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Processing methods for production of solid wood products from plantation-grown *Eucalyptus* species of importance to Australia



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www.fwpa.com.au

FWPA Level 4, 10-16 Queen Street,
Melbourne VIC 3000, Australia

T +61 (0)3 9927 3200 F +61 (0)3 9927 3288

E info@fwpa.com.au W www.fwpa.com.au

**Processing methods for production of solid
wood products from plantation-grown
Eucalyptus species of importance to Australia**

Prepared for

Forest & Wood Products Australia

by

Russell Washusen



**Forest & Wood
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Researcher: Russell Washusen, Honorary Principal Fellow, University of Melbourne

Forest & Wood Products Australia Limited
Level 4, 10-16 Queen St, Melbourne, Victoria, 3000
T +61 3 9416 7544 F +61 3 9416 6822
E info@fwpa.com.au
W www.fwpa.com.au

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Russell Washusen

Honorary Principal Fellow, University of Melbourne

russellwl@harboursat.com.au

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2 Glossary

2.1 Sawmilling

Break-down saw	Head rig used to saw logs into manageable units for resawing.
Cant	A central flitch sized in width for resawing into boards.
Centre board	A central board containing the pith.
Centering device	A device that centres the log so chippers remove about the same amount of wood from opposite sides of the log.
Chipper canter	Chippers configured to produce a four sided cant for sawing.
Chipper/reducers	Chippers that operate ahead of saws to remove unwanted wood from the log before sawing, leaving finished surfaces.
Close coupled machines	Single pass machines where sawing is completed in one pass. They incorporate chippers and saws in a close coupled configuration.
Diametral slabs	Slabs sawn through the centre of the log with the log surface intact on both edges.
End-dogging	Where a hydraulic device is applied to log ends in order to secure the logs so they can be transported through a stationary saw or the saw can be moved through a stationary log.
Face cutting	The process of straightening a sawn face of a log that has deflected during sawing as growth stresses were released.
Flitch	A piece of wood produced during log break-down for re-sawing to final green dimensions.
Grade sawing	The process of sawing logs to eliminate defects from the processing chain as rapidly as possible and to maximise the recovery of high quality boards.
Log profiling	Where chippers are used to remove wood and size boards before sawing.
Re-saw	In conventional hardwood mills the saws used to resaw slabs, flitches and cants produced by the break-down saw. They may be single or multi-saw systems.
Rip-sawing	Sawing along the length of a piece of wood with single or multi-saws. For cants or slabs this will produce one or more sized boards.
Sawing accuracy	The precision of board dimensions attributed to sawing. Variation in sawing accuracy occurs because of movement in the saws, drive mechanisms and set works. With single saw systems processing eucalypts human error and deflection of logs or flitches as growth stresses are released also contribute to variation in sawing accuracy.
Saw kerf	The width of the saw cut.
Scribing saws	Saws operating at right angles to the main saws to size boards.
Slabs	Wood sawn to final board thickness but un-dimensioned in width.
Through-and-through sawing	Where log rotation is not employed during sawing and all saw cuts are more-or less parallel to produce slabs with the full range in potential growth ring alignment.

2.2 Wood and boards

Back-sawn boards	Boards where the growth ring alignment is tangential to the wide face.
Board end splitting	Splits in board ends.
Board grading	Boards graded according to defects present on the board surfaces. Select and standard grades are higher quality boards.
Bow	Deflection of sawn wood away from the log centre where the growth rings are approximately tangential to the widest surface. Eg back sawn boards. Bow is easily straightened during drying.
Collapse	Collapse occurs in low density wood as free water present in the cell lumen is removed during drying and stresses cause the cells to flatten (collapse). Collapse occurs above fibre saturation point where free water is present in the cell lumen. It can be recovered with steam reconditioning applied below fibre saturation point.
Cupping	Distortion of the board across the wide face caused by collapse and/or differential shrinkage between the face and back of the board.
Internal checking	Cracks in the inner part of the board, close to the centre. They are caused by drying stresses from cell collapse and can be closed with steam reconditioning below fibre saturation point.
Moisture content	Water content in wood measured as a percentage of the mass of green wood. Moisture content in green wood can exceed 100%. After air-drying the moisture content is influenced by the ambient conditions.
Nominal board size	Approximate dimensions of dried boards after sawing and drying.
Over-sizing, green sizing	Board dimensions with allowance made for shrinkage, variation in sawing accuracy and deflection of wood to produce accurately sized boards for the intended market after drying.
Quarter-sawn boards	Boards where the growth ring alignment is perpendicular to the wide face of the board.
Recovery	Yield of wood during processing expressed as a percentage of log volume. Recovery may be of sawn wood meeting grade specifications such as select, standard and utility grade. In some mills a pallet grade is also produced. Board recoveries are usually calculated using nominal dried dimensions but are sometimes calculated using final product dimensions or green dimensions.
Spring	Deflection of wood away from the log centre and where the growth rings are approximately perpendicular to the widest surface. eg. quarter-sawn boards. Spring cannot be removed during drying.
Steam reconditioning	A steam treatment applied in the kiln near the end of drying to recover collapse.
Surface checking	Cracks in the board surface caused by drying stresses. They are common on the tangential surface or the wide face of back-sawn boards.
Twist	Where boards distort along their length so the ends are at different angles to each other.
Wood shrinkage	Shrinkage from green condition to a given dried state. Shrinkage varies because of species differences, age of trees and orientation of boards (back-sawn or quarter-sawn). Tangential shrinkage (tangential to the growth rings) is about twice radial shrinkage (perpendicular to the growth rings).
Un-recovered collapse	Collapse that has not recovered during processing either because a steam reconditioning treatment was not applied or the steam reconditioning treatment was inadequate.

2.3 Tree and log

Growth strain

The observed shortening of wood dimensions due to growth stress release when the wood has been removed from a hardwood tree. Growth stresses decline radially from the tree surface, therefore the strains observed decline radially towards the tree centre. For a piece of wood that has different strain on opposite sides it will deflect to produce spring or bow.

Growth stresses

Longitudinal peripheral tensile stresses that develop in standing hardwood trees. They can be particularly severe in eucalypts.

Log end splitting

In eucalypts log end splitting commonly occurs during harvest and transport. The severity of end splitting depends on the fissile nature of the wood and is influenced by the severity of growth stresses, log diameter and log harvesting, handling and storage methods.

Log grading

In Australia log grading is applied by the respective State forest management agencies to market logs. Each State has a different system but all base the grading on log surface features such as diameter, sweep, grain alignment, internal defect on log ends and along the log surface.

Pith

The centre of log that is produced by the growing tip of the tree. It is usually unstable during drying and wood close to the pith often splits.

Tension wood

Abnormal wood produced by hardwoods as a reaction to bending stresses within the tree stem. The tension wood in *E. globulus* has wood fibres that are highly modified in that the S_2 layer of the secondary wall is unlignified or partly unlignified and the cellulose is highly crystalline. Tension wood is extremely unstable during drying and has very high transverse and longitudinal shrinkage. The shrinkage can appear similar to collapse, however, it will not recover with steam reconditioning. Tension wood also exerts extremely high growth stresses when present at the stem surface or log surface.

3 Introduction

This report reviews methods of producing solid wood products (sawn wood and veneer) from plantation-grown eucalypts important to Australia. It examines research and/or industry processing methods that may increase the quality or yield of solid wood products, or improve processing efficiency through improvements in wood flow rates that reduce processing costs and ultimately improve mill profitability and/or plantation value.

The review is based on a Cooperative Research Centre (CRC) for Forestry review (Washusen 2011) that examined reports of processing trials with plantation-grown eucalypts from southern Australia, and some comparable trials with native forest eucalypts. The processing trials were conducted by Australian sawmillers in a number of commercial sawmills located across southern Australia. The mills applied a range of processing technologies that represent those currently available to industry. The aim of the CRC review was to inform industry and the research community of the suitability of the various processing options for production of solid wood from plantation-grown eucalypts across the log diameter range expected from most plantations. This current review retains this approach. However, it has been expanded in scope to include veneer production as well as recent developments in processing in Australia and relevant experience from overseas.

The scope of the review covers all of the major eucalypt plantation species of interest to Australia from both pruned and unpruned stands. In south-eastern Australia these are *Eucalyptus globulus* (southern blue gum) and *E. nitens* (shining gum) and south-western Australia *E. globulus*, *E. saligna* (Sydney blue gum) and *Corymbia* spp (spotted gum). In northern Australia in the higher rainfall areas along the east coast, the main species of interest are *Corymbia citriodora* subsp. *variegata* (CCV) (spotted gum), *E. dunnii* (Dunns white gum), *E. pilularis* (blackbutt) and *E. cloeziana* (Gympie messmate).

The report is divided into three sections: 1) sawing; 2) drying sawn wood; and 3) production of peeled and sliced veneer. While sawmilling and drying sawn wood are linked the two processing stages are discussed separately (except for some brief passing references) because there are certain wood behavioural characteristics that are associated with only one or the other of these processing stages.

3.1 Assumptions of reader knowledge

This review will avoid two major areas of knowledge on the assumption that readers are acquainted with them. These are;

- (i) branch related defects and the effect of pruning on product quality, and;
- (ii) the theoretical longitudinal peripheral growth stress distribution within eucalypt trees and logs.

The Forest and Wood Products Research and Development Corporation (FWPRDC) report by Nolan *et al.* (2005) is a reasonable summary of the wood quality issues found in early research and industry processing trials of plantation-grown eucalypt sawlogs in Australia. There will be no attempt to repeat what is presented there, except for some selected information that is particularly relevant to this review.

Nolan *et al.* (2005) found that defects associated with branches are a constraint to production of conventional sawn products, and quite simply mechanical pruning is a good way of overcoming these defects (if it were commercially viable to do so). While this review acknowledges this situation it will not exclude information that is available from processing trials using logs from un-pruned stands where the processing outcomes are relevant.

Longitudinal peripheral growth stresses and processing solid wood from eucalypts are inexorably linked. There is much information on this linkage written in scientific papers and text books published over the past 50 – 70 years. These papers explain stress distribution and the consequences of the strains that develop with stress release during processing solid wood. It is assumed that readers are aware of this phenomenon, and there is no need to repeat the background information here. The report by De Fégely (2004) produced for the then FWPRDC indicated that the major constraint to processing plantation-grown eucalypts perceived by industry was growth stresses. For this reason this review will consider the effect of different processing options on wood behavioural characteristics from specific resources and the efficiencies of processing, without discussing the theory of growth stresses directly.

4 Sawmilling

In Australia most plantation processing trials conducted in commercial sawmills have involved the two important species planted in southern Australia, *E. globulus* and *E. nitens*. The outcomes have varied considerably (Washusen *et al.* 2004, 2006a, 2006b, 2007a, 2007b, 2009a, 2009b, Innes *et al.* 2008, Blakemore *et al.* 2010a, 2010b), mostly because of differences in wood drying performance. This will be discussed in greater detail later. However, some important differences are due to the sawing equipment and the strategies applied with this equipment. To understand these differences it is important to differentiate the sawing methods. For this review they are categorized as;

- (i) reciprocating single saw systems;
- (ii) reciprocating flow, twin saw, log break-down systems; and,
- (iii) linear flow multi-saw systems.

4.1 Reciprocating single saw log break-down systems

Conventional single-saw systems usually include a single band or circular saw that breaks down logs into manageable units (flitches and slabs) for resawing. In smaller and older conventional mills, the resaw also has a single saw. These single-saw systems have developed over many years to process native forest resources and are well suited to the highly variable quality of native forest logs where grade-sawing is required to maximise product quality. This variability includes a large range in diameter, log shape (circularity, sweep and taper) and internal defect.

4.1.1 The Economics of Processing Project

The Forest and Wood Products Australia (FWPA) PN04.3007 Determining the Economics of Processing Plantation Eucalypts for Solid Timber Production (Innes *et al.* 2008) is a good starting point because it can be used to illustrate why plantation-grown *E. globulus* and *E. nitens* require application of processing methods suited to the diameter of the logs being processed. The results of this project have been fairly widely reported and incorrectly used as evidence that processing plantation-grown eucalypts in Australian sawmills is a doubtful proposition because boards ‘distort too much’ (Nolan 2009).

Examination of Innes *et al.* (2008) reveals that the authors recognized that the sample of logs secured for most processing trials were not what was intended during project development. The logs had a very large diameter range with the majority <40 cm small end diameter (sed) and some as small as 25 cm sed. In the Tasmanian mills designed to process native forest eucalypts, where most of the processing was conducted, either an industry standard quarter-sawing strategy, or a modified ‘through and through’ sawing strategy, was applied to the majority of logs (Figure 1). Both of these strategies produce predominantly quarter-sawn boards, although both are rather primitive and don’t represent a true quarter-sawing strategy, and importantly they are far from best practice by world standards.

It is well known that quarter-sawing strategies require large logs. De Fégely (2004) from the industry survey cited above suggested that quarter-sawing is impossible with native forest regrowth logs <40 cm sed. This is something of an overstatement but if a line needs to be drawn this is a good point to draw it, and it is reasonably consistent with the findings of Haslett (1988) and Waugh and Rozsa (1991). The major reason for this conclusion is that growth stress release in small diameter logs has a major adverse effect on sawing accuracy, board distortion and board end-splitting. In small diameter plantation-grown logs quarter-sawing also produces narrow boards and lower recovery than could be expected from logs of appropriate size (Washusen *et al.* 2004, 2007a, 2009a) and a similar situation exists with native forest logs (Waugh and Rozsa 1991).

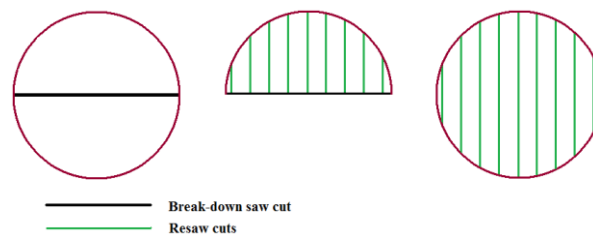


Figure 1: Quarter-sawing strategy (left and centre) and “through-and-through” strategy (right) applied in Tasmanian mills in FWPA PN04.3007 on 25-35 cm sed logs (adapted from Innes *et al.* 2008).

The cutting patterns shown in Figure 1, while aiming to produce quarter-sawn boards, produce a range in growth ring orientation. Some boards are back-sawn, some quarter-sawn and some mixed, which will contribute to different drying rates and drying stress development, and ultimately affect internal and surface checking and distortion (Blakemore and Northway 2009, CSIR 1936). In some cases boards will have growth ring orientation that varies along the board length, particularly in logs where the pith is not centred, and especially as the log diameter declines. This will complicate the internal drying stresses within the board, leading to even greater difficulties during drying.

Although board thickness and width was not measured by Innes *et al.* (2008), with the sawing strategies in Figure 1 it is very probable that excessive variation in thickness or width resulted from flitch and/or slab deflection as a result of growth stress release (de Villiers 1974, Malan and Toon 1980, Waugh 1986). Undersizing of board width would have implications for down-stream processing and could have contributed significantly to the undersizing reported during moulding of

E. globulus boards, which was the major factor that led Nolan (2009) to conclude that *E. globulus* distorts too much. This conclusion simply did not take log diameter into account.

