Project No. PN98.702

Market Knowledge & Development

Australian Government

Forest and Wood Products Research and Development Corporation

Accelerated Testing of Window Joinery made from Eucalypts

Australian Government
Forest and Wood Products Research and Development Corporation

Publication: Accelerated Testing of Window Joinery made from Eucalypts

Project no: PN98.702

Researchers:

D.K. Scown, L.J. Cookson, K.J. McCarthy & N. Chew
CSIRO FFP
Private Bag 10, Clayton South, Victoria 3169

Forest & Wood Products Research & Development Corporation
PO Box 69, World Trade Centre, Victoria 8005
Phone: (03) 9614 7544 - Fax: (03) 9614 6822 - Email: info@fwprdc.org.au
Web: www.fwprdc.org.au

Accelerated Testing of Window Joinery made from Eucalypts

Prepared for the

Forest & Wood Products
Research & Development Corporation

by

D.K. Scown, L.J. Cookson, K.J. McCarthy & N. Chew

The FWPRDC is jointly funded by the Australian forest and wood products industry and the Australian Government.

EXECUTIVE SUMMARY

Objective

The principle objective of the research was to improve the durability and hence the status of ash eucalypts as window joinery through preservative treatment, by demonstrating improved performance compared to untreated windows, and similar performance to light organic solvent preservative (LOSP) treated *Shorea* spp. (meranti) windows. In addition, the performance of the latest azole-containing LOSP formulation when used to protect *Shorea* spp. was assessed, as was the likelihood that the various preservative treatments would protect eucalypt sapwood from lyctine borer. The project incorporated four separate investigations: a window survey; two laboratory bioassays; and an accelerated exposure trial of model windows.

Key Results

1. Window survey

- A survey of 462 windows in service showed that, while there was a wide variety of performance between the four different types of windows (*Shorea* spp., *Thuja plicata* (western red cedar), *Pseudotsuga menziesii* (oregon) and ash eucalypt), untreated *P. menziesii* appeared to perform worst.
- Decay was predominant in the lower joints and sill of affected windows, especially in those windows facing north. Brown rot was the major type of decay found in deteriorated windows. White rot was found in some eucalypt and *T. plicata* windows.
- Untreated ash eucalypt windows in Bairnsdale that had internal joints sealed before assembly, and were regularly maintained (painted), were in good condition after 33 to 43 years service.

Application of Results

The results demonstrate that timber windows can provide service lives in excess of 25 years in Victoria provided regular maintenance is carried out. Preservative treatment of window components, and sealing the end grain within joints prior to assembly, are measures that can increase the service life of windows well beyond 25 years.

2. Fungicidal effectiveness of LOSP-treated eucalypt sapwood

- Solvent-treated test blocks were substantially decayed by the white rotting fungus *Perenniporia tephropora* and the brown rotting fungus *Coniophora olivacea*.
- A second white rotting fungus *Ganoderma cupreum* was less active, but still able to cause significant decay, except in heartwood blocks of *Eucalyptus obliqua* (messmate) and *E. sieberi (*silvertop ash*)*.
- The mean percentage mass loss in solvent-treated heartwood blocks gave an indication of the inherent natural durability of the individual timber species. *E. obliqua* and *E. sieberi* were more durable than *E. regnans* (mountain ash), *E. delegatensis* (alpine ash) and *Shorea* spp.
- None of the LOSP treated blocks were decayed, irrespective of whether the current formulation containing tributyl tin naphthenate (TBTN) or the new formulation containing azoles was used.

- The retention of permethrin in treated sapwood was sufficient to control lyctine borers.

Application of Results

The results show that when eucalypt boards are LOSP treated using a full cell treatment schedule (low pressure Bethell with initial vacuum of -95 kPa), sapwood regions should be protected from decay and lyctine borers.

3. Evaluation of LOSP treatments using the decay tray bioassay

- All vacuum/pressure treatments with LOSP produced sufficient protection from decay to up to 8 mm depth from the uncoated end grain of boards. While the dip treatment provided adequate protection to the end grain of *Shorea* spp. in this bioassay, it failed to protect similar end grain in the eucalypt.
- No clear differences were found in the level of protection provided by the current (tributyl tin containing) or new (azole containing) LOSP formulations.
- There was no apparent difference in the protection provided to 30 mm blocks with regards to the original position in the board relative to the exposed end grain.
- Blocks cut from boards dipped in LOSP were not sufficiently protected from fungal decay. *Shorea* spp. was protected using all other treatment schedules. Blocks cut from eucalypt boards treated using a high pressure Bethell LOSP treatment schedule were the only eucalypt samples protected sufficiently. However, as decay generally begins in the joints of window joinery, LOSP treatment may still provide sufficient extension to the service lives of eucalypt windows.
- Blocks cut from LOSP treated boards, and then shaved of their outer 2 mm had only marginally improved protection from decay in comparison to blocks from untreated boards, indicating minimal preservative penetration.

Application of Results

The new azole containing LOSP formulation appears to be performing as well as the tributyl tin based formulation. Vacuum pressure impregnation of *Shorea* spp. with LOSP has given protection from a white rotting fungus capable of causing extensive decay. Similar treatments protected the end grain of the ash eucalypts, but did not fully protect the side grain. However, as decay generally begins in the joints of window joinery, LOSP treatment may still provide sufficient extension to the service lives of eucalypt windows when treated in final shape and form.

4. Exposure trial of model window frames.

- After three years exposure to a combination of the Accelerated Field Simulator (AFS) and natural weathering on a roof, there was heavy decay in painted untreated *E. regnans*, *E. delegatensis* and *Shorea* spp. window frames. The worst decay was found in the lower rebates of the model windows and greater still in frames that were suspended from another frame in the AFS, *i.e.* those closest to the ground. Only minor decay was detected in *E. sieberi* and *E. obliqua* frames, while there was no decay in *T. plicata* windows.
- Unpainted untreated *E. regnans* windows were in better condition than painted untreated windows.
- Light to light-moderate decay was found in the rebates of *E. regnans* frames that had been treated with the diffusible "No-rot" rods, and one boron-treated *E. obliqua* window had slight decay. The condition of the window frames treated with the "No-rot" rods has not

deteriorated from the first annual inspection, indicating that the diffusible preservative is likely to have halted fungal growth.

- One *E. regnans* window frame treated with the current LOSP formulation had slight decay. There was no decay in the azole-containing LOSP-treated windows, including those treated by three minute dip.
- Metal fixtures in contact with timber treated with the new LOSP treatment (which contains azoles) or boron appeared to corrode more readily than those in contact with the current LOSP treatment. However, metal fixtures in all windows except untreated *E. regnans*, *E. delegatensis* and *Shorea* spp. were replaced after the latest three year inspection.
- Although a direct comparison has not been made, decay appeared to be more advanced using the Accelerated Field Simulator/field exposure technique developed here, than for other standard above ground field test methodologies.
- Green eucalypts treated with Diffusol® by vacuum pressure impregnation at a commercial treatment plant were analysed for boron content in the sapwood (only two boards contained sapwood), and met AS 1604 requirements for lyctine protection.

Application of Results

The benefits to eucalypts of preservative treatment against decay, with either LOSP or boron, were clearly demonstrated. The new LOSP formulation containing azoles performed at least as well as the current TBTN containing formulation. While vacuum pressure impregnation with LOSP can be expected to give best results in the longer term, the benefits of a three minute dip in LOSP was also established in the model window trial. Eucalypts treated with boron by vacuum pressure impregnation for lyctine borer control also gained significant protection from fungal decay, even though the treated timber had been dressed after treatment. LOSP treated timbers had better dimensional stability than boron treated timbers. After three years exposure, the treated eucalypt windows are performing as well as treated *Shorea* spp. windows in the model window exposure trial.

Future Work

The AFS trial should continue to be inspected on an annual basis, with the expectation that clear differences will emerge between the various treated window frame types.

Accelerated testing of window joinery made from eucalypts

D.K. Scown, L.J. Cookson, K.J. McCarthy and N. Chew
May 2004

TABLE OF CONTENTS

Information for CSIRO abstracting:

Contract number	FFP99/194
Products investigated	LOSP, boron
Wood species worked on	*Eucalyptus regnans, E. delegatensis, E. obliqua, E. sieberi, Thuja plicata, Pseudotsuga menziesii, Shorea* spp.
Other materials used	*Perenniporia tephropora, Coniophora olivacea, Ganoderma cupreum*
Location	Clayton laboratories, AFS

INTRODUCTION

The merit of using timber windows has received a boost recently through the Window Energy Rating Scheme (WERS), due to its superior insulating properties compared to competitive materials such as aluminium and steel. The main drawback for timber is susceptibility to biodegradation, primarily through decay. Largely for this reason, relatively few timber windows are installed in northern Australia, whereas in Victoria and Tasmania timber windows are widely used. The aim of this project was to investigate and improve the durability of timber windows.

The timbers used most for window joinery are meranti (*Shorea* spp.) and western red cedar (*Thuja plicata*). *Shorea* spp. is normally treated with light organic solvent preservative (LOSP), while *T. plicata* is naturally durable for above ground uses where it is a class 2 timber[1]. Of the local timbers available, ash eucalypts such as mountain ash (*Eucalyptus regnans*), alpine ash (*E. delegatensis*), silvertop ash (*E. sieberi*) and messmate (*E. obliqua*) are used, but on a smaller scale. These are mostly used untreated, and because the timbers have low natural durability, may suffer from early decay[2].

The problem of durability can be reduced by shielding windows with eaves, or by painting sealed ends before window assembly[3]. Another alternative is to treat to AS 1604[4], but the required penetration is almost impossible to achieve in the heartwood of hardwoods, even in *Shorea* spp.[5] The trials in this project were designed to determine if the thin envelope treatments achievable in hardwood window joinery could provide sufficient durability to be considered 'fit for purpose'.

Previous research by CSIRO, with support from the Timber Promotion Council of Victoria, found that the end grain of *E. regnans* heartwood could be treated with LOSP, but penetration of the side grain was poor[6]. However, it was plausible that this level of treatment might be sufficient to give good service life to windows. Most of the decay in windows is initiated in end grain within joints; hence window joinery LOSP-treated *E. regnans* should be resistant to decay since the end grain of *E. regnans* is readily treated. Although the side grain penetration is shallow, a laboratory decay bioassay with an LOSP formulation and high pressure treatment cycle showed that the heartwood of *E. regnans* can be protected from a severe white rot fungus, as long as the treatment envelope remains intact[7]. However, a later trial with a standard low pressure LOSP cycle and a current (TBTN containing) LOSP formulation gave an envelope treatment that failed to protect *E. regnans*, *E. delegatensis*, light and dark *Shorea* spp. heartwood from the white rot fungus[5]. In this test, *E. obliqua*, *E. sieberi* and *T. plicata* resisted decay due to their moderate or good natural durability. The next generation of LOSP that contains azoles appears to perform better than TBTN containing formulations (unpublished data), so was included in this study.

---

[1] Australian Standard 5604-2003. Timber – Natural durability ratings. Standards Australia, Sydney.

[2] Ellwood, E.L. (1955). Preventing deterioration in exterior joinery. CSIRO DFP, Forest Products Newsletter No. 212, 2pp.

[3] Australian Standard 2047-1999/Amendment 1/2001-01-31. Windows in buildings – Selection and installation. Standards Australia, Sydney.

[4] Australian Standard 1604.1-2000. Specification for preservative treatment. Part 1: Sawn and round timber. Standards Australia, Sydney.

[5] Cookson, L.J. and Trajstman, A. (1996). Decay evaluation of the effectiveness of a LOSP envelope treatment in eucalypt and meranti heartwoods for window joinery. Internat. Res. Group on Wood Preservation, Document No. IRG/WP/96-30099.

[6] Ladu, G.E., Cookson, L.J. and Dougal, E.F. (1995). Treatability of regrowth *Eucalyptus regnans* heartwood using light organic solvent. Wood Protection 3: 33-39.

[7] Cookson, L.J. and Dougal, E.F. (1997). Decay evaluation of the effectiveness of an LOSP envelope treatment in *Eucalyptus regnans* heartwood. Forest Prod. J. 47: 67-73.

For some lyctine susceptible timbers such as *E. obliqua*, boron treatment is a standard industry practice. This treatment may also impart enhanced performance to window joinery constructed from this treated timber. Even though boron is prone to leach, other research has shown that boron treated wood can last 2-4 times as long as untreated timbers[8,9] which should be enough to give acceptable service life for eucalypt windows. Painting may help to lock the boron within the timber substrate.

The focus of the current research was to improve the durability and status of ash eucalypts as window joinery, by demonstrating improved performance compared to untreated windows, and similar performance to LOSP treated *Shorea* spp. which has commercial acceptance.

The project encompassed a number of components including:

1) A survey assessing the performance of timber windows currently in service.
2) Laboratory decay bioassay to assess the ability of the new LOSP formulation to protect eucalypt sapwood.
3) Laboratory decay bioassays of eucalypt and *Shorea* spp. boards treated with both LOSP formulations using a range of treatment schedules.
4) Exposure of model window frames under a combination of field and accelerated field simulator (AFS) conditions.

All of these investigations were completed, and the findings provided in interim reports[10,11,12,13,14 &15]. This final report completes the project and discusses the potential of ash timbers in the window joinery industry.

RECOMMENDATIONS AND CONCLUSIONS

The window survey showed that untreated eucalypt windows can last more than 25 years if properly maintained. Further reliability can be obtained by sealing the end grain prior to window assembly. LOSP preservative treatment of final dimension eucalypt windows by vacuum pressure impregnation (vpi) would give significant improvement to performance, because deepest preservative penetration occurs in the end grain where protection from decay is needed most. Boron treatment as obtained by vpi for lyctine borer immunization will also improve timber window durability. No clear difference was found between the current TBTN containing, and the new azole containing, LOSP formulations, indicating that the new LOSP will be suitable for window joinery timbers including *Shorea* spp. One TBTN treated eucalypt window in the model window exposure trial has decay. The boron and LOSP treatments employed for window treatments also provided sufficient loading of preservative in the sapwood for lyctine control. The model window exposure trial should continue to be inspected

---

[8] Carr, D.R. (1964). Diffusion impregnation for house timbers. Internat. Pest Control 6 (2): 13-19, (3): 11-15.

[9] Drysdale, J.A. (1994). Boron treatments for the preservation of wood- a review of efficacy data for fungi and termites. Internat. Res. Group on Wood Preserv. Document No. IRG/WP/94-30037.

[10] Scown, D.K. and L.J. Cookson (2002). Accelerated testing of window joinery made from eucalypts. Part 1: Fungicidal effectiveness of LOSP treatment of eucalypt sapwood. CSIRO FFP Client Report No. 1175.

[11] Cookson L.J., D.K. Scown and N. Chew (2002). Accelerated testing of window joinery made from eucalypts. Part 2: Evaluation of LOSP treatments using the decay tray bioassay. CSIRO FFP Client Report No. 1192.

