DECAY EVALUATION OF THE PENETRATION OF LOSP INTO *Eucalyptus regnans* HEARTWOOD

L.J. Cookson and E.F. Dougal

CSIRO, Division of Forest Products, Private Bag 10, Rosebank MDC, Clayton, Victoria 3169.
Forestry Section, The University of Melbourne, Parkville, Victoria 3052.

ABSTRACT

The penetration of a light organic solvent preservative into *Eucalyptus regnans* F. Muell. heartwood was examined using a fungal bioassay. Boards two metres long were treated, blocks cut from them, and the freshly cut endgrain sealed with epoxy. Some blocks had two millimetres of surface wood (treated envelope) shaved off. Most unshaved blocks resisted decay. However, almost half of the shaved blocks had decay, indicating limited penetration of preservative past the two mm depth. Treated shaved blocks had less decay than untreated shaved blocks. There was little difference in performance between blocks when they were cut from different positions along the original two metre board.

INTRODUCTION

The locally grown hardwood *Eucalyptus regnans* F. Muell. is being assessed for its use in window joinery as a replacement for the imported timbers meranti and western red cedar. Earlier work with 300 mm long blocks, showed that *E. regnans* heartwood could absorb light organic solvent (white spirit), using a range of different treatment schedules (Ladu *et al.*, in prep). For the pressure treatments, mean retentions ranging from 21.1 kg/m^3 (27.0 l/m^3) to 52.8 kg/m^3 (67.7 l/m^3) for this size of timber were achieved. In other countries and with other timbers, retentions of this order are considered acceptable for LOSP treated commodities (Taylor, 1980; Vinden, 1986; Smith and Orsler, 1992). However, the penetration pattern obtained with *E. regnans* was difficult to interpret. Penetration of the organic solvent was mainly through the end grain. Lateral penetration was shallow and patchy, as revealed by dye carried in the solvent. It was not clear if the lateral penetration would be sufficient to protect long lengths of timber from decay, especially for sections some distance away from the endgrain.

This paper describes the treatment of two metre long boards of *E. regnans* heartwood, with a commercial LOSP. Blocks were cut from the boards, and subjected to decay using a modified planeing test (Willeitner and Gersonde, 1981). Some blocks had the two millimetre outer envelope shaved off, to determine if there was sufficient penetration beyond this depth to prevent decay. Treatment was by a Lowry schedule, at a pressure higher than normally used by the LOSP industry, but which would establish the principle of whether regrowth *E. regnans* heartwood was capable of being penetrated at depth in the side grain.

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MATERIALS AND METHODS

The *E. regnans* boards used in this test came from the same 1939 regrowth material from Toolangi, Victoria. The boards were dressed to dimensions 30 x 80 x 2000 mm. Thirty-five boards were treated, of which 5 contained sapwood and heartwood, and 30 contained only heartwood. A further 3 boards were left untreated. The boards were taken from 8 different trees. The sawing pattern for each board is listed in Table 1. One end of each board was sealed with 4 coats of epoxy resin. The preservative used was Protim 80 WR, which had a specific gravity of 0.80, and contained by weight, 1.77% pentachlorophenol, 0.44% TBTO and 0.40% aldrin, plus wax and resin, dissolved in white spirit.

For treatment, boards were flooded with preservative, an air pressure of 1380 kPa (200 psi) applied for 1 hour, preservative drained away, and a vacuum of -80 kPa pulled for 30 minutes. Boards were then weighed to determine preservative uptake. The boards were left to air dry for 4 months. Nine heartwood boards representing a range of retentions were collected, as well as one sapwood-heartwood board, and blocks cut from them for penetration and decay studies.

