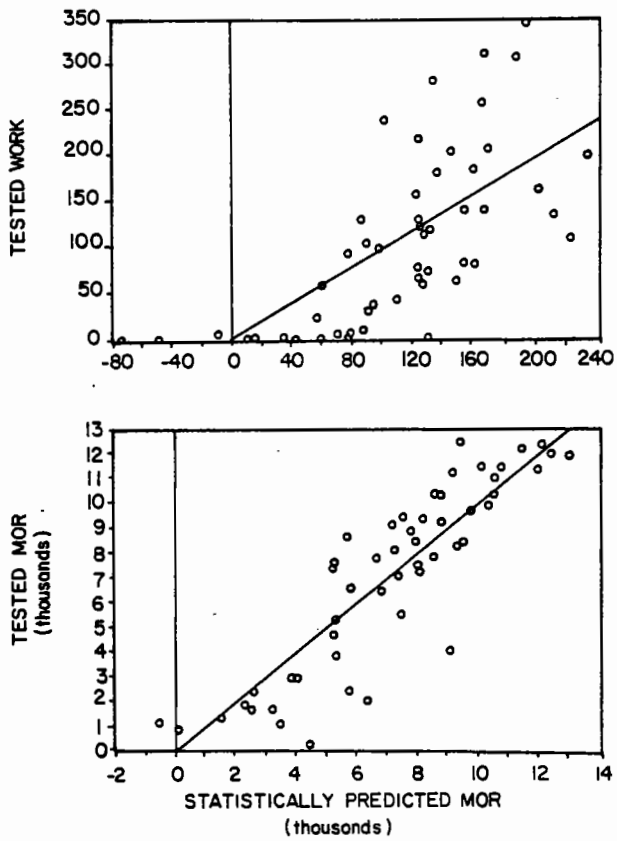


Figure 11. Measured versus acoustically predicted values for a). work-to-maximum load and b). Modulus of rupture (MOR).

characteristic for utility poles since it indicates the amount of resistance to failure a pole can withstand when subjected to sudden impact loads, such as those that occur in storms or automobile collisions. Comparisons between predicted and actual MOR and work-to-maximum load values (Figure 11) indicated that predicted values generally followed actual measurements. Although work values were more scattered, these models generally detected lower strength beams that might cause safety problems. A perfect prediction of either MOR or work-to-maximum load would be indicated by the values falling on the 45-degree line show in the figure.

These initial studies illustrate potential for using signal analysis of acoustic waves to accurately predict the strength and work-to-maximum load of wood. These studies, using relatively simple signal analysis to predict strength properties for small wood beams, have increased the accuracy of our predictions. We hope to acquire more sophisticated signal analysis equipment that we can use to develop predictive models of pole strength. Although these studies are still in the early developmental stages, we feel the value of developing more precise strength measurements can result in substantial savings.

OBJECTIVE V

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

In 1981, air seasoning poles were sampled in 11 pole yards throughout the Pacific Northwest by removing fourteen 6 inch long increment cores from several sites along the length of each pole. These cores were flamed, plated on malt agar, and observed for evidence of fungal growth. The resulting fungi were observed for the presence of clamp connections or other basidiomycete characteristics and the fungi were isolated in pure culture for later identification. Air seasoning poles at an additional 7 yards and freshly cut poles at 6 locations were sampled in 1982 using the same procedures. Preliminary results of this study were presented in 1983 (pg. 49-54). In this process we have examined 21,222 increment cores from 1540 poles (some poles were positioned in ways that prevented removal of all 14 cores).

Because of difficulties in determining exact time of air-seasoning in some locations, poles were grouped into 6 month age classes. The age classes selected were: (i) fresh poles sampled within 4 weeks of cutting; (ii) unpeeled poles with bark intact sampled at the pole yard; and peeled poles air-seasoned for: (iii) 0 to 6 months: (iv) 7 to 12 months; (v) 13 to 18 months; (vi) 19 to 24 months and (vii) 25 months or longer.

---

* This section represents a portion of Paul Przybylowicz's doctoral dissertation.

Identification of the unknown isolates is nearly complete and indicates that a variety of basidiomycetes colonize air-seasoning Douglas-fir

There were relatively low levels of basidiomycetes in poles sampled shortly after felling. Most of these fungi were unidentified suspect fungi that had basidiomycete like characteristics but lacked clamp connections. The importance of these fungi is uncertain since their numbers declined before the poles were peeled. Some of these fungi may also represent heartrot fungi that were not capable of decay after cutting.

Changes in the populations of basidiomycetes during air seasoning of poles.

As air-seasoning time increased, the number of poles colonized by basidiomycetes and the volume of wood occupied also increased (Fig. 12). The volume of wood colonized was estimated by summing the number of cores with basidiomycete isolates in each age class and expressing these sums as a percent of the total number of cores taken in each age class. Basidiomycete frequency as a percentage of cores colonized yields an estimate of the wood volume colonized, while percent poles colonized shows the distribution of decay fungi among poles.

Pole colonization by basidiomycetes occurred rapidly over the first 18 months of air-seasoning (Fig. 12), then declined slightly, probably due to depletion of readily available sapwood substrates. Pole and core colonization patterns were similar, except in the fresh

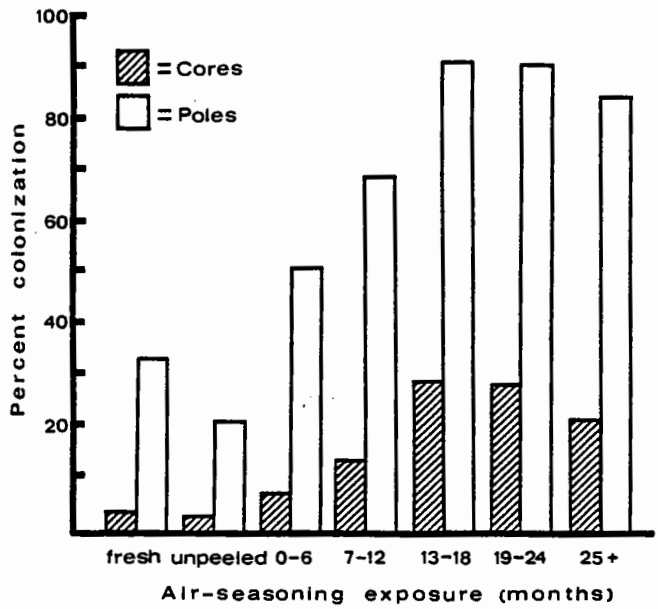


Figure 12. Colonization of Douglas-fir poles air-seasoned for varying times in the Pacific Northwest expressed as percent poles and percent cores colonized by basidiomycetes. Total numbers of poles and cores sampled in each age class is given in Tables 22 and 23, respectively.

age class where the basidiomycetes were spread over a larger number of poles. Colonized poles in the oldest age class averaged about four colonized cores per pole, while freshly cut poles averaged less than one isolate per pole (Table 27).

The average number of isolates per pole increased rapidly to a maximum of 4.7 at 18 months, then declined slightly (Table 27). Using this data, the seven arbitrary age classes could be placed into five distinct groups, based on the average number of isolates per pole : (i) poles with their bark intact, which included the fresh and unpeeled age classes, (ii) poles seasoned for 0 to 6 months, (iii) poles seasoned for 7 to 12 months, (iv) poles seasoned for 13 months to 24 months, and (v) poles seasoned for 25 months or longer. Thus, air seasoning Douglas-fir poles for more than 1 year, which is generally required to dry larger poles, ensures that a high percentage of these poles will be colonized by basidiomycetes by the end of the seasoning period.

Unpeeled poles were sparsely colonized, but the decay fungus population increased dramatically after peeling (Table 27). It appears that the exposure of unprotected nutrient rich sapwood, resulted in a rapid colonization that declined after about 12 months as these nutrients became limiting. The ability to rapidly utilize these non-structural carbohydrates may determine if a decay fungus can successfully colonize the wood.

TABLE 27

FREQUENCY OF BASIDIOMYCETES COMMONLY ISOLATED FROM DOUGLAS-FIR POLES AIR SEASONED FOR VARYING TIME PERIODS IN THE PACIFIC NORTHWEST

FUNGUS SPECIES[a]	PERCENT POLES COLONIZED BY BASIDIOMYCETES SEASONING TIME (MONTHS)							
	FRESH[b]	UNPEELED[c]	0-6	7-12	13-18	19-24	25+	TOTAL
Haematostereum sanguinolentum	1	2	19	26	51	45	48	24
Peniophora spp.	0	0	5	25	49	37	21	17
Sistotrema brinkmanii[d]	1	2	12	19	19	21	20	12
Poria carbonica	T[e]	0	1	9	19	27	39	11
monokaryon	0	0	T	1	2	3	3	1
Epicoccum nigrum[f]	T	4	7	12	24	24	10	10
Poria placenta	1	1	2	8	13	18	16	7
monokaryon	1	0	2	3	7	8	9	4
Coriolus versicolor	6	2	5	3	15	5	8	6
monokaryon	4	1	3	2	2	1	3	2
Stereum hirsutum	1	1	2	5	11	8	5	4
Unidentified basidiomycetes	4	4	7	22	35	32	35	18
Unidentified suspect fungi[g]	20	8	11	6	20	12	12	12
Percent poles with fungi	34.7	22.8	54.4	72.4	92.7	91.6	86.6	61.4
Total number of poles sampled	274	211	283	268	164	154	186	1540
Total number of cores taken	3834	2528	3939	3784	2350	2159	2628	21222

a. The monokaryons are included with the dikaryons and are also shown separately to give a breakdown between dikaryon and monokaryon.
b. Sampled within 4 weeks of felling.
c. Sampled in the yard with the bark intact.
d. This is a species complex.
e. "T" = frequency less than 0.5%.
f. A non-basidiomycete fungus that may influence wood strength.
g. Suspect fungi are those isolates which have basidiomycetous characteristics, but lack clamp connections.