[12] Scown, D.K. and L.J. Cookson (2002). Accelerated testing of window joinery made from eucalypts. Part 3: Exposure trial of model window frames. Installation and first year inspection results. CSIRO FFP Client Report No. 1176.

[13] McCarthy K.J. and L.J. Cookson (2002). Accelerated testing of window joinery made from eucalypts. Part 4: Windows survey. CSIRO FFP Client Report No. 1240.

[14] Scown, D.K. and L.J. Cookson (2003). Accelerated testing of window joinery made from eucalypts. Part 4: Two year inspection results of the exposure trial of model window frames. CSIRO FFP Client Report No. 1308.

[15] Scown, D.K. and L.J. Cookson (2004). Accelerated testing of window joinery made from eucalypts. Part 6: Three year inspection results of the exposure trial of model window frames. CSIRO FFP Client Report No. 1423.

annually, with the expectation that clear differences will emerge between the various treated window frame types.

RESULTS AND DISCUSSION

1. Window survey

The survey included the assessment of 462 windows from 67 houses and provided information regarding length of service, aspect, preservative treatment and physical condition.

***Shorea* spp.**
A total of 187 *Shorea* spp. window frames were inspected, and over half of these were believed by the purchaser to have been LOSP treated (Table 1.1). They were 4-25 years old. Of the 187 windows, only 9 (5%) were found to have some form of biodeterioration, generally brown rot. Where brown rot was evident, it was confined to the lower joints. These affected windows faced north, and at least three had been LOSP treated. Maintenance had been neglected in many of the decaying windows, as most had not been repainted for 15 years.

Table 1.1: Survey results for *Shorea* spp. windows.

Age	Location	Treatment	Last painted (P) or stained (S)	Eave width (mm)	Orientation of deteriorated windows	Comments
4	Skye	LOSP	1997 (P)	500		No deterioration – 8 windows
4	Skye	LOSP	1998 (S)	450		No deterioration – 6 windows
6	Skye	LOSP	1996 (S)	500		No deterioration – 10 windows
6	Carrum Downs	LOSP	1996 (P)	450		No deterioration – 8 windows
6	Viewbank	LOSP	1997 (P)	800		No deterioration – 18 windows
8	Ringwood	LOSP	1994 (P)	500	North	Some early signs of surface softening in bottom joints and sill in one window. –6 windows no deterioration
8	Carrum Downs	LOSP	1994 (S)	500		No deterioration – 8 windows
9	Warrandyte	LOSP	1993 (P)	500	North	Upper storey no deterioration – 3 windows. Lower storey (less protected by eaves) with rusty nails present, no decay – 3 windows.
9	Warrandyte	LOSP	1993 (P)	1800		No deterioration – 4 windows
11	Carrum Downs	LOSP	1991 (S)	500		No deterioration – 7 windows
11	Carrum Downs	LOSP	1991 (S)	450		No deterioration – 7 windows
13	Carrum Downs	?	1989 (P)	450		No deterioration – 8 windows
13	Carrum Downs	?	1989 (P)	500		No deterioration – 7 windows
13	Carrum Downs	?	1998 (P)	500		No deterioration – 7 windows
15	Frankston	LOSP	1998 (P)	450	North and North east	No deterioration in 5 windows.
15	Langwarrin	LOSP	1997 (P)	450	North	Brown rot in bottom joints in main bedroom. First noticed approx 2 years ago. 8 windows no deterioration.
16	Carrum Downs	LOSP	1986 (S)	500		No deterioration – 7 windows

Table 1.1: Survey results for *Shorea* spp. windows (continued).

Age	Location	Treatment	Last painted (P) or stained (S)	Eave width (mm)	Orientation of deteriorated windows	Comments
17	Skye	?	1997 (S)	500		No deterioration – 6 windows
18	Carrum Downs	?	1984 (P)	500	North	Brown rot in bottom joints of 3 windows. Decay first noticed around 8 years ago. No deterioration in 5 windows.
18	Skye	LOSP	1984 (S)	500	North west	Slight soft rot in bottom left-hand joint. First noticed 1 year ago. No deterioration in 10 windows.
18	Chelsea Heights	?	1984 (S)	450	North east	Brown rot in all joints, sill and in one piece of beading in front window. No deterioration in 6 windows.
21	Chelsea Heights	?	1998 (P)	450	North	Brown rot in bottom joints in 2 windows on upper storey. First noticed about 4 years ago. Upper storey no deterioration - 2 windows. Lower storey no deterioration – 7 windows.
25	Wheelers Hill	LOSP	? (S)	1500		No deterioration – 7 windows upper storey and 5 windows lower storey.

Eucalypt

A total of 115 eucalypt windows were assessed for this survey, with wide ranging service lives of 24-70 years (Table 1.2). All of the eucalypt windows were untreated and except for two had been painted. Overall, 18 windows (16%) showed signs of biodeterioration to brown and white rotting fungi. Again, decay was found predominantly in the lower joints and sill of affected windows. The earliest recorded sign of decay was detected after 24 years of service.

The survey incorporated a group of eucalypt windows in buildings at Bairnsdale. These windows were generally in excellent condition (Figure 1.1). The experience of the joinery supplier responsible for the manufacture of these windows was that sealing the end grain within the joints prior to assembly extended the service life of the joint considerably. He claimed that a poorly made joint would last only 15 years whereas a well made joint can be expected to last more than 40 years. He recommended the use of only oil based paints and a flexible sealant in major joints to protect the end grain of the timber from water ingress. Other tips were to fully paint prime the timber before assembly, including the underside of the timber beading to be used against the glass, and the outer frame and underside that would later be hidden against the brickwork after installation.

Table 1.2: Survey results for eucalypt windows.

Age	Location	Treatment	Last painted (P) or stained (S)	Eave width (mm)	Orientation of deteriorated windows	Comments
24	Port Melbourne	No	1998 (P)	0	North east	Slight surface softening in 1 window. No deterioration – 6 windows.
25	Mt. Gambier	No	1990 (P)	1000		No deterioration – 4 windows
28	Mt. Gambier	No	1999 (S)	1000	South east	Deterioration of sill against the glass in 1 window. No deterioration – 6 windows.
32	South Melbourne	No	1997 (P)	100	North	Deterioration mainly in joints. Some noticeable in sill of 1 window. No deterioration in 5 windows.
32	Port Melbourne	No	1996 (P)	100	North and North east	Some brown rot in left joint and sill of 2 windows. No deterioration in 6 windows.
33	Bairnsdale	No Internal joint sealed	1993 (P)	600	?	5 windows very good condition, although 2 windows not painted on underside of sill had 2-3 mm of softened wood underside.
35	Bairnsdale	No Internal joints sealed	Within 10 y (P)	900	East	3 windows no deterioration. One window on east wall (no eaves) in good condition, but quad strip nailed onto window with minor 10-20 mm rot at bottom end. This window also with slight decay on inside due to condensation from glass.
36	Port Melbourne	No	1998 (P)	0	North west	Some brown rot in bottom joints of front window. No deterioration in 6 windows.
36	Mulgrave	No	2001 (P)	300	East	Some decay in bottom left joint and along sill. No deterioration in 6 windows.
38	ACT	No	1991 (P)	500	North west	Slight decay in bottom left joint. No deterioration – 8 windows.
40	Bairnsdale	No Internal joint sealed	Within 10 y (P)	900	?	2 windows no decay, one window minor decay 30mm deep in outer sill corner.
40	Bairnsdale	No Internal joint sealed	Within 10 y (P)	600	?	4 windows good condition, although beading holding glass on one window had been replaced.

Table 1.2: Survey results for eucalypt windows (continued).

Age	Location	Treatment	Last painted (P) or stained (S)	Eave width (mm)	Orientation of deteriorated windows	Comments
40	Bairnsdale	No Internal joints sealed	Within 10 y (P)	600	West	2 windows good condition. 1 window with 30 mm rot in corner adjacent to bricks.
40	Bairnsdale	No Internal joint sealed	Within 10 y (P)	600	?	Window frame in good condition. Timber flyscreen frame on window (not considered a part of the window), with casein glued joint, failed and rotted.
42	Bentleigh	No	1999 (P)	450		No deterioration in 12 windows. Windows painted regularly.
43	Bairnsdale	No Internal joint sealed	Within 10 y (P)	600		3 windows no deterioration. One of these windows is shown in Figure 1.1.
43	Bairnsdale	No Internal joint sealed	Within 10 y (P)	600		2 windows no deterioration
45	Port Melbourne	No	1993 (P)	0	North east	Brown rot in bottom joints and sill. 5 windows no deterioration.
45	Port Melbourne	No	1993 (P)	0	West	Brown rot in all joints, sill and sashes. Window is in poor condition.
46	East Bentleigh	No	1998 (P)	100	North east	Slight surface softening in bottom right joint of 1 window. Early signs of brown rot evident. No deterioration in 7 windows.
70	Glen Iris	No	1998(P)	1000	West	Decay present in left joint. No deterioration in 7 windows

Figure 1.1: Eucalypt window 43 years old in Bairnsdale, with internal joints sealed prior to assembly, in excellent condition. For the purposes of the survey, this figure is considered to show one window.

Thuja plicata

Table 1.3 shows the inspection characteristics of 116 *T. plicata* windows. They ranged in age from 5-40 years. Seven windows (6%) showed signs of fungal attack from both brown and white rotting fungi. Attack was restricted to the bottom joints and sill area of the window (Figure 1.2).

Despite its reputation, there were examples of early fungal decay in WRC windows less than 20 years old, showing that they can still require regular maintenance. Most windows in this age range had been painted or stained around six years ago. This maintenance duration may be too long to prevent fungal deterioration, especially if the paint film has cracked or lifted during that time.

In new joinery construction, the authors have occasionally noticed sapwood bands present on WRC boards. These zones are non-durable, so would be expected to fail first under conditions suitable for fungal attack.

Table 1.3: Survey results for *T. plicata* windows.

Age	Location	Treatment	Last painted (P) or stained (S)	Eave width (mm)	Orientation of deteriorated windows	Comments
5	ACT	No	1996 (S)	0		Some hail damage. No biodeterioration – 10 windows.
8	Warrandyte	No	1993 (P)	500		No deterioration – 2 windows.
10	Glen Iris	No	1998 (P)	1000	North	2 windows with discoloration. No decay in both windows.
12	ACT	No	1998(P)	800		No deterioration – 7 windows.

Table 1.3: Survey results for *T. plicata* windows (continued).

Age	Location	Treatment	Last painted (P) or stained (S)	Eave width (mm)	Orientation of deteriorated windows	Comments
12	Langwarrin	No	1998 (S)	500	North	Surface softening in bottom left joint of window on upper storey. No deterioration 4 other windows upper storey and 6 windows lower storey.
14	Pearcedale	No	1995 (S)	0	?	Windows have gone grey due to physical degradation of surface cells. No decay – 8 windows.
14	East Doncaster	No	1997 (P)	500		No deterioration - 14 windows.
16	Mt. Martha	No	1999 (S)	500	North and north east	Brown rot in bottom left joint and along the sill for 200 mm in one window and brown rot in bottom joints in another. 7 windows no deterioration.
17	Mornington	No	1999 (S)	450	North	Signs of white rot in beading of north facing window. No deterioration – 5 windows.
20	Bairnsdale	No	(P)	0		Window frame plus sliding door with brown rot to 30 mm depth in 3 joints. Needing repair. See Figure 1.2.
22	Red Hill	No	1999 (S)	450		No deterioration – 9 windows. Windows regularly stained.
25	Mt. Gambier	No	1990 (P)	1000	South	1 window has been replaced. Badly deteriorated in joints. No deterioration in 6 windows.
27	ACT	No	1999 (P)	400		No deterioration – 12 windows.
30	ACT	No	2000 (S)	250	West	A little decay found on bottom sill. 7 windows no deterioration.
36	Mulgrave	No	2001 (P)	300		No deterioration. – 6 windows.
40	ACT	No	1995 (P)	500		No deterioration – 4 windows.

Figure 1.2: **Brown rot in a 20 year old untreated western red cedar window.**

Pseudotsuga menziesii

P. menziesii (oregon) windows comprised the smallest sample size of window types examined in the survey (Table 1.4). Ranging in age from 14-46 years, 44 windows were inspected. Of these, 12 had fungal attack, most of which were severely decayed in the bottom joints and along the sill. Of the rots identified, brown rot was responsible for all biodeterioration in *P. menziesii* windows, and was not confined to north facing windows. Maintaining a continuous paint film barrier in *P. menziesii* can be difficult where knots are present, due to differential movement of the timber.

Table 1.4: Survey results for *P. menziesii* windows.

Age	Location	Treatment	Last painted (P) or stained (S)	Eave width (mm)	Orientation of deteriorated windows	Comments
14	Carrum Downs	No	1996 (P)	500	North and west	Extensive brown rot in joints and sill of main bedroom window and brown rot present in bottom joints and sill of lounge window. Decay first noticed approx. 8 years ago. Slight surface softening in 2 other windows. No deterioration in 6 windows.
15	Mt. Gambier	No	2000 (P)	0	South	Deterioration in bottom left joint. No deterioration – 6 windows.

Table 1.4: Survey results for *P. menziesii* windows (continued).

Age	Location	Treatment	Last painted (P) or stained (S)	Eave width (mm)	Orientation of deteriorated windows	Comments
18	Carrum Downs	No	1999 (P)	500	North, north east and west	Windows have been filled/repaired a couple of times. Extensive brown rot present in joints, sill and beading against sill in 4 windows. Early signs of deterioration in 2 other windows.
21	Bairnsdale	No	? (S)	750	?	Five windows in good condition. However, knots and surface checks are noticeable.
35	St Kilda	No	1995 (P)	0	West	Decay present inside against glass, moisture probably arising from condensation. No decay in 3 windows.
40	ACT	No	1995 (P)	500		No deterioration – 4 windows
46	ACT	No	1992 (P)	450		No deterioration – 8 windows. All windows receive regular maintenance.

Windows replaced by repairman

Table 1.5 shows the characteristics of nine failed windows replaced by a local window repairman. They ranged in age from 21-60 years and all were in poor condition. Fungal attack by predominantly brown rotting fungi caused most of the failures. However, white rot was noticeable in three of the windows. As the windows had already been removed from service, we were unable to determine if regular maintenance had been applied to any of the windows. Also, the orientation of deteriorated windows and eave width could not be determined. A 22 years old *Shorea* spp. window was found to contain tin when analysed by scanning electron microscope, suggesting that it had been treated with LOSP. Most LOSP treated *Shorea* spp. windows examined in the main survey (Table 1.1) were in good condition. These failed windows were not included with the main data of the survey as they were not selected randomly.

Table 1.5: Windows removed from service by repairman.

