Processing backsawn Tasmanian regrowth *Eucalyptus obliqua*

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Abstract

In response to changes in log supply, the Tasmanian sawmilling industry carried out an experimental program aimed at developing efficient methods of processing regrowth Eucalyptus obliqua *L'Hérit. into high quality sawn and dried timber similar to that produced from mature logs. The key objective of the program was to explore the drying of backsawn (tangentially sawn) boards to improve both gross recovery and value recovery from smaller logs over that obtained from quartersawing, the traditional method of sawing in Tasmania. Application of conventional processing and drying techniques resulted in large losses of backsawn timber due to end split and surface checking, although pre-drying to fibre saturation point under controlled conditions gave significantly better results than air or shed pre-drying. Several techniques were trialled to reduce degrade of backsawn timber to commercially viable levels, but were unsuccessful.*

Introduction

Historically, the Tasmanian sawmilling industry has had ready access to supplies of mature eucalypt logs for conversion to sawn timber (Australia Senate Standing Committee on Trade and Commerce 1981; Helsham 1988). However, during the 1950s and 1960s, up to 50 spot mills also processed regrowth logs on a part-time, seasonal basis in southern Tasmania. These regrowth logs originated from forest stands regenerated following major wildfires in 1880, 1914, 1918 and 1934, and were used to produce packaging material for the export apple and pear industry. Regrowth wood was favoured because of its pale colour and more rapid drying compared to mature wood. Few regrowth logs were processed into other, higher value sawn timber products during this period because of their refractory sawing and drying characteristics when compared to mature wood.

A downturn in the apple export industry and a shift to cardboard packaging saw the end of milling regrowth logs for packaging. Most of these spot mills ceased operating but a few shifted their focus to producing other sawn timber products from regrowth logs. By the late 1980s, processing of regrowth was centred on two mills, with a small number of satellite operations selling undried timber to them or cutting on contract for them. The two remaining mills were B.G. Clennett (now Clennett Timber Industries), operating at Dover, and J.W. Porta, operating at Geeveston. Most of their product was of short length, thin section and narrow width, and all was quartersawn (cut with growth rings perpendicular to the boards' wide surfaces, see Photo 1). A large mill specifically built to saw regrowth eucalypts commenced operation in the south of Tasmania in 2004 (Neville Smith Tasmania). Their product is also quartersawn.

In 1990, the outcomes of the Helsham Inquiry (Helsham 1988) placed substantial areas of mature forest into reserves, requiring the industry to cut a higher proportion of regrowth material if cutting

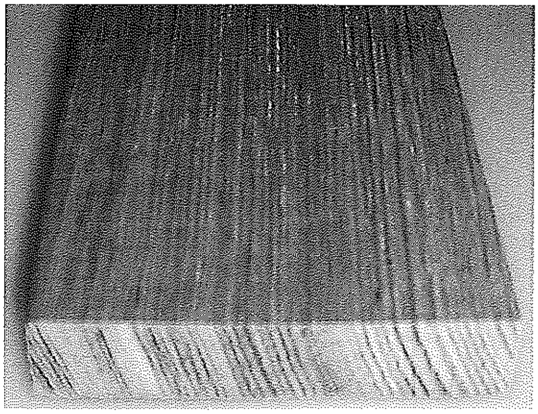


Photo 1. End grain and face of a typical quartersawn board.

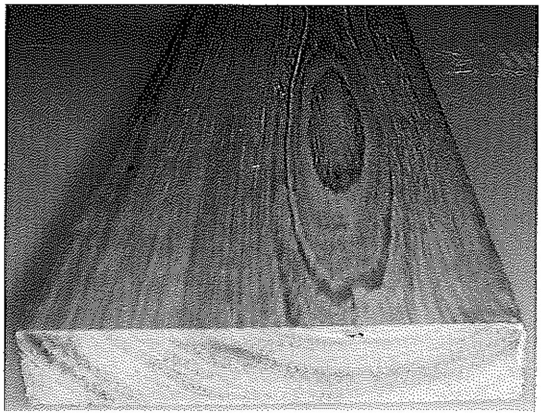


Photo 2. End grain and face of a typical backsawn board.

levels were to be maintained. As a result, the proportion of regrowth in the total sawlog mix rose from about 10% to about 16% (Forestry Commission 1994; M. Wood, pers. comm.). The industry determined that regrowth logs should be allocated to sawmills on the basis of total log allocations for those mills, with the result that regrowth sawing ceased to be a specialist operation (M. Addis, pers. comm.). Subsequent shifts in the resource mix as a result of the Regional Forest Agreement (Commonwealth and Tasmanian Governments 1997) resulted in the proportion of regrowth sawlog in the total mix rising to about 42% (Forestry Tasmania 2002). This will soon increase again to about 50% (Forestry Tasmania 2005), approximately half the volume of which is estimated to be logs of 45 cm or less mid-diameter.

In the early 1990s, the Forests and Forest Industry Council of Tasmania (FFIC) set up a Sawmilling Industry Taskforce to address the effect of the change in resource type. The taskforce identified that traditional quartersawing of small regrowth logs would result in a major decrease in recovery of both timber volume and value when compared to mature logs. They determined that processing solutions should be sought for sawing and drying regrowth that would maintain gross recovery and width recovery of the traditional 25 mm thick product.

Industry sources indicated that an increase of up to 15% in recovery could be expected by backsawing (cutting boards with growth rings tangential to the boards' wide faces, see Photo 2 and Figure 1) (A.V. Jaeger, pers comm). Backsawing was also recognised as an effective means of minimising loss due to spring (edgewise distortion of boards). The recognised downside to backsawing was the higher loss to drying degrade when compared to quartersawing (Waugh and Rozsa 1991; Schaffner 1981).

The key research task identified for this work was the development of drying schedules for backsawn regrowth timber that could be applied commercially. The Sawmilling Industry Taskforce determined that the trials should be focussed on the development of drying schedules for regrowth timber backsawn to 28 mm green thickness, from logs with a mid-diameter of less than 50 cm and length of 5.0 m. The key objective was to produce dry material of satisfactory grade and recovery for sale in the traditional products of flooring, square-dressed timber and mouldings with a finished thickness of 19 mm; that is, product directly comparable to quartersawn material from mature trees. The only species studied, due to limited resources, was *Eucalyptus obliqua*. This species makes up a large proportion of the Tasmanian regrowth resource.

Materials

For Trials 1 to 5 and Trial 7, all logs were *Eucalyptus obliqua* natural regrowth from the southern forests of Tasmania, regenerated following fires of 1914. Logs for Trial 6 were *E. obliqua* regrowth from the Circular Head area in north-western Tasmania, regenerated in 1939 following a wildfire. All sapwood was removed by sawing.

Methods

Trial design

Drying schedules were developed in a highly controllable pre-dryer using the KilnSched drying model (Oliver 1991; Booker 1995). Controls were dried using industry-standard air pre-drying and shelter-shed pre-drying techniques. The scale of operations sought to simulate commercial conditions for both volume and product length. The sample size per treatment was two racks, each of 5.0 m × 1.2 m × 1.5 m (about 4.5 m^3 of timber per rack).

A total of seven sawing and drying trials were conducted over a period of five years (Table 1). The applied drying schedule of temperature, humidity and air velocity in the kiln was selected as the most conservative (slowest) that would be commercially possible under normal industry conditions. All procedures followed were either current or feasible commercial practice.