Another possible cause for undersizing in final products is the selection of incorrect green sizes that do not allow for shrinkage that may be greater than experienced with native forest material. This is particularly important because both strategies in Figure 1 produce a large percentage of back-sawn or partially back-sawn boards for which shrinkage across the wide face of the board is substantially higher than in quarter-sawn boards because of the differences in tangential and radial shrinkage (Kingston and Risdon 1961). Unfortunately, the shrinkage rate was also not recorded.

The Innes *et al.* report is lacking in detail to understand some of the issues that are raised above, making it inappropriate to draw conclusions about the suitability of plantation-grown *E. nitens* or *E. globulus* for sawn timber production. What the report clearly indicates is that the processing methods were inadequate, so this widely reported research was not a rigorous test of the raw material and the conclusions drawn are misleading.

The report by Innes *et al.* (2008) also documents something of a contradictory finding from work conducted in the then Neville Smith Timbers mill at Heyfield, Victoria. A relatively small sample (28 cubic metres) of unpruned logs with a mean diameter of approximately 47.0 cm, from an unthinned plantation of *E. globulus* was processed. A quarter-sawing strategy that is normally applied to Victorian native forest 'ash' was used (Figure 2). With the VicForests grading criteria the logs were equivalent to B-grade or better and similar to the quality (based on external indicators) of the best 'ash' logs commonly processed in Victoria.

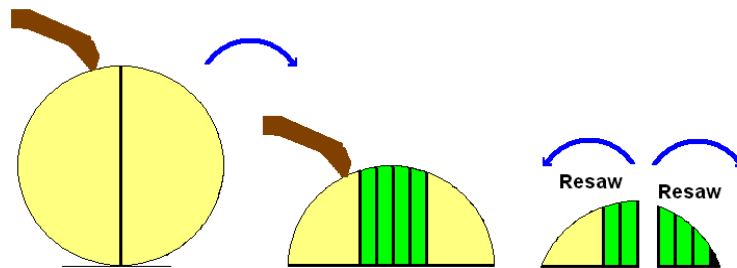


Figure 2: A quarter-sawing strategy similar to the one applied at then Neville Smith Timbers sawmill, Heyfield, Victoria in FWPA PN04.3007 on *E. globulus* logs with sed > 40 cm.

The quarter-sawing strategy produced 32.0 mm thick slabs for drying before rip-sawing to final board dimensions which effectively eliminates spring and undersizing. The final dried product recoveries were approximately 29% and 12% total recovery and select grade and better recovery respectively. This is similar to what is expected from native forest 'ash' processed with similar strategies and higher than reported from comparable processing trials using slab sawing strategies conducted by McCormack Demby Timbers, Morwell, Victoria with 1939 regrowth *E. regnans* (mountain ash) (Washusen *et al.* 2009 c,d) (Figure 3).



Figure 3: Quarter-sawing flitches with a slab sawing strategy at McCormack Demby Timbers, Morwell, Victoria (Source: Washusen *et al.* 2009d)

The recovery from this sample of logs in Victoria was also of interest because the trees had not been pruned. Similar results were found for unpruned 32 year-old *E. globulus* from Silver Creek, Gippsland that had been thinned at 18 years (Washusen *et al.* 2004). These logs were processed by the then Black Forest Timbers, Woodend, Victoria, with a sawing strategy similar to that shown in Figure 2 to produce sized boards for drying (rather than the slab sawing strategy applied at Neville Smith Timbers, Heyfield and McCormack Demby Timbers, cited above). The results of these two trials suggest that plantation-grown *E. globulus* trees can shed branches without any significant degrade developing. For this review no information from the literature or elsewhere has been found in Australia to indicate what percentage of an unmanaged, plantation-grown trees, would produce logs of this quality. However, in Galicia, Spain, a viable industry has emerged, quarter-sawing large diameter (>45 cm sed) *E. globulus* logs carefully selected from unpruned and unthinned stands that have grown beyond the normal pulpwood rotation of 12-15 years. Only a very small percentage, probably less than 2%, of the annual harvest volume in Galicia comprises logs of sufficient diameter from trees that meet form guidelines for avoiding tension wood (Chris Harwood, *pers. comm.*).

4.1.2 The CRC for Forestry Goulds Country processing trial

As indicated above quarter-sawing is a poor sawing strategy for small diameter eucalypts. A general rule of thumb in native forest mills is that when logs are smaller than about 40 cm mid diameter then back-sawing strategies should be applied. The Gould's Country *E. nitens* processing trial, in another Tasmanian native forest eucalypt sawmill, recognized this and used a strategy where all of the smaller logs were back-sawn and larger logs quarter sawn (Washusen *et al.* 2007a, 2009a). This CRC for Forestry trial used pruned *E. nitens* sawlogs from 22-year-old trees grown in a silvicultural trial at a range of stocking densities (100, 200, 300, 400 and ≈ 700 stems ha^{-1}), following thinning and pruning treatments imposed at age 6 years. This plantation was located at Gould's Country, NE Tasmania and is one of the first of Forestry Tasmania's operational plantations of *E. nitens*.

The quarter sawing strategy was similar to that shown on the left in Figure 1. The back-sawing strategy used a single saw and log rotation to produce the pattern similar to Figure 4.

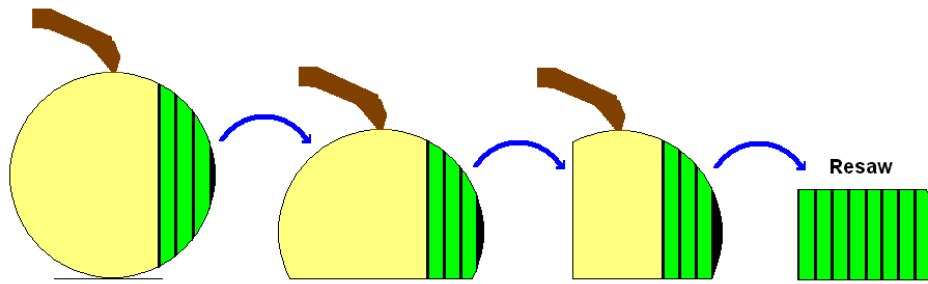


Figure 4: A back-sawing strategy similar to that applied in the CRC for Forestry Goulds Country *E. nitens* processing trial on logs smaller than 38 cm sed.

This trial produced differences in product recovery (Figure 5) with higher recovery in the smaller back-sawn logs. This result was expected (CSIR 1936, Waugh and Rozsa 1991) and illustrates why back-sawing is the preferred option for logs less than 40 cm sed. The differences in recovery of select and standard grades will be discussed in the sawn wood drying section.

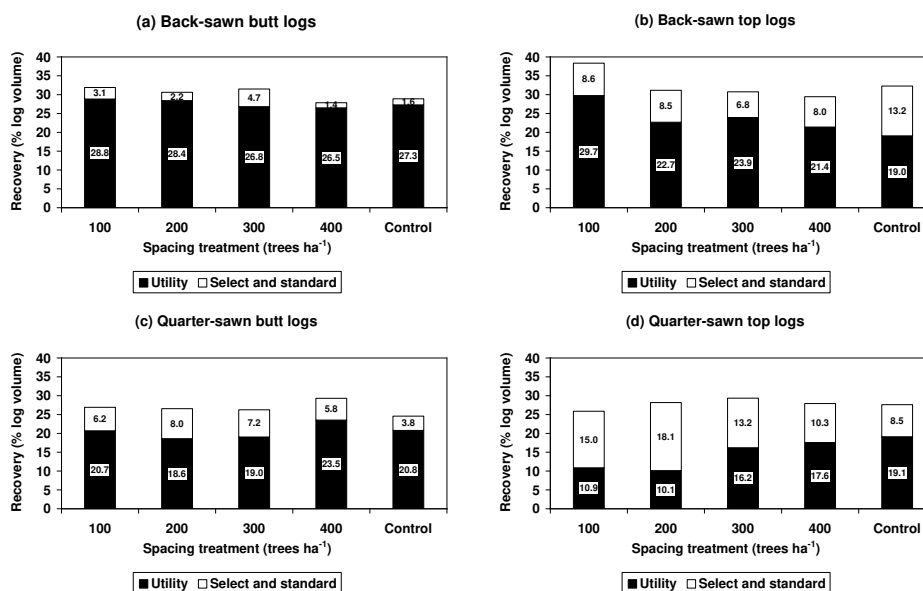


Figure 5: Comparison of recoveries from back-sawing and quarter-sawing strategies applied to logs from the same plantation. For quarter-sawing, logs had a minimum sed of 38 cm, and for back-sawing 25 cm sed (source: Washusen *et al.* 2007a).

The trial also demonstrated the problem of sawing accuracy with both sawing strategies in mills designed to process large-diameter, long-length logs from native forests. While the dogs on the carriage may be capable of restraining spring under ideal conditions (Page 1984, Haslett 1988) in this case the mill was unable to overcome the problem of log and/or flitch deflection as the sawing progressed. The result is boards generally thicker mid-length than at the ends. Similar problems occur in board width. Figure 6 shows some of the thickness variation data produced in back-sawn boards (Washusen *et al.* 2007a). Positive values in Figure 6 represent thickness loss near the ends of the board relative to the mid length of the board. The mid length thickness is represented by the line drawn through the data at zero. Approximately 73% of the measurements at the ends of the boards were thinner than mid-length.

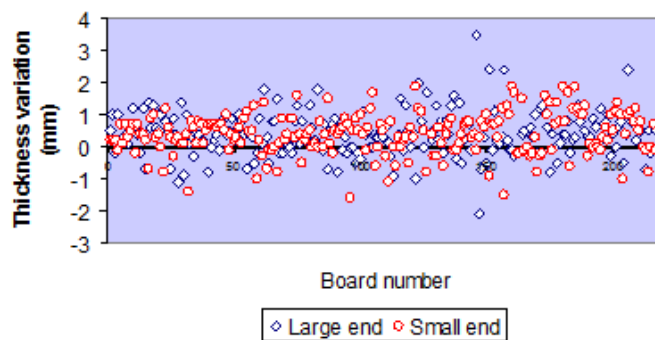


Figure 6: Thickness variation at the small and large end of the log relative to mid length of back-sawn boards from the CRC for Forestry Gould's Country *E. nitens* processing experiments (source: Washusen *et al.* 2007a).

Washusen *et al.* (2009a) found in a further analysis of this data that the standard deviation for thickness from over 1,700 measurements was 0.83 and 0.84 mm for quarter-sawing and back-sawing respectively. In comparison the guaranteed standard deviation from modern sawmill manufacturers are around 0.5 mm and may be much less in practice (Kenneth Westermarck, Viesto Oy, Finland *pers. comm.*). With the actual green target thickness of 27.5-28.0 mm, a standard deviation of 0.83-0.84 mm and thickness shrinkage of 5-6% which equates to about 1.5 mm, some 20% of the board length was < 25 mm before dressing. This had a significant effect of reducing both product recovery and quality.

It is also important to note that during sawing the sawyers applied face cutting with the break-down saw to reduce this thickness variation. This face cutting would have contributed a further small reduction in product recovery and a slowing of the sawing process at this stage, hence increasing the cost of sawing.

Another important result from the Goulds Country trial was that, for sets of back-sawn and quarter-sawn logs that were matched for size across the five thinning treatments, there was no appreciable effect of thinning treatment on processing performance. This suggested that with the processing methods employed, commercial pulpwood thinnings could be obtained from *E. nitens* plantations without compromising the processing performance in the sawmill of the final sawlog crop. However, a non-commercial thinning at an earlier age would increase diameter growth of the retained "sawlog" trees, enabling target log diameters to be reached over a shorter rotation (Forrester *et al.* 2012).

4.1.3 Single saw log break-down systems with line-bars

The addition of a line-bar to single saw log break-down systems, coupled with multi-saws in downstream processing, will help reduce the thickness and width variation with both back sawing and quarter-sawing strategies applied on appropriately-sized logs for these respective strategies (Haslett 1988, Waugh and Rozsa 1991). This is partly because the single break-down saw has a reference (the line-bar) to work off and partly because the head pressures on the dogs can be altered so that maximum pressure is applied on the log at the line bar close to the saw (Figure 7). Correctly used, the line-bar coupled with log rotation can reduce or eliminate the need for face cutting (Haslett 1988), and in the hands of a good operator should improve sawing accuracy (Jim Minster, Timber

Training Creswick, *pers. comm.*). The addition of multi-saw resaws also reduces thickness variation because the saws produce parallel saw cuts.

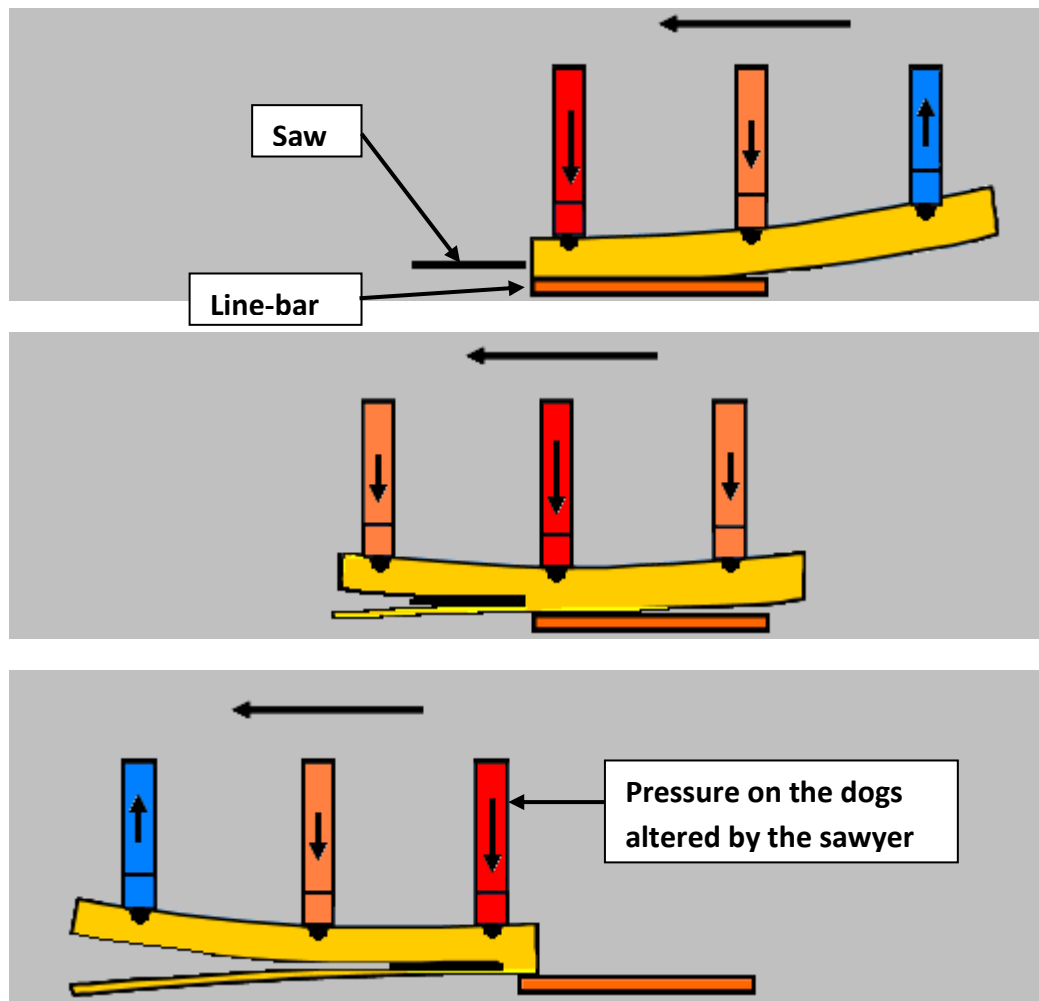


Figure 7: Diagram of the start (top), midway (middle) and end (bottom) of a single pass of a log that has deflected on a line-bar carriage head rig system viewed from above. The location of the line-bar and saw are indicated along with an indication of how pressure is manipulated on the dogs by the sawyer to ensure the sawn surface of a log is kept in contact with the line bar.