Penetration study
Thirty mm long blocks were cut from various positions in the boards. Not all of the white spirit had evaporated from all boards after 4 months, in which case there was rapid bleeding of preservative over the freshly cut endgrain. Therefore, the cut blocks were further dried in an oven for 2 days at 50°C. One endgrain face on each block (the face, 150, 275, 500, 750, 1000, 1250, 1500, 1750, 1975 mm from the uncoated end) was mechanically sanded to expose new endgrain, and there was no bleeding. The cupric acetate colorimetric test for pentachlorophenol, described in AS 1605-1974, was then applied. The non-ionic surfactant used was polyethyleneglycol 3000. Freshly mixed indicator solution was brushed on to the sanded surface of each block. Four further coats of indicator solution were applied after the previous coat had air dried.

Decay study
(i) Block designations
All blocks cut from the boards for the laboratory decay study were 30 mm long. Unlike blocks for the penetration study, these blocks were not oven dried or sanded. From each of the 10 selected boards were cut:
10 blocks for decay.
9 blocks for decay, after they had the outer 2 mm perimeter of the treated envelope shaved off (the original radial and tangential faces of the boards).
4 blocks for sterile controls (to determine if any mass loss was due to factors other than decay).
4 blocks for sterile controls, which had the outer 2 mm perimeter of the treated envelope shaved off.

Tables 2 and 3 give the distance from the uncoated end of the board, from which the blocks for decay were cut.

Three untreated boards were also cut into 30 mm long blocks, so that untreated controls could be included in the decay test. Half of the untreated blocks had the outer 2 mm shaved from each radial and tangential face.

(ii) Artificial weathering and block preparation
All blocks were artificially weathered. They were vacuum impregnated in jars with tap water, and leached in three times their volume of water, on a shaking water bath for five days at 35°C. Water in the jars was changed daily. Blocks were removed from the jars, drained overnight, and placed in vacuum ovens at 40°C for 5 days. Blocks were reconditioned to 12% moisture content, and weighed. Both endgrain faces on each block were then sealed with 3 coats of epoxy resin. Blocks were again weighed (at 12% MC), to determine the mass of epoxy. Prior to placing them into the decay or sterile tray chambers, blocks were sterilised by gamma-irradiation.

(iii) Bioassay method
The decay chambers were stainless steel trays, 320 x 250 x 105 mm deep. The decay fungus was the white-rot *Perenniporia tephropora* (Mont.) Ryv., DFP strain number 7904. Test tubes were laid on the floor of each tray, and molten malt agar poured into the trays to a depth 2-3 mm short of the height of the side-on test tubes. Each tray was then placed in an autoclave bag, and the whole autoclave sterilised. Some trays were left sterile, to house the sterile control blocks. The remainder were inoculated with fungus, and after 2 weeks of growth, a sterile plastic mesh mat was laid on the tubes, and the blocks planted. Blocks were held above the agar (preventing water logging) by the test tubes. This method was similar to that described by Thornton (1979), although the blocks needed to be nearer to the agar due to shorter mycelial growth height of the white-rot compared to *Serpula lacrymans*.

For each board, all blocks for decay (shaved and unshaved) were randomised between and within 2 trays, along with 6 untreated control blocks (3 shaved, 3 unshaved). Also for each board, all sterile control blocks (shaved and unshaved) were randomly placed within the one sterile tray, along with 6 sterile untreated control blocks.

Trays were placed in an incubation room at 25°C for 16 weeks. Blocks were then removed from the trays, weighed to determine moisture content, conditioned back to 12% MC, and weighed again to determine the mass of wood (excluding epoxy mass). The mass loss for each block was then determined, and adjusted to account for the mass change found in the sterile controls.

Besides mass loss, fungal activity was assessed in another way. Blocks were split with the grain across their shortest width, and examined for the presence of whitened wood. The depth of white-rotted wood, as seen from the top and bottom uncoated faces of the blocks, was measured in millimetres.

RESULTS

Treatment results

The mean retention of LOSP for the 30 boards containing just heartwood, was 63.9 kg/m^3 (standard deviation, 24.7), with a range of 25.6-138.3 kg/m^3 (Table 1). Results were similar for the five sapwood-heartwood boards, with a mean retention of 66.5 kg/m^3 (s.d. 37.2), and a range of 37.5-126.9 kg/^{3}.