Sawing

Material for Trials 1 to 5 was sawn at the Western Junction mill of Boral Ltd (now Gunns Ltd) to a common sawing pattern, shown in Figure 1. Initial saw cuts to the log (Figure 1A) were made with a twin circular saw, with the log held by end-dogs. The remainder of the log was then rotated 90° and boards cut from both sides (Figure 1B) with the same twin circular saw. The slabs resulting from initial cuts were cut to width

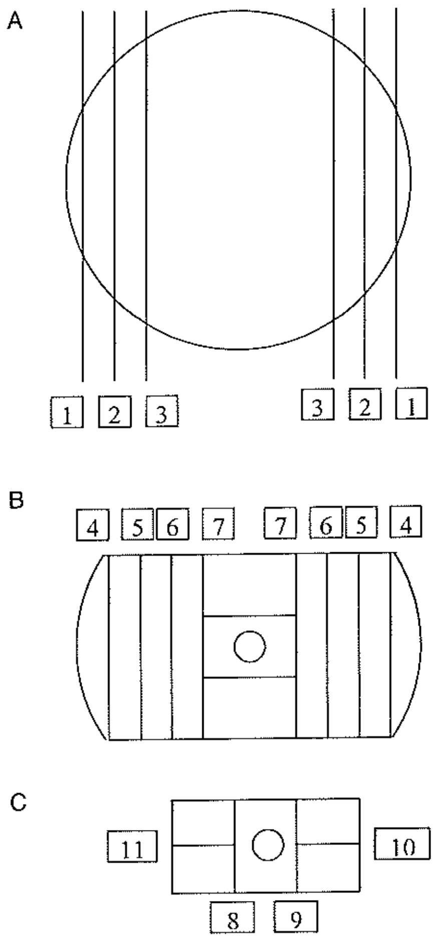


Figure 1. Sawing pattern, Trials 1 to 5; numbers correspond to the order of saw cuts. A, Initial cuts on a twin-saw and the resulting slabs cut to width on a board-edger; B, the log turned 90° and further cuts made with a twin-saw; C, residual core material cut on a breast-bench.

on a single fixed saw and one moving-saw board edger. Core material was sawn on a breast bench (Figure 1C).

Sawing for Trials 6 and 7 was conducted at Britton Brothers Pty Ltd sawmill at Smithton, with a different sawing pattern from previous trials (Figure 2). The log was held on a carriage, with slabbing cuts to target board thickness made from the periphery of the log by a single saw, shown as cuts 1 to 12 in Figure 2. Boards were then cut to width on an edger with one fixed and

Table 1. Summary of trials. (FSP = fibre saturation point)

Trial	Logs	Sawing pattern	Description	Test
1, 2	1914 regrowth, southern forests, 5.1 m long	Purely backsawn by twin saw	Three pre-drying treatments from green to FSP: kiln, open air, shelter shed. Half of each treatment steamed before pre-drying for Trial 1.	• Comparison of drying degrade from three pre-drying treatments. • Effect of pre-steaming on drying degrade.
3	As Trials 1, 2 but 3.6 m long	As Trials 1, 2	Similar to Trials 1 and 2, but maximum width reduced and no pre-steaming.	• Comparison of drying degrade from three pre-drying treatments. • Effect of reduced length and width on end split.
4.1, 5.1	As Trials 1, 2 but 5.0 m long	As Trials 1, 2 plus a quartersawn component	Timber stored block-stacked for various times prior to pre- drying.	• Effect of block stacking on surface checking.
4.2, 5.2	As Trials 1, 2 but 3.0 m long	As Trials 4.1, 5.1	Backsawn and quartersawn air-dried together with varying overhang.	• Comparison of end splitting of backsawn and quartersawn boards. • Effect of overhang on end split.
5.3, 5.4	As Trials 4.1, 5.1	As Trials 4.1, 5.1	Backsawn and quartersawn dried together in the kiln, with fans stopped intermittently in Trial 5.4.	• Comparison of surface checking of backsawn and quartersawn boards. • Effect of intermittent fan stoppage on surface checking.
6	1939 regrowth, Circular Head, 5.0 m long	60% backsawn, 40% quartersawn from single saw	Sawing thickness 25 mm. All timber kiln dried.	• Effect of changed sawing pattern on end splitting. • Comparison of degrade in different resource.
7	As Trials 4.2, 5.2	As Trial 6	Four thicknesses cut (28, 24, 20 and 16 mm) and kiln-dried together.	• Effect of changed sawing pattern on end splitting. • Effect of reduced thickness on surface checking and end splitting.

Note:
- All timber in trials 1–5 was cut to 28 mm thickness.
- Boards from Trials 1 and 2 were cut to a maximum nominal width of 175 mm. Maximum width in all subsequent trials was 125 mm.
- Trials 2, 5.1 and 5.2 were repeats of trials 1, 4.1 and 4.2 respectively.
- Trials 1–5 were sawn at the Western Junction sawmill, then part of Boral, with the pattern in Figure 1. Trials 6–7 were sawn at Britton Brothers sawmill, with the pattern in Figure 2.

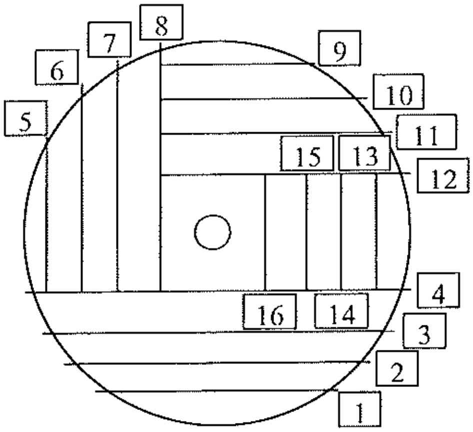


Figure 2. Sawing pattern, Trials 6 and 7. Numbers correspond to the order of saw cuts.

one moving saw. Residual core material was sawn on a conventional three-operator breast bench (cuts 13 to 16 in Figure 2).

Kiln specifications

A purpose-designed research kiln (Photo 3) was constructed for drying timber from green to fibre-saturation point (FSP) ('pre-drying'), as well as for drying from FSP to the final moisture content ('final drying'). The kiln had a timber capacity of 10 m^3 and was end-loaded by rail. It followed the traditional design, having fans and heating coils mounted above the timber, with baffles directing air flow through the stack. The kiln shell was constructed of tilt-up concrete slabs on a single-piece cast base, with all shell components manufactured