Research trials where line-bar carriage single saw systems have been used correctly to process *E. nitens* and *E. globulus* are uncommon. The only known recent trial of this type was conducted by the then Black Forest Timbers, Woodend, Victoria (Washusen *et al.* 2006a). Here a quarter-sawing strategy was applied on a line-bar carriage system coupled with multi-saws for down-stream processing. The cutting pattern was similar to that shown in Figure 2. The logs processed were pruned 16-year-old plantation *E. nitens* from the Otways in Victoria and equivalent diameter and grade 1939 regrowth *E. nitens* from the Central Highlands of Victoria. The aim of this trial was to quantify differences between logs from plantations and native forest regrowth. Log diameters and corresponding product values per log are plotted in Figure 8.

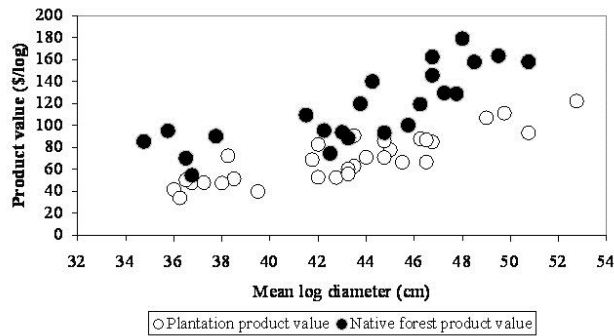


Figure 8: Comparison of product value of 16-year-old pruned *Eucalyptus nitens* and 1939 native forest regrowth *E. nitens* (66 years old) matched on log grade and diameter. All logs were classified as Victorian B-grade. (source: Washusen *et al.* 2006a).

In terms of sawing accuracy the results were good and unlike in the CRC for Forestry processing trail there was a low proportion of undersized boards. However, using the wood grading strategies and market values developed by Black Forest Timbers lower product value was found for the plantation grown logs (Figure 8). Defect associated with wood-moth infestation which affects the tree stem was the primary reason for differences, and graders found no evidence of differences in sizing accuracy or drying defect between the two samples. No other study is known where direct comparisons can be made between plantation and native forest logs because of the difficulties in matching samples and then subjecting logs and boards to identical processing and product evaluation methods.

4.1.4 The Galicia, Spain, experience with quarter-sawing *E. globulus*

In Galicia, Spain, quarter-sawing is commonly applied to plantation-grown *E. globulus* > 45 cm sed in a number of small sawmills equipped with single saw systems. Examples of final products produced from these mills are those produced by Villapol S.A (www.villapol.com). Villapol is supplied with green sawn boards that are dried and resawn. The dressed boards are then laminated into three-board laminates. The laminates are used as appearance-structural beams and also in the production of window frames in Germany (Harwood 2012). Other examples of *E. globulus* products are flooring supplied in Europe by Duro Designs (<http://www.duro-design.com>) (Evan Shield, Argentina, *pers. comm.*).

The logs used in this industry are selected from unthinned and unpruned stands of variable age, but generally beyond the typical pulpwood rotation of 12-15 years. Such stands occur because of the pattern of small-scale forest landholdings in Galicia providing a range of ages based on owner's management intent. Careful selection methods are applied by the mills when purchasing to avoid logs with severe tension wood and ensure they are of appropriate size for quarter-sawing (Manuel Touza, CIS Madera, Spain, *pers. comm.*). Generally, the logs appear to have high growth stresses which are of some concern to processors. This led CIS Madera to propose a number of sawing strategies that would limit the adverse effects of growth stress release (Touza 2001). One proposed sawing strategy (Figure 9) applied scribing saws ahead of a single break-down saw to separate core wood that is under compression from the outer wood of diametral slabs cut through the centre of the log and close to the pith. This appears to eliminate splitting of the diametral slabs but there has been no evidence found that suggests spring is reduced in the outer boards any more than for the

conventional quarter-sawing strategy applied at the then Neville Smith Timbers mill in similar sized logs (Figure 2).

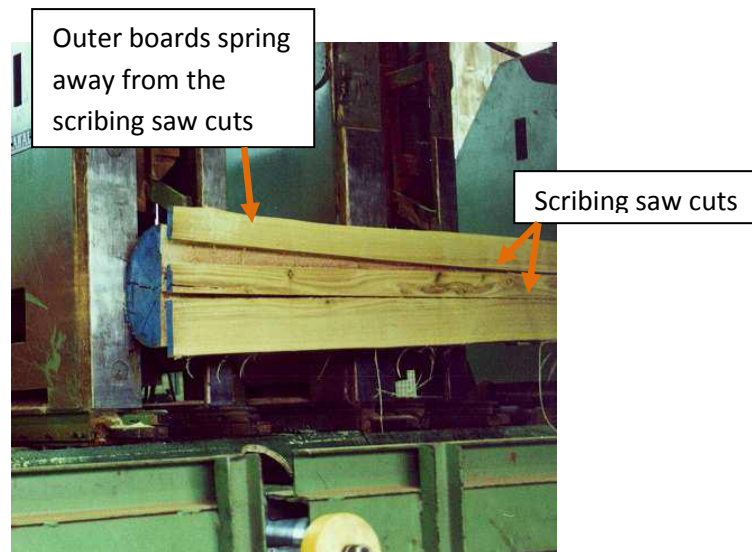


Figure 9: Sawing strategy proposed by CIS Madera to release growth stresses in large diameter plantation-grown *E. globulus* sawlogs (source: Manuel Touza, CIS Madera).

4.1.5 The efficiency of single saw log break-down systems

One of the inevitable failings of single saw log break-down systems is their slow material throughput due the requirement to pass logs backwards and forwards through saws or saws passed backwards and forwards through logs. Where single saw systems employ large diameter circular saws the saw kerf may also exceed 6.0 mm. Allowances for oversizing can also be large in mills aiming to avoid undersized products, for example some 'ash' processors in the past have selected a 32 mm green target thickness to produce nominal 25 mm dried boards (Washusen *et al.* 2006b). While this is acceptable for large diameter, long length native forest logs; for plantation-grown logs of smaller diameter and short log length (required to counter the adverse effects of growth stress release) the strategies applied by single saw log break-down systems become comparatively inefficient in terms of product yield per hour, leading to high processing costs. This becomes even more critical if processing thin section boards is required to minimise drying defect.

4.2 Reciprocating, twin saw, log break-down systems

An important option for improvement of sawmill efficiency is to use twin saw log break-down systems and multi-saw resaws. Twin-saw systems apply sawing strategies that, when coupled with appropriate log rotation, produce cutting patterns that release growth stresses more symmetrically around the log than is possible with single saws. On some occasions eucalypt mills in Australia have employed twin-saw log break-down systems with chipper-reducers that operate ahead of twin band-saws. This effectively means that with the first pass through the saw, four cuts are made (Figure 10). This produces dramatic improvements in material throughput over conventional single-saw systems.

Twin-saw systems have been used to process *E. globulus* with a quarter-sawing strategy at Black Forest Timbers, Victoria, and Auswest Timbers, Western Australia (Washusen *et al.* 2004); and back-sawing strategies at Auswest Timbers and Whittakers Timber Products, Western Australia (Washusen *et al.* 2004, 2009b). *Corymbia* spp. has also been processed at Auswest Timbers. Results from these projects are discussed below.

Chipper reducers



Figure 10. The McKee twin band-saw at Auswest Timbers, Pemberton, equipped with chipper reducers (in this photograph hidden ahead of the saws) that effectively make four cuts with the initial pass. This photograph was taken during a trial back-sawing pruned 22-year-old plantation-grown *Eucalyptus globulus* grown at Vasse in Western Australia and shows the sawing immediately after the first turn-down (source: Washusen *et al.* 2004)

4.2.1 Quarter-sawing *E. globulus* with twin saws

Two different methods of quarter-sawing were tested. At the then Black Forest Timbers mill, logs from an unpruned, thinned stand of 32 year-old *E. globulus* from Silver Creek, Victoria, were split to produce two log halves cut through the centre of the log with one of the twin saws. Each half was put through the twin saws again to produce two flitches for resawing and an accurately sawn centre cant (Figure 11). This is similar to the pattern shown in Figure 2 except there were no slabs cut to final board thickness with the break down saw.

At Auswest Timbers, where the twin saw was equipped with a chipper reducer an innovative sawing strategy was applied to produce 43 mm thick quarter-sawn boards (Figure 12). Logs were selected from 22-year-old pruned and thinned *E. globulus* grown near Vasse, Western Australia. In this case back-sawn flitches were sawn accurately in thickness and then diverted to a resawing line, turned down and sawn to produce quarter-sawn boards on a resaw, the original thickness becoming the width of the quarter-sawn board. This meant that spring could not be removed during resawing, as is normally done in mills set up for quarter-sawing. The sawing strategy also exceeds the 'one third rule' for sawing logs with high growth stresses (Haslett 1988). Here more than 30% of the log diameter has been removed before the log was turned down. For these reasons the sawing strategy is unlikely to be applied commercially. However, spring was a minor problem and given the radical sawing strategy it can be concluded that growth stresses did not hinder sawing. This was also evident from an examination of slabs (Figure 13) produced from close to the log centre during an associated back-sawing trial with logs from the same trees - splitting was very uncommon.

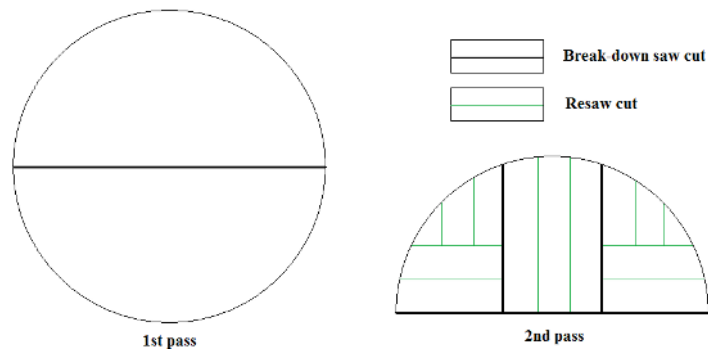


Figure 11: Sawing strategy applied at the then Black Forest Timbers with a twin saw and multi-saw resaw to process 32 year-old thinned and unpruned *E. globulus*.

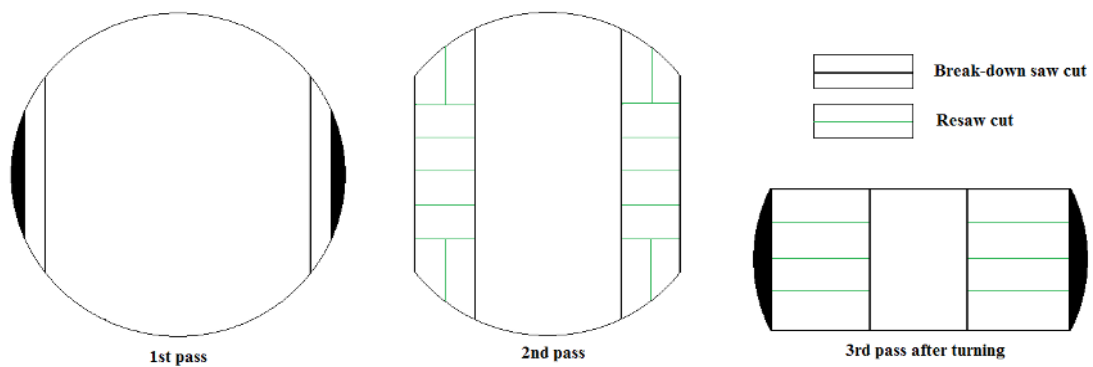


Figure 12: The sawing strategy applied at Austwest Timbers, Pemberton, Western Australia to process thinned and pruned 22 year old *E. globulus*. The dark zones represent wood removed with chipper reducers prior to sawing.



Figure 13: Slabs produced during sawing trials in thinned and pruned 22-year-old *E. globulus* at Auswest Timbers, Pemberton, WA. Splitting of slabs like these was rare suggesting that growth stresses did not hinder the sawing process (source: Washusen *et al.* 2004).

Both of these trials indicated that *E. globulus* could be quarter-sawn with few difficulties even though minor spring was evident in dried boards before skip dressing. This level of spring generally did not prevent further processing of boards suitable for appearance applications.

4.2.2 Back-sawing with twin saws

Back-sawing was only conducted at the Auswest Timbers mill in Pemberton, with the 22-year-old, pruned and thinned *E. globulus*. Back-sawing was tested with these logs because an earlier processing trial reported by Moore *et al.* (1996) using the second logs (the butt logs were used for production of peeled veneer) from 13 year-old trees from the same plantation produced promising results with a back-sawing strategy. At Auswest Timbers standard sawing strategies for *E. diversicolour* (karri) native forest regrowth were applied. Green target thickness was 28 mm to produce nominal 25 mm dried boards. Examples of slabs produced from this back-sawing strategy are shown in Figure 13. The wood was dried by the WA Forest Products Commission using drying methods developed for mature native forest *E. calophylla* (marri).

This trial produced recoveries that were higher than those in all of the other studies in conventional eucalypt sawmills reported here (total recovery 40.2% and recovery of select grade and better 36.1% of log volume). Likely contributing factors were the back-sawing strategy, the accuracy of sawing, and the exceptional drying results in logs where tension wood was scarce. The very high recovery was unexpected as back-sawing with unthinned and unpruned *E. globulus* logs in most earlier trials had produced poor results, primarily due to drying degrade on the wide face of boards. These earlier results (prior to about 2002) had suggested that quarter-sawing was essential for processing *E. globulus*.

Subsequent back-sawing trials conducted by Auswest Timbers with 10-22 year old pruned *Corymbia* logs also produced good results (Washusen 2006). Flooring produced from randomly selected boards from a kiln drying experiment incorporating periodic high humidity treatments are shown in Figure 14.