The influence of air-seasoning location on colonization of Douglas-fir poles by basidiomycetes

The frequency of basidiomycete isolation from air-seasoning poles varied considerably between yards, especially in the younger age classes (Table 28). For example, the percentage of "unpeeled" poles containing basidiomycetes in different yards ranged from 3 to 100%; suggesting that pole source, time in storage, and conditions between cutting and delivery to the yard can greatly influence colonization of unpeeled poles. Prompt transport of poles from the forest to the yard should decrease the probability of pole colonization before peeling.

Variation in pole colonization between yards decreased with increased air-seasoning time probably because nearly all poles in the older age classes were heavily infested. This suggested that poles were being colonized by basidiomycetes in all the yards studied. These results indicate that inoculum levels of wood-decaying basidiomycetes are high throughout the Douglas-fir pole producing region in the Pacific Northwest. Because of the long rainy season and a relatively short summer that limits pole drying, this region is less than ideal for air seasoning poles. The location of air-seasoning yards in the drier climate east of the Cascade mountains would probably speed drying and reduce the risk of basidiomycete colonization; however, increased transportation costs might make kiln or Boulton drying more cost-effective.

TABLE 28

FREQUENCY OF BASIDIOMYCETES ISOLATED FROM DOUGLAS-FIR POLES AIR SEASONED FOR VARYING TIME PERIODS IN POLE YARDS IN THE PACIFIC NORTHWEST

YARD NUMBER	PERCENT POLES COLONIZED BY BASIDIOMYCETES SEASONING TIME (MONTHS)[a]						
	FRESH[b]	UNPEELED[c]	0-6	7-12	13-18	19-24	25+
1	10	-	-	-	-	-	-
2	51	-	-	-	-	-	-
3	24	-	-	-	-	-	-
4	26	-	-	-	-	-	-
5	50	-	-	-	-	-	-
6	55	-	-	-	-	-	-
7	-	25	74	74	-	-	65
8	-	-	28	88	-	87	-
9	-	6	35	25	-	-	90
10	-	100	85	95	100	-	-
11	-	-	-	55	67	-	68
12	-	-	-	-	75	-	-
13	-	50	55	-	91	100	100
14	-	-	-	-	-	100	100
15	-	3	53	0	97	85	100
16	-	-	-	-	96	-	-
17	-	-	-	-	-	95	-
18	-	-	-	-	100	-	100
19	-	7	29	53	-	76	-
20	-	-	-	-	-	89	-
21	-	25	25	65	-	-	100
22	-	-	-	-	-	100	100
23	-	16	86	84	100	-	-
24	-	26	66	90	-	95	85
Number of yards in age class	6	9	10	9	8	9	10
Average percent poles with decay fungi	36.1	28.6	53.6	69.8	90.6	91.8	90.8
Similar groups[d]	A	A	A	A	B	B	B

a. (-) = no poles sampled at this yard.
b. Sampled within 4 weeks of felling.
c. Sampled with bark intact at pole yard.
d. Age classes with the same letter not significantly different.

Poles from both the Coast Range and the western slopes of the Cascade mountains were sampled during this study, but these poles were mixed in the seasoning yards and there was no way to differentiate between them. However, fresh-cut poles sampled in the forest could be identified. Three locations in the Coast Range were sampled and, of 140 poles, 30.3% contained basidiomycetes. Of 134 poles from three locations in the Cascade mountains, 41.7% were colonized by basidiomycetes. Pole colonization by basidiomycete in these two distinct areas were not significantly different (Student's t-test, $p = 0.05$) suggesting that pole source has little effect on pole colonization by decay fungi.

Occurrence of different basidiomycete species in air-seasoning poles

The basidiomycete species isolated from air-seasoning poles changed dramatically as air-seasoning time increased (Table 29). Although P. carbonica and P. placenta account for most of the decay in Douglas-fir poles in service, these two species were not the most frequently isolated basidiomycetes from air-seasoning poles. While P. carbonica was infrequently isolated from poles early in air seasoning, it steadily increased after the first year to become the second most prevalent basidiomycete in poles air seasoned for 25 months or longer. Poria placenta followed a similar trend, but at a lower level of wood colonization.

TABLE 29

NUMBER OF BASIDIOMYCETES ISOLATED FROM DOUGLAS-FIR POLES AIR SEASONED FOR VARYING TIME PERIODS IN THE PACIFIC NORTHWEST

CORES WITH BASIDIOMYCETES PER POLE	NUMBER OF POLES SEASONING TIME (MONTHS)							
	FRESH[a]	UNPEELED[b]	0-6	7-12	13-18	19-24	25+	TOTAL
0	179	163	129	74	12	13	25	595
1	63	32	60	58	15	25	27	280
2	19	5	43	40	18	14	18	157
3	6	5	23	28	24	22	20	128
4	4	4	7	22	18	11	19	85
5	2	0	9	15	16	12	27	81
6	0	2	4	9	19	17	17	68
7	0	0	3	13	15	6	10	47
8	1	0	2	4	11	8	8	34
9	0	0	1	2	2	10	7	22
10	0	0	1	2	5	4	4	16
11	0	0	1	1	3	6	1	12
12	0	0	0	0	1	5	1	7
13	0	0	0	0	2	0	2	4
14	0	0	0	0	2	0	0	2
16	0	0	0	0	1	1	0	2
Total no. of cores with decay fungi	153	85	379	611	765	703	722	3418
Number of Poles sampled	274	211	283	268	164	154	186	1540
Mean no. of cores with decay fungi per pole	0.6	0.4	1.3	2.3	4.7	4.6	3.9	
Standard deviation	1.0	1.0	1.9	2.4	3.2	3.5	3.0	
Similar groups[c]	A	A	B	C	D	D	E	

a. Sampled within 4 weeks of felling.
b. Sampled with bark intact at pole yards .
c. Age classes with same letter are not significantly different

Most of the decay fungi isolated from air-seasoning Douglas-fir poles also have been isolated from other substrates. Poria carbonica and P. placenta are important causes of decay of Douglas-fir in poles, pilings, wooden boats and lumber. Poria carbonica is the most frequently isolated decay fungus from Douglas-fir poles in service in the Pacific Northwest accounting for 56% of the decay fungi isolated, and similar patterns of occurrence of these species have been found for Douglas-fir poles in service in the Northeast.

Haematostereum sanguinolentum was commonly isolated from air-seasoning poles and its isolation frequency increased with air-seasoning time to a maximum at 13 to 18 months, after which it remained relatively constant. This species is a white rot fungus that causes heartrot in living conifers and can continue to decay the wood after the tree is cut. This fungus has not been reported from poles in service, probably because it is mostly in the sapwood where it is killed during preservative treatment.

The distribution of Coriolus versicolor between the age classes was relatively even, except for the 13 to 18 month class in which its high frequency was due to a 30 pole sample from one yard in which 15 poles were infested with this fungus. Coriolus versicolor causes a soft white spongy rot of dead sapwood, and a white rot of heartwood. This widely distributed fungus attacks wood in storage and in service, has been reported in treated southern pine and Douglas-fir poles.

The distributions of Peniophora spp., Sistotrema brinkmanii and Epicoccum nigrum were similar between age classes of air-seasoned Douglas-fir poles. These fungi all increased to a maximum frequency after 1 year, then declined, suggesting that these species were utilizing the easily accessible carbohydrates in the sapwood.

Peniophora spp. represents a group of white rot fungi that are difficult to separate into individual species. They are common in conifer sapwood, and although capable of decaying wood, are generally limited to the sapwood where they should be eliminated in the pressure treating process.

Sistotrema brinkmanii is a brown rot fungus that is common in soil or decaying slash and may be causing strength loss in Douglas-fir poles.

Epicoccum nigrum is a non-basidiomycete soft-rot fungus found in preservative treated southern pine poles where it may cause some strength loss.

Twenty-two additional basidiomycetes were isolated from air-seasoning Douglas-fir poles (Table 30,31), with the greatest variety of species isolated during the first 6 months of air seasoning. The decreasing species numbers were probably caused by increased competition among basidiomycetes and imperfect fungi for available nutrients. Many of these decay fungi have been reported to cause decay in poles, lumber and other wood products; however, these species were isolated at relatively low frequencies from the air-seasoning poles and probably do not pose a serious threat to pole

strength. As treatment practices change, the basidiomycete species causing decay of poles in service may also change, and relatively unimportant fungi may cause decay problems in poles, especially if they survived the initial treatment. This is clearly illustrated with CCA-treated Douglas-fir. While conventional oil-borne cycles should sterilize a pole, eliminating any fungi that colonized prior to treatment, ambient temperature CCA treatments will allow these fungi to survive in the heartwood. Unless the pole is subsequently kiln-dried for a sufficient period to heat the pole interior, these fungi will be ideally poised to cause internal decay in service.