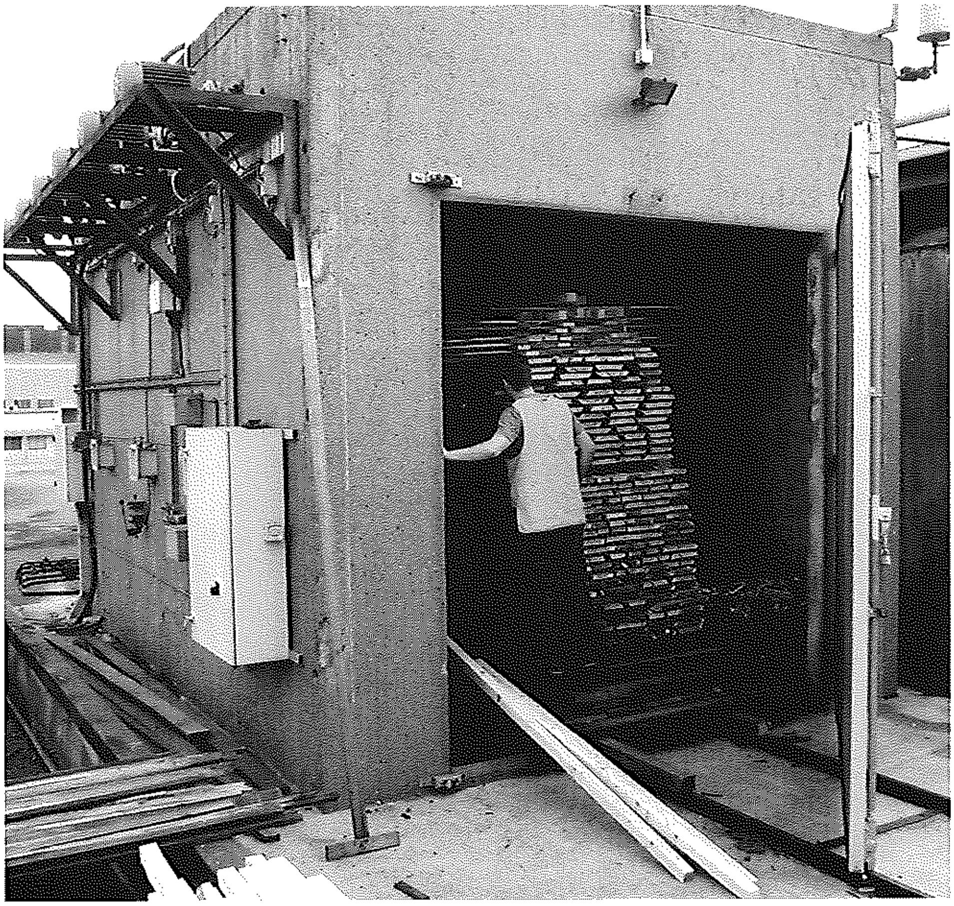


Photo 3. FFIC research kiln.

from silica-slag concrete for strength and thermal insulation.

The air circulation system consisted of six shrouded axial fans, each of 1.0 m diameter and with 16 variable pitch blades, shaft-driven from externally mounted motors. A variable-speed drive delivered a reversible rack-entry air velocity infinitely variable from 0 m/s to 6 m/s, with an accuracy of ± 0.1 m/s from 0.5 to 1.0 m/s and ± 0.3 m/s from 1.0 to 6.0 m/s.

The heat delivery system consisted of finned-tube steam coils on both sides of the fans. It allowed control of temperature over the range from ambient to 150°C, with an accuracy of ± 2°C from ambient to 30°C and ± 5°C from 30° to 150°C. The kiln climate was monitored by four wet- and dry-bulb thermometer pairs on each side of the stack, mounted at stack mid-height. Venting was provided by three vents in each side. Humidification was provided by mains pressure cold-water spray, giving a relative humidity of 30–95% ± 5%. The control system was a Honeywell Plantscape multi-loop controller.

Processing trials

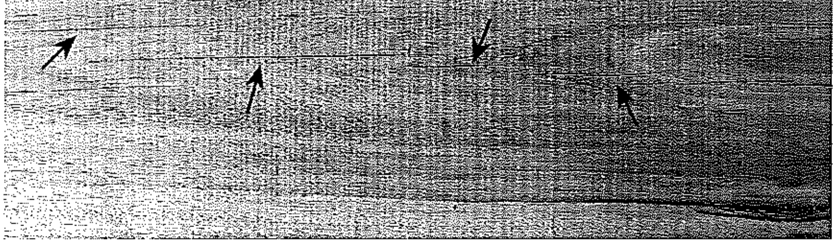
A summary of the processing trials conducted is shown in Table 1.

Trials 1 and 2 had two aims: to compare kiln, shelter-shed and air pre-drying from green to FSP, and to test the effect on pre-drying of pre-steaming. Log length was 5.1 m, with end splits docked from logs before sawing. Boards were sawn to 28 mm thickness following the pattern shown in Figure 1. Maximum board width was 175 mm plus overcut to allow for shrinkage, with width increments of 25 mm and a goal of maximising width recovery. Boards were randomised and racked into four half-height racks for each of the three pre-drying treatments, with two of the four half racks for each treatment of Trial 1 steamed for 11 hours at 65°C before pre-drying. Steamed and unsteamed racks were alternated when building stacks for pre-drying. Sixteen sample boards per treatment were weighed weekly during the three pre-drying treatments and then oven-dried for determination of moisture content throughout drying. Random samples were taken for measurement of green density, basic density and initial moisture content. The three treatments were pre-drying under full control using a conservative schedule (Table 2) developed using the KilnSched timber drying model (Oliver 1991), pre-drying in open air, and air pre-drying in an enclosed shed. Trial 2 was a repeat of Trial 1 except that no pre-steaming was done.

Following pre-drying, all timber was steamed for six hours (including a two-hour heat-up period) at 98°C for recovery of collapse shrinkage ('reconditioned'), cooled for 14 hours and then final-dried in a kiln (Table 3).

All dry timber was machined to 25 mm thickness by removing approximately the same thickness from each side, evaluated, then machined to 19 mm and re-evaluated. Boards were visually assessed for surface check (Photo 4). Any length of board clear of end split but exhibiting surface

Photo 4. Typical surface checking on a backsawn board.



check across the face was tallied as surface checked, regardless of the number or size of the checks.

Trial 3 was as Trial 1 and 2 except that maximum target sawing width was reduced to 125 mm (plus overcut) and board length reduced to 3.6 m in an attempt to decrease losses to end split, and no timber was steamed prior to pre-drying.

Trial 4 had two parts:

- *Trial 4.1.* The aim of this trial was to assess the effect on surface checking of block-stacking timber for a period prior to pre-drying. Green backsawn boards 28 mm thick, 125 mm (plus overcut) wide and 5.0 m long were randomly divided into four packs. Two packs were fully wrapped in plastic and all four packs were stacked in a fully enclosed shed. After four weeks, and every week thereafter until week fourteen, 15 boards were randomly selected from each pack and partially pre-dried for fourteen days under fully controlled conditions of 20°C temperature, 1.5°C wet-bulb depression and 0.5 m/s air velocity. Length of boards affected by surface check on each face was measured before and after the 14 days pre-drying, and then the boards were discarded.
- *Trial 4.2.* The aims of this trial were to compare end splitting between backsawn and quartersawn boards, and to assess the effect of overhang on end split. Boards for this trial were 28 mm thick, 125 mm (plus overcut) wide and 3.0 m long. Equal numbers of backsawn and quartersawn boards (210 each) were pre-dried in open air, then reconditioned and final-dried (Table 3). One end of each board was flush with racking sticks, with the other end overhanging by up to 300 mm in 50 mm increments. Length of end splits was measured green, at FSP and dry. In addition, approximately 2.0 m^3 of quartersawn boards the same size were block-stacked for up to 10 weeks in increments of two weeks before being racked with either zero overhang at both ends, or zero at one end and 300 mm at the other. Boards were pre-dried in open air then reconditioned and final-dried (Table 3) and assessed for end splitting every two weeks.

