CONTROLLING DECAY FUNGI COLONIZING AIR-SEASONED DOUGLAS-FIR HEARTWOOD WITH HIGH TEMPERATURE EXPOSURES

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INTRODUCTION

Douglas-fir is a preferred species for high-voltage transmission lines because of its large size and high strength. However, the moderately durable heartwood of this species will decay if not handled properly (Graham 1983). Deep incising, through-drilling of the groundline zone, kerfing, predrilling for cross arms or hardware, and long heating cycles have effectively minimized decay problems, and the low levels of internal decay that continue to occur (Graham 1983) can be successfully controlled by applying volatile fungicides (fumigants) to the wood in service (Helsing et al. 1984).

Although long heating cycles eliminate established decay fungi, rising energy costs favor increased air-seasoning times and shortened heating cycles. Yet longer air-seasoning times increase the probability that decay fungi will enter wood during seasoning and cause some damage, and shorter heating cycles increase the risk that fungi in the wood will survive the treatment process. Such pretreatment decay is prevalent in southern pine poles, which have a large band of decay-susceptible sapwood (Lindgren 1952; Toole 1973). Even though conventional high-temperature treating cycles kill fungi in wood, air seasoning for long periods can cause significant strength loss. Thus, poles with internal decay often meet treatment specifications but may fail during installation or within the first few service years of service.

A previous summary paper on pretreatment decay assumed that problems in Douglas-fir would be similar to those in southern pine (Taylor 1980). Although studies have been conducted on the heating properties of wood poles (MacLean 1934, 1935, 1946; Graham and Womack 1972) and fungal survival at elevated temperatures (Chidester 1937, 1939), there have been no reports on survival of decay fungi in Douglas-fir. Because of concern among treaters and users, workers at the Forest Research Laboratory initiated a study

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to determine the extent of fungal colonization during air seasoning, the effect these fungi have on wood properties, and the ability of these fungi to survive the pressure-treatment process. This study is still underway, and the results reported herein summarize the progress to date.

MATERIALS AND METHODS

Seasoning Study

The extent of fungal colonization during air seasoning was investigated by sampling 1,540 Douglas-fir poles from 16 pole yards throughout the Pacific Northwest as well as from 6 sites where freshly cut poles were still in the woods (Przybylowicz 1985). Poles were grouped into categories based on length of air seasoning; because pole owners often lacked accurate records of cutting dates, categories were 6-month age classes. Fourteen 15-cm-long cores were removed from seven sites along the length of each pole and then returned to the Forest Research Lab, where they were flamed to kill any surface contaminants and embedded in a malt agar for culturing. In total, 21,222 cores were tested by these procedures. Cultures were observed for fungal growth, which was then microscopically examined for characteristics of basidiomycetes, the major decay fungi. These fungi were identified with keys (Nobels 1965; Stalpers 1978) and matings or were sent to the U.S. Forest Products Laboratory (Madison, WI) for verification.

Temperature Study

The air-seasoning study showed that six fungi--Haematostereum sanguinolentum, Peniophora spp., Sistotrema brinkmanii, Poria carbonica, Poria placenta, and Epicoccum nigrum--accounted for 71% of the total number of isolates. Two of these fungi, Poria carbonica and Poria placenta, are the most commonly isolated decayers of Douglas-fir in service (Eslyn 1970; Graham and Corden 1980; Zabel et al. 1980); their isolation from poles during the first 10 years of service suggested that decay fungi might survive the treatment process. Although temperature sensitivity of fungi has been studied (Chidester 1937, 1939; Miric and Willeitner 1984), none of the fungi typical of air-seasoned Douglas-fir have been tested. Because P. carbonica and P. placenta can cause significant strength loss, their ability to survive at elevated temperature was investigated.