Window type	Age	Location	Treatment	Painted (P) or stained (S)	Comments
T. plicata	21	Springvale	No	P	Brown rot present in joints and sill. Window has been replaced.
Shorea spp.	22	South Oakleigh	LOSP	P	Severe brown rot in bottom joints and sill. Window has been removed from service. Decay first noticed 2 years ago. Analysis showed the presence of tin.
T. plicata	24	South Oakleigh	No	S	Brown rot in bottom joints and sill. Window has been replaced.
P. menziesii	26	South Oakleigh	No	P	Window replaced 2 years ago. Severe brown rot present in all joints, sill and sashes.
T. plicata	32	Clayton	No	P	Brown rot in bottom joints and sill. Window has been replaced.
T. plicata	40	Oakleigh	No	P	White rot in bottom joints and 100 mm along sill and sash. Window has been replaced.
Eucalypt	45	Springvale	No	P	Severe white rot in bottom left joint and along sill. Window has been replaced.
Eucalypt	50	Oakleigh	No	P	White rot present in bottom joint. See Figure 1.3. Window has been replaced.
Eucalypt	60	Clayton	No	P	Brown rot present in bottom joints. Window replaced around three years ago.

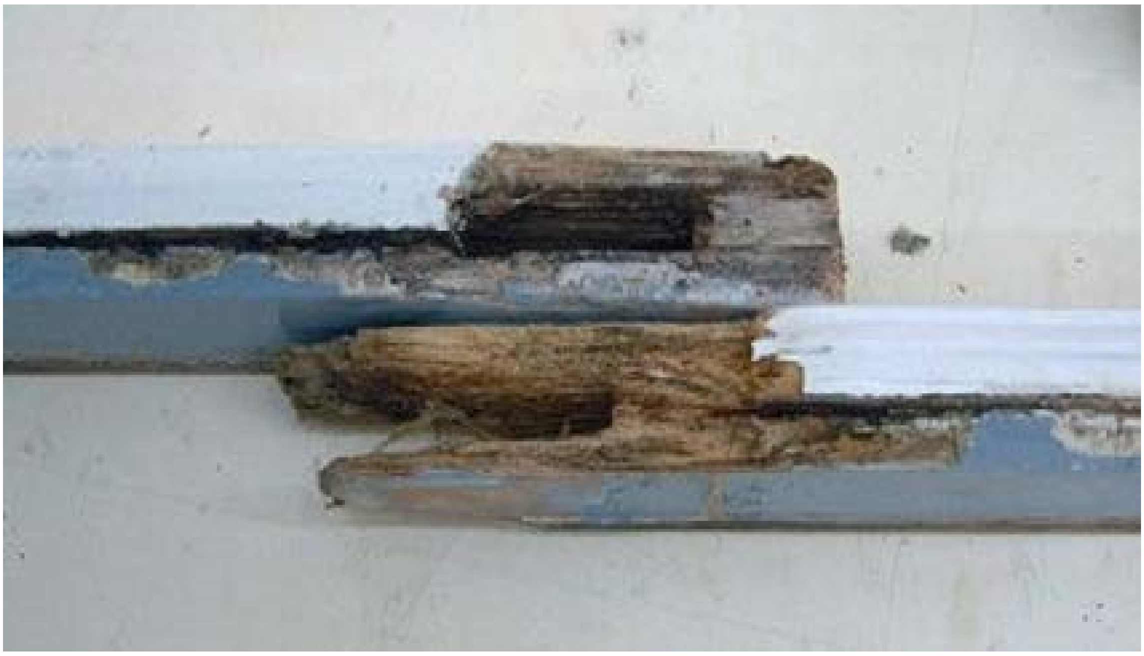


Figure 1.3: White rot in bottom joint of dismantled 50 year-old eucalypt window.

Other impressions on window performance obtained from manufacturers and repairmen were that dark coloured paint accelerates failure, probably due to the increased UV degradation resulting from the tendency of darker paints to absorb heat rather than reflect it, or perhaps the greater absorption of heat leading to increased wood movement. Also, windows behind dense shrubbery may be more susceptible to decay, probably from increased humidity.

2. Fungicidal effectiveness of LOSP treated eucalypt sapwood

The objective of this study was to demonstrate whether the current and next generation formulations of LOSP were able to prevent decay when fully impregnated into eucalypt sapwood test blocks, as would occur during commercial treatment. AS 1604.1-2000 requires 0.08% m/m elemental tin for H3 treatments. Earlier research (Cookson, unpublished) found that *E. regnans* sapwood treated to this retention using TBTN could still be decayed by the white rotting fungus *Perenniporia tephropora*. Sapwood would normally be a minor component in sawn eucalypts for LOSP treatment. Therefore, commercial treatment schedules would be influenced by heartwood rather than sapwood penetrations and absorptions. As LOSP is used undiluted (in the unpublished trial mentioned above, LOSP was diluted), the sapwood can be expected to be over-treated according to AS 1604.1.

In the current study, LOSP was examined at the concentration that would be used in a commercial treatment plant (undiluted). The treatment schedule was -95 kPa for 30 minutes, followed by 150 kPa for 60 minutes (low pressure Bethell). Sapwood and heartwood test blocks of *Eucalyptus regnans* (mountain ash), *E. delegatensis* (alpine ash), *E. obliqua* (messmate), *E. sieberi* (silvertop ash) and *Shorea* spp. (meranti) were treated. The solution uptakes achieved and retentions of the active ingredients are provided in Table 2.1. The mean retentions of permethrin achieved in the sapwood of the various eucalypts ranged from 0.05 to 0.11% m/m, which is well above the minimum requirement of 0.006 % m/m for lyctine control, and 0.02% m/m for termite control in the sapwood.

Table 2.1: Mean (and standard deviation) LOSP retentions achieved in 20 x 20 x 10 mm blocks after vacuum pressure impregnation.

Timber species	Uptake of solution L/m³	235WR % (m/m) retention of elemental tin	P410WR % (m/m) retention of azoles	% (m/m) retention of permethrin
Shorea spp.	487.3 (41.9)	1.06	0.52	0.27
E. regnans (sapwood)	278.2 (28.7)	0.52	0.21	0.11
E. regnans (heartwood)	151.3 (9.9)	0.27	0.13	0.07
E. delegatensis (sapwood)	236.7 (34.1)	0.29	0.13	0.07
E. delegatensis (heartwood)	224.2 (42.1)	0.31	0.12	0.06
E. sieberi (sapwood)	139.6 (3.7)	0.20	0.09	0.05
E. sieberi (heartwood)	136.2 (14.3)	0.17	0.09	0.05
E. obliqua (sapwood)	185.9 (31.2)	0.28	0.12	0.06
E. obliqua (heartwood)	143.6 (3.8)	0.16	0.09	0.05

The treated test blocks were artificially weathered, and exposed to three species of decay fungi. One white rotting fungus (*P. tephropora*) and the brown rotting fungus (*Coniophora olivacea*) were able to substantially decay the solvent (white spirit) treated control test blocks (Figures 2.1 & 2.2). The second white rotting fungus, *Ganoderma cupreum*, was less active, but was still able to cause significant decay (Figure 2.3). Those timbers with in-ground heartwood of natural durability class 3 (*E. obliqua, E. sieberi*) had greater resistance in the decay trial than the class 4 timbers *E. regnans, E. delegatensis* and *Shorea* spp.

None of the LOSP treated blocks, using either LOSP formulation, was decayed. The results show that when eucalypt sapwood is LOSP treated using a prolonged schedule, it will be protected from decay.

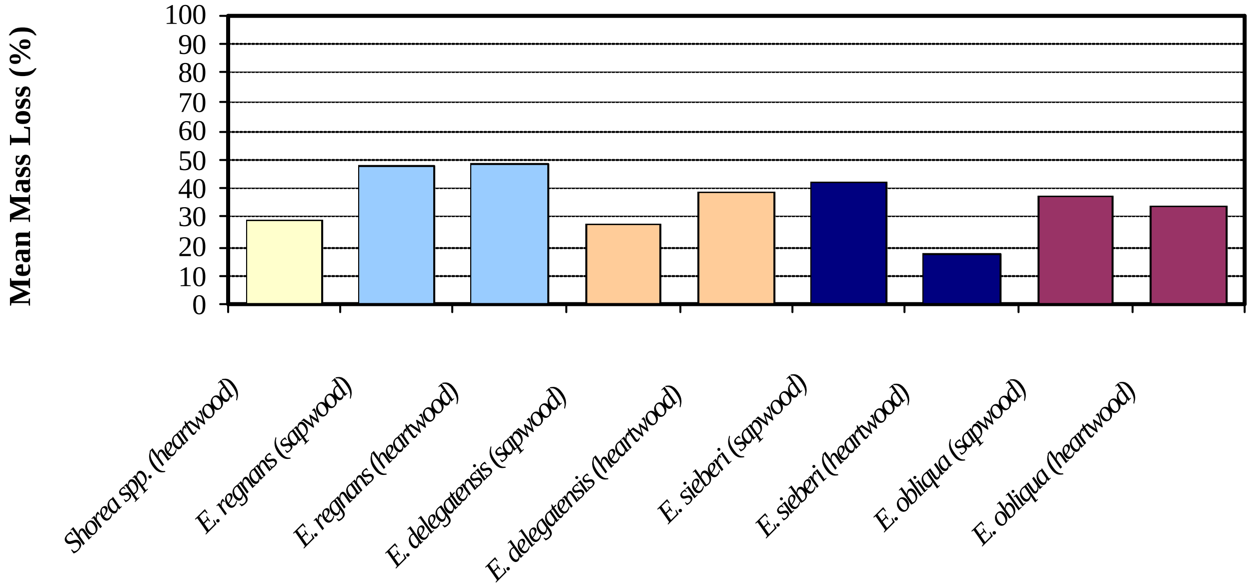


Figure 2.1: Mean percentage (%) mass losses caused by *P. tephropora* in solvent treated blocks.

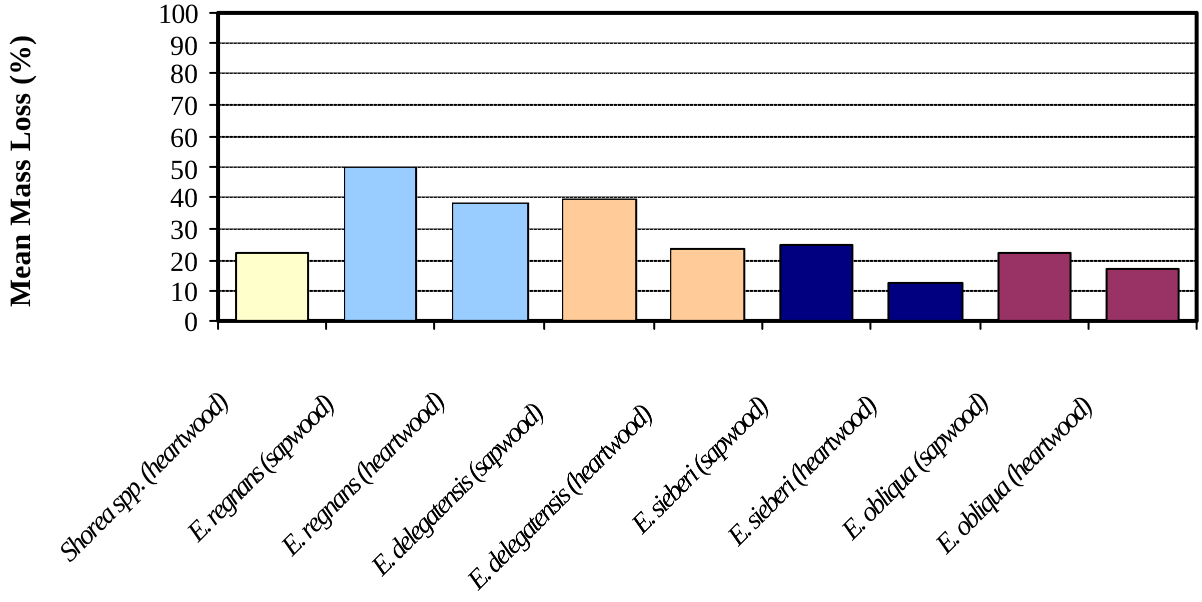


Figure 2.2: Mean percentage (%) mass losses caused by *C. olivacea* in solvent treated blocks.

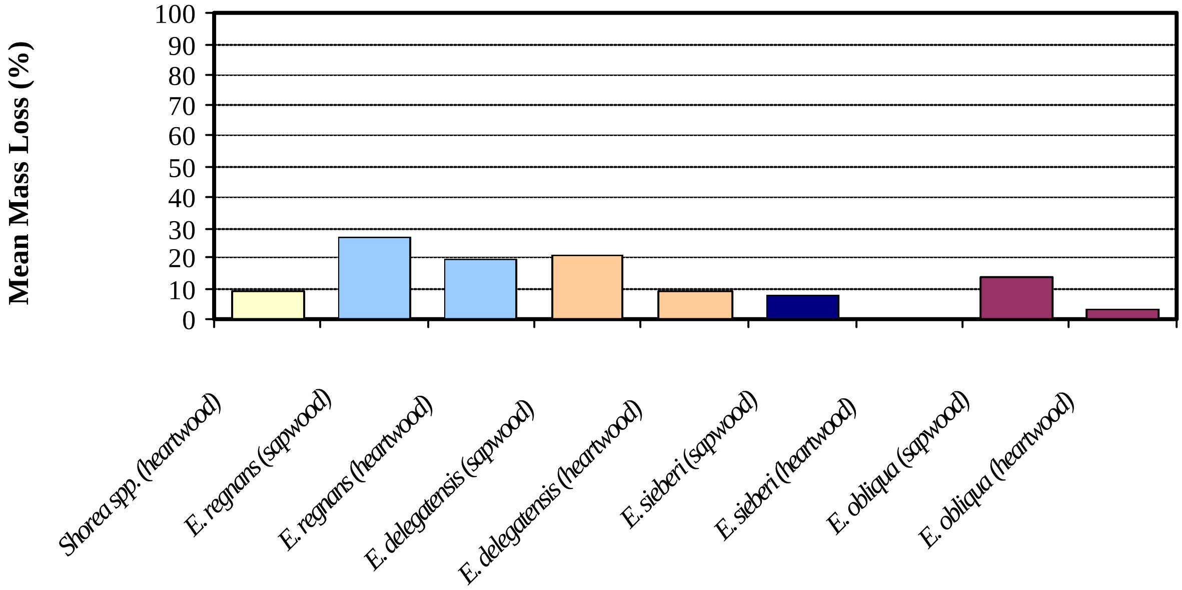


Figure 2.3: Mean percentage (%) mass losses caused by *G. cupreum* in solvent treated blocks.