Colonization of air-seasoning Douglas-fir poles by monokaryotic basidiomycetes

The techniques used in this study could not differentiate between expansion of existing fungal colonies in wood and establishment of new colonies.

Colonies resulting from basidiospore germination on wood are generally monokaryotic, and their prevalence in air-seasoning poles suggests that basidiospores initiated colonization in the air-seasoning yards (Table 29). Poria placenta and Coriolus versicolor monokaryons accounted for about one half of the total isolates of these fungi, suggesting high local spore populations. Lower frequency of P. carbonica monokaryons was probably due to the presence of fewer basidiospores and a slower growth rate in wood.

TABLE 30
FREQUENCY OF BASIDIOMYCETES ISOLATED FROM DOUGLAS-FIR POLES AIR SEASONED FOR VARYING TIME PERIODS IN THE PACIFIC NORTHWEST

FUNGUS SPECIES	PERCENT POLES COLONIZED BY BASIDIOMYCETES							
	SEASONING TIME (MONTHS)							
	FRESH[a]	UNPEELED[b]	0-6	7-12	13-18	19-24	25+	TOTAL
Haematostereum sanguinolentum	1.1	1.9	19.1	25.4	51.2	44.8	48.4	24.2
Peniophora spp.	0	0	4.6	24.6	49.4	36.6	21.0	16.8
Sistotrema brinkmanii[c]	1.1	1.9	12.0	18.7	18.9	21.4	20.4	12.5
Poria carbonica	0.4	0	1.1	7.8	16.5	23.4	36.6	10.1
Epicoccum nigrum[d]	0.4	3.8	6.7	11.6	23.8	24.0	9.7	9.9
Phanerochaete sordida	5.1	0.5	2.1	2.2	9.1	11.0	5.2	4.2
Stereum hirsutum	1.1	0.9	1.8	5.2	11.0	8.4	5.4	4.2
Poria placenta monokaryon	0.8	0	2.1	3.4	6.7	8.4	9.1	3.8
Poria placenta	0	0.9	0.4	4.9	6.7	9.7	6.5	3.5
Coriolus versicolor	1.8	1.4	2.1	1.1	12.8	3.9	4.8	3.4
Coriolus versicolor monokaryon	2.9	0.9	3.2	1.5	1.8	1.3	2.7	2.1
Gloeophyllum saeparium	0.4	0.5	0.7	0	3.0	6.5	7.5	2.1
Fomitopsis cajanderi	0.4	2.4	1.4	2.2	1.8	1.3	1.6	1.6
Schizophyllum commune	0.4	0.5	1.1	0.4	6.1	1.9	1.1	1.4
Poria carbonica monokaryon	0	0	0.4	0.7	2.4	3.2	2.7	1.1
Cystostereum pini-canadense	0	0	2.8	0	0	0	0	0.5
Phlebia "A" monokaryon	0.8	0.5	1.1	0.4	0.6	0	0	0.5
Schizophyllum commune monok.	0.8	0	1.1	0	1.8	0	0	0.5
Phlebia radiata monokaryon	0.4	0	0.4	0.4	1.2	0.6	0	0.4
Poria cinerascens monokaryon	0	0	1.4	0	1.2	0	0	0.4
Fomitopsis pinicola monokaryon	1.2	0.5	0.4	0	0	0	0.5	0.4
Heterobasidion annosum	0	0	0.4	0.4	0	0.6	0	0.2
Fomitopsis pinicola	0.4	0	0.4	0	0	0	0	0.1
Phlebia gigantea	0	0.5	0.4	0	0	0	0	0.1
Poria xantha	0	0	0	0	0	0	0.5	0.1
Poria cinerascens	0	0	0	0	0.6	0	0	0.1
Phlebia albida monokaryon	0	0	0	0	0	0.6	0	0.1
Crustoderma dryinum	0	0	0	0	0	0	0.5	0.1
Poria xantha monokaryon	0	0	0	0	0	0.6	0	0.1
Fomitopsis cajanderi monokaryon	0	0	0.4	0	0	0	0	0.1
Unidentified basidiomycetes	4.4	3.8	7.1	22.0	34.8	32.5	34.9	17.6
Unidentified suspect fungi[e]	20.4	7.6	11.0	5.6	20.1	11.7	12.4	12.5
Total number of poles with basidiomycetes[f]	95	48	154	194	152	141	161	945
Total number of poles sampled	274	211	283	268	164	154	186	1540

a. Sampled within four weeks of felling. b. Sampled with bark intact in the yard.
c. This is a species complex. d. A non basidiomycete fungus that may influence wood strength.
e. Suspect fungi are those isolates which have basidiomycetous characteristics, but lack clamp connections.
f. Does not equal the sum of the column as one core may have more than one fungus.

TABLE 31

FREQUENCY OF BASIDIOMYCETES ISOLATED IN CORES FROM DOUGLAS-FIR POLES AIR SEASONED FOR VARYING TIME PERIODS IN THE PACIFIC NORTHWEST

FUNGUS SPECIES	NUMBER OF CORES COLONIZED BY BASIDIOMYCETES							
			SEASONING TIME (MONTHS)					
	FRESH[a]	UNPEELED[b]	0-6	7-12	13-18	19-24	25+	TOTAL
Haematostereum sanguinolentum	3	7	116	153	193	191	205	868
Peniophora spp.	0	0	14	93	176	110	58	451
Sistotrema brinkmanii[c]	3	4	70	108	41	51	69	346
Poria carbonica	1	0	5	31	36	64	124	260
Epicoccum nigrum[d]	1	9	22	44	51	63	26	216
Phanerochaete sordida	3	18	10	19	8	11	13	82
Stereum hirsutum	5	3	6	6	39	7	12	78
Poria placenta monokaryon	15	1	6	6	16	21	7	72
Poria placenta	3	2	5	14	21	15	10	70
Coriolus versicolor	2	0	7	9	13	21	18	70
Coriolus versicolor monokaryon	0	2	1	17	14	19	15	68
Gloeophyllum saeparium	1	1	2	0	5	17	17	43
Fomitopsis cajanderi	11	2	9	4	3	2	5	36
Schizophyllum commune	1	1	9	2	17	3	2	35
Poria carbonica monokaryon	0	0	1	2	4	5	5	17
Cystostereum pini-canadense	0	0	13	0	0	0	0	13
Phlebia "A" monokaryon	2	1	3	1	1	0	0	8
Schizophyllum commune monok.	2	0	3	0	3	0	0	8
Phlebia radiata monokaryon	1	0	1	1	2	1	0	6
Poria cinerascens monokaryon	0	0	4	0	2	0	0	6
Fomitopsis pinicola monokaryon	3	1	1	0	0	0	1	6
Heterobasidion annosum	0	0	1	1	0	1	0	3
Fomitopsis pinicola	1	0	2	0	0	0	0	3
Phlebia gigantea	0	1	1	0	0	0	0	2
Poria xantha	0	0	0	0	0	0	1	1
Poria cinerascens	0	0	0	0	1	0	0	1
Phlebia albida monokaryon	0	0	0	0	0	1	0	1
Crustoderma dryinum	0	0	0	0	0	0	1	1
Poria xantha monokaryon	0	0	0	0	0	1	0	1
Fomitopsis cajanderi monokaryon	0	0	3	0	0	0	0	3
Unidentified basidiomycetes	14	13	25	82	81	82	111	408
Unidentified suspect fungi[e]	85	19	40	19	39	23	24	249
Total number of cores with basidiomycetes[f]	150	84	372	591	722	643	667	3229
Total number of poles sampled	3834	2528	3939	3784	2350	2159	2628	21222

a. Sampled within four weeks of felling.
b. Sampled with bark intact in the yard.
c. This is a species complex.
d. A non basidiomycete fungus that may influence wood strength.
e. Suspect fungi are those isolates which have basidiomycetous characteristics, but lack clamp connections.
f. Does not equal the sum of the column as one core may have more than one fungus.

In studies of Douglas-fir log deterioration, P. carbonica was isolated more frequently from logs exposed for longer times, further suggesting that P. carbonica does not successfully compete with the many decay fungi present in initial stages of wood colonization, but gradually invades as these fungi exhaust the more readily available food sources.

Basidiomycete distribution in air-seasoning Douglas-fir poles

More basidiomycetes were isolated from the outer shell of poles in all age classes than from the inner portions except at the pole ends (Fig. 13). The outer 2 inches and the inner 4 inches of the cores corresponded roughly to the sapwood and the heartwood, respectively. The frequency of basidiomycetes in the outer portions of the cores decreased significantly at the butt, probably due to the removal of sapwood from the butt during peeling to reduce pole taper.