Figure 14: *Corymbia* spp. flooring produce from a kiln drying experiment with 10-22 year old pruned logs back-sawn at Auswest Timbers Pemberton, WA (Photo: Russell Washusen).

Recoveries of select grade boards for these successive trails at Auswest Timbers using standard back-sawing strategies for *E. diversicolour* with pruned *E. globulus* and *Corymbia* spp. logs are plotted for the diameter range of 17-63 cm sed (Washusen and Clark 2005) (Figure 15). This is the approximate full diameter range that this mill is capable of processing.

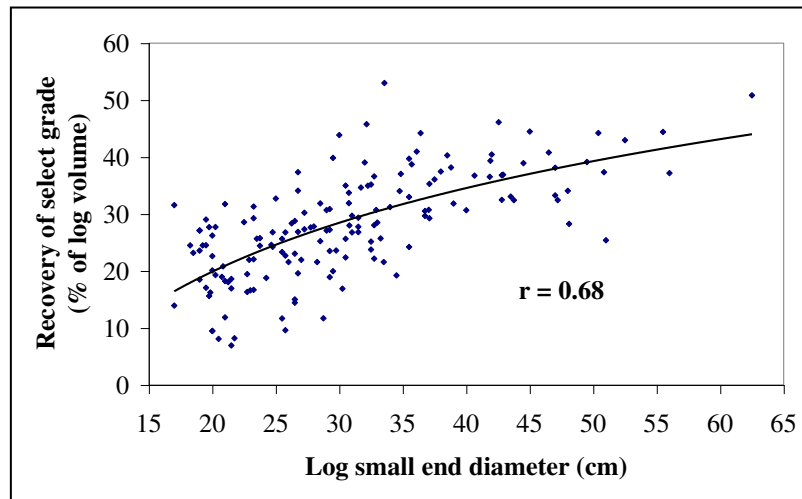


Figure 15: Recoveries of select grade boards from successive trials at Auswest Timbers Pemberton with pruned *Corymbia* spp. and *E. globulus* plotted for the full diameter range of 17-63 cm sed processed in the trials (Source: Washusen and Clark 2005).

To determine if the good results using back-sawing strategies with *E. globulus* were repeatable, a second trial was conducted on logs from a 17-year-old thinned and pruned provenance trial of *E. globulus* grown near Manjimup, WA. This trial was reported in the FWPA-PRC114-0708 Western Australian Clearwood Eucalypt report (Washusen *et al.* 2009b) which processed a number of provenances of *E. saligna* and *E. viminalis* (ribbon gum) in addition to *E. globulus*. The sawing was conducted on the small log line at Whittakers Timber Products (Figure 16). At the time of this trial this mill was the newest dedicated hardwood mill in Australia with examples of contemporary technology for twinsaws and multi-saw resaws. The process involves scanning log dimensions, selecting the sawing strategy that will produce the best recovery and computer control of the sawing process during log break-down. The end-dogging system also has a log turn-down device that eliminates the requirement to release the log during log turn-down, potentially speeding up the sawing process.





Figure 16. The sawing system at Whittakers Timber Products processing 17-year-old pruned plantation-grown eucalypts. Top: sawing on the twin band-saw; Lower left: the hydraulic turn-down device in operation; Lower right: scanning of the central cant prior to re-sawing on the multi-saw (source: Washusen *et al.* 2009a)

One limitation of twin-saw systems is that they do have a maximum log diameter limit that is more restrictive than conventional single saw systems. For plantations where log diameter can quickly exceed this limit, this may not be ideal. In this project even with 17-year-old trees some logs had to be rejected at harvest because they exceeded the log diameter limit for this mill of 45 cm sed.

The recovery of boards at Whittakers Timber Products was lower than reported by Washusen *et al.* (2004) for the 22 year-old *E. globulus* processed by Auswest Timbers, discussed above. This was because a 100 mm x 108 mm centre cant from each log and all boards failing to meet standard grade were chipped. Had these boards been included the graded recoveries would have been similar to those produced at Auswest Timbers for logs of equivalent diameter.

In this trial sawing accuracy was assessed directly on boards as a ratio of the length of board undersized to the total length of boards produced, for all boards including those rejected at grading. For the 16 samples of logs, representing 16 provenances across the three species, this ratio expressed as a percentage ranged from 0.0% - 5.2% of total board length produced. For the three provenances of *E. globulus* the range was 0.4% - 3.2%, which was much lower than the 20% undersize found during the CRC for Forestry processing trial on *E. nitens* discussed earlier.

The undersizing at Whittakers was not due to deflection of the sawn face of the log (as was the case in the CRC for Forestry trial with *E. nitens*) but arose from splitting of logs during sawing, which is a different manifestation of growth stress release. Figure 17 shows an example of the log end-splitting observed that contributed to undersized product. Here a 17-year-old *E. saligna* log has had four slabs removed during log break-down without turning the log down. This produced a cant that is 105 mm in thickness (the final green board width) and approximately 250 mm in height with the rounded surface of the log visible. The treatment of this log was a departure from the usual recommendation to turn eucalypt logs after chip, boards or slabs have been removed equal to about 33% of the log diameter. In this case more than 60% of the diameter was removed. This was technically a failure in the computer software that can be overcome with re-programming. However, this problem has been observed in other trials and with other species (Washusen *et al.* 2004; Washusen 2006) where the sawyer has had greater control of the sawing process. It appears to be

very easy to mistakenly remove too many slabs before turning the log down. As log diameter declines this issue becomes increasingly important.

Changes in the growth-stress balance within logs also have more subtle effects that may not be as noticeable as log end splitting. During a trial with plantation-grown *E. dunnii* at the Boral Koolkhan sawmill in northern New South Wales (Harwood *et al.* 2005), splitting ahead of the saws was observed during resawing of centre cants on a multi-saw. This probably was the result of a similar phenomenon, the cant being too thin relative to its height.

Splitting ahead of saws is one of the least recognised problems associated with growth stress release because it may not become apparent until after the wood has been dried. In the numerous trials conducted by industry in collaboration with CSIRO this issue has emerged frequently. To overcome this it is important to release growth stresses uniformly from around the log. The use of chipper canters (discussed in Section 2.3) to remove wood more-or-less simultaneously from 4 sides of the log is a good solution.



Figure 17. Log end-splitting in 17-year-old *Eucalyptus saligna*, the consequence of sawing to produce a cant that is too narrow relative to the log diameter (source: Washusen *et al.* 2009a).

4.2.2.1 Back-sawing *E. globulus*

One of the clear outcomes of these two projects with pruned and thinned *E. globulus* grown in Western Australia is that the species when managed with pruning and early thinning can be back-sawn with few problems developing during sawing and drying. This has important implications for processing *E. globulus* (and all of the species relevant to this review) because a high proportion of logs smaller than 40 cm sed are likely to be produced in plantations. If they can be back-sawn with multi-saw systems, growth stress release is controlled better, sawing accuracy improved, board width increased and higher recoveries obtained, in comparison to quarter-sawing. In addition, improvements in sawmill efficiency with higher volume throughput for the capital and labour costs are more likely with back-sawing than quarter-sawing (CSIR 1936).

4.2.3 Improvements in the efficiency of twin saw systems

An example of improvements in efficiency is the development of single operator sawmills such as the mill shown in Figure 18. This is a plan view of the layout of a mill that is equipped with a log centering device, chipper reducer, twin band saw and board edger.

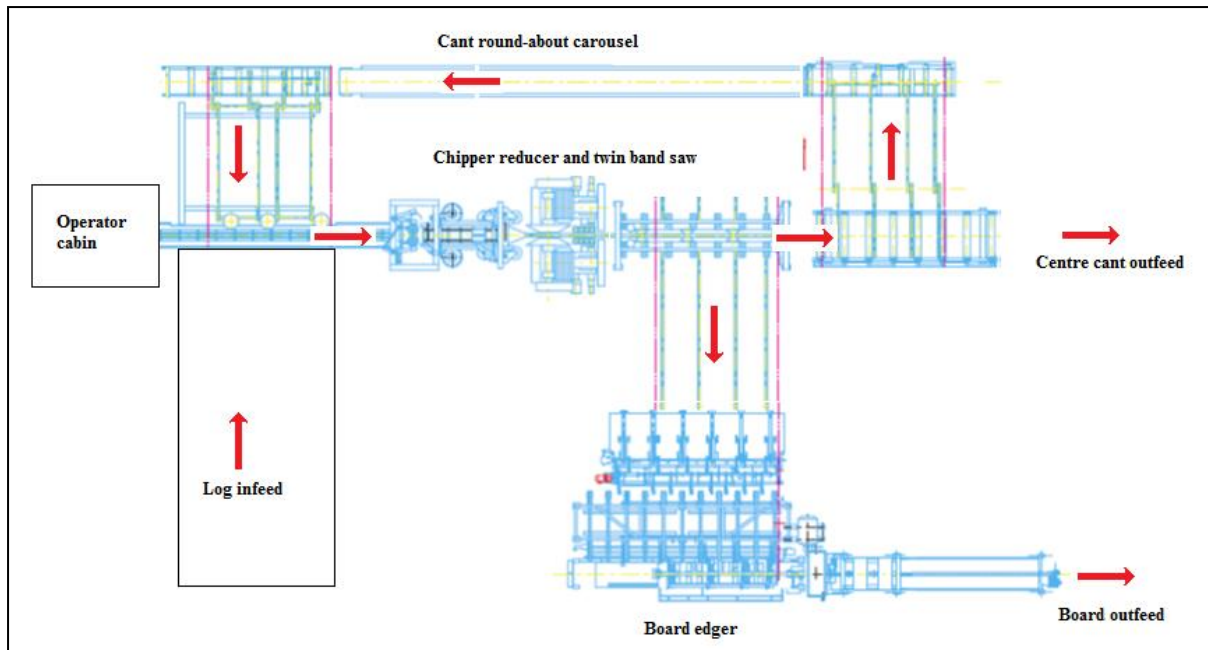


Figure 18: Plan view of a single operator sawmill for processing back-sawn boards from logs < 40 cm sed (Adapted from original source: Soderham Eriksson, Sweden).

In addition to requiring only a single operator the mill demonstrates one additional important innovation for twin saw systems. The requirement for end dogging which is shown in Figures 10 and 16 is eliminated and replaced with twin parallel chains and eight feed rollers that operate directly on the log to move it through the saws. Elimination of end-dogging has two important impacts on the efficiency of sawmilling. Firstly, it may help prevent log end splitting that can be induced by the end dogs; and most importantly, the wood flow through the saw can be changed from reciprocation to a single (linear) flow direction. The flow direction for this mill is indicated by the arrows in Figure 18. While the wood still circulates through the twin saw the wood flow through the saw itself is linear. This linear flow results in better use of the capital cost of the sawing system and associated infrastructure and improved productivity per person over any given time frame. A mill of this type has a recorded capacity of around 115,000 m³ per year log intake operating on 2 shifts (Evan D. Shield, *pers. comm.*) suggesting that it is a very efficient sawmill, potentially reducing the cost of sawing in comparison to conventional twin saw systems.

This mill is currently being proposed for processing back-sawn boards from plantation-grown *E. nitens* in Chile (Evan D. Shield, *pers. comm.*) and it has potential application for all of the species of interest to Australia where logs are less than 40 cm sed.

4.3 Limitations of single and twin saw systems

The main issues identified in the processing trials with single and twin-saw systems discussed so far that limit sawmilling efficiency and potentially limit product value as a consequence of the sawing process are:

- sawing accuracy of single-saw systems
- large saw kerf, particularly the kerf of large-diameter circular saws
- log-end and cant end-splitting
- splitting ahead of the saw

- the requirement to rotate logs during sawing
- the reciprocation of logs through breakdown saws (or saws through logs), and in older conventional systems the reciprocation of logs, flitches and slabs through resaws.

Other problems arising from growth-stress release that do occur are associated with board deflection, either as spring in quarter-sawn boards and flitches or bow in back-sawn boards and flitches. In general, this has not hampered the sawing process, as the sawing methods themselves are designed to reduce the extent of this deflection or to eliminate it during resawing. The choice of log length has a major bearing on board deflection. In the trials in Australian sawmills described above, sawlog length was usually conservative (2.7 m -3.3 m) with the aim of reducing deflection to manageable levels and limiting recovery loss during the resawing process.

So what happens if more symmetrical cutting patterns than those possible with twin-saw log breakdown systems are applied, end-dogging of logs eliminated and the flow of wood made linear as opposed to a reciprocating flow? In the following sections the consequences of these changes are discussed.

4.4 Linear flow multi-saw systems

Linear flow multi-saw systems are usually associated with softwood processors. However, they are used to process eucalypts in South America and have been applied by Forest Enterprises Australia Ltd (FEA) in Tasmania to process *E. nitens* on a commercial scale along with softwood. The benefits of linear flow have already been discussed in Section 4.2.3 - linear flow speeds up the sawing process potentially reducing processing costs. Modern linear sawmills also apply chippers and saws to remove wood from around the log more-or-less simultaneously. In terms of growth stress release this is a major advantage over mills where wood is only removed from one or two sides of the log before the log is rotated. There are two basic types of linear sawmills that are discussed below;

- (i) Linear mills with close coupled saws and chippers
- (ii) Sawing lines with separated chipping and sawing components.

4.4.1 Close coupled saws and chippers

In Australia, a number of trials have been conducted with close coupled linear sawing systems with *E. globulus*, *E. nitens*, *E. pilularis*, *E. dunnii* and CCV. The then FEA Ltd mill in Bell Bay, Tasmania processed small-diameter *E. nitens* for structural products on a commercial scale, using a HewSaw R200. Processing trials have also been conducted using the HewSaw R250 at the Carter Holt Harvey softwood sawmill, Yarram, Victoria (formerly N.F. McDonnell & Sons) (Figure 19). These two sawing systems apply chippers to remove wood from around the log to produce a profiled cant simultaneously with or just ahead of small-diameter circular saws (Figure 20). This strategy eliminates the problem of growth-stress imbalance by removing wood simultaneously from around the log.

The HewSaw R250 and R200 complete the sawing in a single pass. Log diameter ranges are 14–34 cm sed and 14–25 cm sed respectively. At conservative feed rates into the saws, total log volume input is around 120,000 m³ of logs per year in a single shift. This is a much greater volume than can be processed by any conventional hardwood sawmill in Australia where trials have been conducted with plantation-grown eucalypts.

The potential ramifications of high throughput are that, if a suitable resource were available, the cost of sawmilling could fall dramatically, improving the profitability of growing and processing eucalypts.



Figure 19: The HewSaw R250 at the Carter Holt Harvey Mill in Gippsland (formerly NF McDonnell & Sons) (source: Washusen *et al.* 2007b).



Figure 20: Diagrammatic representation of the internal arrangement of chippers and saws in the HewSaw R250 (source: www.hewsaw.com).

To understand how effective these systems are at processing logs with high and variable growth stresses, research has been conducted with the HewSaw R250 at the Carter Holt Harvey mill (formerly NF McDonnell & Sons) in Gippsland, Victoria with 17 year-old unthinned *E. nitens* from a Forests New South Wales genetics trial (Washusen *et al.* 2007b). Logs used were up to 5.0 m long —

much longer than in the other trials conducted by conventional sawmills in Australia that are reported here.