3. Evaluation of LOSP treatments using the decay tray bioassay

The objective of this study was to evaluate the performance of LOSP treatments of the heartwood of hardwood timber samples of larger dimensions. The preservative treatment of hardwoods often results in preservative penetration patterns that are less uniform than those achieved when treating very small timber samples, such as those in the previously described soil-block trial. LOSP treatments utilizing both formulations and a variety of treatment schedules were used to treat *E. regnans* (mountain ash), *E. delegatensis* (alpine ash) and *Shorea* spp. In this study, one metre long boards, with one end epoxy coated to prevent LOSP penetration in that direction, were treated. Blocks were then removed from various distances along the treated board for bioassay against the white rotting fungus *P. tephropora*.

Preservative treatment

Table 3.1 shows the mean retention of LOSP achieved using the various treatment schedules. To enable direct comparison, the retentions are expressed as uptake per total volume of wood. It should be noted however that penetration was far from uniform, so that actual retentions in the treated zones were quite different (and higher) than indicated in the table, and there was a great deal of poorly treated heartwood core. The results suggest that *Shorea* spp. was slightly more treatable than the eucalypts.

Table 3.1: Mean retention (standard deviation) in L/m^3 of the six boards treated using specified treatment cycles.

LOSP formulation/ Treatment method	Timber species/retention L/m^3		
	E. regnans	*E. delegatensis*	*Shorea* spp.
New/dip treatment	3.7 (1.2)	2.8 (0.5)	6.7 (2.7)
New/commercial	9.6 (2.7)	12.6 (3.0)	20.9 (6.5)
Current/commercial	9.6 (1.7)	10.8 (4.8)	14.0 (7.0)
New/low pres. Bethell	20.0 (9.6)	22.7 (8.0)	33.3 (23.8)
New/high pres. Bethell	38.6 (14.3)	44.6 (20.8)	101.9 (95.8)

Decay of untreated timbers

In the fungal decay trial, all untreated timber blocks were decayed by the white rotting fungus *P. tephropora* (Table 3.2). Decay in both eucalypts was most severe in the 8 mm long blocks with exposed end grain uncoated (more than 40% mean mass loss), and less in the 30 mm long blocks that had the end grain epoxy coated, preventing fungal attack from that direction. These results confirm that the timber species involved are non-durable, although the *Shorea* spp. used for this trial was slightly more resistant to decay than the eucalypts.

Table 3.2: Percentage mean mass loss (standard deviation) of untreated timbers exposed for 28 weeks to *P. tephropora*.

Block type/length	Timber species/mean mass loss (%)		
	E. regnans	*E. delegatensis*	*Shorea* spp.
Unshaved 30 mm block	19.9 (7.0)	27.4 (8.8)	12.1 (5.0)
Shaved 30 mm block	19.8 (6.6)	17.9 (7.6)	13.4 (5.0)
8 mm block	42.8 (10.9)	44.9 (12.1)	15.3 (4.0)

Decay of eight mm long blocks

AS 1604 requires 8 mm penetration from any surface for timber thicker than 35 mm and exposed to hazard level 3 conditions, as occurs for window joinery. Although the timbers were 30 mm thick (and therefore, 5 mm penetration would have been sufficient), 8 mm was examined so that conclusions could be drawn for larger sectioned timbers. Previous work has shown that 8 mm penetration from the side grain cannot be achieved in eucalypt heartwood[7], but may be possible in the end grain. End grain treatment was examined by docking 8 mm blocks from the uncoated end of treated boards, to determine if they were resistant to decay by the white rotting fungus. In fungal laboratory bioassays, a preservative treatment can be considered to have prevented decay if the mean mass loss is less than 3%[16]. All vacuum/pressure treatments with LOSP produced sufficient penetration up to 8 mm from the end grain to prevent significant decay (Table 3.3), as all mean mass losses were below 3%. Dip treatment failed to protect (and therefore penetrate) this same distance from the end grain, as mean mass losses of 11.5% occurred for *E. regnans* and 10.9% for *E. delegatensis*. In comparison, the dip treatment provided sufficient protection to the end grain of *Shorea* spp. It is uncertain whether this increased resistance in *Shorea* spp. was due to deeper LOSP penetration during dipping, or the slightly higher natural durability of the *Shorea* spp. used in these trials. As with the eucalypts, all other treatment schedules provided adequate protection to the 8 mm end grain of *Shorea* spp. boards (Table 3.3).

[16] AWPC (1997). Protocols for the assessment of wood preservatives. Australasian Wood Preservation Committee, Corporate Initiatives, Melbourne.

Table 3.3: Percentage mean mass loss (standard deviation) of 8 mm long treated blocks exposed for a total of 28 weeks to *P. tephropora*.

LOSP formulation/ Treatment method	Timber species/mean mass loss (%)		
	E. regnans	*E. delegatensis*	*Shorea* spp.
New/dip treatment	11.5 (9.8)	10.9 (5.9)	2.2 (1.6)
New/commercial	2.2 (1.3)	1.9 (1.3)	0.9 (0.2)
Current/commercial	1.1 (0.2)	1.0 (0.3)	1.1 (0.3)
New/low pressure Bethell	1.0 (0.2)	1.3 (0.6)	0.9 (0.2)
New/high pressure Bethell	1.2 (0.1)	1.3 (0.5)	1.1 (0.2)

Decay of unshaved blocks

Bioassay blocks 30 mm long, and removed from four defined distances from the uncoated end of the original treated boards, were exposed to *P. tephropora*. These blocks were exposed with the original side grain treatment envelope undisturbed ('unshaved' blocks). For each treatment, mean mass loss results for blocks taken from each position along the board appeared to be similar, with no clear trend of blocks nearer the uncoated end being more protected by treatment (Table 3.4).

Table 3.4: Percentage mean mass loss (standard deviation) of 30 mm long treated unshaved blocks exposed for a total of 28 weeks to *P. tephropora*, in relation to the distance from the uncoated end of the original board from which the bioassay block was removed.

LOSP formulation/ Treatment method	Distance of furthest edge from uncoated end			
	120 mm	470 mm	720 mm	950 mm
	E. regnans			
New/dip treatment	11.8 (5.8)	9.2 (5.2)	13.0 (5.9)	12.3 (3.2)
New/commercial	9.5 (4.4)	7.2 (3.5)	9.6 (3.5)	9.9 (5.8)
Current/commercial	9.3 (6.2)	7.3 (4.4)	6.8 (6.5)	7.5 (8.1)
New/low pressure Bethell	8.2 (4.7)	9.3 (5.3)	8.1 (5.2)	11.5 (6.0)
New/high pressure Bethell	1.6 (1.3)	2.0 (2.0)	3.2 (3.1)	4.7 (4.3)
Mean all treatments	8.1	7.0	8.1	9.2
	E. delegatensis			
New/dip treatment	10.4 (4.5)	8.9 (2.3)	12.2 (3.0)	8.0 (4.3)
New/commercial	8.4 (3.5)	10.3 (5.4)	8.9 (3.3)	11.2 (5.0)
Current/commercial	6.7 (3.1)	7.2 (4.3)	6.0 (2.9)	5.8 (2.5)
New/low pressure Bethell	5.5 (3.7)	3.9 (2.5)	7.1 (4.7)	5.5 (3.5)
New/high pressure Bethell	2.1 (1.6)	2.4 (2.7)	1.3 (1.5)	2.3 (1.7)
Mean all treatments	6.6	6.5	7.1	6.6
	Shorea spp.			
New/dip treatment	6.9 (4.7)	6.2 (5.0)	5.6 (4.3)	6.3 (4.7)
New/commercial	1.4 (2.0)	1.7 (2.8)	2.0 (2.1)	1.7 (2.0)
Current/commercial	3.1 (2.7)	3.0 (5.3)	2.8 (5.0)	2.9 (4.0)
New/low pressure Bethell	0.6 (0.9)	1.5 (2.6)	1.7 (3.3)	2.9 (3.2)
New/high pressure Bethell	0.6 (1.3)	0.2 (0.1)	0.1 (0.4)	0.4 (0.7)
Mean all treatments	2.5	2.5	2.4	2.8

As the distance of unshaved block from the uncoated end appeared to have little influence on decay results, these mass losses were combined to provide the summary of decay results shown in Table 3.5. None of the dip treated boards received full protection from fungal decay, as mean mass losses ranged from 6.2 to 11.6%.

For the eucalypts, the high pressure Bethell LOSP treatment provided protection from white rot, with only 2.9% mean mass loss for *E. regnans* and 2.0% for *E. delegatensis*. However, the other less severe (but more commercial) vacuum pressure impregnation schedules failed to prevent decay, with mean mass losses ranging from 5.5% to 9.7% for both timber species. Nevertheless, similar untreated blocks had mean mass losses of 19.9% for *E. regnans* and 27.4% for *E. delegatensis* (Table 3.2), indicating improved fungal resistance through treatment. *Shorea* spp. on the other hand received protection from significant fungal attack through all vacuum/pressure treatment cycles with LOSP (Table 3.5). There was no clear difference in the protection provided by either the 'current' or 'new' LOSP formulations.

Table 3.5: Percentage mean mass loss (standard deviation) of 30 mm long treated unshaved blocks exposed for a total of 28 weeks to *P. tephropora*, irrespective of block distance from uncoated end.

LOSP formulation/ Treatment method	Timber species/mean mass loss (%)		
	E. regnans	*E. delegatensis*	*Shorea* spp.
New/dip treatment	11.6 (5.0)	9.9 (3.8)	6.2 (4.4)
New/commercial	9.1 (4.3)	9.7 (4.2)	1.7 (2.1)
Current/commercial	7.8 (6.1)	6.4 (3.0)	2.9 (4.1)
New/low pressure Bethell	9.3 (5.2)	5.5 (3.6)	1.7 (2.6)
New/high pressure Bethell	2.9 (3.0)	2.0 (1.9)	0.3 (0.3)

Shaved blocks

Along with the unshaved blocks, another set of bioassay blocks were cut from the treated boards at four specified distances from the original coated ends (Table 3.6). These blocks then had the outer 2 mm of side grain removed ('shaved' blocks). The purpose of this exercise was to determine if significant protection was afforded by side grain penetration beyond a 2 mm depth. As with the unshaved blocks, there was no clear trend in fungal resistance with respect to distance that the blocks were cut from the original uncoated end.

As the distance of shaved block from the uncoated end appeared to have little influence on decay results, these mass losses were combined to provide the summary of decay results shown in Table 3.7. No LOSP treatment was sufficient to prevent fungal degradation below the 3% mean mass loss threshold. This result confirms that penetration was limited and patchy in the central heartwood of the hardwood boards examined. Nevertheless, mean mass losses were slightly lower than for similar untreated blocks (19.8% for *E. regnans*, 17.9% for *E. delegatensis* and 13.4% for *Shorea* spp. (Table 3.2)).

Table 3.6: Percentage mean mass loss (standard deviation) of 30 mm long treated shaved blocks exposed for a total of 28 weeks to *P. tephropora*, in relation to the distance from the uncoated end of the original board from which the bioassay block was removed.

LOSP formulation/ Treatment method	Distance of furthest edge from uncoated end			
	90 mm	440 mm	690 mm	920 mm
	E. regnans			
New/dip treatment	18.0 (6.5)	15.8 (3.1)	13.4 (6.0)	13.7 (5.9)
New/commercial	14.2 (7.5)	16.7 (9.7)	14.0 (5.0)	14.1 (4.0)
Current/commercial	16.3 (7.5)	15.9 (10.7)	12.6 (10.5)	11.3 (8.9)
New/low pressure Bethell	11.7 (4.7)	14.6 (5.6)	13.7 (7.9)	17.8 (10.3)
New/high pressure Bethell	4.6 (3.5)	4.4 (1.8)	5.8 (5.0)	6.8 (5.4)
Mean all treatments	13.0	13.5	11.9	12.7
	E. delegatensis			
New/dip treatment	14.2 (8.3)	17.6 (4.8)	13.3 (8.1)	15.1 (5.9)
New/commercial	12.9 (7.4)	13.8 (6.9)	12.6 (6.0)	10.6 (5.2)
Current/commercial	12.7 (6.2)	20.1 (10.5)	12.7 (7.0)	16.7 (5.6)
New/low pressure Bethell	6.5 (5.4)	8.0 (3.4)	10.4 (5.8)	11.5 (4.2)
New/high pressure Bethell	3.0 (2.1)	3.9 (2.1)	5.0 (3.5)	5.0 (2.3)
Mean all treatments	9.9	12.7	10.8	11.8
	Shorea spp.			
New/dip treatment	9.2 (5.5)	9.4 (7.3)	10.1 (8.1)	12.7 (8.9)
New/commercial	5.6 (6.4)	5.7 (5.2)	7.2 (7.3)	4.8 (4.3)
Current/commercial	11.6 (11.1)	11.6 (8.7)	11.9 (9.3)	12.6 (11.2)
New/low pressure Bethell	2.8 (3.4)	6.7 (6.1)	6.9 (6.9)	7.5 (6.1)
New/high pressure Bethell	5.0 (7.1)	4.5 (5.9)	6.4 (7.2)	6.9 (8.4)
Mean all treatments	6.8	7.6	8.5	8.9

Table 3.7: Percentage mean mass loss (standard deviation) of 30 mm long treated shaved blocks exposed for a total of 28 weeks to *P. tephropora*, irrespective of block distance from uncoated end.

LOSP formulation/ Treatment method	Timber species/mean mass loss (%)		
	E. regnans	*E. delegatensis*	*Shorea* spp.
New/dip treatment	15.2 (5.5)	15.0 (6.7)	10.3 (7.2)
New/commercial	14.7 (6.6)	12.5 (6.2)	5.9 (5.6)
Current/commercial	14.0 (9.1)	15.5 (7.7)	11.9 (9.5)
New/low pressure Bethell	14.5 (7.3)	9.1 (4.9)	6.0 (5.7)
New/high pressure Bethell	5.4 (4.0)	4.2 (2.5)	5.7 (6.8)

In summary, dip treatments with LOSP provided least protection to the hardwood window components, indicating that vacuum pressure impregnation should be favoured by window manufacturers. All of the vacuum pressure impregnation schedules with LOSP provided adequate protection to the end grain of treated boards, which in window joinery is the most important region in need of protection. Both LOSP formulations appeared to give similar levels of protection.

The vacuum pressure impregnation schedules also protected the side grain of *Shorea* spp., but not the side grain of eucalypts, except when the high pressure Bethell schedule was employed.

While this result suggests that *Shorea* spp. is more suited to LOSP treatment for window joinery than *E. regnans* and *E. delegatensis*, the fungal resistance in the side grain was improved for the eucalypts. However, blocks that were exposed to fungal decay after having the outer 2 mm shaved off were much more susceptible to decay, indicating that the depth of penetration via the tangential and radial surfaces of the hardwood boards is less than this. Since decay is generally initiated in the joints of window joinery, LOSP treatment is still expected to provide sufficient extension to the service lives of eucalypt windows.