Table 2. Pre-drying schedule for timber that was kiln pre-dried from green (Trials 1–3, 5.3, 5.4, 6 and 7).

Time (days)	Dry-bulb temp. (°C)	Wet-bulb temp. (°C)	Air speed (m/s)
0	23.0	21.5	0.5
7	23.0	21.0	0.5
14	24.0	21.5	0.5
21	24.0	21.0	0.5
28	24.0	21.0	0.5
35	25.0	20.5	0.5
42	25.0	20.0	0.5
49	25.0	20.0	0.5
54	25.0	20.0	0.5

Table 3. Final-drying schedules (Trials 1–3, 4.2, 5.2–5.4, 6 and 7).

Drying time (h)	Dry-bulb temp. (°C)	Wet-bulb temp. (°C)	Air speed (m/s)
0.0	19.0	17.0	1.3
0.5	31.0	28.0	1.5
1.0	33.0	29.0	1.8
1.5	39.0	34.0	2.0
2.0	43.0	38.0	2.0
2.5	45.0	40.0	2.0
3.0	48.0	41.0	2.0
3.5	55.0	45.5	2.0
4.0	59.0	50.0	2.0
4.5	61.0	51.0	2.0
5.0	66.0	54.0	2.0
6.0	65.0	52.0	2.0
7.0	65.0	50.5	2.0
8.0–49.0	65.0	50.0	2.0

Trial 5 comprised four independent experiments all using the same source material:

- *Trial 5.1.* A repeat of Trial 4.1, except that two-thirds of the boards were quartersawn and one-third backsawn.

- *Trial 5.2.* A repeat of Trial 4.2, using half the number of boards but of 5.0 m length. The effect of block-stacking for a period of time prior to drying on end split in quartersawn material was also investigated.
- *Trial 5.3.* The aims of this trial and trial 5.4 were to compare surface checking in backsawn and quartersawn boards, and to assess the effect of intermittent fan stoppage on formation of surface checks. Green backsawn and quartersawn boards 28 mm thick, 125 mm (plus overcut) wide and 5.0 m long were randomly divided into four half racks. They were then kiln-dried following the schedules in Tables 2 and 3. Boards were then machined to 25 mm thickness and evaluated, then machined to 19 mm and evaluated again.
- *Trial 5.4.* A repeat of Trial 5.3 but with the drying fans stopped for 40 minutes every three hours during drying in an attempt to reduce surface checking by allowing drying stresses to relax.

The aim of Trial 6 was to assess the effect of a changed sawing pattern on end splitting. For the trial, 240 green boards of 25 mm thickness and 75–150 mm (plus overcut) width were cut using the second sawing pattern (Figure 2). Log length was 5.0 m, with logs from north-western Tasmania. Both quartersawn and backsawn timber were studied. All material was kiln-dried following the schedules in Tables 2 and 3. Boards were then machined to 22 mm thickness and evaluated, then machined to 19 mm and evaluated again.

Trial 7 was carried out to assess the effect of the second sawing pattern on southern forest timber and to examine the processing behaviour of thinner boards. Logs 3.0 m long were sawn following the pattern of Trial 6, with green-sawn thicknesses of 28, 24, 20 and 16 mm. Boards randomly selected for Trial 7 were measured for green end splitting. All boards were kiln pre-dried together following the schedule in Table 2. Racks were removed from the kiln as they reached 20% average moisture content and reconditioned. All timber was final-dried together using the schedule in Table 3. Trial boards were then progressively machined to the thicknesses given in Table 4, and were evaluated following each machining. In addition, the remainder of the sawn boards were dried along with the experimental boards, machined to final thickness and commercially graded to Australian Standard 2796 (Standards Australia 1999).

Measurements

For calculation of initial moisture content, green density and basic density, freshly cut samples were weighed and their volume determined by water displacement. Samples were then oven dried to Australian Standard 1080.1 (Standards Australia 1999) and re-weighed. Initial moisture content (dry basis) was calculated as mass of water initially present divided by oven-dry sample mass. Green density was calculated as initial mass divided by initial volume, and basic density was calculated as oven-dry mass divided by initial volume. Moisture contents of sample boards during pre-drying were similarly determined by weighing them during pre-drying, and then oven drying and reweighing them. Differences in drying rate were evaluated by comparing moisture content of all sample boards in each treatment at each time point.

Statistical analysis

Statistical analyses were carried out using SigmaStat 3.0 (Systat Software 2004). Where two groups were compared, a t-test was performed; where the data failed

Table 4. Machining thickness sequence, Trial 7.

	Initial board thickness (mm)			
	28	24	20	16
1st machining	25	22	18	14
2nd machining	22	19	16	12
3rd machining	19			

normal distribution or equal variances tests, a rank sum test was performed. Where more than two groups were compared, a one-way ANOVA was performed; where the data failed normal distribution or equal variances tests, a one-way ANOVA on ranks test was performed, with all-pairwise comparisons using Dunn's test. Significance was indicated by $P < 0.05$.

Results

Comparison of kiln, shed and air pre-drying of backsawn boards (Trials 1, 2 and 3)

Log sizes and sawn recovery for Trials 1–3 are shown in Table 5, and width and grade recovery are shown in Table 6. Sawn volume recovery was 36–37% (Table 5),

Table 5. Log sizes and recovery into sawn boards based on nominal dry sizes for Trials 1, 2 and 3.

	Log volume (m^3)		Average log sizes (m)		Sawn volume recovery	
	delivered	docked	length	mid-diameter	m^3	%
Trial 1	106.4	103.9	5.1	0.48	37.2	36
Trial 2	107.6	105.1	5.1	0.49	38.8	37
Trial 3	75.5	72.5	3.6	0.48	25.9	36

Table 6. Volume and grade recovery by board width from Trials 1, 2 and 3. Sawn volume was calculated on a nominal dry basis (25 mm thickness × tabulated width); sawing was to 28 mm target green thickness, with overcut on width. Maximum board width for Trial 3 was 125 mm.

		Width (mm)						
		175	150	125	100	75	50	
Volume recovery								**Total**
Trial 1	Volume (m^3)	22.4	6.6	4.3	1.8	1.2	0.8	37.2
	Volume (%)	60.4	17.8	11.6	4.9	3.2	2.2	100.0
Trial 2	Volume (m^3)	20.4	8.6	6.1	1.6	1.4	0.6	38.8
	Volume (%)	52.6	22.2	15.7	4.2	3.7	1.6	100.0
Trial 3	Volume (m^3)			11.9	11.1	2.4	0.5	25.9
	Volume (%)			45.9	43.0	9.3	1.8	100.0
Grade recovery (%)[1]								**Average**
Trial 1	Select	29.0	31.6	22.7	27.9	21.0	16.9	24.8
	Standard	46.7	42.6	52.1	39.6	41.3	23.4	40.9
	Utility	24.3	25.9	25.9	32.6	37.7	59.7	34.3
Trial 2	Select	28.6	29.6	25.2	26.3	23.7	19.4	25.5
	Standard	48.0	48.8	47.9	37.4	36.1	19.2	39.5
	Utility	23.4	21.6	26.6	36.3	40.2	61.4	35.0
Trial 3	Select			31.9	19.2	18.7	15.3	21.4
	Standard			38.9	46.7	39.7	28.4	38.4
	Utility			29.2	34.1	41.6	56.3	40.2

[1] The three grade classes total 100% for each board width in each trial.

with recovery of Select and Standard grade boards from the first two boards of approximately 25% and 40% respectively. Select and Standard grade recovery were reduced in Trial 3 to 21% and 38% respectively, principally due to decay and insect damage. Initial moisture content and green density of boards in Trial 1 are shown in Figures 3 and 4. Mean initial moisture content was 89%, and mean green density 877 kg/m^3. Pre-drying times and final dried moisture contents for Trials 1–3 are shown in Table 7. Final dried moisture contents were similar in each case. Kiln pre-drying time was approximately one-half to one-third that required for shed or air pre-drying.