The distribution of pentachlorophenol was examined using the cupric acetate colorimetric test. The colour reaction worked best on those blocks from boards with higher retentions, producing red areas due to the formation of copper pentachlorophenate. The reaction was absent or unclear, in most blocks from boards with lower retentions. For those blocks that showed a clear reaction, penetration was patchy and shallow. Penetration was mainly from the endgrain. Colour diminished with distance from the uncoated end. In several boards, colour appeared to follow the endgrain pathway for the full two metre length from the uncoated end to the coated end. Most boards had fine microscopic checks following rays, more visible after fine sanding. End grain penetration may have followed both checks, and vessels that lack tyloses. The lateral penetration or treatment envelope was mostly only 0.5-1.0 mm deep.

Decay results

Mass loss data

In the decay test, untreated unshaved blocks, had a mean mass loss of 8.1% (s.d. 4.3), with a range of 0.0-19.6%. The unshaved treated blocks with treatment envelope intact, from different board positions, had a mean mass loss ranging from 0.0-0.8% (Table 2). Only one out of 100 blocks had a mass loss of more than 1.5%, and its mass loss was 3.8%. This block came from nearest the coated end, from the board with the second highest preservative retention.

The shaved untreated blocks had a mean mass loss of 8.3% (s.d. 4.3), with a range of 0.8-14.4% (Table 3). This was similar to the unshaved blocks. However, the shaved treated blocks had significantly more decay than unshaved treated blocks, with means ranging from 1.6-4.0% (Table 3). Forty out of 90 blocks had mass losses above 3.0%, indicating that lateral penetration was often not sufficient beyond 2 mm depth to prevent decay. However, the means were lower than the mean mass loss for untreated blocks.

There was no clear trend of mass loss in relation to distance from the uncoated end grain in the original boards (Tables 2 & 3).

Depth of white-rotted wood

The depth of white-rotted wood found in blocks, was also useful in evaluating the effectiveness of the treatment. Splitting blocks revealed that decay was mainly localised to the bottom face nearest the agar, rather than being uniform throughout the block. There was a clear delineation between a bottom layer of white-rotted wood, and sound wood. This layer followed the grain, suggesting that decay could quickly colonise by following vessels, but was much slower moving through rays or through cell walls. Some blocks, mainly those that were untreated, were also attacked from the top and side faces.

The untreated unshaved blocks, had a mean decay depth of 12.3 mm (s.d. 5.7 mm), with a range of 2-19 mm (Table 4). This mean amounted to 41.0% of the cross-section being colonised and at least partially decayed by fungus (12.3 divided by 30 mm). In comparison, the treated unshaved blocks, with treatment envelope intact, had much less decay. For these blocks, the mean depth of white-rotted wood was only 0.45 mm, or 1.5% of the cross-section. The range was 0-7 mm. Eleven out of 100 blocks had white-rotted

wood of more than 1 mm depth, and these were all from blocks cut from boards with the lower retentions (Table 4).

The shaved untreated blocks had a mean decay depth of 10.7 mm (s.d. 4.9 mm), with a range of 2-20 mm (Table 5). This mean amounted to 41.1% of the cross-section being colonised and at least partially decayed by fungus (10.7 divided by 26 mm). This was similar to the unshaved blocks. However, the shaved treated blocks contained significantly more white-rotted wood than unshaved treated blocks. The mean depth of white-rotted wood was 4.2 mm, or 16.3% of the cross-section. The range was 0-19 mm. Sixty-nine out of 90 blocks had white-rotted wood of more than 1 mm depth (Table 5). The mean decay depth was still lower than for the untreated blocks. There was a tendency for shaved blocks from boards with high preservative retentions, to have less decayed wood. The 27 blocks from the three boards with lowest retentions, had a mean decay depth of 5.8 mm. The 27 blocks from the three boards with highest retentions, had a mean decay depth of 2.6 mm.