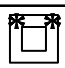
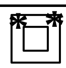
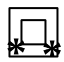
4. Exposure trial of model window frames

The objective of this study was to assess the performance of a range of hardwood timbers, preservative formulations and treatment schedules in an exposure trial designed to replicate and accelerate the decay hazards that are particular to those faced by window joinery.

Untreated timbers

A summary of the results of inspection of the model window frames constructed from untreated timbers after three years exposure is presented in Table 4.1. Results for individual model windows are given in the Appendix.

Table 4.1: Mean decay ratings (of three replicates) in top and bottom rebates of untreated model window frames.

Species	Variation	Mean decay rating in rebate with asterisk			
		Top Row		Lower Row	
					
E. delegatensis	Painted white	7.7	5.2	6.3	0.3
E. obliqua	Painted white	8.0	6.8	7.8	7.2
E. sieberi	Painted white	8.0	8.0	8.0	7.3
Shorea spp.	Painted white	7.7	1.8	7.7	0.2
Thuja plicata	Painted white	8.0	8.0	8.0	8.0
E. regnans	Painted white	7.8	6.5	6.8	2.7
E. regnans	Rebate sealed/ painted white	7.7	4.0	6.5	6.5
E. regnans	Unpainted	7.8	7.0	7.8	7.3

Rating scale: 8 = sound, 0 = destroyed

Decay was most severe in painted window frames constructed from *E. regnans* (mountain ash), *E. delegatensis* (alpine ash) and *Shorea* spp. It is accepted that the heartwood of these timbers is non durable[17]. Minor decay was also detected in frames made of untreated *E. obliqua* (messmate) and *E. sieberi* (silvertop ash), as was found in the soil-block bioassay, and is consistent with their higher in-ground natural durability rating of 3. The data in Table 4.1 show that the extent of decay was greatest in the bottom rebates. Furthermore, the decay was more severe in the windows that were suspended beneath another window frame (the lower row) (Figure 4.1). There was no decay in *T. plicata* (western red cedar) windows.

Unpainted *E. regnans* windows were in better condition than the painted windows. The trial demonstrated that a poorly maintained paint film can accelerate decay. The timber became wet

---

[17] Australian Standard AS 5604-2003. Timber – Natural durability ratings. Standards Australia, Sydney, NSW, 2003.

as water was able to bypass the paint layer at the joints and between the glass and timber beading (there was no putty or sealant). The paint appeared to have acted as a water trap. Accordingly, once wet, the painted timber required a much longer time to dry, accelerating decay.

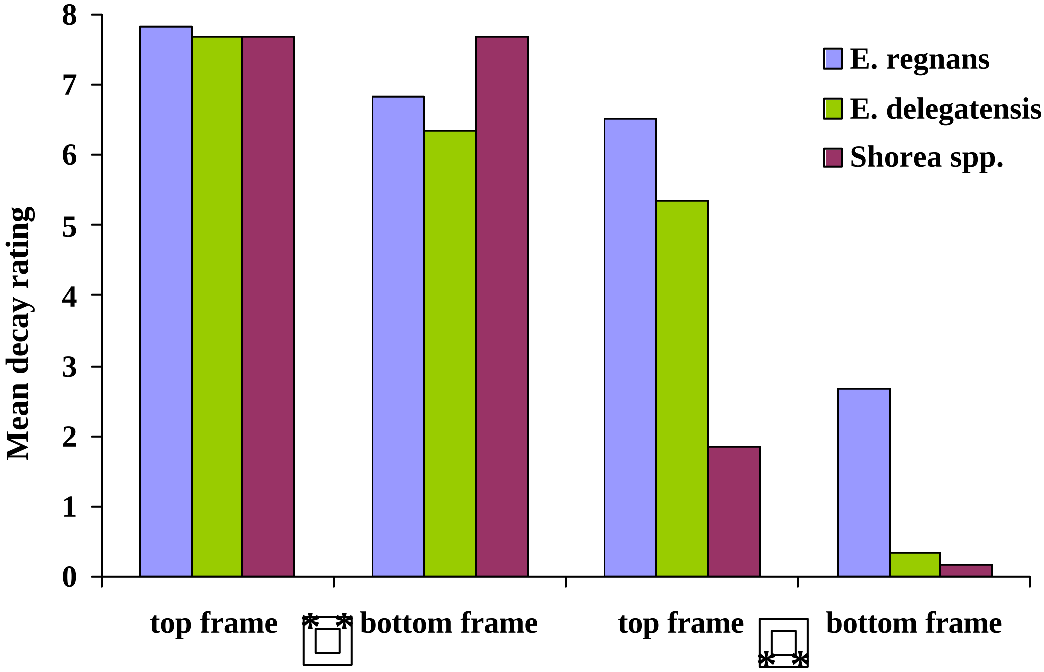


Figure 4.1: Comparison of mean decay ratings in the upper and lower rebates of painted/untreated window frames made from *E. regnans*, *E. delegatensis* and *Shorea* spp. according to whether frames were suspended in the top or bottom row within the exposure bin.

Most painted window frames constructed from untreated *E. regnans*, *E. delegatensis* or *Shorea* spp. failed to decay after three years exposure. Severe decay was often denoted by heavy discolouration of the paint. This discolouration also gave an insight into the pattern of attack, as the decay appeared to originate at the ends of the particular component (within the rebate) and moved progressively away from the rebate, along the grain. This phenomenon is clearly illustrated in Figure 4.2. The value of maintaining the paint coating was also demonstrated in the window survey.

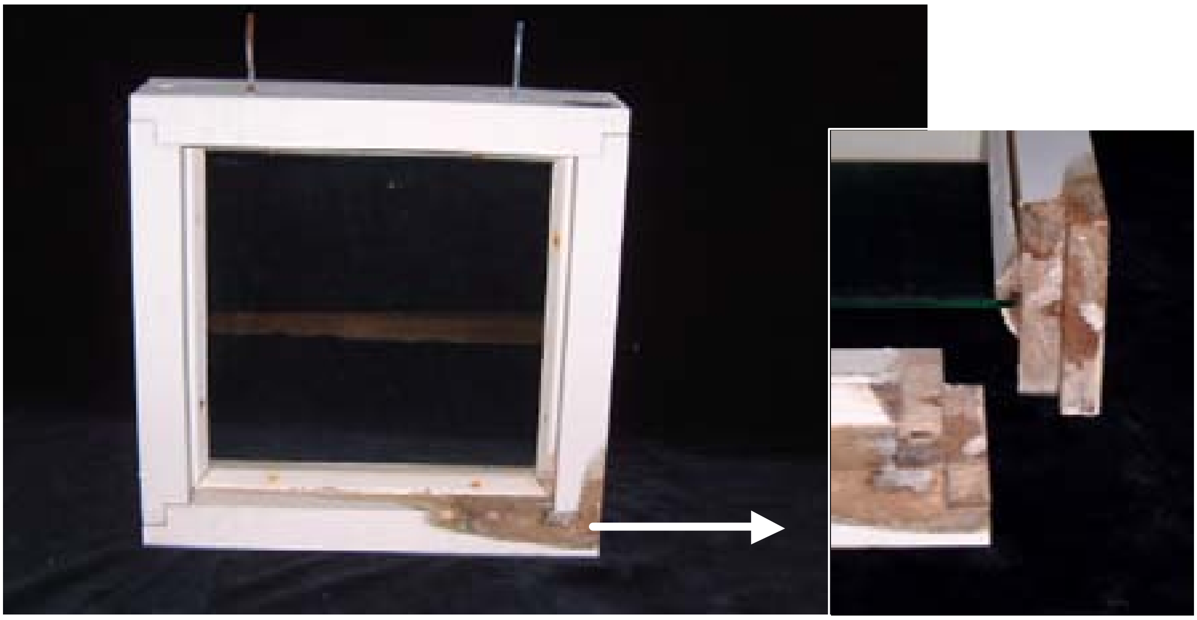


Figure 4.2: Discolouration in the paint due to severe decay in the bottom component of a *Shorea* spp. model window frame. The inset illustrates the extent of the decay in the rebate.

The practice of sealing the end grain before window assembly appeared to promote window durability when 30-40 year-old ash windows were examined in Bairnsdale[13]. The end grain in these windows had been sealed with a lead-based paint which is no longer available. It was thought that additional protection to untreated windows might be obtained by end sealing the internal rebates with primer prior to window assembly. Some evidence in support of this procedure was obtained in the lower rows of frames, where the bottom rebate for end sealed windows had a mean rating of 6.5 compared to 2.7 for similar windows with unsealed rebates. However, a similar trend was not observed in the top row of windows (Table 4.1). While at least some of the aspects of the good performance of joints sealed with lead-based paints can be attributed to the good fungicidal properties of this type of paint, it is likely that the performance of joints with sealed end grain would have been better if the paint used was oil-based, instead of the water-based paint. Figure 4.3 illustrates typical decay in the rebate of an untreated *E. regnans* window that had the end grain sealed prior to assembly.

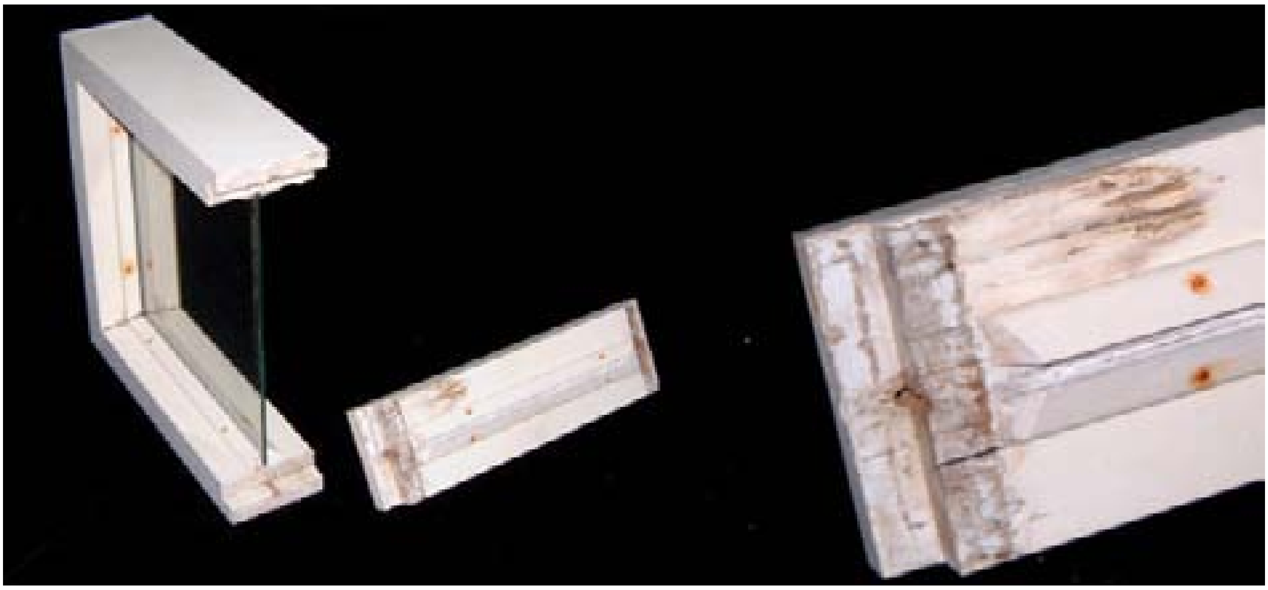


Figure 4.3: Heavy white rot in the rebate of an *E. regnans* model window frame with sealed end grain.

Boron-treated timbers

Boron treated eucalypt samples cut from the boards used for window construction were chemically analysed. The results are presented in Table 4.2. The retention of elemental boron required for lyctine borer control is 0.047 % m/m based on oven-dried wood. Sapwood from two boards of *E. regnans* (a non-susceptible timber) contained 0.059 and 0.077% m/m boron, thereby meeting minimum requirements. All other boards lacked sapwood. The treatment of green hardwoods with boron by vacuum pressure impregnation has been shown in a more extensive study normally to satisfy AS 1604 requirements for H1 lyctine control[18]. The whole heartwood cross-sections of *E. sieberi*, *E. delegatensis* and *E. obliqua* contained mean boron contents of between 0.013 and 0.028% m/m, while *E. regnans* heartwood had a higher mean boron content of 0.042% m/m (Table 4.2).

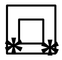
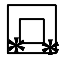
Table 4.2: Boron content as % m/m oven dried wood analysed in the heartwood of eucalypt boards.

Timber species	Replicate board number						Mean
	1	2	3	4	5	6	
E. delegatensis	0.021	0.044	0.032	0.020	0.024	0.026	0.028
E. obliqua	0.012	0.008	0.013	0.010	0.011	0.022	0.013
E. sieberi	0.015	0.014	0.012	0.014	0.009	0.023	0.015
E. regnans	0.026	0.065	0.027	0.052	0.046	0.033	0.042

A summary of the results of the inspection of the boron-treated window frames after three years exposure is presented in Table 4.3, and results for individual replicates are provided in the Appendix.

[18] Cookson, L.J., Scown, D.K. and McCarthy, K. (1998). Boron treatment methods for lyctid susceptible hardwoods growing in Tasmania. Internat. Res. Group on Wood Preserv. Document No. IRG/WP/98-30168.

Table 4.3: Mean decay ratings (of three replicates) in top and bottom rebates of model window frames constructed from timbers treated with a commercial application of boron.

Species	Variation	Mean decay rating in rebate indicated with asterix			
		Top Row		Bottom Row	
					
E. delegatensis	Painted white	8.0	7.6	8.0	7.8
E. obliqua	Painted white	8.0	7.6	8.0	8.0
E. sieberi	Painted white	8.0	8.0	8.0	8.0
E. regnans	Painted white	8.0	8.0	8.0	8.0
E. regnans	No-rot rods/ painted white	8.0	7.3	7.8	7.2

The results suggest that the H1 boron vacuum pressure treatment used to protect hardwoods from lyctine borer also significantly improved resistance to decay. Only slight decay was found in the rebates of two window frames made from boron-treated *E. delegatensis* and *E. obliqua* (Table 4.3 and Figure 4.4). A similar result of improved resistance to decay was found for softwood interior house framing treated with boron for the control of *Anobium*[19].

E. regnans window frames treated with "No-rot" boron diffusion rods also had much less decay than similar untreated windows (Table 4.3). Three of the six windows with "No-rot" rods had light or light-moderate decay, the maximum depth of decay was 6 mm. Decay had not developed significantly since the first year inspection, suggesting that the preservative diffusion from the rods is sufficient to halt decay.

Timber swelling and movement was the main problem associated with the boron-treated timbers. This was probably due to the hygroscopic nature of boron. These windows were regularly sprayed with water in this accelerated test. It is feasible that wood swelling would be less under normal service conditions.

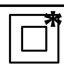
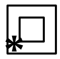
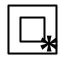
Figure 4.4: Slight decay in the rebate of a boron-treated *E. obliqua* window frame.