The characteristic related to growth stress release that was of most importance was bow in boards near the log periphery. Photographs of the range in bow observed during the trial are shown in Figure 21. These photographs were taken immediately at the conclusion of sawing. Figure 22 plots longitudinal growth strain displacement (LGS, a measure of peripheral longitudinal growth stress) measured on standing trees and maximum bow for each log. The maximum bow recorded with boards placed on their edges was <160 mm (Figure 22). Bow of this magnitude was of little consequence to board handling or stacking, although modifications to board handling systems such as the incorporation of tray sorters (Figure 23) or longer lugs on conveyors would improve material flow. There is also evidence to suggest that bow can be controlled by sawmillers by adjusting the depth the chippers (Washusen *et al.* 2007b, 2009d). Importantly, bow is eliminated during drying so it is not a grade-limiting defect.



Figure 21: The approximate range in board deflection for 17-year-old *Eucalyptus nitens* logs observed in trials with the HewSaw R250 (source: Washusen *et al.* 2007b).

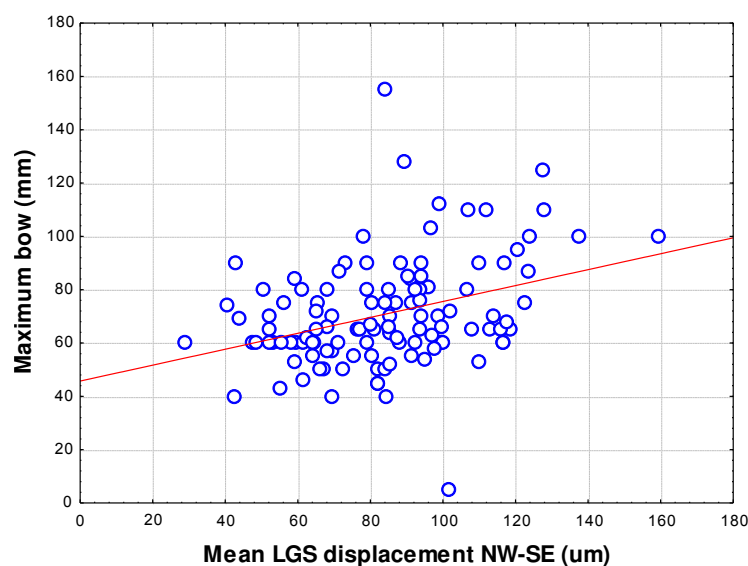


Figure 22: Plot of longitudinal growth strain displacement and the maximum bow recorded for 17 year-old *E. nitens* logs (source: Washusen *et al.* 2007b).



Figure 23: A tray sorter installed at the Havesa Timber sawmill, Hamina, Finland. The sorter can pick up boards and transports them sideways from the conveyor at the end of a HewSaw R250 without elevation of the boards. The tray sorter is an alternative to sling sorters that may cause problems for handling bowed eucalypt boards (source: Washusen 2008).

The advantage of being able to produce boards of this length is that product value is linked to board length (as well as to width and thickness). For example, with current ash eucalypt markets in Australia, if average board length is <3.0 m there is a discount applied of 10% to the wholesale price, and for boards <1.8 m in length there is a discount of 50% (Ken Last, formerly FWPRDC, *pers. comm.*).

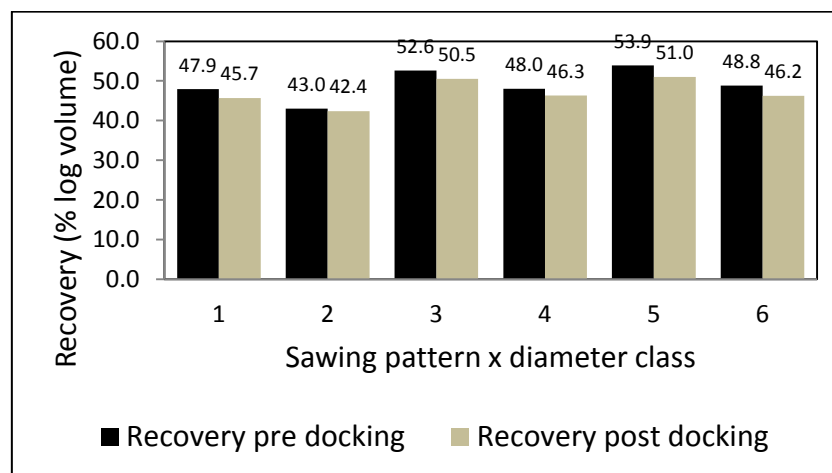


Figure 24: Plot showing loss in green volume recovery due to end splits for 3 different sawing patterns on a HewSaw R250 and two diameter classes for each sawing pattern (source: Washusen *et al.* 2007b).

There is another less obvious advantage in having logs of this length. Some log-end splitting resulting from harvesting and handling is common in eucalypts. Although worsening of the splitting can be

minimised by the sawing process, as discussed above, if log end-splits show up in board ends they are docked, reducing the recovery of sawn boards. In this trial in 17-year-old *E. nitens* with 5 m logs, log end-splitting accounted for 1.2-2.9% loss in recovery for the six samples processed (Figure 24). This compares to 5% loss in the Gould's Country trial in 22-year-old *E. nitens* with 2.7 m logs (Washusen *et al.* 2007a). An assessment of log end-split severity indicated that the 17-year-old logs tended to have worse end splitting than the 22 year-old logs. The reason for the difference in loss due to docking end splits is that as a proportion of log and board length the end-split length was less in the 17-year-old logs. While the results were presented differently, this lower loss due to end-splitting in longer logs was also found in a subsequent CRC for forestry trial at the Carter Holt Harvey mill (Blakemore *et al.* 2010a). Docking of end splits in this trial would account for approximately 2.0% loss in recovery, the same as the mid range recorded by Washusen *et al.* (2007b).

4.4.1.1 Disadvantages of close coupled machines

There is one disadvantage with the sawing pattern employed by these close coupled machines; many boards containing the pith are produced. As log diameter declines the percentage of board length affected increases. This is because the sawing pattern produces boards through the centre of the logs (Figures 20 and 21) which commonly produce drying defect (splitting) associated with the pith. An example of this degrade, in small diameter *E. pilularis* processed with a HewSaw R200 at the then FEA mill, Bell Bay is shown in Figure 25. The degrade shown was sufficient to suggest that processing this resource would not be viable (Washusen *et al.* 2009d), although this can be overcome to some extent by altering the sawing pattern to produce a larger centre board and selecting species less susceptible to this type of drying degrade such as CCV (Washusen and Innes 2007, Washusen *et al.* 2009e).



Figure 25: The HewSaw R200 at the former FEA mill site at Bell Bay, Tasmania processing *E. pilularis* (left) and drying defect associated with the pith in small diameter *E. pilularis* (right) (source: Washusen *et al.* 2009d).

The HewSaw R250 and R200 also have one other disadvantage in that the sawing pattern is set and must be changed manually when saws are installed. In order to optimise recovery logs require careful sorting by diameter. This no doubt contributed to low recoveries reported for one sawing pattern in a trial at the FEA mill reported by Blackburn *et al.* (2011). HewSaw close coupled machines also have an option for scan and set capacity (the HewSaw R250 PLUS and R200 PLUS) where logs are scanned prior to sawing and the sawing pattern altered automatically to optimise product recovery.

4.4.2 Sawing lines

In order to address the problem of drying wood with the pith included, one option is to saw around the pith and segregate the boards containing the pith from the drying process. This is normal practice during quarter-sawing and back-sawing in conventional eucalypt sawmills. In the case of close coupled single pass machines like the HewSaw R250 and R200 the various processing components can be separated into individual machines. Sawing lines configured in this way are common in the softwood industry and they would retain the same stress release attributes as the close coupled machines indicated above.

An example of one such machine is the HewSaw SL 250 PLUS quartet at United Sawmills Ltd, Finland (Figure 26). Another version of this sawing line is the HewSaw SL 250 PLUS trio, the cutting pattern of which is shown in Figure 27. Both of these mills have scan and set capability and are primarily designed to process softwood, however, they have all of the attributes required to process eucalypts. The three main components of the SL 250 trio are the Cant Chipping, Cant Sawing/Edging and Rip Sawing machines. If required the thickness of the final cant can be varied to avoid the problems of end splitting and the narrower centre boards diverted from drying. The mills can also process logs from 2.4-6.0 m length and from 10 cm sed to 40 cm sed and 50 cm led (large end diameter). Line speed is 60-150 m min⁻¹ (Washusen 2008, 2009). The length range gives greater flexibility for controlling board deflection and the larger diameter range makes it more universally flexible for processing eucalypts than the close coupled versions of the HewSaw.



Figure 26: A HewSaw SL 250 at United Sawmills Ltd, Pori, Finland (source: Washusen 2008).

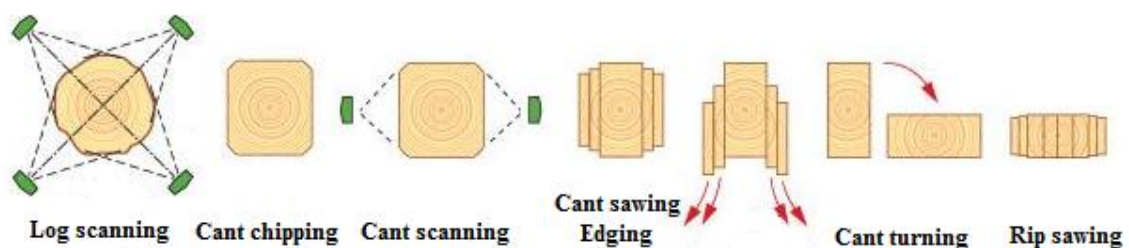


Figure 27: The sawing pattern of the HewSaw SL 250 PLUS trio showing the role of the separate components in the sawing line (source: www.hewsaw.com).

4.4.3 The implications of linear flow

The implications of moving from conventional reciprocating carriage, overhead end-dogging and single and twin saw log break-down systems to linear sawmills either equipped with a close coupled machine or with the processing components arranged in a sawing line is best demonstrated through modelling. A number of models are available that represent the Whittakers MEM Tally Twin and Cobra Multi-mate resaw located at Greenbushes, Western Australia, a HewSaw R250 and a HewSaw SL 250 PLUS trio (Washusen 2008, 2009). These models have been developed over several years with the assistance of a number of industry contributors, the most important of these are listed in the notes below Table 1.

Table 1: Modelled sawing costs for given log intake ranges for three sawing systems.

Processing system	Annual log intake for 2 shifts (cubic metres)	Modelled sawing costs based on 2007 prices and 15 year mill life (\$ per cubic metre of log intake)
MEM Tally Twin and resaw*	36,000 – 45,000	\$55-\$65
HewSaw R250**	200,000 – 260,000	\$18-\$22
Hewsaw SL 250 PLUS Trio***	260,000 – 320,000	\$15-\$20

* Source of costs and log throughput: Whittakers Timber Products (WA), Auswest Timbers (WA), Black Forest Timbers (Vic)

** Source of costs and log throughput: NF McDonnell & Sons (SA), Carter Holt Harvey (Vic), D&R Henderson (Vic), Forest Enterprises Australia (Tas)

*** Source of costs and log throughput: NF McDonnell & Sons (SA), Carter Holt Harvey (Vic), D&R Henderson (Vic), Viesto (Finland), Forest Enterprises Australia (Tas)

Table 1 provides annual log intake and modelled sawing costs based on 2007 prices and 15 year mill life for the three mills. Sawing costs declined substantially compared to conventional reciprocating sawing systems by applying close coupled linear systems and even greater reductions with the sawing line. The primary reason for the reduction in costs is better utilization of the capital equipment and labour.

Sawing lines and the close coupled single pass machines are rarely applied worldwide for processing eucalypts. One exception is the COFUSA/URUFOR mill located in Rivera, Uruguay and supplied from COFUSA's Rivera plantation-grown *E. grandis* (flooded gum). The sawn and dried wood is marketed under the trade name Red Grandis (www.ucfp.com). In 2010 the mill was processing 400,000 m³ of sawlogs annually, making it the largest eucalypt sawmill in the world. This is tangible evidence that it is possible to develop eucalypt sawmills of this scale if the supply requirements can be met (Evan D. Shield, *pers. comm.*).

In Australia, it will be very difficult to find a suitable supply of logs for a high throughput sawing line in the foreseeable future. However, there are some softwood mills with suitable sawing systems that have capacity to take on a hardwood resource if it were available as part of their feedstock and if it had appropriate resource characteristics. The former FEA mill at Bell Bay is an example of this where unpruned and unthinned *E. nitens* was processed with softwood. Given the large differences in sawing costs the softwood mills would have a competitive advantage over conventional hardwood processors.

An alternative approach may be to adopt more automated systems with low labour input such as the single operator mill shown in Figure 18. Production costs for this sawmill are not available for comparison with those in Table 1.

Of course for the mill examples discussed above, this is only relevant for logs smaller than 45 cm sed for the Twin band saw, and 40 cm sed for the linear sawmills and the single operator mill. Except for the HewSaw R250 and R200 which have a 'through-and-through' sawing pattern from which a proportion of quarter-sawn boards can be derived, these mills normally only produce back-sawn boards.

4.4.4 High speed quarter sawing

Apart from the quarter-sawn boards that can be produced with the HewSaw R250 and R200 it is unknown if linear mills can be adapted to quarter-saw. Experimentation with the HewSaw R250 (Blakemore *et al.* 2010a), which attempted to produce flitches from the top and bottom of the cant for resawing quarter-sawn boards in an off line pallet mill, indicated that spring was excessive. This experiment used logs of 3.6 m length and 32 cm sed and produced 75 mm thick flitches for resawing from the top and bottom of the cant. This is a very radical cutting pattern given the length and diameter of the logs and it is not surprising that it produced excessive spring. However, on this mill there was no other log length option that could be tested because of the restrictions imposed by the log infeed deck and sawn board conveyors.

As indicated earlier the HewSaw SL 250 PLUS trio sawmill can process logs up to 40 cm sed and down to 2.4 m lengths. At these limits it may be possible to produce flitches for quarter-sawing. The experimentation conducted by Auswest Timbers on the McKee twin band saw (Washusen *et al.* 2004) using pruned and thinned 22-year-old *E. globulus* logs 3.0 m long and > 40 cm sed suggested that quarter-sawing of large-diameter *E. nitens* logs using a similar strategy may be possible, if drying back-sawn wood of this species produces too much drying defect for high value markets.

4.4.4.1 A conventional quarter-sawing mill with improved linear flow

Given the projected plantation eucalypt log supply situation in Australia it is extremely unlikely that a new dedicated linear sawmill for processing eucalypts could be justified in the foreseeable future. The only species grown in sufficient volume is *E. globulus* and the resource characteristics of this species suggest it is unsuitable because of the common occurrence of tension wood. One possible option for processing eucalypts with a quarter-sawing strategy is to alter the processing methods of suitable existing eucalypt saw mills by eliminating as much of the reciprocation of wood as possible.