For both the shaved and unshaved treated blocks, there was no clear trend of decay depth in relation to distance from the uncoated end grain in the original boards (Tables 4 & 5).

DISCUSSION

P. tephropora DFP 7904 caused a mean mass loss of only 8% in the untreated *E. regnans* control blocks. This strain is one of our most active white-rotters in laboratory tests. It is often the most preservative tolerant species when tested against treated eucalypt (Cookson and Greaves, 1986; Johnson *et al.*, in prep). Perhaps the main reason for the low mass loss, was that blocks were end grain sealed on their transverse faces. This probably slowed the rate at which blocks became wet. However, the wood had reached fibre saturation point at least by the end of the test. The sterile controls had moisture contents of about 27%. This should be enough for fungi to begin decaying wood, after which the moisture content would increase. Decayed untreated blocks had moisture contents of about 38%. End grain sealing, also appeared to slow the rate of penetration of the fungus through the wood. There were fewer exposed vessels for it to move rapidly through. Additionally, the blocks were larger than often used in other bioassays. Nurmi (1988) end sealed blocks cut from spruce (*Picea abies*) and pine (*Pinus sylvestris*), and obtained lower than usual mass losses with certain brown-rot fungi. End-sealing was thought to slow the penetration of fungi through these softwoods.

Although mass losses were low, they were sufficient to allow a comparison between shaved and unshaved blocks. Also, the depth of fungal colonisation was often more extensive than suggested by the mass loss figures. Presumably, much of this bleached wood was still in the process of being decayed. A mean of 41% of the wood in untreated controls was whitened or fungal colonised, compared to the mean mass loss of 8%.

For those boards where the PCP indicator produced a red colour reaction, a trend was seen where colour reduced with greater distance from the uncoated end grain. However, this trend was not born out in the decay test. The level of fungal activity was fairly constant in blocks cut from over the length of the board.

LOSP treatment was able to protect most of the unshaved *E. regnans* heartwood blocks from decay. In fungal bioassays, mass loss below 3% is usually considered to be insignificant. Only one of the treated unshaved blocks had more than 3% mass loss. The treatment also prevented fungal colonisation in most blocks, with only 11 of the 100 unshaved blocks affected at depth more than one millimetre. Those blocks with more extensive colonisation than one millimetre, all came from boards where retentions were lower than the mean. It is not known if this low level of fungal colonisation would also occur during the normal service life of window joinery.

For *E. regnans* heartwood, the complete treatment envelope must be confined to the outer wood fibres, as decay was common when the outer two mm was shaved off. Standards call for five to six mm lateral penetration in non-durable timbers that are used externally and above ground (Australian Standard, 1604-1980; TPAA, 1979). The penetration results achieved for *E. regnans* would seem not to be sufficient to pass the standard for treated wood. The treated zone is normally determined by chemical means, which might give different results to this biological assessment. However, from the distribution of PCP found here, and from earlier work with Sudan Black (Ladu *et al.*, in prep), it seems unlikely that the standard would be met on this count. Whether these depths are necessary in an LOSP treated window frame, that was treated in final form, painted, and re-painted every five to seven years, is not known. It is unlikely that this depth of penetration is being reached in other timbers, especially meranti. Yet failure of LOSP treated window joinery in Victoria is rare.

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TABLE 1. Uptake of Protim 80 WR by 2 m long boards, sealed at one end, during a Lowry schedule of 1 hour at 1380 kPa.

Sawing pattern: f = flat, q = quarter sawn, i = intermediate, f-i = pattern on both ends between flat and intermediate, f+f-i = one end flat, other end between f and i.