Douglas-fir heartwood blocks, 2.5 x 2.5 x 10 cm long, were sterilized for 45 minutes at 121°C, coated on the sides with paraffin wax to retard moisture loss during incubation, and inoculated on each transverse face with an agar square containing either P. carbonica or P. placenta. The inoculum was held in place by water-soaked blocks, 2.5 x 2.5 x 1.25 cm, secured with a rubberband (Figure 1A). The inoculated samples were then placed in a humid chamber and incubated for at least 6 weeks at room temperature (21°C) to insure complete colonization.

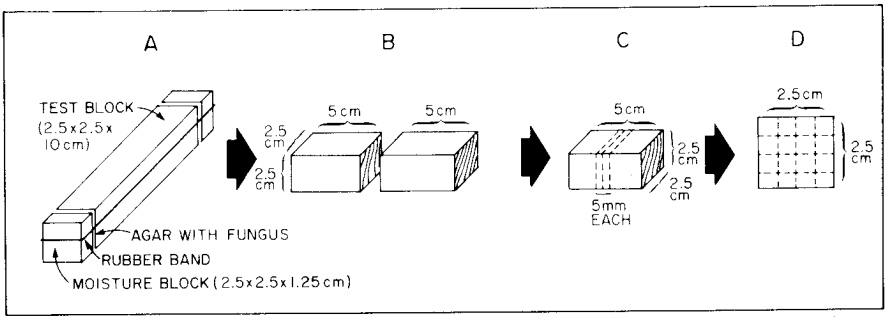

Figure 1. Test blocks used for temperature studies: (A) Apparatus assembled following inoculation with the test fungus; (B) block cut in half for temperature study; (C) location of sampling zone for determining fungal survival; (D) cross-sectional view of sample wafer showing cutting pattern.

Following incubation, the wax was removed and the heartwood blocks were cut in half (Figure 1B). For each temperature tested, a set of three blocks was drilled and a copper constantan thermocouple inserted in the hole. These blocks were used to measure internal wood temperature during immersion. All blocks were sealed in plastic bags to retard moisture loss and then immersed in a constant-temperature water bath. Internal wood temperature was monitored, and three blocks were removed at selected times after internal temperature reached targets of 49.0, 54.5, 60, 65.5, 71, and 76.5°C. Three blocks maintained at room temperature (21°C) were used as a basis for determining initial level of fungal colonization.

Following temperature exposure, the plastic was removed from the blocks, and two 5-mm-thick cross section wafers were cut from the middle of each block (Figure 1C). Each wafer was cut into 16 squares (Figure 1D), and the four inner squares were placed onto malt agar medium. The plates were monitored for evidence of fungal growth, which was examined for characteristics of the test fungi.

RESULTS AND DISCUSSION

Seasoning Study

The culturing of cores removed from poles that were freshly cut and those air-seasoned for 25 or more months in a seasoning yard showed that a wide variety of decay fungi colonized Douglas-fir poles during air seasoning. The following 30 species (all basidiomycetes except *Epicoccum nigrum*) were isolated and are listed here in order of isolation frequency:

Haematostereum sanguinolentum
Peniophora spp.
Sistotrema brinkmanii
Poria carbonica
Epicoccum nigrum
Fomitopsis cajanderi
Cystostereum pini-canadense
Phlebia "A" monokaryon
Schizophyllum commune monokaryon
Phlebia radiata monokaryon
Poria cinerascens monokaryon

Coriolus versicolor
Phanerachaete sordida
Stereum hirsutum
Poria placenta monokaryon
Poria placenta
Gloeophyllum saeparium
Coriolus versicolor monokaryon
Schizophyllum commune
Poria carbonica monokaryon
Fomitopsis pinicola monokaryon
Heterobasidion annosum
Fomitopsis pinicola
Phlebia gigantea
Poria xantha
Poria cinerascens
Phlebia albida monokaryon
Crustoderma dryinum
Poria xantha monokaryon
Fomitopsis cajanderi monokaryon

Four species--H. sanguinolentum, Peniophora spp., P. carbonica, and P. placenta--were the most prevalent, although infrequent in freshly cut and unpeeled poles, and the frequency of isolating them increased as seasoning time lengthened. Haematostereum sanguinolentum and Peniophora spp. were found primarily in the outer portions of the poles, reflecting their preference for sapwood; however, the more external location of these fungi suggests that conventional treating cycles and wood preservatives themselves would inactivate the fungi, preventing further attack. Poria carbonica and P. placenta were isolated most frequently from the inner portions of the poles, suggesting that these fungi may survive inadequate treatment cycles. Epicoccum nigrum, the one non-basidiomycete, was the fifth most frequently isolated fungus. A member of the Fungi Imperfecti, E. nigrum causes a soft rot in southern pine (Zabel et al. 1980); however, its effect on Douglas-fir is unknown.