Basidiomycetes isolated from the inner core zone were concentrated at the pole ends. This was probably due to heartwood exposure that allowed easy access while enhancing diffusion of oxygen and water.

Basidiomycete distribution on and along the pole changed with increasing air-seasoning time (Fig. 14). Peeling the poles exposed nutrient rich sapwood, while allowing the wood surface to dry and creating checks that were ideal for colonization. As a result, there was rapid colonization by fast-growing basidiomycetes such as Schizophyllum commune and Peniophora spp. These fungi probably have little effect on pole strength, but they may modify the wood to allow colonization by other decay fungi.

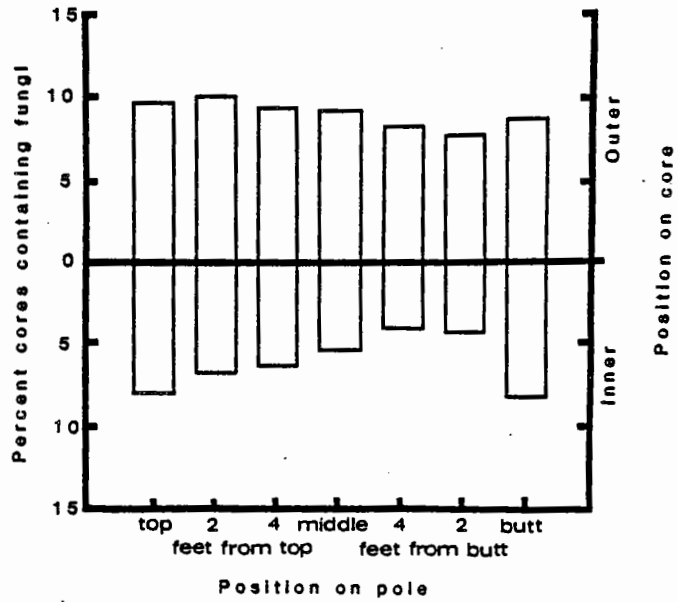


Figure 13. Distribution of basidiomycetes along the length of Douglas-fir poles air-seasoned for varying time periods in the Pacific Northwest. The inner portion of the core is the inner 4 inches of each core, and is mostly heartwood. The outer portion of the core is the outer 2 inches of each core, and is mostly sapwood.

Basidiomycete frequency in the inner pole zone in the 7-12 month age class was about the same as in the outer 2 inches of the poles, except near the butt end (Fig. 14). As seasoning time increased, basidiomycete frequency increased at a greater rate in the outer 2 inches of the poles than from the inner portion, except near the butt end.

Basidiomycete species distribution showed distinct patterns along the pole length (Fig. 15). Haematostereum sanguinolentum, Peniophora spp. and Sistotrema brinkmanii were the most prevalent basidiomycetes isolated in the 0-6 month age class (Table 29), and were most common in the sapwood (Fig. 15), while P. carbonica and P. placenta were found most frequently in the inner wood zones. Poria carbonica was particularly concentrated in the butt ends, accounting for about 25% of the isolates from these sections. The latter two fungi, which were isolated most frequently from the heartwood, probably have a competitive advantage in this zone, which may partially explain their prevalence in Douglas-fir poles in service. The prevalence of these two fungi in the heartwood increases the risk that they will survive an inadequate treating cycle, and later cause decay of wood in service.

The results of these studies indicate that air seasoning Douglas-fir poles for more than 1 year assures that most of the poles will be colonized by basidiomycetes. As the seasoning time increased, the basidiomycete populations shifted from fast-growing, sapwood colonizers, to slower-growing heartwood colonizers capable of causing significant decay in Douglas-fir.

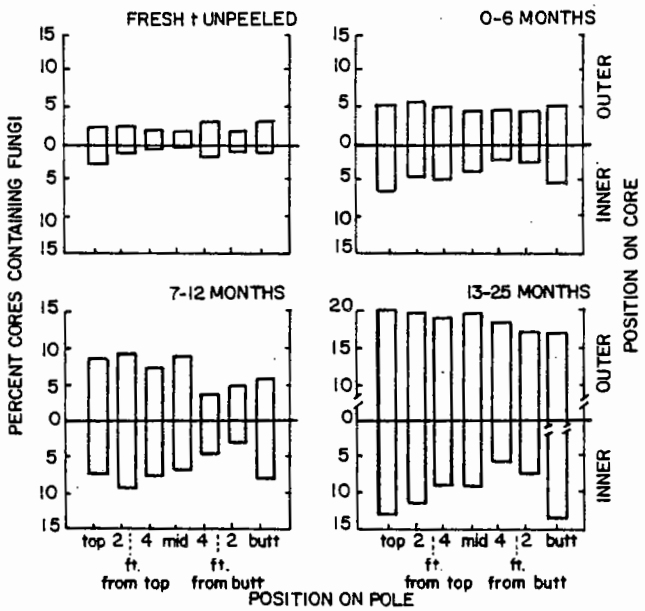


Figure 14. Distribution of basidiomycetes in four age groups along the length of Douglas-fir poles air-seasoned for varying time periods in the Pacific Northwest. The inner core position was the inner 4 inches of each core, which was mostly heartwood. The outer core position was the outer 2 inches of each core, which was mostly sapwood. The four groups plotted are the age classes grouped by analysis of number of isolates per pole.

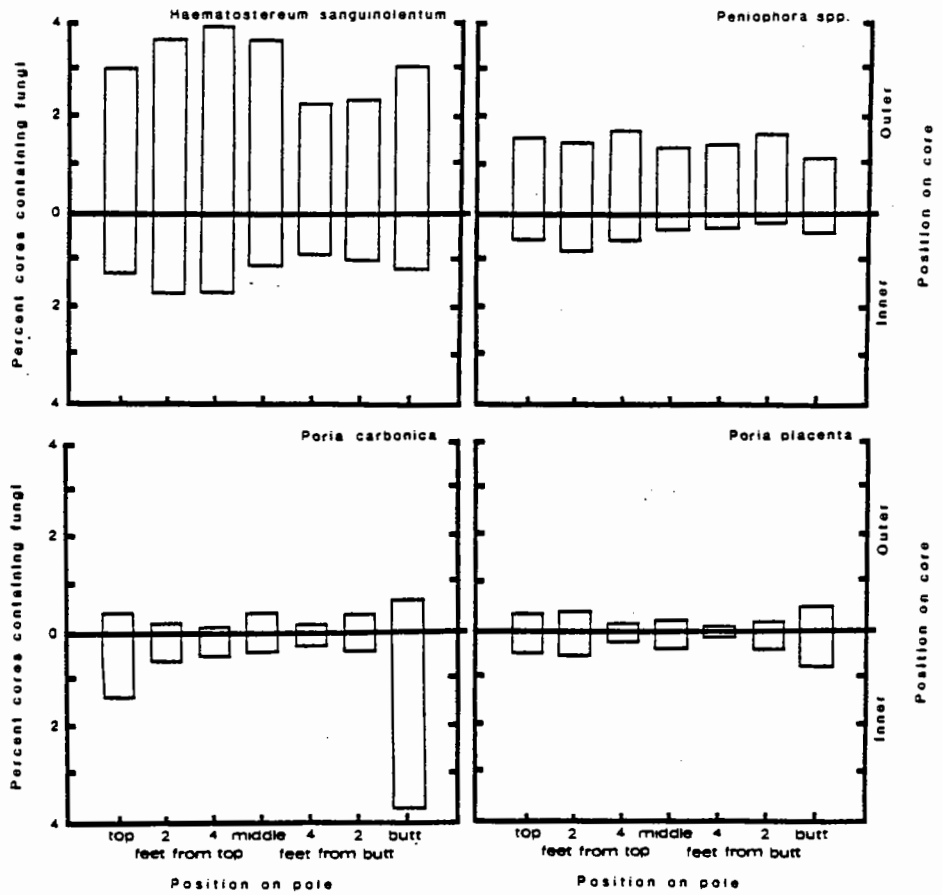


Figure 15. Distribution of four basidiomycetes along the length of Douglas-fir poles air-seasoned for varying time periods in the Pacific Northwest. The inner core position was the inner 4 inches of each core, which was mostly heartwood. The outer core position was the outer 2 inches of each core, which was mostly sapwood.

Basidiomycetes isolated mostly from the heartwood, e.g. Poria carbonica and P. placenta, were uncommon in poles seasoned less than 1 year. Thus, limiting air seasoning to less than 1 year may avoid some potential decay problems. Requiring heating times that insure adequate internal heating during preservative treatment would also improve decay control. Another promising approach is the use of fumigants, which could be placed in the ground line area of poles during framing. These chemicals would eliminate basidiomycetes from wood zones most prone to decay.

Initial colonization of poles probably occurs through exposed end grain. Since fungi colonize wood at a faster rate in this direction, most of the wood samples were taken near the pole ends during this study. Thus, the results may not represent the actual frequency of basidiomycetes in the entire pole because of the limited number of cores taken per pole. Each pole was sampled by removing 14 cores, representing less than 0.01% of the wood volume of a 40 foot pole, 12 inches in diameter. Removing more cores per pole might have changed the percentage of colonized poles and improved the estimates of wood volume colonized by basidiomycetes. Similarly, sampling the middle of the pole may have altered frequency since fungi may have only colonized the exposed heartwood at the end, while the heartwood in the middle of the poles remained relatively free of basidiomycetes. Since the ends of air-seasoned poles are trimmed prior to treatment, much of this wood is removed.