Sample board moisture contents during Trials 1–3 are shown in Figures 5, 6 and 7 for kiln, shed and air pre-drying respectively. Half of the sample boards from each treatment were steamed in Trial 1. There was no significant effect on drying rate from steaming prior to pre-drying, or from height in stack (data not shown). Sample board moisture contents from steamed and unsteamed racks were therefore combined.

Shed and air drying in Trial 3 were more rapid than in other trials. Trial 3 was the only one conducted over the summer months, which is likely to be the main cause for this difference. Boards from Trial 3 were

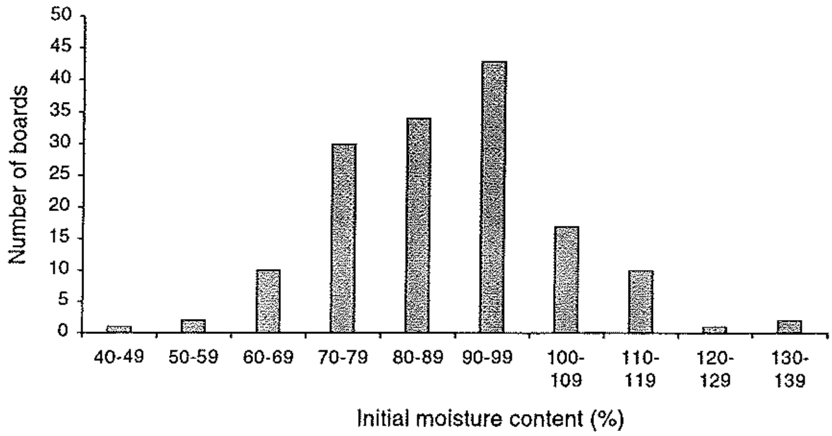


Figure 3. Initial moisture content of 150 sample boards from Trial 1.

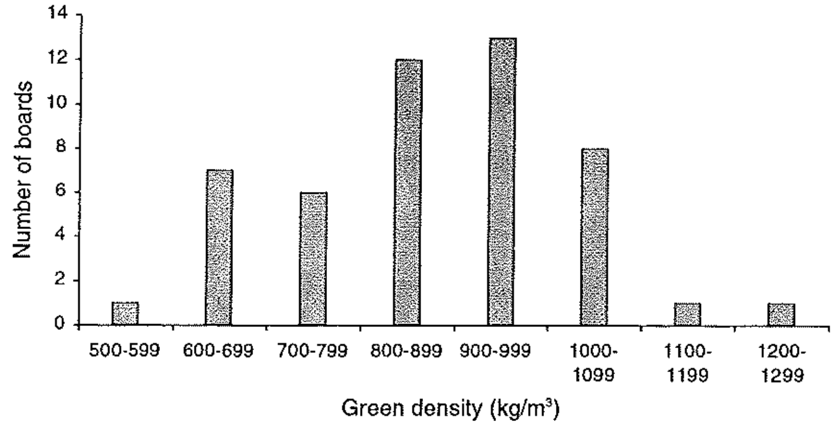


Figure 4. Green density of 50 sample boards from Trial 1.

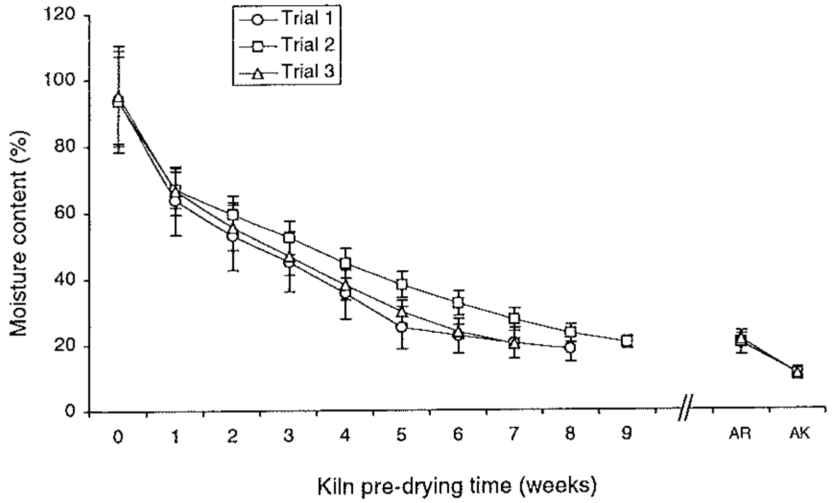


Figure 5. Mean moisture content of 16 sample boards per trial during kiln pre-drying from green, Trials 1–3. Steamed and not-steamed boards have been combined. Error bars show one standard deviation on each side of mean. (AR = after being 'reconditioned' (see text, p. 6); AK = after being final-dried in the kiln)

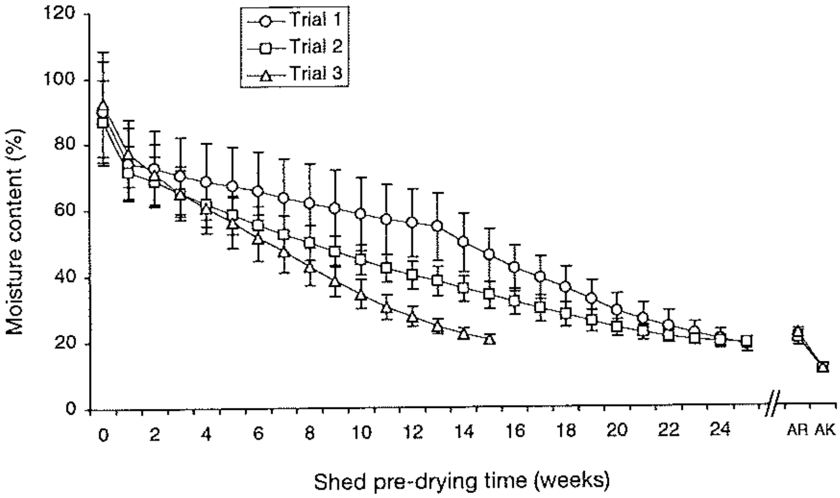


Figure 6. Mean moisture content of 16 sample boards per trial during shed pre-drying from green, Trials 1–3. Steamed and not-steamed boards have been combined. Error bars show one standard deviation on each side of mean. (AR and AK as for Figure 5)