[19] M. Hedley, D. Page and B. Patterson (2002). A new technique for testing the decay resistance of framing lumber. Internat. Res. Group on Wood Pres. Document No. IRG/WP02-20247.

LOSP-treated timbers

A summary of the results of the inspection of the LOSP-treated window frames after three years exposure is presented in Table 4.4, and results for individual replicates are provided in the Appendix.

Table 4.4: Mean decay ratings (of six replicates) in model frames constructed from LOSP-treated timbers.

New LOSP formulation-treated using commercial schedule					
Species	**Variation**	**Mean decay rating in rebate**			
					
E. delegatensis	Painted white	8.0	8.0	8.0	8.0
E. obliqua	Painted white	8.0	8.0	8.0	8.0
E. sieberi	Painted white	8.0	8.0	8.0	8.0
Shorea spp.	Painted white	8.0	8.0	8.0	8.0
E. regnans	Painted white	8.0	8.0	8.0	8.0
E. regnans	Painted, brown	8.0	8.0	8.0	8.0
E. regnans	Unpainted	8.0	8.0	8.0	8.0
New LOSP formulation -treated using Low Pressure Bethell schedule					
E. regnans	Painted white	8.0	8.0	8.0	8.0
New LOSP formulation -treated using Dip treatment					
E. regnans	Painted white	8.0	8.0	8.0	8.0
Current commercial LOSP formulation, Protim Timberlife®-treated using a commercial schedule					
E. regnans	Painted white	8.0	8.0	8.0	7.7

After three years exposure in the AFS and on the roof at Clayton, the LOSP-treated window frames were in good condition with only the one *E. regnans* window frame with slight decay. This *E. regnans* frame had been treated with the current LOSP formulation and had prominent decay, particularly where the glass was in contact with the timber (Figure 4.5).

Figure 4.5: Decay in a window frame made from *E. regnans* treated with the current commercial LOSP formulation.

Corrosion
After two years exposure the galvanized screws used in the construction of some of the window frames were heavily corroded. Many of these screws required replacement, particularly those windows that were constructed from timbers treated with boron or the new LOSP formulation. After three years exposure, most of the galvanized screws in the remaining window frames have been replaced. The only window frames with the original screws are those constructed from untreated *E. regnans*, *E. delegatensis* and *Shorea* spp.

After three years exposure the LOSP treatments appeared to provide the best combination of decay resistance and stability.

ACKNOWLEDGEMENTS

This project began with the advice and in-kind support of the Timber Promotion Council of Victoria (Boris Iskra), Osmose Pty Ltd (Mike Iley and Ian Southen), Koppers Arch Wood Protection Pty Ltd (Jenny Holmes and Dr Joely Taylor), Canterbury Windows (Peter Leeke), J.L. Gould Sawmills Pty Ltd (David Goding) and Eureka Timber Co. (John Corrigan). We would also like to thank the Forest and Wood Products Research and Development Corporation for financially supporting this research. We appreciate the help provided by many people who contributed information and assistance to the window survey, including Mr Frank vandenHoff of Great Southern Joinery, Mr Anthony Carlson, window repairer, and the staff of CSIRO FFP.

MATERIALS AND METHODS

1. Window survey

Windows of known age and timber type were located by asking window manufacturers, window repairmen and CSIRO Forestry & Forest Products staff for their assistance. Most windows in the survey from Victoria were examined by one of the authors, for factors such as the presence of external surface decay, eave width and maintenance procedures. Information on windows from the ACT and Mount Gambier were provided by other CSIRO FFP staff.

2. Materials

Timber

The timber species incorporated in these studies and their respective suppliers were:

- *Eucalyptus regnans* (mountain ash), supplied by J.L. Gould Sawmills Pty Ltd, Alexandra, Victoria.
- *E. delegatensis* (alpine ash), supplied by J.L. Gould Sawmills Pty Ltd, Alexandra, Victoria.
- *E. obliqua* (messmate), supplied by Eureka Timber Company, South Ballarat, Victoria.
- *E. sieberi* (silvertop ash), supplied by Bob Humphreys, c/o Don Real Timber, Beaconsfield, Victoria.
- *Shorea* spp. (meranti), supplied by Canterbury Windows Pty Ltd. Springvale, Victoria and Bayswood Timber Wholesalers Pty Ltd, Hallam, Victoria.
- *Thuja plicata* (western red cedar), supplied by Canterbury Windows Pty Ltd. Springvale, Victoria.

All timbers were kiln-dried except for the *E. obliqua*, which was air-dried only.

Treatment formulations

Protim Solignum Limited (now a part of Osmose) supplied LOSP formulations for timber treatment:

a) A new LOSP formulation (P410WR), developed by Osmose, contained the active ingredient propiconazole (Wocosen tech.) at 0.245 % m/vol, tebuconazole (Preventol A8) at 0.245 % m/vol, and permethrin at 0.26 % m/vol.

b) A commercially available LOSP used for comparison, Timberlife® (235WR), which contains 4.6% m/vol TBTN (active Sn 0.99% m/vol) and permethrin 0.26% m/vol.

3. Fungicidal effectiveness of LOSP treatment of eucalypt sapwood

Preparation of treated blocks

Five timber types were included in the assessment; all four eucalypt species and *Shorea* spp. Blocks for treatment were cut from both heartwood and sapwood from all eucalypt species, while only *Shorea* spp. heartwood was used. The blocks for this bioassay were 20 x 20 mm cross section x 10 mm in the grain direction.

Treatment solutions were either of the LOSP formulations, or white spirit alone as a solvent control. Blocks were treated by drawing a vacuum of -95 kPa for 30 minutes, introduction of the preservative whilst the system was still under vacuum, releasing the vacuum and then applying 150 kPa air pressure for one hour. Each block was weighed before and immediately after treatment to determine the retention of preservative. Retentions were based on mass of solution uptake, and the concentrations of active based on the assumption that the solution had a specific gravity of 0.797. More blocks were treated than needed in the bioassay, allowing selection of blocks that had retentions closest to the mean retention for each set.

After treatment, the blocks were wrapped in plastic bags for two weeks, to slow the rate of solvent drying and allow for any chemical immobilisation reactions to occur. Treated blocks were then spread out on trays and left to air dry for two weeks. All of the blocks were subjected to artificial weathering. This consisted of five days leaching in jars in a shaking water bath maintained at 35°C. The water in the jars was three times the volume of the blocks, and was changed daily. Blocks were then vacuum oven dried for five days at 40°C and -90 kPa. The weathered blocks were reconditioned to 12% m.c., weighed, and sterilised by gamma irradiation.

Fungal soil-block bioassay

Three basidiomycete fungi were used in this bioassay, two white-rotting fungi (*Perenniporia tephropora* and *Ganoderma cupreum*) and a brown-rotting fungus (*Coniophora olivacea*). The characteristics of these strains are given in Table 2.2.

Table 2.2: Basidiomycetes used in the bioassays. (Information compiled originally by G.C. Johnson & M.A. Tighe)

Nomenclature	DFP isolate No.	Brown rot (BR) or white rot (WR)	Distribution	Preferred substrate (not exclusive)
Perenniporia tephropora (Mont.) Ryv.	7904	WR. Boron tolerant	Tropical and subtropical	Softwood and hardwood
Ganoderma cupreum Bresadola	3896	WR.	Ubiquitous	Hardwood and softwood
Coniophora olivacea (Fr.) Karst.	1779	BR	Ubiquitous	Softwood and hardwood

The test vessels used were 250 ml screw-capped glass jars each containing 150 g of 'Toolangi forest loam' soil moistened to 60% moisture content. Two poplar sapwood veneer feeder strips previously soaked overnight in 1% malt extract solution were placed on the soil in each jar. Jars were autoclaved for 2 h. The feeder strips were inoculated with the appropriate test fungus. One set of jars was left uninoculated as a sterile control to determine if there was any mass loss or gain not attributable to fungal attack.

After 14 days the fungi had grown sufficiently on the feeder strips, so sterilised test blocks were planted. There were six replicate blocks per fungus/preservative/timber-species/wood-type combination. Each jar contained two replicate blocks from the same combination. All fungi and sterile controls were incubated at 25°C. Relative humidity was at least 85%, as jars were placed in trays containing water, and each tray enclosed in a large plastic bag. After 12 weeks' incubation, blocks were removed from the jars, weighed to determine moisture content, reconditioned to 12% m.c., and weighed once more to obtain individual mass losses. A mean mass loss greater than 3% is considered to be an indication that the preservative retention has failed to control the fungus.

4. Evaluation of LOSP treatments using the decay tray bioassay

Timber preparation

The timber species used in this study were E. *regnans, E. delegatensis* and *Shorea* spp.

Timbers were dressed and docked to produce boards measuring 1000 x 80 x 30 mm. One end of each board was sealed with three coats of a two-part epoxy, to become the 'coated end', and prevent the influx of preservative from that direction during treatment. Twelve boards of each species were prepared for each treatment.

LOSP treatment

Both LOSP formulations were used for treatment. Two sets of boards were treated with either LOSP using a schedule that could be readily applied commercially:

- A commercial schedule involving:
  - an initial vacuum of –60 kPa for 10 minutes
  - introduction of preservative under vacuum
  - application of a pressure of 50 kPa for 15 minutes
  - removal of preservative formulation
  - final vacuum of –85 kPa for 20 minutes

The ‘new’ formulation was also used to treat sets of boards using a range of treatment schedules:

- A low pressure Bethell schedule involving:
  - an initial vacuum of –95 kPa for 30 minutes
  - introduction of preservative under vacuum
  - application of a pressure of 150 kPa for 30 minutes
  - removal of preservative formulation
  - final vacuum of –95 kPa for 30 minutes
- A high pressure Bethell schedule involving:
  - an initial vacuum of –95 kPa for 30 minutes
  - introduction of preservative under vacuum
  - application of a pressure of 1380 kPa for 30 minutes
  - removal of preservative formulation
  - final vacuum of –95 kPa for 30 minutes
- A three minute dip

The boards were weighed before and immediately after treatment to determine formulation uptake. They were then left stickered for six weeks to allow for the evaporation of residual solvent. Six replicate boards representing a range of retentions were then selected from the twelve that were treated, for the decay assessment.

Bioassay specimen preparation

Ten blocks measuring 30 mm along the grain were cut from each board for the decay study according to the schematic diagram illustrated in Figure 3.1. Four blocks with the furthest edge 150, 500, 750 and 980 mm from the uncoated end, remained intact. A second group of four blocks, the distance of the furthest edge of each from the uncoated end of the board being 120, 470, 720 and 950 mm, was cut and then ‘shaved’ to remove the outer two millimetres from the radial and tangential surfaces (hence removing the original treated surface). There were two 30 mm sterile control blocks cut from each board, one shaved block at 440 mm, and one unshaved block 690 mm from the uncoated end. An 8 mm block was cut from the uncoated end to assess end grain penetration, and another was cut 158 mm from the uncoated end to act as a sterile control. 8 mm was chosen as the length of the end grain block because AS 1604.1-2000[4] requires this depth of envelope, including end grain penetration, for timbers with a lesser cross-sectional dimension of 35 mm or more. Although these blocks had cross-sectional widths of 30 mm, larger sections can be used in window joinery.

Untreated control blocks were cut from three or more different untreated sections of each timber species for inclusion in the trial. Untreated control blocks included blocks 30 mm long of shaved and unshaved dimensions, and 8 mm long blocks.

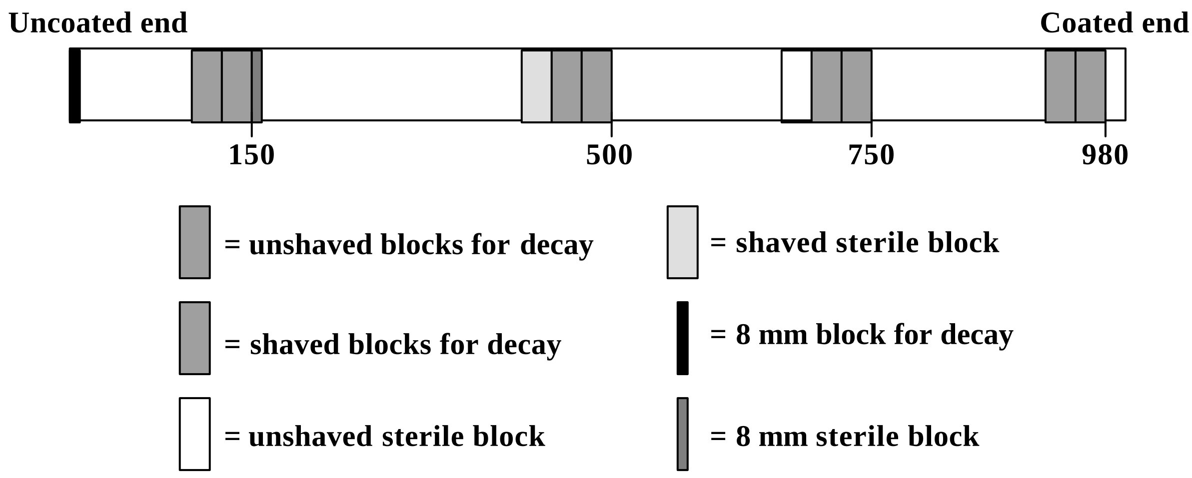


Figure 3.1: Position of blocks cut from LOSP treated 1000 mm long boards. Coated end grain was painted with epoxy to prevent preservative penetration in that direction.

Artificial weathering

Once cut, the blocks were separated on wire racks, and allowed to air dry for four weeks. All blocks were then artificially weathered by placing them in vacuum ovens at 40°C for five days. They were not leached, as during re-drying many blocks of this size would check and split excessively, thereby disrupting the treatment envelope to an extent not seen in maintained windows. Also, the LOSP preservatives tested are accepted H3 treatments, known from previous work to be leach resistant. Blocks were conditioned to 12% moisture content (MC), and then both end grain faces on each 30 mm block were sealed with three coats of epoxy resin. Once painted, the blocks were again reconditioned to 12% MC and weighed. Prior to placement in the decay or sterile tray chambers, all of the blocks were sterilised by gamma-irradiation.

Decay tray bioassay

The decay chambers were stainless steel trays, 320 x 250 x 105 mm deep. Two litres of molten malt agar (1% malt extract, 2% agar) were poured into each tray. The trays were then covered with a sheet of aluminium foil, placed in an autoclave bag, and autoclaved. Once sterilised, some trays were left, to house the sterile control blocks, while the remainder were inoculated. The decay fungus was the white-rot *P. tephropora*, DFP strain number 7904. After a two week growth period, a sterile plastic mesh mat was laid over the agar surface and the blocks planted.