Board number	Tree code	Untreated mass (gm)	Sawing pattern	Uptake kg/m^3	Cut for bioassay
36	6	2760	f-i	25.6	yes
43	?	3467	f-i	36.5	no
23	12	2389	q	40.2	yes
35	6	2497	f+f-i	40.2	no
12	5	2649	q	42.1	no
4	12	2436	f	43.5	no
37	6	2875	i	44.0	yes
5	12	2415	f	51.5	yes
18	10	2654	i	51.5	no
14	4	2524	f	52.7	no
11	4	2914	f	53.5	no
26	10	2610	i	56.3	no
16	4	2696	i	57.7	yes
28	10	2599	i	57.9	no
20	10	2561	q	59.2	no
19	10	2658	f-i+i	60.2	yes
21	1	2392	i	61.0	no
15	2	2457	q	61.0	no
3	12	2419	i	62.5	no
34	6	2603	f+f-i	64.6	no
9	12	2362	f+f-i	65.8	yes
13	4	2500	i+f-i	68.5	no
27	10	2265	q	69.6	no
30	10	2489	i	70.0	yes
6	5	2693	q-i	75.2	no
33	2	2665	i	85.4	no
29	10	2349	i	96.7	no
22	6	2727	f	100.4	yes
2	12	2447	f+i	124.6	no
7	12	2340	f	138.3	no
Mean				63.9	
Boards with a large proportion of sapwood					
42	8	3506	i+i-f	37.5	yes
41	8	3443	f	39.0	no
40	2	2711	f-i	52.9	no
39	5	2976	f	76.2	no
38	4	2786	f	126.9	no
Mean				66.5	

TABLE 2. Percentage mass loss of unshaved blocks cut from boards, after 16 weeks with *P. tephropora*.

Board number	Retn kg/m^3	Distance of furtherest edge of block from uncoated end (cm) 3	15	27	50	75	100	125	150	175	197
36	25.6	0.0	0.5	0.2	1.3	1.0	0.4	0.4	1.0	0.5	0.3
42(sap)	37.5	0.2	0.5	0.2	0.3	0.1	0.6	0.7	1.0	1.2	1.3
23	40.2	+0.2	0.2	1.0	1.0	+0.1	0.7	0.3	0.2	0.5	0.3
37	44.0	0.8	0.7	1.4	1.5	0.6	0.5	1.4	1.3	0.7	0.7
5	51.5	+0.1	0.1	0.1	0.4	0.0	0.3	0.3	0.6	0.5	0.4
16	57.7	0.1	+0.1	0.6	0.6	0.6	0.2	0.5	0.5	+0.1	0.6
19	60.6	+0.4	0.2	0.0	0.1	0.0	0.1	+0.2	+0.1	0.0	0.4
9	65.8	+0.3	0.0	0.3	0.3	0.0	0.3	0.5	0.1	0.0	0.3
30	70.0	+0.3	0.3	0.1	0.0	0.2	0.1	0.1	1.1	0.3	3.8
22	100.4	+0.2	0.1	0.3	0.1	0.2	+0.1	0.0	+0.2	+0.1	0.1
Mean	55.3	0.0	0.3	0.4	0.6	0.3	0.3	0.4	0.6	0.4	0.8
s.d.	21.0	0.3	0.3	0.5	0.5	0.4	0.3	0.4	0.5	0.4	1.1

Untreated controls: n = 30, mean = 8.1%, s.d. = 4.3, range = 0.0-19.6%

TABLE 3. Percentage mass loss of shaved blocks cut from boards, after 16 weeks with *P. tephropora*.

Board number	Retn kg/m^3	Distance of furtherest edge of block from uncoated end (cm) 12	24	47	72	97	122	147	172	194
36	25.6	3.1	1.0	1.6	12.6	5.2	3.0	2.2	2.5	6.5
42(sap)	37.5	0.9	3.0	1.4	2.8	1.2	3.5	3.1	5.0	2.7
23	40.2	1.6	1.8	1.6	3.9	2.3	3.8	4.3	1.1	3.1
37	44.0	0.9	4.5	4.8	5.4	4.8	6.5	6.5	10.0	7.4
5	51.5	1.5	0.8	0.9	5.5	7.1	0.7	7.1	1.1	0.8
16	57.7	5.0	5.6	0.2	3.8	1.9	1.7	5.3	5.7	1.8
19	60.6	3.2	6.4	4.2	1.1	4.0	2.6	2.2	1.4	4.7
9	65.8	1.3	0.2	0.2	0.1	4.2	0.6	1.3	3.1	+0.1
30	70.0	4.2	2.0	1.2	4.3	0.6	1.0	2.9	7.5	4.3
22	100.4	0.6	1.8	0.3	0.4	0.3	0.9	0.3	1.7	0.7
Mean	55.3	2.2	2.7	1.6	4.0	3.2	2.4	3.5	3.9	3.2
s.d.	21.0	1.5	2.1	1.6	3.6	2.2	1.9	2.2	3.1	2.5