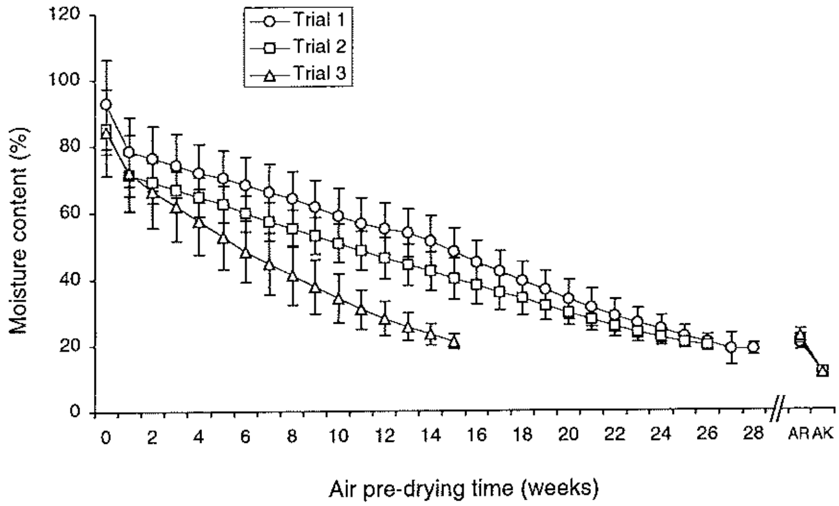


Figure 7. Mean moisture content of 16 sample boards per trial during air pre-drying from green, Trials 1–3. Steamed and not-steamed boards have been combined. Error bars show one standard deviation on each side of mean. (AR and AK as for Figure 5)

Table 7. Pre-drying time and final dried moisture content (standard deviation in brackets) for 16 sample boards per treatment for each pre-drying treatment of Trials 1, 2 and 3.

	Trial 1		Trial 2		Trial 3	
Pre-drying method	Pre-drying time (days)	Moisture content (%)	Pre-drying time (days)	Moisture content (%)	Pre-drying time (days)	Moisture content (%)
Kiln	53	10.8 (1.9)	64	10.8 (0.9)	50	10.7 (0.9)
Shed	175	11.0 (1.2)	173	10.9 (1.0)	103	11.1 (1.3)
Air	196	11.3 (1.4)	187	11.4 (0.8)	106	11.2 (1.2)

Table 8. Mean end splits before pre-drying (green) and after final drying for all boards from Trials 1, 2 and 3, shown as percentage of board length and as mean length per board. Trial 1 and 2 boards were 5.1 m long, Trial 3 boards were 3.6 m long, and there were 240 boards per treatment per trial. (Different letter superscripts signify significant differences (Dunn's test) between groups for each trial considered separately. Unmarked data were not tested.)

	Trial 1				Trial 2				Trial 3			
Pre-drying	Green		Dry		Green		Dry		Green		Dry	
method	%	m	%	m	%	m	%	m	%	m	%	m
Kiln	20	1.0	20	1.0[a]	21	1.1	22	1.1[a]	28	1.0	30	1.1[a]
Shed	21	1.0	25	1.2[b]	20	1.0	23	1.2[b]	29	1.0	31	1.1[a]
Air	21	1.1	25	1.2[b]	20	1.0	24	1.2[b]	29	1.0	32	1.1[a]

narrower than those from Trials 1 and 2, which also could have increased the rate of drying as the edges of boards became exposed during drying due to shrinkage, so that boards could dry from their edges.

End splitting recorded after sawing and again after drying is shown in Table 8. Loss to end splits was very high, at approximately 1.0 m per board when green and 1.1 m when dry. In Trials 1 and 2, there was significantly less end splitting during kiln pre-drying than either shed or air pre-drying, which were similar. End-split length was independent of board length.

Overall surface check results following final drying are shown in Table 9. There was no significant effect of steaming prior to drying on surface check (data not shown), so steamed and not-steamed results were combined. Kiln pre-dried timber underwent significantly less surface checking than did shed or air-dried timber, which had similar levels of checking. However, in the three trials, only 29%, 32% and 32% respectively of kiln pre-dried boards were free of surface checking on both faces after machining to 19 mm. There was an effect of height in stack on surface checking in kiln-dried timber, with more surface checking in the bottom-half rack than either of the two top-half racks (data not shown). This is probably due to greater restraint of cupping of boards in the bottom-half rack. The board face cut furthest from the centre of the tree (the 'outer' face) almost invariably had more surface checking than the inner face. Backsawn boards as used in Trials 1–3 generally 'cup' during drying; the growth rings tend to flatten since tangential shrinkage is normally around twice radial shrinkage. Restraint of this cupping induces a higher tension stress in the outer face, which is presumably the source of the larger amount of surface checking.

A greater proportion of kiln pre-dried boards had either one or both faces clear of surface checks than did air or shed pre-dried boards (Table 9). However, only approximately half of the kiln-dried boards had at least one clear face at 25 mm thickness. This increased by approximately

Table 9. Board length exhibiting surface checking on best and worst faces at 25 mm and 19 mm machined thicknesses, and proportion of boards with faces clear of surface checking for all boards from Trials 1, 2 and 3. (Different letter superscripts signify significant differences (Dunn's test) between groups within an individual trial and separately for boards of different machined thickness. Unmarked data not tested.)

Pre-drying method	25 mm thick boards					19 mm thick boards				
	Board length (%) with surface checking on best and worst face		Proportion (%) of boards with 0–2 clear faces			Board length (%) with surface checking on best and worst face		Proportion (%) of boards with 0–2 clear faces		
	best	worst	0	1	2	best	worst	0	1	2
Trial 1										
Kiln	9[a]	28	53	30	17	6[a]	24	46	25	29
Shed	7[b]	18	62	28	10	5[b]	16	55	30	15
Air	9[b]	21	60	27	13	7[b]	18	52	30	18
Trial 2										
Kiln	11[a]	28	51	28	21	6[a]	24	42	26	32
Shed	17[b]	42	60	27	13	13[b]	36	54	29	17
Air	18[b]	43	63	23	14	15[b]	38	56	26	18
Trial 3										
Kiln	11[a]	27	48	30	22	5[a]	18	41	27	32
Shed	16[b]	38	67	21	12	12[b]	31	63	22	15
Air	20[b]	41	78	12	10	17[b]	35	71	15	14

Table 10. Mean board end-split lengths as a percentage of board length for various overhangs when green, at FSP (following air pre-drying) and following final drying for all boards (30 boards per overhang per sawing orientation) from Trial 4.2. Boards were 3.0 m long. (FSP = fibre-saturation point)

Overhang (mm)	Mean end split (%) – backsawn			Mean end split (%) – quartersawn		
	green	at FSP	after final drying	green	at FSP	after final drying
0	14	15	15	6	7	7
50	17	18	18	6	7	7
100	11	12	12	4	11	11
150	14	15	16	5	12	12
200	11	13	14	5	12	13
250	12	14	15	4	14	14
300	12	14	14	5	19	19

8% on machining to 19 mm thickness. Further trials were aimed at decreasing losses to end splits and surface checks.