Further sampling of freshly treated poles, especially near the ends, is needed to determine if these fungi survive the treatment cycles.

It is apparent that a variety of basidiomycetes colonize air-seasoning Douglas-fir and that the species composition shifts with length of air seasoning.

B. WOOD DECAY POTENTIAL OF FUNGI ISOLATED FROM AIR-SEASONING DOUGLAS-FIR POLES

Evaluation of the wood decay potential of fungi isolated from the air-seasoning poles is nearing completion. In these tests, Douglas-fir heartwood sticks were exposed to a number of isolates of each of the basidiomycete species identified in our studies. Twelve sticks exposed to each isolate were wet tested for toughness using a pendulum, while an additional fourteen sticks were oven dried and tested for breaking radius. The methodology for these tests was previously presented in more detail ('84 Ann. Rept. pg. 58-62).

The results of pendulum and breaking radius tests on 234 isolates of 26 basidomycete species, including monokaryons of 15 of these species, indicates that there is a substantial variation between isolates of some fungal species (Table 32). In last year's report we were unable to directly compare tests run at two separate times; however, a conversion factor was developed to account for the non-fungal test differences. The results suggest significant differences in strength reduction produced by individual isolates of 15 out of 34 fungal species and 12 out of 31 of the fungi in the

TABLE 32

AVERAGE IMPACT BENDING VALUES AND BREAKING RADII OF DOUGLAS-FIR HEARTWOOD WAFERS EXPOSED TO SELECTED BASIDIOMYCETES FOR 4 WEEKS IN A MALT AGAR CULTURE SYSTEM.[a]

FUNGAL SPECIES	NUMBER OF ISOLATES	AVERAGE IMPACT BENDING VALUE	% ISOLATES GREATER THAN CONTROL[b]	AVERAGE BREAKING RADIUS	% ISOLATES GREATER THAN CONTROL[b]
Androdia serialis	4	7.59 (6.656)	50 (+)	1.68 (0.460)	100 (+)
A. serialis monokaryon	1	3.71 (1.234)	0 (NA)	1.22 (0.221)	0 (NA)
Coriolus versicolor[1]	7	4.60 (5.035)	29 (-)	1.21 (0.183)	86 (-)
C. versicolor monokaryon	9	6.73 (5.145)	56 (-)	1.26 (0.270)	89 (-)
Crustoderma dryinum	7	16.84 (5.117)	86 (+)	2.18 (0.753)	100 (+)
C. dryinum monokaryon	1	6.89 (5.004)	100 (NA)	1.50 (0.365)	100 (NA)
Cystostereum pini-canadense	2	3.86 (2.092)	0 (-)	1.30 (0.152)	100 (-)
Fomitopsis cajanderi	5	11.03 (6.687)	100 (+)	1.68 (0.491)	100 (+)
F. Cajanderi monokaryon	5	7.05 (5.581)	60 (-)	1.44 (0.312)	100 (-)
Fomitopsis pinicola	2	15.22 (5.622)	100 (+)	2.30 (0.830)	100 (+)
F. pinicola monokaryon	6	6.40 (5.053)	50 (+)	1.82 (0.635)	100 (+)
Gloeophyllum saeparium	9	2.88 (5.095)	11 (+)	1.36 (0.344)	89 (-)
Haematostereum sanguinolentum	7	4.52 (5.079)	14 (-)	1.26 (0.247)	75 (-)
Heterobasidion annosum	6	1.58 (1.935)	0 (-)	1.25 (0.243)	67 (-)
Peniophora sp	17	3.68 (4.610)	12 (-)	1.26 (0.229)	82 (-)
Phanerocheate sordida	9	3.98 (5.373)	22 (-)	1.26 (0.187)	67 (NA)
Phellinus weirii	1	9.37 (5.154)	100 (NA)	1.19 (0.214)	0 (-)
Phlebia "A"	3	4.19 (2.695)	0 (-)	1.14 (0.185)	0 (-)
Phlebia "A" monokaryon	14	2.53 (3.712)	0 (-)	1.26 (0.213)	86 (NA)
Phlebia albida post:fr	1	2.87 (0.473)	0 (NA)	1.21 (0.221)	0 (NA)
P. albida monokaryon	1	4.05 (2.331)	0 (NA)	1.33 (0.151)	100 (-)
Phlebia gigantea	3	3.64 (2.618)	0 (-)	1.29 (0.215)	100 (-)
Phlebia radiata	4	4.14 (3.116)	0 (-)	1.33 (0.429)	50 (-)
P. radiata monokaryon	6	2.71 (3.119)	0 (-)	1.18 (0.178)	17 (+)
Phlebia subserialis	6	3.59 (1.812)	0 (-)	1.23 (0.212)	67 (NA)
P. subserialis monokaryon	1	4.03 (2.246)	0 (NA)	1.22 (0.221)	0 (+)
Type 16	2	3.72 (1.251)	0 (-)	1.25 (0.171)	67 (+)
Type 16 monokaryon	6	3.84 (1.955)	0 (-)	1.22 (0.187)	50 (NA)
Pleuroflammula puberula	1	4.82 (3.462)	0 (NA)	1.12 (0.158)	0 (+)
Poria carbonica	9	8.17 (5.095)	68 (+)	1.88 (0.749)	100 (+)
P. carbonica monokaryon	8	9.43 (4.542)	88 (+)	1.53 (0.510)	100 (-)
Poria cinerascens	5	2.71 (3.408)	0 (-)	1.20 (0.205)	21 (-)
P. cinerascens monokaryon	6	4.81 (3.538)	33 (-)	1.29 (0.186)	100 (+)
Poria placenta	10	19.59 (2.704)	100 (+)	2.60 (0.683)	100 (+)
P. placenta monokaryon	10	20.36 (1.728)	100 (+)	2.39 (0.692)	100 (+)
Poria xantha	6	17.31 (5.218)	100 (+)	2.48 (0.698)	100 (+)
P. xantha monokaryon	5	20.85 (2.073)	100 (+)	2.82 (0.733)	100 (-)
Schizophyllum commune	6	4.32 (1.984)	0 (-)	1.22 (0.192)	33 (-)
S. commune monokaryon	6	3.41 (1.375)	0 (-)	1.22 (0.204)	67 (-)
Sistotrema brinkmanii	6	4.07 (1.620)	0 (-)	1.23 (0.196)	50 (-)
Stereum hirsutum	10	5.73 (4.909)	30 (-)	(0.229)	30 (+)

a. Impact values represent mean of tests per isolate, while breaking radius represents mean of tests. Value in parenthesis represents standard deviation

b. Based on T test at $\alpha = .05$. Figure in parenthesis represents differences between isolates of the same species where + = significant difference at $\alpha = .05$, - = no difference and NA = not applicable.

pendulum and breaking radius test, respectively. With a few exceptions, isolates of the same fungal species that varied in their ability to increase breaking radius also varied in their effects on resistance to impact bending. The results also indicate that degradation by dikaryons was significantly different from monokaryons of the same species; however, not all dikaryons caused more damage than monokaryons and there was an almost equal split between fungi whose monokaryons caused more damage and those whose dikaryons caused more decay. The results suggest that monokaryons, which presumably initiate wood attack are capable of causing substantial degradation.

The effects of fungal exposure on resistance to impact bending and bending radius (Figure 16,) indicate that there were distinct differences in decay capability between the isolates and that these differences fall into three categories: non-decayers, moderate decayers and serious decayers. Only 4 of the 25 fungi were classified as non-decayers. One of these fungi, Schizophyllum commune, is a common inhabitant of Douglas-fir sapwood and has been reported to cause little damage. The remaining "non-decay" fungi are relatively uncommon isolates and do not appear to be important in Douglas-fir. The majority of fungi tested were capable of causing "moderate" decay in our tests. Included within this group are six of the ten species most commonly isolated from Douglas-fir in Pacific Northwest air-seasoning yards ('83 Ann. Rept., pg. 51). Two of the other commonly isolated species are Schizophyllum commune, a non-decayer, and Epicoccum nigrum, a member of the Fungi Imperfecti,