Temperature Study

Culturing of wood from the three blocks maintained at room temperature (control) demonstrated that P. placenta and P. carbonica had thoroughly colonized the test blocks. Readings from the thermocouples indicated that the blocks took approximately 20 minutes to reach the desired internal temperature, and this time was used as time zero for all tests.

Temperatures over 65.5°C for even short periods (>90 minutes) generally killed P. carbonica in test blocks, although roughly one half of the pieces cultured from blocks exposed for 1.5 hours at 65.5°C produced growth (Table 1). Exposures for 0.5 hour at 76.5°C and 1 hour at 71°C completely eliminated the fungus, whereas momentary exposures at 76.5°C significantly reduced its survival. Exposure at 54.5°C had little effect on survival after 12 hours, but completely eliminated the fungus after 24 hours. These results are similar to those reported by Chidester (1937), who suggested that temperatures below 65.5°C could not completely eliminate decay fungi in wood and suggested 76 minutes at 68.2°C as ideal for sterilizing wood. Our findings suggest that 3 hours at temperatures over 60°C will eliminate P. carbonica from wood. This temperature should be readily reached in a 10-hour treatment cycle at 93°C (MacLean 1946; Graham and Womack 1972).

Exposure of P. placenta-colonized blocks to temperatures ranging from 49 to 76.5°C indicated that this fungus was slightly less sensitive to high temperature than P. carbonica (Table 1). Although P. placenta was capable of surviving long exposure at 49 and 54.5°C, its survival was sharply reduced at 54.5°C, and the

fungus was virtually eliminated by exposures longer than 3 hours at 60°C. Exposure at temperatures above 60°C, even for short periods, eliminated the fungus. These results suggest that exposure to temperatures of 60°C or greater for at least 6 hours or 65.5°C for 3 hours will eliminate P. placenta established in the wood, again supporting Chidester's (1937) temperature and time recommendations.

Table 1. Survival of P. carbonica and P. placenta in temperature-exposed Douglas-fir heartwood blocks, as measured by culturing+

Exposure Period (hours)	Temperature, °C					
	49	54.5	60	65.5	71	76.5
	%					
	P. 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	0	0	0	0
24	100	0	0	0	0	0
Control	100	100	100	100	100	100
	P. placenta					
0	100	71	83	83	8	0
1	92	71	62	46	0	0
2	67	87	62	0	0	0
3	100	50	21	0	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

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

IMPLICATIONS

Although numerous basidiomycetes colonize Douglas-fir during air seasoning, two of the more important fungi, P. carbonica and P. placenta, can be killed by exposure to temperatures above 65.5°C. This temperature can be attained in 12-inch diameter material by conventional oil-borne treatment cycles greater than 8 hours (MacLean 1946). The applicability of our results to waterborne treatments is less clear. Although treatments with chromated copper arsenate (CCA) at ambient temperatures have

little effect on internal fungal flora, treatments with ammoniacal copper arsenate (ACA) should result in sufficient heating to control decay fungi established in the wood and minimize damage (Dost 1984). Since excessively high moisture contents or wood defects can alter heat transfer in treatment cylinders, the exposure of air-seasoned material to heating periods longer than the minimum would be desirable. However, kiln-drying, recommended by one author (Taylor 1985), seems unnecessary when treating with oil-borne penta and creosote or waterborne ACA because internal wood temperatures reached with these processes should be sufficient to eliminate decay fungi.

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