End splitting and the effect of board overhang (Trials 4.2 and 5.2)

End-split lengths in backsawn and quartersawn boards when green, at fibre saturation point following air pre-drying and following final drying, with various lengths of board overhang, are shown for boards in Trial 4.2 in Table 10. Similar results were obtained from Trial 5.2 (data not shown). Loss to end split of quarter-sawn boards with low overhang was much lower than that in backsawn boards when dry, although end splits were longer in quartersawn boards with large overhang after drying. There was no effect of

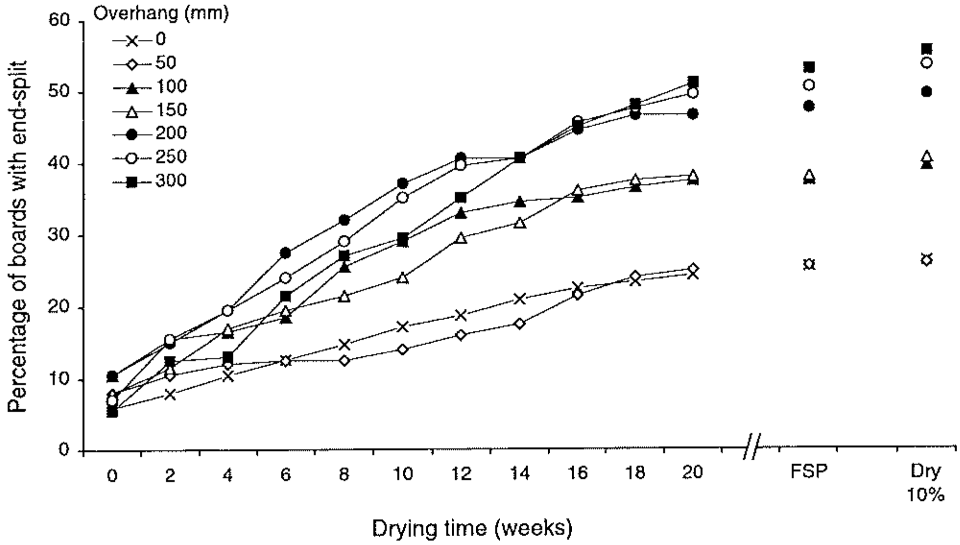


Figure 8. Effect of overhang length on end splitting during drying, in 30 quartersawn boards per overhang; Trials 4.2 and 5.2 were combined. (FSP = fibre-saturation point)

overhang on growth of end-split length during drying in backsawn boards, whereas overhang of 100 mm or more in quartersawn boards caused an increase in end-split growth during drying. The number of quartersawn boards with end splitting that was 25 mm or greater in length increased with both drying time and board overhang (Figure 8). Backsawn boards were not tested as there was no effect of overhang on end-split length in backsawn timber (Table 10).

Effect of block stacking and plastic wrapping of stacks on surface checking (Trials 4.1 and 5.1)

In nine out of 66 cases (comparing 15 boards per treatment for each case), the surface check of boards from plastic-wrapped stacks was significantly less than that of block-stacked boards (five out of 22 cases for Trial 4.1 timber which was all backsawn, four out of 22 cases for the backsawn group timber from Trial 5.1, and none of the 22 cases for the quartersawn timber of Trial 5.1; *t*-tests were used to compare individual board measurements of surface check). In the other 57 of the 66 cases, there was no difference in surface check between plastic-wrapped and block-stacked boards. There was no effect on surface check of time spent block-stacked or wrapped.

Effect of intermittent fan stoppage on surface checking (Trials 5.3 and 5.4)

There was no significant difference in surface check between boards pre-dried using fan stoppages and those pre-dried not using fan stoppages (Table 11). The amount of surface check decreased with height up the stack for backsawn boards but not for quartersawn boards. A greater proportion of quartersawn boards than backsawn boards had one or two clear faces (Table 12). The proportion of check-free boards is low given the care with which they were dried. There was no significant effect of intermittent fan stoppages on individual board measurements of surface check (data not shown). The amount of surface check in some boards increased on machining from 25 mm to 19 mm. A randomly selected sample of these boards revealed this to be a result of machining into internally checked regions of the boards. The affected timber had visibly wider growth rings than the non-affected

Table 11. Surface checking (percentage of board length affected after final drying) for backsawn and quartersawn timber with and without timed fan stoppages for all boards (160 per sawing orientation per treatment) from Trials 5.3 and 5.4. (Different letter superscripts signify significant differences (Kruskal-Wallis one way ANOVA on ranks) between surface check of boards of different machined thicknesses dried with or without fan stoppages.)

	25 mm thick boards		19 mm thick boards	
	best face (%)	worst face (%)	best face (%)	worst face (%)
Timed fan stoppages				
Backsawn	13.6[a]	30.9[c]	11.5[a]	21.2[c]
Quartersawn	10.2[b]	18.1[d]	5.8[b]	14.7[d]
No fan stoppages				
Backsawn	13.3[a]	26.8[c]	10.2[a]	23.1[c]
Quartersawn	15.1[b]	26.5[d]	10.6[b]	14.2[d]

Table 12. Percentage of boards with or without surface check at 25 and 19 mm thickness for all boards from Trials 5.3 and 5.4 (160 per sawing orientation per treatment).

	Number of clear faces on 25 mm thick boards			Number of clear faces on 19 mm thick boards		
	0	1	2	0	1	2
Timed fan stoppages						
Backsawn (%)	74	8	18	68	11	21
Quartersawn (%)	30	15	55	18	15	67
No fan stoppages						
Backsawn (%)	73	12	15	70	13	17
Quartersawn (%)	31	22	47	25	16	59

timber, and a very low dry density (mean of 315 kg/m^3 from the samples taken).

Sawing and drying Eucalyptus obliqua *from north-western Tasmania (Trial 6)*

The timber from north-western Tasmania (sawn using the pattern shown in Figure 2) produced 61% backsawn boards, 14% quartersawn boards and 25% transitional or mixed sawn boards (with elements of both backsawn and quartersawn). Much less end split was observed than in previous trials (Table 13, compare with Table 8). Quartersawn timber suffered significantly less end split than did either backsawn or mixed-sawn timber. End split in mixed-sawn timber grew during drying much more than did end split in backsawn or quartersawn boards. There was significantly less surface check in dried quartersawn boards from this eucalypt stand than in either backsawn or mixed-sawn boards (Table 14).

Application of new sawing patterns to southern Eucalyptus obliqua, *and effect of board thickness on dried quality (Trial 7)*

This trial processed approximately 60 boards of 28 mm thickness, and 120 boards each of 24, 20 and 16 mm thicknesses, for a total of 420 boards, with all boards kiln pre-dried. There was generally less loss to end split following drying than in earlier trials (Table 15), but losses were still very high at 5–17% of board length. Measurement of the length of each board (clear of end-split sections) affected by surface check or machining skip following machining to each thickness showed no significant reduction in

Table 13. Mean board end-split lengths (m) per end in green and dry boards, and mean growth in end split (m) on drying, for all boards (total 240) from Trial 6. Boards were 5.0 m long. (Different letter superscripts signify significant differences (Dunn's test) between sawn orientation groups when comparing green, dry or growth figures.)

	Green	Dry	Growth
Backsawn	0.11^a	0.17^a	0.06^a
Quartersawn	0.05^b	0.10^b	0.05^a
Mixed sawn	0.13^c	0.30^c	0.18^b

Table 14. Percentage of total board length degraded by surface checking when green, and following drying and machining to 22 mm and 19 mm thickness, for all boards from Trial 6. (Different letter superscripts signify significant differences (one-way ANOVA) within thickness groups; green data were not tested as a very small number of boards had surface-check.)