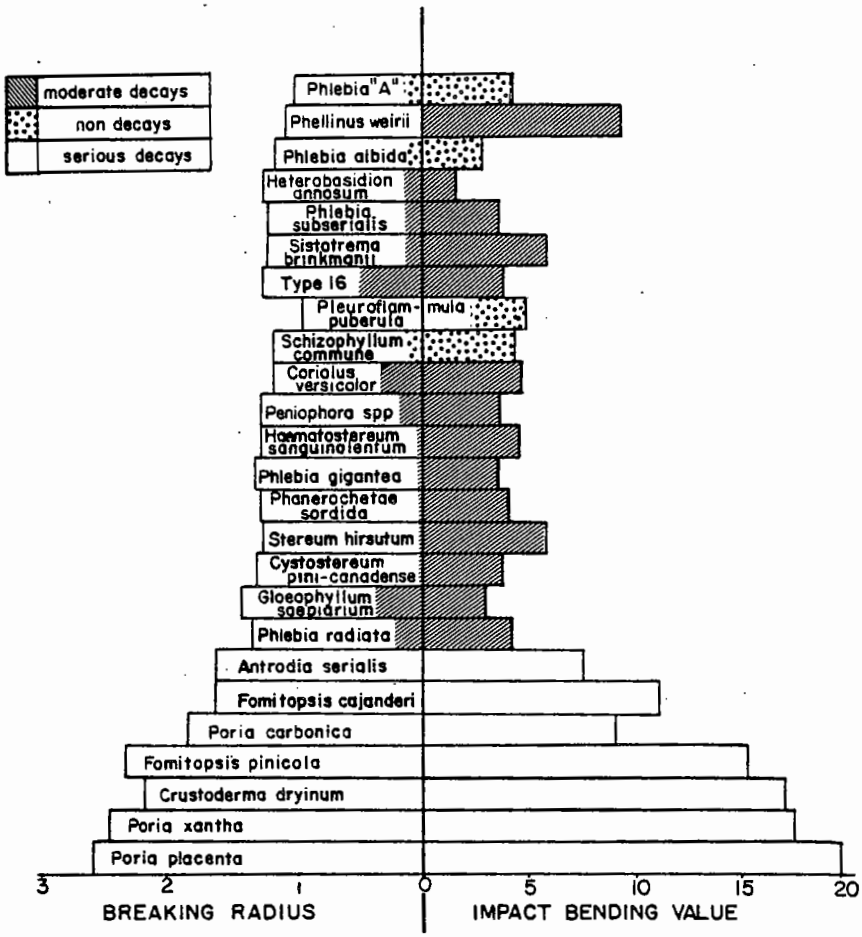


Figure 16. Comparisons between breaking radius and impact bending resistance of Douglas-fir wafers exposed to a selected group of Basidiomycetes.

whose ability to decay Douglas-fir has not been tested. The results suggest that while these fungi are causing some strength loss in air-seasoning material, the losses do not appear to be significant.

Seven of the fungi tested were classified as serious decayers of Douglas-fir. Of these fungi, only P. placenta, P. carbonica, and F. cajanderi were isolated very frequently. The former two fungi are the most commonly isolated fungi in decaying Douglas-fir utility poles in service. The presence of these fungi in air-seasoning poles suggests the potential for serious wood degradation during the air seasoning process. The third fungus, F. cajanderi, is a decayer of living trees that can continue to decay wood in service. This species was present at uniformly low levels over the course of air seasoning and may only be a problem in trees infected in the woods.

The remaining fungi, F. pinicola, P. xantha, A. serialis and C. dryinum were all present at low levels in the air seasoning wood and, although they can cause substantial decay, they do not appear with sufficient frequency to cause a serious problem.

The results indicate that, while a variety of basidiomycetes with the potential to cause wood decay are colonizing Douglas-fir during the air seasoning process, only a limited number are capable of substantially altering wood properties. However, the other fungi colonizing Douglas-fir may act to alter wood properties to allow colonization by more aggressive decay fungi. The results also illustrate the importance of testing several isolates of a given fungal species for decay capability, since isolate variation can

seriously influence the results. Similarly, monokaryons appear to play important roles in degradation by some fungal species. The ability of monokaryons to cause decay may reflect a low probability of encountering another monokaryon of the same species for dikaryon formation. These results have little impact on how the poles are handled in the yard, but may affect strategies for minimizing colonization during the air seasoning process.

C. EFFECT OF EXPOSURES TO ELEVATED TEMPERATURE ON SURVIVAL OF PORIA PLACENTA AND PORIA CARBONICA ESTABLISHED IN WOOD.

Because of the prevalence of P. placenta and P. carbonica in the air-seasoning Douglas-fir poles inspected in various yards throughout the Pacific Northwest and fears that these fungi might be surviving the treatment process, we evaluated the ability of these two fungi to withstand exposure to temperatures ranging from 49°C to 76°C for time periods up to 24 hours.

Douglas-fir heartwood blocks (2.5 x 2.5 x 10 cm), normally used for our laboratory studies of fumigant effectiveness, were inoculated by placing agar squares colonized by the test fungus (P. placenta or P. carbonica) on each transverse block face and placing a small moistened block (2.5 x 2.5 x 1.25 cm) on each end. The moistened blocks were attached to the large blocks with rubberbands and the block assemblies were incubated in a moist chamber until the fungus had thoroughly colonized the wood. The colonized blocks were cut in half to produce two 2.5 x2.5 x 5 cm blocks that were used for all temperature testing.

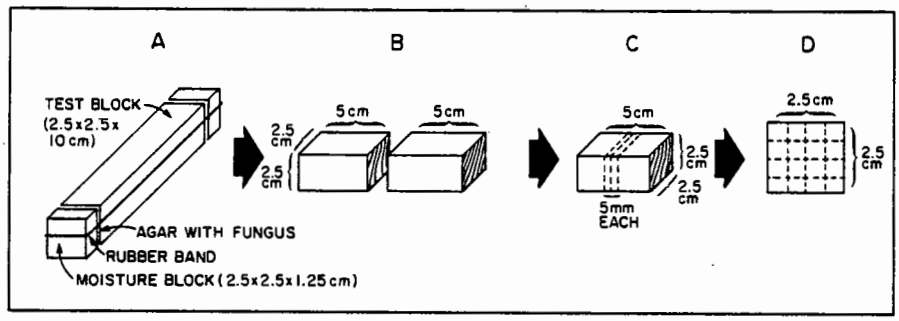


Figure 17. Schematic of blocks used for measuring effects of temperature on survival of P. carbonica and P. placenta

Temperature studies were performed by sealing blocks in plastic and immersing them in a water bath maintained at the desired temperature by use of heating coils. Thermocouples were placed in holes drilled to the center of three blocks which were used to measure internal wood temperature . All blocks were immersed in the water bath until they reached the desired temperature, which was used as the zero time point. At selected times beginning at time zero, three blocks were removed from the water bath, two 5 cm wide sections

were cut from the middle of the block and 4 squares were cut from these sections for plating on malt agar in petri dishes. The dishes were observed for evidence of fungal growth, which was used as a measure of survival following temperature exposure.

The results indicate that exposure to temperatures above 71°C, even for short periods (< 1 hour) effectively eliminated P. carbonica and P. placenta from the blocks (Table 33). Exposure to temperatures below 71°C produced more variable results, Poria carbonica survived 1.5 hours at 65.6°C but succumbed after 3 hours at 60 or 65.5°C. Below this temperature, there was little effect on fungal survival, except after exposure at 54.5°C for 24 hours. Poria placenta also was eliminated after short exposures (< 2 hours) at 65.5°C and after 6 hours at 60°C; however, even long exposures (24 hours) at 49 or 54.5°C had little effect on survival. The results suggest that heating the wood to the currently recommended 68.2°C for 75 minutes should eliminate these two fungi from wood that has been air-seasoned for long periods. These temperatures should be readily achieved in a conventional oil-borne treatment cycle. While the relatively high temperatures used with the Chemonite® (ammoniacal copper arsenate) process should also achieve a sufficient internal temperature, it is doubtful that ambient temperature treatments with CCA have any effect on survival of internal decay fungi.

We intend to follow up these laboratory results with field tests in cooperation with a local wood treating company to determine

TABLE 33

SURVIVAL OF P. CARBONICA AND P. PLACENTA IN TEMPERATURE-EXPOSED DOUGLAS-FIR HEARTWOOD BLOCKS, AS MEASURED BY CULTURING.[a]

EXPOSURE PERIOD (hours)	TEMPERATURE, °C					
	49	54.5	60	65.5	71	76.5
	%					
	Poria carbonica					
0	100	100	100	100	96	33
0.5	--	--	--	--	--	0
1.0	100	100	63	0	0	0
1.5	--	--	--	54	0	--
2	100	88	--	--	--	--
3	100	100	0	0	0	0
6	92	96	0	0	0	0
9	100	100	0	0	0	0
12	100	92	2	0	0	0
24	100	0	0	0	0	0
Control	100	100	100	100	100	100
	Poria placenta					
0	100	71	83	83	.8	0
1	92	71	62	62	46	0
2	67	87	62	62	0	0
3	100	50	21	21	0	0
6	100	50	0	0	0	0
9	92	100	0	0	0	0
12	75	29	0	0	0	0
24	33	67	0	0	0	0
Control	100	100	96	100	100	100

[a] Each value represents 24 wood chips cultured from three blocks exposed at each temperature for the specified time.

internal temperatures that develop during treatment and the effect of these temperatures on fungal survival in test poles.

D. DECAY DEVELOPMENT STUDY

This experiment was designed ("81 Ann. Rep. pg 44-45) to determine the volume of wood that becomes occupied by decay fungi during air seasoning. In this study sterile 6 foot pole sections were placed horizontally in air seasoning at 6 month intervals at four Pacific Northwest pole yards. Five pole sections were removed at 1, 2 or 3 years from each yard and returned to Corvallis for sampling. Moisture content of each section was 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 using a resistance type moisture meter. Increment cores were removed to the center at 6" intervals around the circumference 1 inch from each end and at 6 inch intervals inward. These cores were cultured for the presence of decay fungi, which were identified using keys and stock cultures. The diagram for pole exposure is reproduced here for reader convenience (Table 34).