In 2007, CSIRO, in consultation with Neville Smith Timbers (NST), produced a model of the NST Southwood mill in Tasmania to model mill door prices for plantation-grown logs (Innes *et al.* 2008). This mill changed hands and was operated by Gunns Ltd until 2011 and is now owned by Del Vista Forest Products. It was demonstrated from trials with short length native forest logs, and from Gunns Ltd staff observations of normal processing operations, that serious bottle necks in the processing line can slow the mill's operation significantly (Joshua Turnbull, Trevor Innes, Gunns Ltd, *pers. comm.*).

The mill is set up with two single saw log break-down units that produce flitches of variable dimensions for re-sawing on two MEM twin band saws. Boards produced on the twin saws are sent directly to a green chain for sorting and slabs diverted to a scanning multi-rip. Gunns Ltd staff

estimated the mill capacity to be around 45,000 m³ log intake per annum in a single shift processing native forests eucalypts up to 5.4 m in length. The two twin saws process these long flitches relatively efficiently in several passes. However as the log length declines material throughput slows substantially.

This may be overcome by substituting one of the twin saws with a multi-saw such as the HewSaw NS250 (www.hewsaw.com). This multi-rip machine can process accurately dimensioned cants in a single pass to produce either back-sawn or quarter-sawn boards. This would be a modification that mimics some of the attributes of the Whittakers Timber Products mill in WA where an MEM Cobra Multi-mate is installed for resawing cants.

The HewSaw NS250 (Figure 28) has feed speeds of 60-200 m/min, providing a substantial improvement in mill performance with both short and long length logs. In order to produce accurately dimensioned cants modifications are required to the log break-down system and to handle boards efficiently new board handling systems are required at the outfeed. The sawing pattern for the mill with the incorporation of the multi-rip machine is shown in Figure 29a and 29b for 50 cm and 60 cm sed logs respectively.



Figure 28. The HewSaw NS ripsaw is an example of a sawing line component that can be used in line to improve material flow rates and the economies of scale of conventional mills processing quarter-sawn boards (source www.hewsaw.com).

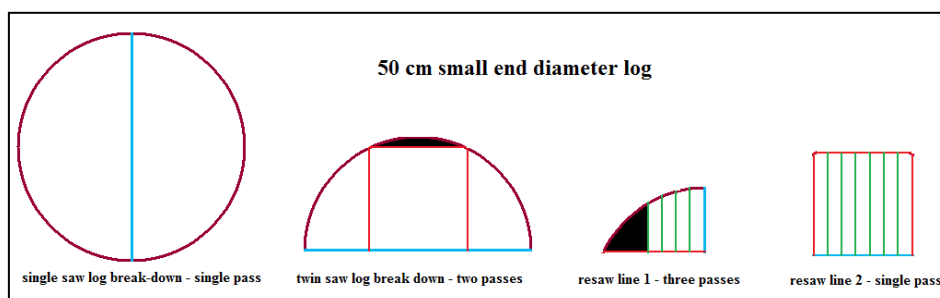


Figure 29a: Sawing pattern and number of passes for 50 cm sed log (source: Washusen and Harwood 2011).

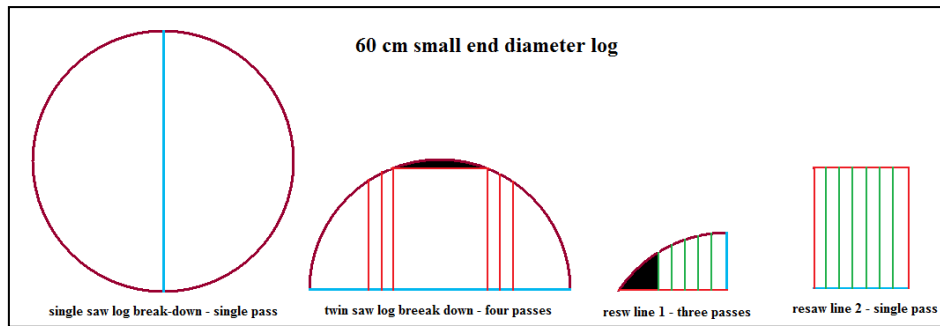


Figure 29b: Sawing pattern and number of passes for 60 cm sed logs (source: Washusen and Harwood 2011).

The CRC for Forestry modelled the performance of this proposed mill with the inclusion of the HewSaw NS 250 rip-saw with the assistance of Gunns Ltd staff and Veisto Oy, Finland (Washusen and Harwood 2011). The model simultaneously calculates mill door log prices and processing costs for a given Internal Rate of Return (IRR) for the sawmill, product value and log intake rate. For this model the intake rate was estimated to be 100,000 m³ per year for a two shift operation (approximately 10% higher than current estimates from Gunn’s staff if the mill operated on two shifts). The results for a 10% IRR and product value of \$190 to \$350 m⁻³ of log intake are shown in Figure 30. The payable mill door prices ranged from \$52 to \$210 per m⁻³, giving some indication of possible returns to growers. The estimates of product value from pruned *E. nitens* are about mid-range for those obtained from CRC for Forestry research trials (Washusen et al. 2007b). Higher proportions of select and standard grades were indicated to be possible with subsequent CRC for Forestry experimentation (Blakemore *et al.* 1010 a-b). These results suggest that it could be viable to process Forestry Tasmania’s thinned and pruned *E. nitens* and *E. globulus* with this type of mill modification while paying growers an acceptable log price, provided that a sufficient volume of sawlogs was available to the mill. The minimum volume of logs being approximately 100,000 m³ of plantation-grown and native forest eucalypts meeting the logs specifications of 40-60 cm sed.

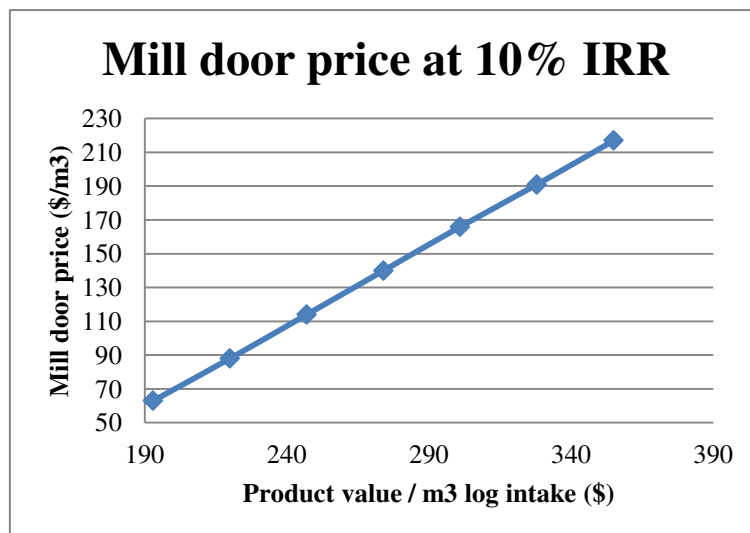


Figure 30: Mill door prices at 10% IRR for product values used for modelling (source: Washusen and Harwood 2011).

4.5 The impact of tension wood on sawing

Tension wood is a major concern in *E. globulus*. As a general rule tension wood was scarce in all of the processing trials in Australia that are reported here. In some trials logs with high levels of tension wood, detected by examination of wood cores, were deliberately excluded from processing trials, and at other times trees were selected from stands managed by thinning and pruning, which have been found to reduce tension wood occurrence and severity. In Galicia, Spain, tension wood is also avoided with the tree selection methods imposed there.

In one study in Australia the impact of tension wood was quantified. This was in a 22 year stand of *E. globulus* from Vasse, WA, that had been thinned and pruned (Washusen *et al.* 2004). Damaging levels of tension wood, in the form of unrecovered collapse, were found in boards from 6% of the *E. globulus* logs. This led to total recovery 3.9% lower, on average, than for logs free of tension wood and of the same diameter range. Had the tension wood been present at the log periphery when sawing was conducted it would also have contributed to excessively high growth stresses (for example see Nicholson *et al.* 1972, Boyd 1977). However, in this study the tension wood was overgrown with normal wood.

The impact of tension wood in this thinned and pruned stand was minor. However, the combined characteristics of excessively high growth stresses and abnormal shrinkage in trees where tension wood is more common or where tension wood is located at the stem periphery will make processing logs with significant levels of tension wood very difficult.

It is known that tension wood is very common in unthinned stands grown on conventional pulpwood regimes at typical harvest age of about 12 years (Washusen 2000) and this has contributed to poor processing outcomes for sawn wood. It is also known that tension wood is uncommon in thinned stands, but the relative contributions of stand management, genetics and site to tension wood formation are still uncertain. The CRC for Forestry has an ongoing research project to clarify these effects in *E. globulus*.

5 Drying sawn wood

Drying of boards sawn from plantation-grown *E. globulus* and *E. nitens* has been reasonably well researched and the results have varied. There is no doubt that both species can produce high quality timber. An example of what is possible with plantation-grown *E. nitens* is shown in Figure 31. This piece of furniture was produced among other decorative products from boards processed at Black Forest Timbers, Victoria, where the sawing and drying of which was reported by Washusen *et al.* (2006a).

In order to produce products like this, boards must be dried without significant drying defects developing.

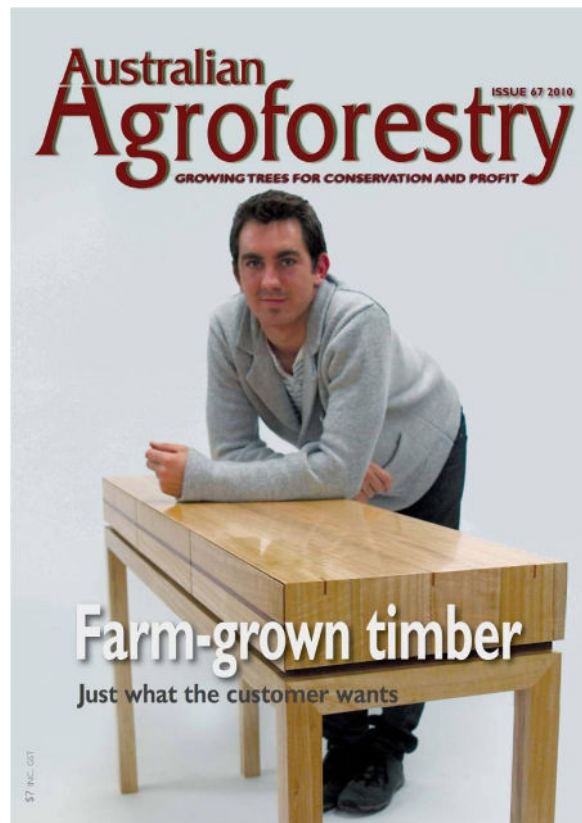


Figure 31: Furniture produced from 16 year-old *E. nitens* (source: Agroforestry News, Issue 67, 2010).

5.1 Tension wood

Damaging levels of tension wood can cause the most severe defects arising from the drying process.

Tension wood differs anatomically from normal wood in a number of ways. The most striking difference is the presence of fibres where the S_2 layer has been highly modified in that lignin has not been deposited normally during cell formation (Figure 32). These tension wood fibres are very unstable during drying and the wood consequently has abnormally high transverse and longitudinal shrinkage. The transverse shrinkage appears similar to shrinkage resulting from cell collapse in normal wood, however, unlike normal wood the shrinkage is unrecoverable during normal steam reconditioning treatments applied in commercial sawmills to recover collapse. The defect in dried boards appears as high shrinkage (Figure 33), surface and internal checking and distortion in the form of spring, bow (that may not be present after sawing), cupping and twist.

While tension wood is very common in *E. globulus*, the susceptibility of other species to tension wood formation is not well understood. However, in contrast to the thinned and pruned *E. globulus* described by Washusen *et al.* (2004) in which tension wood was easily identified; during processing of *E. nitens* in all of the CRC for Forestry trials (Washusen *et al.* 2007a, 2009a, Blakemore *et al.* 2010a, 2010b), damaging levels of tension wood were uncommon. These logs were sourced from three different plantations, two thinned and pruned plantations in Tasmania and one unthinned and unpruned plantation in southern NSW, and there was little impact on recovery or product quality. This suggests that damaging levels of tension wood are less common in *E. nitens* than *E. globulus*.

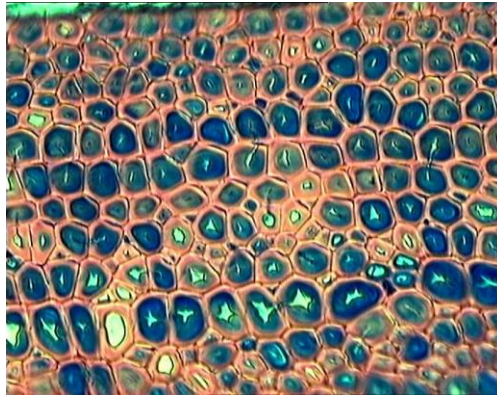


Figure 32: Transverse section of tension wood from plantation-grown *E. globulus* double stained with safranin (red; lignin stain) and alcian blue (blue; cellulose stain). The blue (dark) layers are unligified (source: Washusen 2000).



Figure 33: High shrinkage and cupping from damaging levels of tension wood in 22 year-old *E. globulus* (source: Washusen *et al.* 2004)

5.2 Drying defect in normal wood (in the absence of tension wood)

There are two sources of drying degrade in normal wood that impact on the potential to produce high quality final products similar to the example in Figure 31. These are surface checking and internal checking.

Blakemore and Northway (2009) provide a review of mechanisms for both of these forms of drying degrade and the state of knowledge of their occurrence, particularly in the native forest resource in south eastern Australia. Both surface and internal checking are due to internal stresses that are generated by differential shrinkage during drying. This shrinkage is due to either: (i) normal shrinkage within the cell wall, which occurs below fibre saturation point, or (ii) collapse shrinkage in the early stages of drying, above the fibre saturation point (i.e. when cell lumens contain water). As a generalisation, normal shrinkage is responsible for surface checking in back-sawn boards where shrinkage across the board face and hence drying stresses are high, while collapse shrinkage is responsible for internal checking.

5.2.1 Check propensity of *E. globulus* with industry standard drying methods

Eucalyptus globulus is susceptible to both internal and surface checking when tension wood is present. However, its collapse propensity is not well understood. Blakemore and Northway (2009) suggest that it is collapse prone but do not indicate whether or not tension wood is implicated.

5.2.1.1 Internal checking in *E. globulus*

The best way of determining collapse propensity is to examine the occurrence and severity of internal checking. Innes *et al.* (2008) examined a sample of *E. globulus* boards by cross cutting 40 cm from the end of each board. They found that 87-92% of boards had no visible internal checks, while

a further 8-11% had a subjective 'minimal check' rating. Given the sawing strategies applied were not optimum (discussed earlier in the sawing section) this check propensity may be higher than may otherwise be the case. This suggested internal checking and collapse was a minor problem in these samples of *E. globulus*. Innes *et al.* (2008) gave no indication of the grades of boards that were assessed, surface check occurrence was not reported, and there was no indication as to whether tension wood was implicated with checking.