	Green (%)	22 mm (%)	19 mm (%)
Backsawn	0.5	22.0^a	15.3^a
Quartersawn	0.3	0.3^b	0.1^b
Mixed sawn	0.3	19.2^a	12.9^a

Table 15. Mean end-split length per board, green and dry, and growth in end split on drying for four sawn thicknesses and three orientations, for all boards (total 420) from Trial 7. Boards were 3.0 m long.

		Green		Dry		Growth	
Thickness		length (mm)	%	length (mm)	%	mm	%
28 mm	Backsawn	296	9.9	512	17.0	216	7.1
	Quartersawn	140	4.6	199	6.6	59	2.0
	Mixed sawn	167	5.6	343	11.4	176	5.9
24 mm	Backsawn	102	3.4	204	6.8	102	3.4
	Quartersawn	156	5.2	231	7.7	75	2.5
	Mixed sawn	109	3.8	269	9.3	160	5.5
20 mm	Backsawn	133	4.4	246	8.1	114	3.8
	Quartersawn	36	1.2	200	6.6	164	5.4
	Mixed sawn	207	6.9	318	10.6	111	3.7
16 mm	Backsawn	196	6.4	444	13.3	248	6.8
	Quartersawn	82	2.4	440	5.1	358	2.7
	Mixed sawn	133	4.4	366	11.9	234	7.6

surface checking degrade for the combined three sawing orientations as sawing thickness was reduced, with approximately 80% of the length of boards free of surface check following the second machining (Table 16). Reducing sawn thickness from 28 mm to 24 mm decreased surface checking degrade in backsawn boards. There was more surface checking in backsawn boards than in quartersawn or mixed-sawn boards for all sawing thicknesses following machining to final finished thickness when comparing the best face (Table 17).

Commercial standard grading was applied to the remaining boards (combined sawing orientation, approximately 800 boards), involving a reduced level of scrutiny in poorer light conditions than that applied under experimental conditions to the rest of the trials (e.g. Trials 1–3, Table 6). Better grading outcomes resulted under this method (Table 18).

Conclusions

A set of seven trials was conducted to investigate alternative methods of drying and handling backsawn regrowth *Eucalyptus obliqua* logs, using quartersawn logs as controls. The trials demonstrated that kiln

Table 16. Mean percentage of board length (clear of end split) clear of surface check and machining skip on each wide face for four original thicknesses, at machining thicknesses from Table 4, all sawing orientations combined. 'Best' is the best face at a given thickness as determined by surface checking, 'worst' is the other face. For all boards from Trial 7 (sixty 28 mm thick boards, 120 for each of the other three thicknesses).

	1st machining		2nd machining		3rd machining	
Thickness	best (%)	worst (%)	best (%)	worst (%)	best (%)	worst (%)
28 mm	50	14	77	71	91	83
24 mm	52	15	77	66		
20 mm	50	8	81	86		
16 mm	54	16	86	74		

Table 17. Percentage of board length clear of surface check and machining skip following second machining on best and worst faces for three sawing orientations for all boards from Trial 7.

	Initial and machined thickness							
	28→22 mm		24→19 mm		20→16 mm		16→12 mm	
Face	best (%)	worst (%)	best (%)	worst (%)	best (%)	worst (%)	best (%)	worst (%)
Backsawn	55	58	73	74	73	87	83	77
Quartersawn	80	71	82	44	99	95	99	76
Mixed sawn	81	58	82	56	97	76	89	52

Table 18. Percentage of number of whole boards by grade of best face to Australian Standard 2796: 1999, combining sawing orientation for all commercially graded boards from Trial 7 (approximately 800).

		Grade to AS2796: 1999		
	No. of boards	Select	Standard	High feature
28→19 mm	132	45	34	21
24→19 mm	200	54	30	16
20→16 mm	217	61	34	5
16→12 mm	247	54	34	11

pre-drying resulted in less drying degrade than shed or open-air pre-drying. Pre-drying was also approximately two to three times faster in the kiln than in the shed or open air. Uniformity of final dried average moisture contents was satisfactory with all three pre-drying regimes. Backsawn boards had much higher losses to end split and surface checks than did quartersawn or mixed-sawn boards.

End-split losses were very large in all the trials, with average green end split of approximately one metre per board in Trials 1–5 (lower values were observed in Trials 6 and 7 using a different sawing pattern). Length of end split was independent of log length. Growth in end split during drying was comparatively minor, and significantly lower in kiln pre-dried boards than in shed or air pre-dried boards. Overhang of board ends beyond racking sticks had a minimal effect on end split in backsawn timber but caused a significant increase in end split of quartersawn timber. For quartersawn timber, length of end split and number of boards with end split increased with drying time as well as with the amount of board overhang. Boards with end split require additional handling to remove the end split section prior to sale.

The overall proportion of board length affected by surface checking was also significantly lower in kiln pre-dried boards than in those pre-dried in the shed or in the air. The number of boards with either one or two faces clear of surface checking was, in most cases, higher from the kiln pre-dried stock than from either shed or air pre-dried stock. At a machined thickness of 25 mm from a green thickness of 28 mm, approximately 20% of kiln pre-dried boards had two clear faces, almost twice that of boards shed or air pre-dried. Another 30% of kiln pre-dried boards had one clear face, 5–10% more than in shed or air pre-dried boards. There was generally no significant difference between the amount of surface checking from shed and air pre-drying. This, combined with the small difference in drying rate, calls into question the value of shelter shed pre-drying over open air pre-drying. The practice of pre-steaming provided no significant reduction in either drying degrade or drying time.

Storing timber stacks wrapped in plastic or in an enclosed shed for between four and 14 weeks prior to drying significantly decreased the amount of surface checking in only a few cases. There was no significant reduction in surface check from intermittently stopping fans during pre-drying.

The numbers of boards with two clear faces was substantially higher for quartersawn stock than for backsawn, but the actual values were still low. For 28 mm green thickness, approximately 50% of quartersawn boards at 25 mm machined dry thickness and 60% at 19 mm machined dry thickness had two clear faces.

A single batch of regrowth *Eucalyptus obliqua* from north-western Tasmania proved much less prone to surface checking than southern regrowth timber when sawn and dried in the same way, although on a different occasion. Again, however, quartersawn boards of this material underwent significantly less surface checking and end split, both green and following drying, than did backsawn or mixed-sawn boards.

Application of a changed sawing pattern to regrowth *E. obliqua* from southern Tasmania resulted in approximately half the losses per board to end split, compared to the original sawing pattern. However, the changed pattern produced a lower proportion of backsawn material. Decreasing sawn thickness decreased end splitting and surface checking in backsawn material, but was not effective for quartersawn and mixed-sawn timber. Commercial standard grading indicated better grade outcomes than expected from experimental measurements.

The experimental work did not indicate that Tasmanian *Eucalyptus obliqua* regrowth material from the locations studied could be satisfactorily backsawn and dried to meet commercial imperatives in terms of either surface checking or end splitting even when processed under rigorous and highly controlled conditions. The outcomes from the experimental work also did not suggest other avenues of processing research that might deliver more commercially successful outcomes. Mills currently processing regrowth *E. obliqua* in Tasmania do not backsaw due to high degrade, principally surface checking, and instead use quartersawing, with associated lower recovery. Their source log mix will decrease in diameter as younger regrowth is cut, so wide boards (150 mm and greater) will become increasingly hard to obtain unless a commercially viable means of backsawing and drying this timber is found.

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