In addition to the untreated pole sections, sections were treated by flooding with a 20% ammonium bifluoride solution and exposed at the same four locations for 0, 1, 2 or 3 years. These poles were similarly sampled and the results will be discussed with the untreated poles.

At this point, we have sampled all of the pole sections exposed at the test sites and are in the process of identifying the last sets from the 3 year air-seasoning exposures. Following these

TABLE 34

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

INSTALLATION AND REMOVAL OF POLE SECTIONS[a]

DECAY DEVELOPMENT STUDY

FIVE 6' -LONG SECTIONS HORIZONTAL

MONTHS IN TEST	1 YEAR REMOVAL	2 YEAR REMOVAL	3 YEAR REMOVAL
0	T[b] x[c]	x T	x T
3			
6	x	x	
9			
12	o[d] o	x	
15			
18	o	x	
21			
24		o o	
27			
30		o	
33			
36			o o

a = One pole section was added to each study group as a replacement if needed.
b = Treated sections.
c = Untreated sections at start of seasoning.
d = End of seasoning.

identifications, we will begin analyzing for the distribution of fungi to develop estimates of the wood volume occupied by decay fungi during air seasoning.

The preliminary results indicate that a variety of fungi, similar to those isolated from the air-seasoning Douglas-fir poles colonized the pole sections (Tables 35-38). These findings indicate that exposing sterile sections was a viable method for studying colonization. One startling result was the prevalence of decay fungi. Although the levels varied, every pole section contained decay fungi after 2 or 3 years of air-seasoning, indicating that any pole that is air-seasoned for that time period should be considered to be infested and needs to be adequately heated during the treatment process to insure that the infestation is eliminated. Similarly, wood treated at ambient temperatures should be sterilized before or after preservative treatment to eliminate these fungi.

The results also indicate that ammonium bifluoride treatments limited colonization by some decay fungi, but generally the treatments had little influence on overall degree colonization. This finding correlates with earlier studies that examined the potential of using ammonium bifluoride to prevent decay of untreated wood. This lack of control may stem from an inability of chemical to move through moist, green wood, but may also reflect the lower levels of chemical present. These concentrations may be sufficient in a treated wood product where the conventional preservative acts as a barrier, but they are not sufficient to act as the sole toxicant.

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	NONE	ABF
Unidentified Basidiomycetes	7	3	30	0	16	24	269	119	84
Unidentified suspect fungi	16	9	67	0	39	29	226	131	58
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	0	0	0
Crustoderma dryinum	0	0	0	0	0	0	1	0	0
Epicoccum nigrum	7	2	3	0	1	0	0	0	0
Fomitopsis cajanderi	0	0	0	0	0	0	0	0	1
Gloeophyllum saeparium	6	0	6	0	2	12	6	9	8
Haematostereum sanguinolentum	54	6	129	0	60	8	7	0	0
Peniophora spp.	0	0	22	0	8	0	23	4	0
Phanerochaete sordida	0	0	18	0	0	0	0	0	0
Phlebia albida	0	0	1	0	0	1	0	0	0
Poria carbonica	18	22	36	0	73	115	299	212	194
Poria carbonica monokaryon	7	2	6	0	0	1	-[b]	-	-
Poria placenta	1	9	3	0	9	23	76	26	40
Poria placenta monokaryon	4	12	0	0	0	1	-	-	-
Poria xantha	0	0	0	0	0	0	1	0	15
Schizophyllum commune	0	0	3	0	0	0	0	0	0
Sistotrema brinkmanii	2	1	4	0	6	0	13	0	1
Stereum hirsutum	2	1	8	0	1	2	68	0	9
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. Matings to determine if isolates are mono- or dikaryons are in progress. All isolates are reported as dikaryons.

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

TABLE 36
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[c]	ONE	ABF
Unidentified Basidiomycetes	22	12	35	0	90	31	101	148	39
Unidentified suspect fungi	9	14	14	0	15	30	43	77	39
Coriolus versicolor	4	2	3	0	23	1	11	17	2
Coriolus versicolor monokaryon	0	0	0	0	0	0	0	1	0
Crustoderma dryinum	1	4	0	0	0	0	0	-[b]	-
Epicoccum nigrum	2	0	2	0	0	0	0	0	0
Fomitopsis cajanderi	0	0	0	0	0	0	3	0	0
Fomitopsis cajanderi mono.	1	0	0	0	0	0	0	0	0
Gloeophyllum saeparium	11	5	8	0	41	29	46	50	5
Haematostereum sanguinolentum	15	3	1	0	38	10	2	9	1
Peniophora spp	16	3	39	0	19	0	32	13	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	67	250	186
Poria carbonica monokaryon	4	3	6	0	4	0	-	-	-
Poria placenta	22	7	10	0	17	17	11	73	28
Poria placenta monokaryon	11	15	0	0	31	0	-	-	-
Poria xantha	0	0	0	0	0	0	0	1	0
Schizophyllum commune	3	0	7	0	2	0	4	1	0
Schizophyllum commune mono.	3	1	0	0	0	0	-	-	0
Sistotrema brinkmanii	1	2	0	0	19	0	11	18	0
Stereum hirsutum	4	1	3	0	3	6	13	12	3
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. Matings to determine if isolates are mono - or dikaryons are in progress. All isolates are reported as dikaryons.

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

TABLE 37

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[c]	NONE	ABF
Unidentified Basidiomycetes	41	5	47	0	36	13	103	117	15
Unidentified suspect fungi	21	18	33	0	27	11	26	23	36
Androdia serialis	0	0	0	0	1	0	0	0	1
Coriolus versicolor	0	0	0	0	1	0	0	0	0
Epicoccum nigrum	11	1	7	0	2	0	0	0	0
Fomitopsis cajanderi	0	0	0	0	0	1	2	0	0
Gloeophyllum saeparium	0	0	1	0	1	0	0	0	1
Phanerochaete sordida	0	0	1	0	0	0	0	0	0
Peniophora spp.	0	0	100	0	61	0	49	61	1
Heterobasidion annosum	0	0	1	0	0	0	0	0	0
Poria carbonica	2	3	3	0	4	5	0	2	0
Poria carbonica monokaryon	0	0	3	0	0	3	-[b]	-	-
Poria placenta	10	12	9	0	15	3	10	-	-
Poria xantha	0	0	2	0	0	0	1	0	1
Sistotrema brinkmanii	0	0	1	0	1	0	1	0	0
Stereum hirsutum	0	1	15	0	13	1	5	6	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. Matings to determine if isolates are mono - or dikaryons are in progress. All isolates are reported as dikaryons.

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

TABLE 38

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[c]	ONE	ABF
Unidentified Basidiomycetes	26	2	6	0	31	7	57	86	48
Unidentified suspect fungi	66	27	14	0	26	34	26	61	29
Coriolus versicolor	0	0	1	0	0	0	0	0	0
Crustoderma dryinum	0	0	0	0	0	0	0	1	0
Epicoccum nigra	3	4	9	0	4	1	0	0	0
Fomitopsis cajanderi	0	0	0	0	3	0	0	0	0
Gloeophyllum saeparium	10	0	11	0	6	0	12	19	4
Haematostereum sanguinolentum	1	0	2	0	7	0	0	0	0
Peniophora spp	0	0	46	0	51	1	45	24	1
Phlebia radiata	0	0	0	0	1	0	0	0	0
Poria carbonica	60	15	51	0	74	38	85	243	82
Poria carbonica monokaryon	0	0	5	0	0	1	-[b]	-	-
Poria placenta	56	15	16	0	53	42	21	116	27
Poria xantha	0	0	1	0	2	0	0	1	1
Schizophyllum commune	0	0	1	0	0	0	0	0	0
Sistotrema brinkmanii	1	1	0	0	9	1	1	9	1
Stereum hirsutum	4	0	21	0	9	0	18	12	4
Phanerochaete sordida	0	0	1	0	5	0	0	0	0
Heterobasidion annosum	0	0	0	0	0	1	0	0	0
Type 16	0	0	0	0	0	0	1	0	0
No. of cores with decay fungi	205	61	165	0	228	110	222	167	375
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. Matings to determine if isolates are mono - or dikaryons all in progress. All isolates are reported as dikaryons.

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

The other significant preliminary finding was the prevalence of P. carbonica, the principal decayer of Douglas-fir in service. This species seemed to be present in abundance at the three northern locations but not the southern site. This difference may reflect the drier conditions at the southern site. Poles returned from this site were generally more deeply checked than those from the other locations, indicating drier poles. We have not yet analyzed the moisture content data from these poles.

Over the next year we plan to complete a more detailed analysis of the data to develop estimates of degree of colonization. These results should prove useful for those who depend on air-seasoning to bring poles to lower moisture contents prior to preservative treatment.