In the two studies on *E. globulus* reported by Washusen *et al.* (2004, 2009b), internal check assessment was only conducted as part of normal grading of boards by a visual inspection of board ends. Internal checks were absent or rare. Destructive internal check assessment by cross-cutting boards was not conducted for either back-sawn or quarter-sawn boards.

These projects in Australia generally indicate that well managed *E. globulus* plantations with appropriate thinning and pruning schedules are not overly prone to internal checking.

At the Villapol SA factory near Lugo, Spain (discussed earlier and reported by Harwood 2012) quarter-sawn *E. globulus* boards 32-34 mm thick are air dried in a sheltered location for 8 months. Water sprays applied in hot conditions during air-drying followed by final kiln drying for 1 month to 12% moisture content without steam reconditioning. Based on an evaluation of cross cut boards at the Villapol mill, internal checking is very uncommon with less than 1% of boards exhibiting visible internal checks (Harwood 2012). An example of these cross cut boards from Villapol is shown in Figure 34 (left). Moulded window frames are produced in Germany using the laminated products from Villapol (Figure 34 - right) and internal checks are not a problem for this market. The Villapol mill obtains green sawn boards from several small sawmills that process logs selected from numerous plantations. The tree selection methods which target dominant trees in uniform stands and avoid edge trees and leaning trees, screen out severe tension wood. However, none of the plantations are thinned or pruned and the genetic origins of the plantations are not known.



Figure 34: Quarter-sawn dried *E. globulus* boards at Villapol, cross-cut prior to laminating and showing no visible internal-checking (left); and cross section of moulded window frames (source: Harwood 2012).

It is reasonable to say that from these studies in Australia and the experience at Villapol SA that internal checking is not a serious problem in plantation-grown *E. globulus* provided that logs with high levels of tension wood are avoided and appropriate sawing strategies are applied.

5.2.1.2 Surface checking in *E. globulus* back-sawn boards

Washusen *et al.* (2009b) quantified surface checking severity on the graded face of each back-sawn board produced before grading and expressed surface check severity as the ratio of board length with surface check to total board length. For the three southern Tasmanian provenances of *E. globulus* studied (Geeveston, Police Point and Franklin), the range of check severity was 2.0 - 5.0%. According to the Forest Industries Federation of Western Australia grading criteria most boards were Prime Grade (equivalent to select grade in AS 2796), indicating that surface checking was a minor defect in this study.

The results generally support the findings of Washusen *et al.* (2004) that *E. globulus* sawlogs grown in thinned and pruned plantations can be back-sawn effectively and, if dried with care, little surface checking will occur. However, a question remains about the suitability of the drying method employed by the Forest Products Commission. The 28 mm green thickness boards were air-dried in sheltered conditions for 12 months to 10-12% moisture content without kiln drying or reconditioning (Washusen *et al.* 2009b). Almost certainly, drying time could be reduced substantially by kiln drying, without the development of additional surface checking.

These results are very important because they indicate *E. globulus* free of tension wood can be processed with back-sawing strategies, and therefore logs smaller than 40 cm sed can be processed relatively efficiently, with lower sawing costs and higher recoveries than would be obtained with quarter-sawing of logs > 40 cm sed.

5.2.2 Check propensity of *E. nitens* with industry standard drying methods

Both Innes *et al.* (2008) and Washusen *et al.* (2007a, 2009a) quantified internal check occurrence in plantation-grown *E. nitens* after application of industry standard drying practices. Washusen *et al.* (2007a, 2009a) also quantified surface check severity on both back and quarter-sawn boards.

Innes *et al.* (2008) found, in an assessment of a sub-set of *E. nitens* boards cross-cut in the same way as their *E. globulus* study, that 56-65% of boards had no visible internal checks, a further 25-31% had a subjective 'minimal check' rating and 6-17% a subjective moderate to heavy check rating. No information on surface checking was given.

Table 2: Percentage of *E. nitens* boards with internal and surface checks and mean number of internal checks per board for the Goulds Country Phase 1 processing trial (from Washusen *et al.* 2007a).

% of boards with surface checks	Lower logs	Upper logs
Back-sawn	69.5	45.4
Quarter-sawn	21.9	11.8
% of boards with internal checks	Lower logs	Upper logs
Back-sawn	73.3	34.3
Quarter-sawn	73.1	23.1
No. of internal checks per board	Lower logs	Upper logs
Back-sawn	7.58	1.99
Quarter-sawn	4.10	0.74

Washusen *et al.* (2007a) found internal checks assessed at mid-length of a sub-sample of boards to be even more common than reported by Innes *et al.* (2008) and surface checks to be common on both back-sawn and quarter-sawn boards. Table 2 summarises the findings for upper and lower logs and for both sawing strategies. Upper log and lower log refer to the top log and butt log (each \approx 2.7 m in length) from the pruned stem.

From the studies of Innes *et al.* (2008) and Washusen *et al.* (2007a, 2009a) it can be seen that internal and surface checking was very common in *E. nitens*. There were reductions in checking levels with increasing height up the stem, and quarter-sawing produced better results than back-sawing.

Little else can be made of these two projects because the records of monitoring procedures and recording equipment failed to produce adequate information on board handling methods and board moisture content, which is crucial for understanding drying behaviour.

5.2.3 Controlled drying and optimum reconditioning of *E. nitens*

While drying defect was anticipated, the inadequacies of the monitoring procedures in the two critical projects described above led the CRC for Forestry to undertake a series of further controlled experiments to understand the drying behaviour and check propensity of plantation-grown *E. nitens*. This research is described by Blakemore *et al.* (2010a, 2010b).

This follow up research applied accurate sawing, controlled drying and careful moisture content monitoring to test the effectiveness of commercially available drying treatments and experimental pre-treatments for plantation-grown *E. nitens*.

The research applied a steam reconditioning treatment to boards at a mean moisture content of 15% in the drying stack. At this moisture content steam reconditioning has been shown to maximise collapse recovery in a commercial setting (Blakemore and Langrish 2008, Blakemore and Northway 2009). Seven drying treatments tested are listed in Table 3.

Table 3: Source of logs, sawing orientation and drying and reconditioning treatments for CRC for Forestry research into drying plantation-grown *E. nitens*.

Plantation	Sawing	Board green thickness (mm)	Drying	Steam Recondition (MC %)
Gould's Country / Tumut	Back	28	1. Controlled air drying / kiln drying ¹	15% mean
Gould's Country / Tumut	Back	28	2. Industry propriety kiln drying ¹	Unknown
Gould's Country / Tumut	Back	28	3. Mild pre-drying schedule / kiln drying (Treatment 3) ¹	15% mean
Gould's Country / Tumut	Back	20	4. As for treatment 3 ¹	15% mean
Gould's Country / Tumut	Quarter	25 / 28	5. As for treatment 3 ¹	15% mean
Gould's Country / Tumut	Quarter	25 / 28	6. Boron diffusion / Treatment 3 ¹	15% mean
Lisle	Quarter	9	7. Mild pre-drying schedule / kiln drying ^{1,2}	15% mean

Source: ¹ Blakemore *et al.* (2010a); ² Blakemore *et al.* (2010b)

Surface check severity was assessed on the dried boards on the best face following planing, assuming that end splits were docked. Internal check severity was assessed by cross-cutting all boards to determine internal check number and aggregate cross-sectional area before and after reconditioning. Examples of the internal check condition before and after reconditioning are shown in Figure 35.

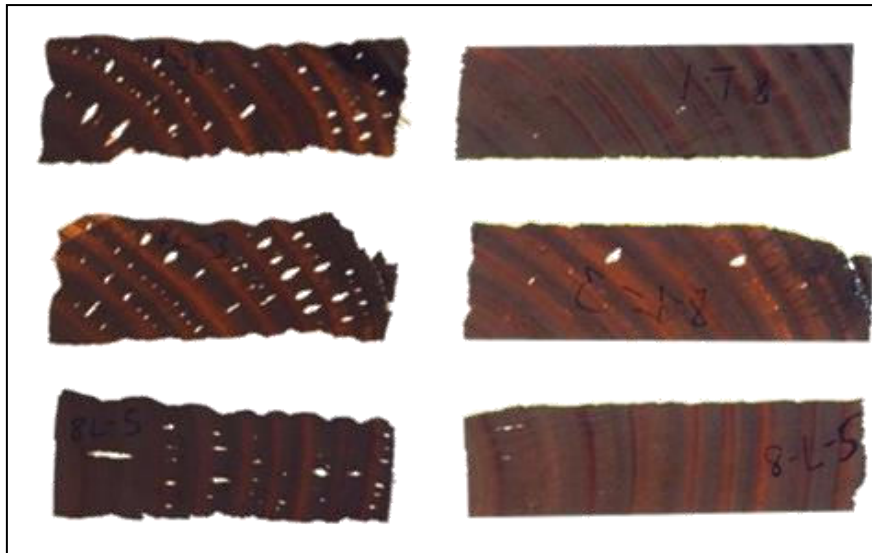


Figure 35: Matched cross-sections of three *E. nitens* boards before reconditioning (left) and after reconditioning (right) (source: Blakemore *et al.* 2010a).

Generally, there was little difference between the drying methods evaluated in Table 3 except for thin-section quarter-sawn boards which were virtually check-free. However, there was a general substantial improvement in drying performance relative to the earlier *E. nitens* trials. This improvement can be seen by comparing data with that reported by Washusen *et al.* (2007a, 2009a). Figure 36a-b gives the percentage of boards with surface and internal checking for back-sawing and quarter-sawing, with the data produced from the drying experiments listed in Table 3 combined where appropriate. There were large reductions in the percentage of boards affected in all of the drying experiments, with the best result for thin section quarter-sawn boards.

Figure 36a-b does not show how much improvement there was at the individual board level; it simply signifies the percentage of boards in which the defect was present. Figure 37 plots the surface check length to board surface area ratio for back sawn boards from Washusen *et al.* (2007a) and Blakemore *et al.* (2010a). The comparison between the two projects is not exact, because; (i) the sets of boards did not match exactly, and; (ii) surface check assessment in Blakemore *et al.* (2010a) excluded 50 mm portions of boards which were docked when cutting wafers for study of internal checks. However, this resulted in only a very small fraction of the board length being excluded from surface checking assessment. Therefore, a reasonable, although not exact, comparison of surface checking in the two studies can be made.

Figure 37 shows that the surface check severity was reduced substantially in the back-sawn boards. Together with fewer boards being affected, this suggests good potential to improve the wood quality and recoveries reported by Washusen *et al.* (2007a, 2009a). The factors contributing to the improvements are not known for certain, but a combination of correct oversizing of green boards through more accurate sawing, the steam reconditioning treatment at a mean moisture content of 15%, the controlled conditions during air and pre-drying and correct weighting of drying stacks all probably contributed to improvements.

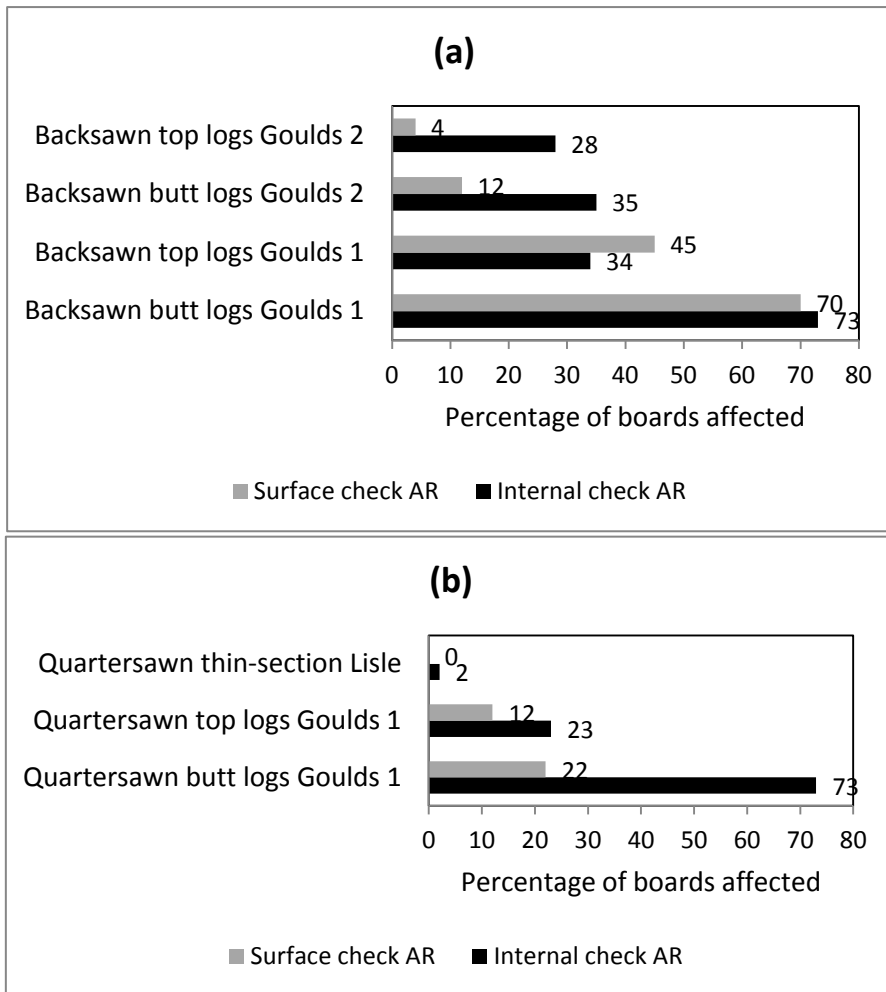


Figure 36a-b: Comparison of the percentage of *E. nitens* boards with internal and surface checking between studies: AR = after reconditioning; Gould's 1 = Washusen *et al.* (2007a); Gould's 2 = Blakemore *et al.* (2010a); Lisle = Blakemore *et al.* (2010b); Upper and lower log locations refer to the top log and butt log from the lower stem.

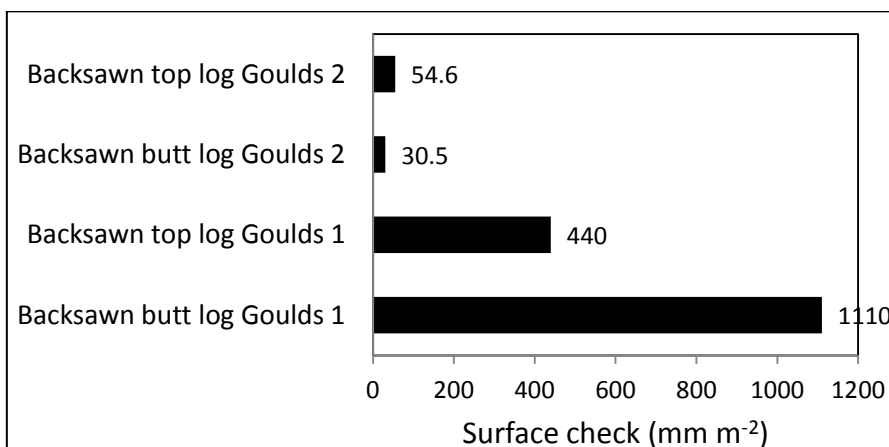


Figure 37: Comparison of surface check aggregate length to board surface area for backsawn boards from Gould's 1 (Washusen *et al.* 2007a) and Gould's 2 (Blakemore *et al.* 2010a).