The 30 mm blocks were positioned so that the epoxy coated sides were perpendicular to the plastic mesh. Two 8 mm blocks cut from the same timber species and treatment schedule group were sandwiched together with one untreated 8 mm block of the same timber species placed between them. The treated blocks were positioned with the original treated ends facing the untreated block. Placing 1 mm thick plastic mesh strips between the 8 mm blocks, and holding them together with a rubber band, completed the ‘sandwich’. These three-block assemblies were positioned on their edge, with the grain horizontal. There was a total of 72 decay and sterile trays. There were about 15 blocks per tray. Blocks from different boards and different species were fully randomised between the trays.

Trays were placed in an incubation room at 25ºC for 12 weeks. The 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 remaining. It was found that mass losses resulting from this first exposure were insufficient to provide comparative results. Therefore, the same test blocks were re-sterilized and exposed to *P. tephropora* for a further 16 weeks using the same technique, except that blocks were not sandwiched together. The 8 mm treated blocks were positioned with the original treated ends facing the agar. Total exposure was therefore 28 weeks. The mass loss for each block was expressed as a percentage of original block weight. The mass loss for each block was adjusted to account for any change in mass observed in the sterile controls. Mean percentage mass loss was calculated for the shaved and unshaved treated wood blocks at each distance from the uncoated end of the boards. A mean percentage mass loss and standard deviation were also calculated for the shaved and unshaved untreated control blocks.

5. Exposure trial of model window frames

Timber preparation

The timber species incorporated in this study were *E. regnans, E. delegatensis, E. obliqua, E. sieberi, Shorea* spp. and *T. plicata*.

Timbers were dressed and docked to produce boards measuring 1000 x 80 x 30 mm. The model window frames were to be constructed using a simple butt join at each corner, hence a 15 mm rebate was cut into both ends of the boards prior to treatment.

LOSP treatment

All kiln-dried boards were divided into groups of 12 for treatment with LOSP formulations. The replicate boards were treated with either preservative formulation using a range of treatment schedules:

- A commercial schedule involving:
    - an initial vacuum of –60 kPa for 10 minutes
    - introduction of preservative under vacuum
    - application of a pressure of 50 kPa for 15 minutes
    - removal of preservative formulation
    - final vacuum of –85 kPa for 20 minutes
- A low pressure Bethell schedule involving:
    - an initial vacuum of –95 kPa for 30 minutes
    - introduction of preservative under vacuum
    - application of a pressure of 150 kPa for 30 minutes
    - removal of preservative formulation
    - final vacuum of –95 kPa for 30 minutes
- A three minute dip

The boards were weighed before and immediately after treatment to determine formulation uptake. They were then stickered for six weeks to allow for the evaporation of residual solvent.

Boron treatment

In addition to the kiln dried timber, 12 green *E. regnans*, *E. delegatensis*, *E. obliqua* and *E. sieberi* boards, measuring 2400 x 90 x 45 mm, were collected immediately after they were cut from the saw log and wrapped in plastic. The green timbers were vacuum pressure treated with boron (Diffusol®) through the Eureka Timber Company. The latter arranged for the timbers to be treated at Beaufort treatment plant, following the procedure generally used to protect sapwood from lyctine borers. After treatment the timbers were air dried and reconditioned. Boards were then dressed and docked to 1000 x 80 x 30 mm.

Window construction

From each metre long board, a 300 mm length and a 270 mm length were docked from opposing ends. The original ends of the cut lengths of LOSP treated boards already had a 15 mm rebate treated in final form. A second 15 mm rebate was cut into the new end (Figure 4.6). Treated components with a fresh rebate cut into one end were dipped in the appropriate preservative to ensure that the freshly exposed timber surface was properly treated. LOSP-treated boards were dipped for three minutes while boron-treated boards were dipped in diluted Diffusol® for 15 minutes. After dipping the ends, the boards were wiped free of excess preservative formulation and stickered to air dry for one week. Timbers were treated as one metre lengths to produce penetration patterns more similar to those obtained in commercial practice. Smaller windows were made so that they would fit into the space available in the AFS.

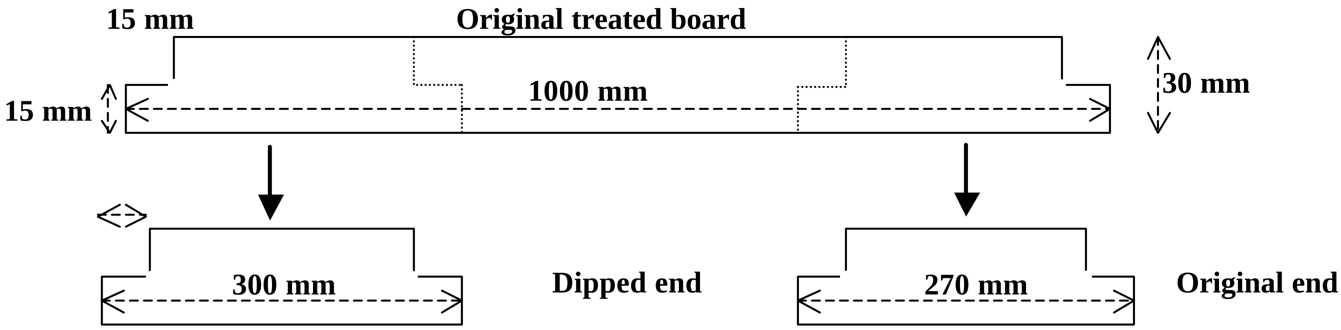


Figure 4.6: Diagram showing window components cut from original treated board.

The 300 and 270 mm lengths cut from each board were kept together and paired with a set of components that had been cut from a board from the same formulation/treatment schedule combination and that also had a similar preservative uptake. This combination made up one model window frame.

The model window frames were designed so that they could be easily disassembled during the annual inspections. The two 270 mm components were brought together to sit within the rebates of the two 300 mm components (Figure 4.7).

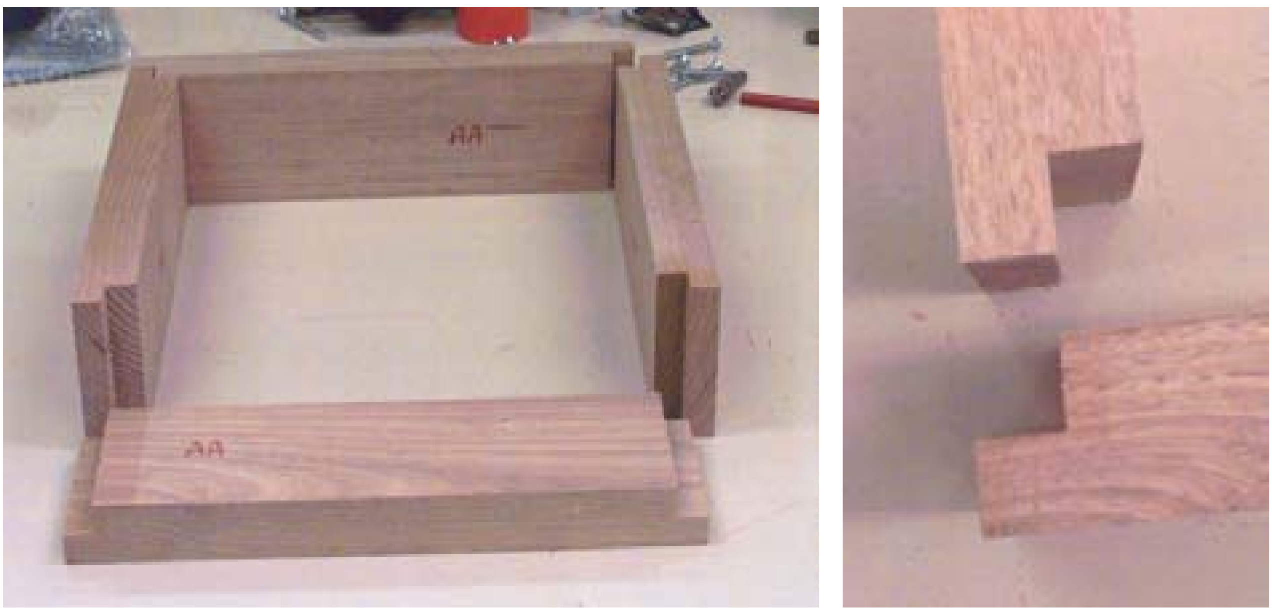


Figure 4.7: Construction of the model windows showing positioning of 270 mm long components within the rebate of the 300 mm components (left) and a close-up view of the butt joint (right).

The components were arranged so that two originally treated rebates came together in one butt joint. Two butt joints were made up by an originally treated rebate meeting a dipped rebate and the fourth butt joint consisted of two dipped rebates coming together (Figure 4.8).

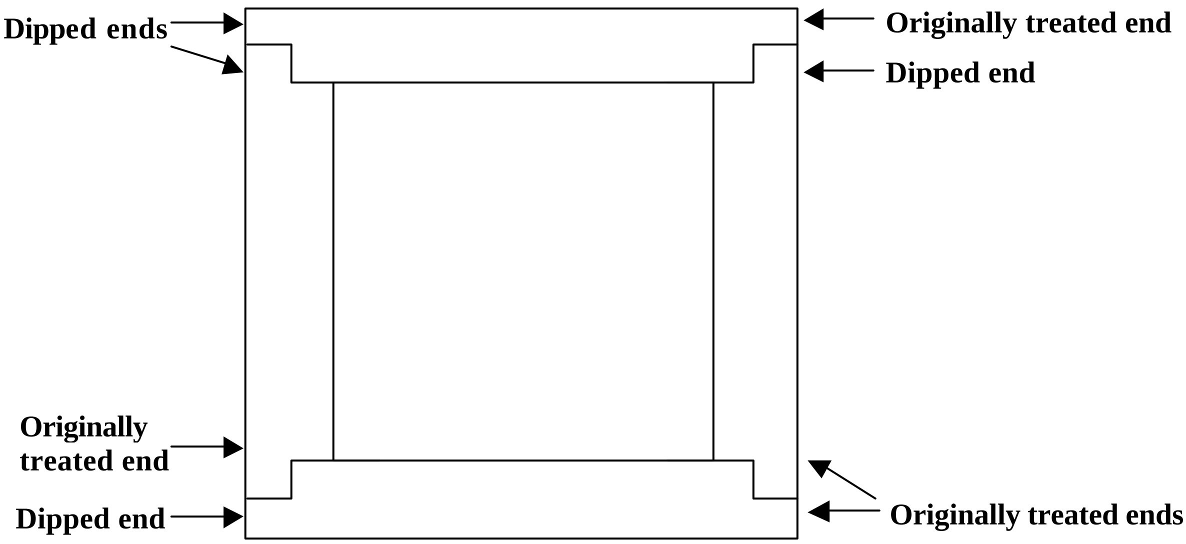
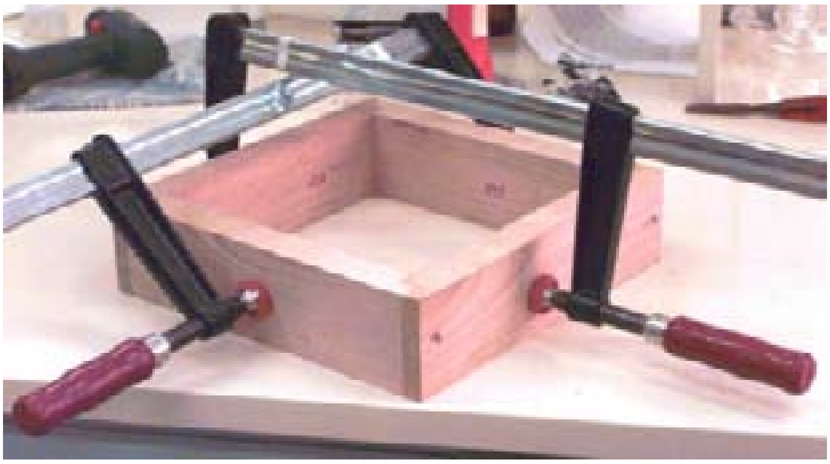


Figure 4.8: Arrangement of treated rebates with the model window frames.

Once positioned, the window frame was clamped in place and held together with a single screw driven into each of the four butt joints through the overlapping rebate (Figure 4.9).

(a)



(b)

Figure 4.9: Arranged components of a model window frame being clamped (a) and a single screw being driven into the overlapping rebate to fix the butt joint (b).

When the window frames were secure, they were glazed with a single piece of glass measuring 238 mm square held in place with LOSP-treated *Shorea* spp. beading (glass and beading supplied by Canterbury Windows). The beading was not fixed tight to the glass, so that water hitting the glass or condensation could flow down the glass and pond inside the beading and come into contact with the test timber.

From the twelve boards in each species/formulation/treatment schedule combination, six model window frames were produced. Most windows were then painted, as indicated in Table 4.5, using Dulux Weathershield® low sheen acrylic (in either clotted cream or mission brown). Additionally, multiple groups of six *E. regnans* window frames were constructed so that further variations could be included in the trial. These additional groups involved either LOSP-treated timber or untreated timber. These variations for *E. regnans* included:

- Unpainted windows.
- Painting the rebates to seal the end-grain prior to construction and painting the window frame before glass was installed to seal the timber beneath the beading and glass.
- Painting window frames after installation of the glass to leave timber beneath the beading and glass exposed, using white or dark brown coloured paint
- Installation of Preschem No-Rot® diffusible preservative rods 35 mm back from each rebate. These rods consist of Boron (124g/kg) present as 582g/kg disodium octaborate tetrahydrate and 110g/kg fluorine present as 243g/kg sodium fluoride.

In total, 138 model window frames were included in the exposure trial encompassing 23 variations of six replicates. A summary of the species/treatment type/variation combinations is presented in Table 4.5.

Table 4.5: Summary of the species/treatment type/variation combinations included in the model window exposure trial.

Preservative formulation	Untreated	Untreated	Untreated	LOSP (new)	LOSP (new)	LOSP (new)	LOSP (new)	LOSP (new)	LOSP (current)	Boron	Untreated
Treatment schedule	-	-	-	Com.	Com.	Com.	L.P.B	Dip	Com.	Dip	-
Variation	Un-painted	Rebate painted (white)	Painted (white)	Painted (white)	Painted (brown)	Un-painted	Painted (white)	Painted (white)	Painted (white)	Painted (white)	No-Rot rods, painted (white)
E. regnans (mountain ash)	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
E. delegatensis (alpine ash)			✓	✓						✓	
E. obliqua (messmate)			✓	✓						✓	
E. sieberi (silvertop ash)			✓	✓						✓	
Shorea spp. (meranti)			✓	✓							
Thuja plicata (western red cedar)			✓								

Com. = commercial schedule, L.P.B = low pressure Bethell, Dip = three minute dip.