Untreated controls: n = 30, mean = 8.3%, s.d. = 4.3, range = 0.8-14.4%

TABLE 4. Depth (mm) of whitened wood in sidegrain, of unshaved blocks cut from boards, after 16 weeks with *P. tephropora*.

Board number	Retn kg/m^3	Distance of furtherest edge of block from uncoated end (cm) 3	15	27	50	75	100	125	150	175	197
36	25.6	0.0	0.5	0.5	2.0	3.0	0.0	0.0	7.0	0.0	0.0
42(sap)	37.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2.0	1.0	1.0
23	40.2	1.0	0.5	4.0	5.0	0.0	2.0	1.0	0.0	3.0	2.0
37	44.0	0.0	0.0	0.0	0.0	0.0	0.0	0.5	0.5	0.0	0.0
5	51.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2.0	2.0	0.5
16	57.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
19	60.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
9	65.8	0.0	0.0	0.0	0.0	0.0	0.0	0.5	0.0	0.0	0.0
30	70.0	0.0	0.0	0.0	0.0	0.5	0.0	0.0	0.5	0.0	1.0
22	100.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Mean	55.3	0.1	0.1	0.5	0.7	0.4	0.2	0.2	1.2	0.6	0.5
s.d.	21.0	0.3	0.2	1.3	1.6	0.9	0.6	0.3	2.2	1.1	0.7

Combining all treated blocks: mean = 0.45mm, cross-section = 1.5%.

Untreated controls: n = 30, mean = 12.3mm, s.d. = 5.7, range = 2.0-19.0mm, % cross-section = 41.0%

TABLE 5. Depth (mm) of whitened wood in sidegrain, of shaved blocks cut from boards, after 16 weeks with *P. tephropora*.

Board number	Retn kg/m^3	Distance of furtherest edge of block from uncoated end (cm) 12	24	47	72	97	122	147	172	194
36	25.6	5.0	5.0	0.0	19.0	16.0	10.0	2.0	4.0	7.0
42(sap)	37.5	2.0	6.0	4.0	6.0	3.0	5.0	6.0	9.0	5.0
23	40.2	3.0	3.0	4.0	9.0	2.0	6.0	7.0	4.0	5.0
37	44.0	0.5	0.0	2.0	4.0	5.0	11.0	9.0	8.0	16.0
5	51.5	3.0	2.0	2.0	10.0	12.0	1.0	9.0	2.0	0.0
16	57.7	6.0	2.0	0.0	1.0	0.5	4.0	5.0	3.0	2.0
19	60.6	5.0	8.0	7.0	1.0	5.0	4.0	1.0	1.0	2.0
9	65.8	1.5	0.0	0.5	0.0	9.0	0.0	4.0	1.0	0.0
30	70.0	6.0	4.0	5.0	2.0	0.0	0.0	4.0	7.0	3.0
22	100.4	4.0	4.0	1.0	2.0	0.5	4.0	3.0	2.0	2.0
Mean	55.3	3.6	3.4	2.6	5.4	5.3	4.5	5.0	4.1	4.2
s.d.	21.0	1.9	2.5	2.4	5.9	5.4	3.8	2.7	2.9	4.7

Combining all treated blocks: mean = 4.23mm, cross-section = 16.3%.

Untreated controls: n = 30, mean = 10.7mm, s.d. = 4.9, range = 2.0-20.0mm, % cross-section = 41.1%

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