OBJECTIVE VI

DETERMINE THE EXTENT OF AND POTENTIAL FOR EXTERNAL DECAY OF PRESERVATIVE TREATED DOUGLAS-FIR IN GROUND CONTACT.

A. EVALUATE THE FUNGAL ASSOCIATES AND CONDITION OF IN-SERVICE INORGANIC ARSENICAL TREAT DOUGLAS-FIR.

While there is little evidence of significant surface decay in Douglas-fir treated with oil-borne preservatives (creosote and pentachlorophenol), surface damage has been found on Cellon treated poles and might also be a problem on poles treated with waterborne preservatives such as CCA or ACA. Since the status of penta is questionable and many utilities refuse to use creosote-treated wood, the only currently acceptable alternatives for protecting wood poles are waterborne chemicals. In other regions of the world, there have been reports of surface decay by soft rot fungi on wood treated with these chemicals.

In order to assess the probability of surface decay developing on waterborne ACA or CCA treated Douglas-fir, we solicited utilities for locations of older lines treated with these chemicals. Unfortunately, few utilities in our area purchased poles treated with these chemicals and we found only one older Chemonite treated line. These poles, treated in 1946, were located in Portland, Oregon. The poles were visually examined for evidence of deterioration below ground and the worst pole surface was sampled. Two 5/8" diameter by 2" long plugs were removed from adjacent locations at three equidistant points 6 inches below the groundline. These plugs were placed in sterile glass tubes and returned to the laboratory.

One core from each location was cut into three equal sections and 9 small chips were removed from each section and placed on malt agar in petri dishes. These dishes were observed for evidence of fungal growth, which was immediately subcultured for later identification. The plated chips were observed for one month to insure that any fungi present in the wood had a chance to grow. The other core taken from each location was used to prepare anatomical sections for detailed microscopic study. These sections were observed for evidence of conventional deterioration and soft rot damage. Sections (30μ thick) were cut sequentially from the outer surface and stained using a safranin O/picroaniline blue series.

The poles, which represent one of the oldest ACA lines in this country, were in remarkably good shape; although some had been remedially treated in 1968 with Osmoplastic or Vapam. The cores from all poles exhibited little evidence of surface softening typical of soft rot damage in other wood species, although three of the twenty poles had visible internal decay with a minimal outer shell (2"). The remaining poles did not have decay in this zone.

Culturing of wood chips from these poles revealed the presence of a diverse microflora, with virtually every chip yielding some evidence of fungal colonization. At present we have grouped these fungi into some 50 distinct isolates and are in the process of identifying these groups in cooperation with Dr. C. J. K. Wang of the SUNY College of Environmental Science and Forestry at Syracuse. Several of the fungi

are new or rare species. We had not anticipated the large number of fungal types and are presently sorting through the results. Oddly, only 2 cores revealed the presence of the basidiomycetes that are typically associated with brown or white rot, suggesting that the ACA treatments provide highly effective long term protection against these fungi.

Microscopic examination of the first six sections cut from the outer zone of each core revealed the presence of fungal hyphae in 95% of the cores. Although it is not possible to distinguish between fungi that were present at the time of preservative treatment and those that later colonized the wood, cultural results suggest that most of the hyphae were the result of subsequent colonization. This finding indicates that a variety of fungi are capable of invading ACA treated wood, although their effects on wood properties was less clear. Hyphae in many cores were associated with a variety of wood damage; however, cell wall erosion was most common, being found in 63% of the cores examined. Erosion is commonly associated with both conventional basidiomycete decayers and soft rot fungi. In addition to the erosion, 24% of the cores contained evidence of soft rot cavities. Soft rot has been reported on inorganic salt treated hardwoods, but has not been previously reported on Douglas-fir treated with these chemicals. While soft rot cavities were present, it is important to note that these cavities had only penetrated in the first 5-6 tracheids from the surface after 38 years of service. This rate of damage is not likely to seriously affect pole strength, but does indicate that soft rot may be a hazard in areas with high nutrient

levels that accelerate attack by these fungi. These conditions are common in agricultural soils and seem to stimulate soft rot attack.

We will continue to examine older, inorganic salt treated lines, as they are identified, to provide data on the long term performance of these chemicals. At present, it appears that Chemonite provides excellent external protection from conventional brown and white rot fungi as well as soft rot fungi.

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

This past summer we examined the non-basidiomycete flora present in our Douglas-fir test poles that have been treated with fumigants. These tests were performed by removing extra increment cores at the same time we performed our normal field sampling. The cores were visually examined for evidence of deterioration and small chips were cut from specific zones of each increment core, plated onto malt agar, and observed for evidence of fungal growth, which was immediately subcultured for later identification and characterization. Using these procedures, we examined the following treatments and time periods after initial fumigant treatment:

CHEMICAL TREATMENT	YEARS AFTER TREATMENT
Vapam	9, 15
Vorlex	7, 9, 15
Chloropicrin	9, 15
Allyl alcohol	7
Methylisothiocyanate (100%)	1, 7
(20%)	7
Control	--

These procedures resulted in the isolation of 18 distinct taxa or tentative species from the poles (Table 39). The relative frequency of the various isolates indicates that fumigation has markedly altered the characteristic microflora in the wood and that different fumigants create slightly different microfloras. Even the practice of wrapping the exterior of Vapam treated poles, which has had little effect on basidiomycetes, has affected the species of Fungi Imperfecti isolated.

Generally, Scytalidium lignicola and Scytalidium sp. were the most commonly isolated organisms. At one time, a Scytalidium sp. was proposed as a potential biological control since it produces a fungitoxic compound, scytalidin. While this control method did not perform well in the field, it might have some potential in fumigant treated poles where competition is much lower. We hope to study this idea under a separate USDA-funded proposal.

Poles treated only 7 years ago had a sharply reduced microflora compared to similar control poles and it appears that the residual fumigant concentrations continue to inhibit colonization. Cores removed from these poles still emit odors characteristic of the various fumigants.

Since the effect these fungi have on fumigant effectiveness remains uncertain, we have evaluated several characteristics of individual isolates. A number of non-basidiomycetes cause a type of wood decay called soft rot. We have evaluated soft rot capability of half of the isolates in a standard vermiculite burial test and found that several of the isolates were capable of causing substantial

weight losses over a 3 month period on pine sapwood. While these losses do not transfer directly to the more decay resistant Douglas-fir heartwood, they suggest that the fungi present in the fumigant treated poles are potential wood destroyers. One of the more destructive isolates was Scytalidium lignicola, which also causes soft rot of southern pine.

As this study progresses, we plan to evaluate the ability of these fungi to inhibit growth of decay fungi and the ability of these fungi to grow on fumigant treated wood. This information is particularly important with regard to the effects these fungi may have on fumigant longevity and retreatments.

TABLE 39

IDENTITY AND RELATIVE FREQUENCY OF FUNGI ISOLATED FROM FUMIGANT AND NON-FUMIGANT-TREATED DOUGLAS-FIR POLES 7 OR 15 YEARS AFTER FUMIGATION.

FUNGAL SPECIES	Wt. Loss in SR (%)[a]	VAPAM (UW)[b] 15yr	VAPAM (W)[b] 15yr	VORLEX (W) 7yr	VORLEX (W) 15yr	CHLORO-PICRIN (W) 15yr	CHLORO-PICRIN (W) 7yr	CONTROL 15yr	CONTROL MIT 100% 7yr	CONTROL MIT (20%) 7yr
Scytalidium lignicola	3.42	9.0	16.0	0.5	6.0	3.0	4.0	11.0	-	-
Scytalidium sp A	2.59	6.0	1.0	8.0	-	7.0	3.0	10.0	-	-
Pennicilium italicum	-	0.5	2.0	-	0.5	1.0	-	1.5	-	-
Penicillium sp. A	0.0	2.0	0.5	-	0.2	0.8	10.0	-	-	-
Pennicilium sp. B	-	-	-	-	1.0	3.0	-	0.7	-	-
Penicillium sp. C	-	-	-	-	-	3.5	-	-	-	-
Trichoderma viride	2.70	-	2.0	0.5	-	1.0	1.0	2.0	-	-
Trichoderma sp.	-	-	-	-	-	-	-	1.0	-	-
Oidiodendron sp.	2.68	-	8.0	-	-	-	-	-	-	-
Graphium sp. B.	0.0		-	1.5	-	-	-	-	-	-
Cladosporium sp.	0.0	-	1.0	1.0	-	-	-	1.5	-	-
Aureobasidium pullulans	-	-	-	-	1.0	-	-	2.0	-	-
Unknown X3	-	-	-	-	-	-	-	2.0	-	-
Scytalidium sp. B-	-	-	0.5	-	-	-	-	-	-	-
Mycelia sterilia	-	-	-	-	-	-	-	1.0	-	-
Unknown X6	-	-	1.5	-	0.5	-	-	-	-	-
Scytalidium thermophillum	-	-	1.0	-	-	-	-	-	-	-
Unknown X8	-	1.0	-	-	-	-	-	-	-	-

a. SR = soft rot as measured in a three month vermiculite burial test. - in this column denotes isolated not yet tested for soft rot capability.

b. W = wrapped at time of treatment; UW = unwrapped