Exposure

The construction of the model windows was completed in January 2001. Replicates were initially exposed on a roof at the CSIRO Forestry and Forest Products, Clayton laboratory (Figure 4.10). This initial exposure period coincided with the summer months in Melbourne. Since the poor performance of timber windows has been associated with the deterioration of the coat of paint protecting the wood, it was believed that an attempt to subject the model window frames to a "worst case scenario" would benefit from possible damage to the paintwork induced by the hot summer sun. At the end of April the window frames were removed from the roof and exposed in the accelerated field simulator (AFS) at Clayton.

Figure 4.10: Summer exposure of model window frames on the roof of the Clayton laboratory.

The accelerated field simulator (AFS) is located at CSIRO Forestry and Forest Products, Clayton laboratory. Conditions in the AFS are maintained at 28 ºC and 85 % relative humidity. These are optimal conditions for the promotion of wood decay, particularly soft rot. The model window frames were exposed in the AFS by suspending the frames inside a concrete bin measuring 1.2 x 0.9 x 6.0 metres. The windows were paired so that those made up from boards with similar retentions of the same preservative were together. The window of each pair with the higher retention was suspended from the other which, in turn, was itself suspended from a 1200 mm long metal rod that rested on top of the concrete bin. Three pairs of frames were suspended from each metal rod. There were 23 metal rods in total and window frame pairs were randomly distributed throughout this set-up. The windows were arranged in order of descending preservative retention so that the effect of any preservative leaching from the treated timber in the top frame onto the bottom frame would be minimised. The arrangement of window frames within the AFS is illustrated in Figure 4.11.

A watering system was laid in the base of the concrete bin. Fine mist sprays were connected in series so that 25 parallel groups of three sprays ran the length of the bin. Each line of three sprays was positioned between two racks of windows hanging from the top of the bin, with a set of sprays occurring both before the first frame and after the last. Soil to a depth of 150 mm was placed over this sprinkling system and bark from an old wood yard was spread across the top of the soil to provide a source of wood decaying fungal inoculum. The watering system was turned on for about five minutes each week.

Figure 4.11: Exposure of model window frames during the nine cooler months of the year in the AFS.

Window inspection

The model windows were inspected after twelve months of exposure (three months in the sun and nine months in the AFS). Each frame was dismantled and individual components probed with a knife to detect decay. The depth and location of decay was noted. Specimens were given a performance rating of between 8 and 0 based on the amount of cross-section lost[20] (Table 4.6).

Table 4.6: Decay ratings given to timber samples based on the degree of fungal attack.

Rating	Cross-section lost	Depth of decay (mm) from surface		Description of decay
		Flat surface	End grain	
8	No loss, sound	0	0	No decay
7	Up to 15 %	0-2.5	0-5	Light decay
6	15-30 %	2.5-5.0	5-10	Light-moderate decay
5	30-45 %	5.0-7.5	10-15	Moderate decay
4	45-60 %	7.5-9.0	15-20	Moderate-heavy decay
3	60-75 %	9.0-11.5	20-25	Heavy decay
2	75-90 %	11.5-13.5	25-30	Severe decay
1	90-99 %	13.5-15	30-35	Severe-destroyed
0	100 %	15+	35+	Destroyed

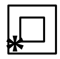
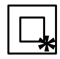
A specimen rated 3 is considered to be unserviceable.

After inspection the windows were reassembled and placed back on the roof of the Clayton laboratory to begin another exposure cycle.

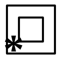
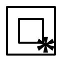
[20] J.D Thornton, G.C. Johnson, and N-K. Nguyen (1991). An in-ground natural durability field test of Australian timbers and exotic reference species. VI. Results after approximately 21 years exposure. Material und Organismen 26 (2): 145-155.

APPENDIX Assessment of model window frames after three years.

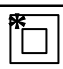
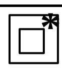
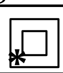
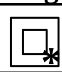
i) Untreated window frames.

			Condition in rebate, decay rating (depth of decay (mm)).			
Frame No.	**Variation**	**Position**				
			E. regnans			
MA 1	Painted white	Top	8	8	7 (2)	8
MA 2	Painted white	Bottom	7 (1)	8	8	8
MA 3	Painted white	Top	7 (2)	8	6 (8)	6 (10)
MA 4	Painted white	Bottom	6 (10)	8	0 (150)	0 (150)
MA 5	Painted white	Top	8	8	6 (5)	6 (5)
MA 6	Painted white	Bottom	6 (6)	6 (6)	0 (50)	0 (50)
			E. delegatensis			
AA 1	Painted white	Top	6 (6)	8	6 (10)	7(5)
AA 2	Painted white	Bottom	2 (30)	8	0 (70)	0 (50)
AA 3	Painted white	Top	8	8	7 (5)	7 (2)
AA 4	Painted white	Bottom	7 (5)	7 (5)	2 (30)	0 (70)
AA 5	Painted white	Top	8	8	2 (30)	2 (30)
AA 6	Painted white	Bottom	7 (5)	7 (2)	0 (150)	0 (150)
			E. sieberi			
SA 1	Painted white	Top	8	8	8	8
SA 2	Painted white	Bottom	8	8	7(4)	8
SA 3	Painted white	Top	8	8	8	8
SA 4	Painted white	Bottom	8	8	7 (2)	7 (2)
SA 5	Painted white	Top	8	8	8	8
SA 6	Painted white	Bottom	8	8	7 (3)	8
			E. obliqua			
MS 1	Painted white	Top	8	8	8	8
MS 2	Painted white	Bottom	8	8	7 (3)	7 (3)
MS 3	Painted white	Top	8	8	5 (15)	6 (10)
MS 4	Painted white	Bottom	7 (1)	8	7 (2)	7 (2)
MS 5	Painted white	Top	8	8	7 (3)	7 (2)
MS 6	Painted white	Bottom	8	8	7 (2)	8
			***Shorea* spp.**			
M 1	Painted white	Top	8	8	0 (120)	0 (120)
M 2	Painted white	Bottom	8	8	0 (150)	0 (150)
M 3	Painted white	Top	6 (10)	8	0 (90)	8
M 4	Painted white	Bottom	6 (8)	8	0 (150)	0 (150)
M 5	Painted white	Top	8	8	1 (40)	2 (25)
M 6	Painted white	Bottom	8	8	0 (150)	1 (40)
			T. plicata			
WR 1	Painted white	Top	8	8	8	8
WR 2	Painted white	Bottom	8	8	8	8
WR 3	Painted white	Top	8	8	8	8
WR 4	Painted white	Bottom	8	8	8	8
WR 5	Painted white	Top	8	8	8	8
WR 6	Painted white	Bottom	8	8	8	8

i) Untreated window frames (cont'd…).

			Condition in rebate, decay rating (depth of decay (mm)).			
Frame No.	**Variation**	**Position**				
			E. regnans			
MA 7	Unpainted	Top	8	8	7 (2)	8
MA 8	Unpainted	Bottom	7 (2)	8	7 (2)	8
MA 9	Unpainted	Top	7 (1)	8	7 (2)	7 (2)
MA 10	Unpainted	Bottom	8	8	7 (5)	7 (5)
MA 11	Unpainted	Top	8	8	7 (2)	7 (2)
MA 12	Unpainted	Bottom	8	8	6 (6)	6 (6)
MA 13	No-rot rods, painted white	Top	8	8	7 (3)	8
MA 14	No-rot rods, painted white	Bottom	8	8	6 (6)	7 (2)
MA 15	No-rot rods, painted white	Top	8	8	7 (5)	7 (1)
MA 16	No-rot rods, painted white	Bottom	7 (1)	8	7 (5)	7 (5)
MA 17	No-rot rods, painted white	Top	8	8	7 (2)	8
MA 18	No-rot rods, painted white	Bottom	8	8	8	8
MA 19	Rebate sealed, painted white	Top	7 (3)	8	0 (70)	0 (70)
MA 20	Rebate sealed, painted white	Bottom	8	8	7 (5)	8
MA 21	Rebate sealed, painted white	Top	8	8	2 (30)	7 (5)
MA 22	Rebate sealed, painted white	Bottom	7 (2)	8	7 (5)	6 (10)
MA 23	Rebate sealed, painted white	Top	8	8	8	7 (3)
MA 24	Rebate sealed, painted white	Bottom	8	0 (80)	6 (10)	6 (10)

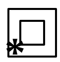
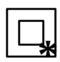
ii) Treatment of *E. regnans* with new LOSP formulation using a Low Pressure Bethell schedule.

Frame No.	**Mean retn. Of formulation (L/m^3)**	**Variation**	**Position**	**Condition in rebate, decay rating**			
							
MANLP 1	10.3	Unpainted	Top	8	8	8	8
MANLP 2	13.0	Unpainted	Bottom	8	8	8	8
MANLP 3	14.5	Unpainted	Top	8	8	8	8
MANLP 4	17.7	Unpainted	Bottom	8	8	8	8
MANLP 5	28.1	Unpainted	Top	8	8	8	8
MANLP 6	37.9	Unpainted	Bottom	8	8	8	8

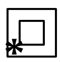
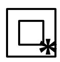
iii) Treatment with new LOSP formulation using a Commercial schedule.

Frame No.	Mean retn. Of formulation (L/m^3)	Variation	Position	Condition in rebate, decay rating			
E. delegatensis							
AAN 1	5.5	Painted white	Top	8	8	8	8
AAN 2	9.0	Painted white	Bottom	8	8	8	8
AAN 3	10.1	Painted white	Top	8	8	8	8
AAN 4	11.2	Painted white	Bottom	8	8	8	8
AAN 5	13.2	Painted white	Top	8	8	8	8
AAN 6	34.5	Painted white	Bottom	8	8	8	8
E. sieberi							
SAN 1	4.7	Painted white	Top	8	8	8	8
SAN 2	8.5	Painted white	Bottom	8	8	8	8
SAN 3	9.9	Painted white	Top	8	8	8	8
SAN 4	13.2	Painted white	Bottom	8	8	8	8
SAN 5	21.7	Painted white	Top	8	8	8	8
SAN 6	28.8	Painted white	Bottom	8	8	8	8
E. obliqua							
MSN 1	7.4	Painted white	Top	8	8	8	8
MSN 2	18.6	Painted white	Bottom	8	8	8	8
MSN 3	21.4	Painted white	Top	8	8	8	8
MSN 4	23.3	Painted white	Bottom	8	8	8	8
MSN 5	25.5	Painted white	Top	8	8	8	8
MSN 6	34.8	Painted white	Bottom	8	8	8	8
***Shorea* spp.**							
MN 1	12.1	Painted white	Top	8	8	8	8
MN 2	13.4	Painted white	Bottom	8	8	8	8
MN 3	15.4	Painted white	Top	8	8	8	8
MN 4	24.7	Painted white	Bottom	8	8	8	8
MN 5	33.7	Painted white	Top	8	8	8	8
MN 6	49.6	Painted white	Bottom	8	8	8	8
E. regnans							
MANC 1	5.2	Painted white	Top	8	8	8	8
MANC 2	5.5	Painted white	Bottom	8	8	8	8
MANC 3	6.0	Painted white	Top	8	8	8	8
MANC 4	6.9	Painted white	Bottom	8	8	8	8
MANC 5	7.1	Painted white	Top	8	8	8	8
MANC 6	7.1	Painted white	Bottom	8	8	8	8
E. regnans							
MANC 7	7.7	Painted brown	Top	8	8	8	8
MANC 8	7.7	Painted brown	Bottom	8	8	8	8
MANC 9	7.4	Painted brown	Top	8	8	8	8
MANC 10	8.5	Painted brown	Bottom	8	8	8	8
MANC 11	9.6	Painted brown	Top	8	8	8	8
MANC 12	10.1	Painted brown	Bottom	8	8	8	8
E. regnans							
MANC 13	11.0	Unpainted	Top	8	8	8	8
MANC 14	12.1	Unpainted	Bottom	8	8	8	8
MANC 15	12.6	Unpainted	Top	8	8	8	8
MANC 16	14.8	Unpainted	Bottom	8	8	8	8
MANC 17	17.8	Unpainted	Top	8	8	8	8
MANC 18	24.4	Unpainted	Bottom	8	8	8	8

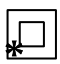
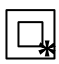
iv) Treatment of *E. regnans* with new LOSP formulation by dipping.

Frame No.	Mean retn. Of formulation (L/m^3)	Variation	Position	Condition in rebate, decay rating.			
							
MAND 1	2.7	Painted white	Top	8	8	8	8
MAND 2	3.0	Painted white	Bottom	8	8	8	8
MAND 3	3.6	Painted white	Top	8	8	8	8
MAND 4	4.4	Painted white	Bottom	8	8	8	8
MAND 5	4.9	Painted white	Top	8	8	8	8
MAND 6	5.5	Painted white	Bottom	8	8	8	8

v) Treatment of *E. regnans* with a current commercial LOSP formulation, Protim Timberlife® using a commercial schedule.

Frame No.	Mean retn. Of formulation (L/m^3)	Variation	Position	Condition in rebate, decay rating.			
							
MAOC 1	7.1	Painted white	Top	8	8	8	8
MAOC 2	8.5	Painted white	Bottom	8	8	8	8
MAOC 3	9.0	Painted white	Top	8	8	8	8
MAOC 4	11.5	Painted white	Bottom	8	8	8	8
MAOC 5	14.0	Painted white	Top	8	8	8	8
MAOC 6	21.9	Painted white	Bottom	8	8	8	7 (2)

vi) Commercial treatment of green timbers with boron.

			Condition in rebate, decay rating (depth of decay (mm)).			
Frame No.	Variation	Position				
			E. regnans			
MAB 1	Painted	Top	8	8	8	8
MAB 2	Painted	Bottom	8	8	8	8
MAB 3	Painted	Top	8	8	8	8
MAB 4	Painted	Bottom	8	8	8	8
MAB 5	Painted	Top	8	8	8	8
MAB 6	Painted	Bottom	8	8	8	8
			E. delegatensis			
AAB 1	Painted	Top	8	8	8	8
AAB 2	Painted	Bottom	8	8	8	8
AAB 3	Painted	Top	8	8	7 (1)	7 (1)
AAB 4	Painted	Bottom	8	8	7 (2)	8
AAB 5	Painted	Top	8	8	8	8
AAB 6	Painted	Bottom	8	8	8	8
			E. sieberi			
SAB 1	Painted	Top	8	8	8	8
SAB 2	Painted	Bottom	8	8	8	8
SAB 3	Painted	Top	8	8	8	8
SAB 4	Painted	Bottom	8	8	8	8
SAB 5	Painted	Top	8	8	8	8
SAB 6	Painted	Bottom	8	8	8	8
			E. obliqua			
MSB 1	Painted	Top	8	8	7 (2)	8
MSB 2	Painted	Bottom	8	8	8	8
MSB 3	Painted	Top	8	8	7 (2)	8
MSB 4	Painted	Bottom	8	8	8	8
MSB 5	Painted	Top	8	8	8	8
MSB 6	Painted	Bottom	8	8	8	8