Comparison of internal checking before and after reconditioning demonstrated clearly that the majority of internal checks visible prior to reconditioning could be closed by reconditioning (Blakemore *et al* 2010a, 2010b) producing major reductions in the number of visible internal checks after reconditioning. Therefore it appears that with good drying practices internal checks associated with normal wood can be closed.

Blakemore and Northway (2009) raised the issue of the implications of closed and open internal checks for secondary processing and performance in service in their FWPA review. They determined that it was unclear from a scientific perspective if closed checks were a problem during secondary processing. While some industry sources believe that closed internal checks lead to defective products, Blakemore and Northway indicated that there is no validated scientific evidence to support this assertion.

To help clarify this situation a pilot study was undertaken by the CRC for Forestry to investigate check propagation in service (Blackburn *et al.* in preparation). A small sample of forty board sections, 400 mm x 90 mm x 24 mm thick, and expected to contain closed internal checks based on the work of Blakemore *et al.* (2010) were selected for assessment from the drying studies above. The board sections were split to produce two matching 9 mm thick boards that exposed internal surfaces. Check number and length were assessed before and after a 4-week drying treatment at 9% EMC (equilibrium moisture content). Internal checks tended to open and extend in the radial direction and the study concluded that “the level of checking observed both pre and post treatment would not be acceptable for production of high value furniture. However, the treatment did not worsen checking to unacceptable Australian Standard grading levels for ‘Select Grade’ furniture feedstock timber, and even at lower EMC levels the sample boards would prove suitable for utility architectural products such as framing, flooring or wall panelling”. A larger study is needed to confirm these conclusions.

In summary, substantial reduction in visible internal checking in *E. nitens* is possible with good drying practices and it can be largely eliminated by sawing thin-section boards. In the longer term it will be possible to reduce the level of internal checking in *E. nitens* by breeding, as research has demonstrated that checking is under a substantial degree of genetic control (Blackburn *et al.* 2010).

5.2.4 *E. nitens* recovery and drying defect comparisons with native forest eucalypts

Table 4 gives comparisons with four existing native forest timbers from recent FWPA studies examining wood quality differences between thinned and unthinned native forest regrowth logs from across southern Australia. This work is summarised in Washusen *et al.* (2009c). The information of importance relates to surface check severity, total recovery and select plus standard grade recovery. Internal check assessment is not included in Table 4 because destructive analysis was not undertaken on the native forest regrowth.

With the exception of regrowth *E. sieberi*, the results for plantation-grown *E. nitens* from Gould’s 1 (Washusen *et al.* 2007a) for both the back-sawn and quarter-sawn wood (Table 4) was worse than found in these comparable studies for each sawing strategy. However, with the application of controlled drying and steam reconditioning at mean 15% moisture content this drying defect was brought into line with the native forest samples. Given that surface checking was the major grade limiting defect found by industry graders (Washusen *et al.* 2007a) there is considerable scope to improve the recovery of select and standard grades from thinned and pruned *E. nitens* plantations.

The market acceptance of these grades will depend on whether closed internal checks and surface checks (particularly for backsawn boards, where they will be more prevalent) affect final product quality.

Table 4: Comparison of surface check severity, grade recovery and select plus standard grade recovery for native forest eucalypts and Forestry Tasmania *E. nitens*.

Species	History	Sawing method	Surface check (mm m ⁻²)	Recovery all grades (% log vol)	Recovery select & standard grade (% log vol)
<i>E. fastigata</i>	NSW Regrowth unknown age ¹	Quarter	73	20.8 ⁵	3.8 ⁵
<i>E. diversicolour</i>	WA Regrowth unknown age ¹	Back	51	28.2 ⁶	7.9 ⁶
<i>E. regnans</i>	Vic Regrowth 1939 ¹	Quarter	41	25.8 ⁶	3.7 ⁶
<i>E. regnans</i>	Tas Regrowth 1934 ¹	Quarter	13	30.8 ⁶	19.3 ⁶
<i>E. seiberi</i>	Vic Regrowth unknown age & 1957 ¹	Back	738	31.1 ⁶	0.0 ⁶
<i>E. nitens</i>	Tas Gould's 1 butt logs ²	Quarter	120	26.9 ⁶	6.8 ⁶
<i>E. nitens</i>	Tas Gould's 1 top logs ²	Quarter	80	27.9 ⁶	14.3 ⁶
<i>E. nitens</i>	Tas Gould's 1 butt logs ²	Back	1110	29.8 ⁶	2.5 ⁶
<i>E. nitens</i>	Tas Gould's 1 top logs ²	Back	440	31.2 ⁶	9.1 ⁶
<i>E. nitens</i>	Tas Gould's 2 butt logs ³	Back	55	NA	NA
<i>E. nitens</i>	Tas Gould's 2 top logs ³	Back	31	NA	NA
<i>E. nitens</i>	Tas Lisle ⁴	Quarter / 9 mm	0	NA	NA

¹ Washusen *et al.* (2009c); ² Washusen *et al.* (2007a); ³ Blakemore *et al.* (2010a); ⁴ Blakemore *et al.* (2010b); ⁵ Based on final flooring sizes; ⁶ Based on nominal dried dimensions.

5.2.5 Processing *E. nitens* sawn boards in Chile

The experience with processing *E. nitens* in Chile appears to be a similar story to Australia. Initial trials conducted with thick section boards proved to be unsuccessful because of the development of severe drying degrade associated with cell collapse. This is not surprising given the problems ash sawmillers in Victoria have with drying boards greater than 28 mm thickness from native forest 1939 regrowth *E. nitens* (Greg McNulty, Ryan and McNulty Sawmill Pty Ltd, Benall, Victoria, *pers. comm.*). Similarly, McKenzie *et al.* (2003) and Waugh and Yang (1994) respectively, found difficulties with drying thicker sectioned boards from thinned and pruned 17 year old *E. nitens* grown in New Zealand (40 mm green thickness) and older unthinned and unpruned *E. nitens* grown in Tasmania (35 mm dried thickness).



Figure 38: Thin section (12 mm) *E. nitens* boards and sliced veneer (left), and docked board ends showing no signs of internal checking (right). All products produced in Chile (Photo: Evan Shield).

Proposed processing strategies for *E. nitens* in Chile are to back-saw all logs <40cm sed and quarter-saw all logs >40 cm sed. Recent trials producing back-sawn boards have had some success (Evan D. Shield, *pers. comm.*). These trials processed 16 mm nominal thickness boards to produce 12 mm thick final products. Examples of boards of these dimensions are shown Figure 38.

6 Veneer production

6.1 Peeled veneer with spindle-less lathes

The emergence of a eucalypt veneer processing industry over the past 10-15 years using spindle-less lathes (Figure 39) in Asia has been quite remarkable. In China the area of eucalypt plantations is more than 3.6 M ha and currently 60% of all harvested logs are processed into peeled veneer using small portable spindle-less lathes (Roger Arnold, China Eucalyptus Research Centre, *pers. comm.*). In 2011 there were more than 5,000 veneer processors peeling eucalypt in China processing 15M m³/year of logs mostly in the 8-20 cm sed range with billet lengths of 1.2 m. Eucalypt veneer is usually air dried (Figure 39) but there are some processors now developing high temperature veneer driers to improve moisture content consistency and reduce damage to veneer through weathering.

The veneer is generally of low quality (Washusen *et al.* 2007c) and there is some inconsistency in veneer thickness and surface texture with veneer produced with spindle-less lathes (Nguyen Quang Trung, Vietnamese Academy of Forest Science, *pers. comm.*). Most veneer is used for internal sheets for laminated panels for concrete form work, furniture or decorative panels. Face grade veneer is either synthetic or sourced from more conventional veneer supplies such as poplar. However, some eucalypt veneer is face grade (Mo Wenbin, Manager, Qi Po Veneer Mill, Guangxi Province, China *pers. comm.*). In a trial with logs of *E. urophylla* x *grandis* hybrid conducted at the Dongmen Forest Farm, southern Guangxi Province, China where a veneer drier was used, recoveries for 15-20 cm sed logs ranged from 49-66% D-grade or better according to AS/NZS 2269:2004 Plywood-Structural (Washusen *et al.* 2007c).



Figure 39: Processing peeled veneer from small diameter eucalypts with a spindle-less lathe (left) and air drying peeled veneer sheets at the Qi Po Veneer mill, Guangxi Province, P.R. China. (Photos: Russell Washusen).

In Australia, processing trials have been conducted by the CRC for Forestry (Zbonak *et al.* 2012) with unthinned and unpruned *E. dunnii* and CCV with a spindle-less lathe similar to those used in China (Figure 40). Log samples were selected from Ellangowan in north-eastern New South Wales (mean annual rainfall 1050 mm) and Kingaroy in south-eastern Queensland (mean annual rainfall 873 mm).

Overall gross recoveries of veneer were similar to those reported above (50% to 70%) with significantly lower recoveries for both species for logs from the drier Kingaroy sites.

Spotted gum displayed veneer stiffness exceeding 15 GPa, making it an excellent candidate for structural applications, while *E. dunnii* also demonstrated good potential for structural applications, achieving stiffness above 10 GPa.



Figure 40: Processing of *Corymbia citriodora* subsp *variegata* into veneer sheets using an Omeco spindle-less lathe (source: Zbonak *et al.* 2012).

6.2 Conventional peeled veneer

Small scale veneer production trials have also been conducted at the Ta Ann veneer mill (Figure 41) in Smithton, Tasmania (Blakemore *et al.* 2010b). Logs were obtained from a Forestry Tasmania 21 year-old *E. nitens* silvicultural trial in a plantation near Lisle, NE Tasmania. Five pruned and five unpruned logs were processed. Veneer 2.4 mm thick was produced from 1.91 m long billets with normal processing strategies for the Ta Ann mill. Recoveries relevant to AS/NZS 2269:2004 were calculated and dynamic wood stiffness estimated from specific gravity and acoustic wave velocity.

Mean recoveries of D-grade and better veneer sheets were 58% and 45% and recoveries of A and B-grade veneer were 12% and 6% for pruned and unpruned logs respectively. The range of dynamic stiffness was 8-11 GPa which was substantially lower than veneer from native forest logs.



Figure 41: Lathe with partly peeled *E. nitens* billet (left), the veneer conveyor and veneer stacker at the Ta Ann mill, Smithton, Tasmania (right) (Source: Blakemore *et al.* 2010b).

In a larger trial at the Ta Ann/Forestry Tasmania Southwood mill Farrell *et al.* (2011) indicated that improvements in peeled veneer stiffness would be possible with *E. nitens* as acoustic wave velocity which is associated with wood stiffness is under strong genetic control.

Farrell *et al.* (2011) also indicated that improvements in moisture content consistency of veneer sheets and reduced veneer drier energy consumption were possible by sorting veneer by moisture content prior to drying.

6.3 Sliced veneer

Sliced veneer production is an option for all plantation-grown eucalypts. From native forests in Victoria *E. nitens* is often sawn to produce flitches for production of quarter-sliced veneer, one of the major reasons for this is its clean appearance. It follows that plantation-grown pruned *E. nitens* could be processed in the same way. In Chile, quarter-sliced veneer from *E. nitens* is an important option because of the high supply volume (Evan D. Shield, *pers. comm.*). An example of sliced veneer produced in Chile is shown in Figure 38.

E. globulus is also used for production of sliced veneer in Spain. While colour consistency may be a problem the veneer has excellent appearance at its best (Evan D. Shield, *pers. comm.*). Harwood (2012) gives an account of quarter-sliced veneer production at Asperal (www.losan.es), located near Santiago de Compostella, in Spain. The veneer is 0.6 mm thick (Figure 42) and produced from unpruned logs with minimum diameter of 50 cm and preferably > 70 cm. Veneers go to decorative markets and are tailored to individual customers. The Asperal factory has a research laboratory for measuring veneer properties, including colour, and matching them to customer specifications.



Figure 42: Quarter-sliced veneer produced at Asperal, Spain from *E. globulus* (Source: Harwood 2012).

7 Conclusions

This review examined primary production methods for processing sawn wood and veneer from plantation grown eucalypts important to Australia. The primary source of information was from processing trials conducted by industry in Australia, however, other relevant research and industry experience from Australia and overseas was examined. Given that plantations can be managed to produce logs with a range of mean diameter, from under 20 cm sed to over 60 cm sed, appropriate processing options for this expected diameter range, including conventional and new or emerging processing methods have been included for discussion.

Initial trials in Tasmania with plantation-grown *E. globulus* and *E. nitens* indicated that existing 'ash' processors are poorly equipped to saw plantation-grown logs that may have smaller diameter and shorter length than their current native forest sources. These trials highlight the inadequacies of the sawing methods employed rather than being a rigorous test of the raw material.

In other trials with *E. globulus* both surface checking and internal checking are minor problems in logs derived from trees that have been managed with a thinning treatment that has reduced tension wood occurrence and severity. Such logs can be back-sawn and dried with few problems and logs > 40 cm sed can be quarter-sawn with good results. For stands where thinning and pruning have not been applied logs may still be quarter-sawn if careful tree selection methods are applied to eliminate severe tension wood. With quarter-sawing, boards up to about 43 mm thickness have been processed in Australia and at least 34 mm thickness in Spain with good results.

The good results with back-sawing *E. globulus* has important implications for processing because a high proportion of logs smaller than 40 cm sed are likely to be produced in plantations. If they can be back-sawn with multi-saw systems, growth stress release is controlled better, sawing accuracy improved, board width increased and higher recoveries obtained, in comparison to quarter-sawing. In addition, improvements in sawmill efficiency with higher volume throughput for the capital and labour costs are more likely with back-sawing than quarter-sawing. This is also relevant for all of the other species considered important in Australia. These being *E. nitens*, *E. saligna*, *Corymbia* spp, *E. dunnii*, *E. pilularis* and *E. cloeziana*.

For *E. nitens*, processing thick section boards (>25 mm nominal dried) is not recommended with conventional drying methods. In addition from drying trials conducted by the CRC for Forestry poor results from trials in Tasmanian sawmills have been attributed to one or a combination of the following; poor sawing accuracy, inappropriate control of wood drying in ambient conditions, non-optimal steam reconditioning treatment and incorrect weighting of drying stacks. Sawing thin section back-sawn and quarter-sawn boards <25 mm thickness will improve drying results if boards are dried carefully above fibre saturation point and a steam reconditioning treatment applied at a mean moisture content of 15%.

With appropriate sawing and drying strategies the grade recoveries from trials with *E. nitens* are comparable to those from regrowth logs of some important native forest eucalypt species that are both back-sawn and quarter-sawn. If thickness of quarter-sawn boards is reduced to 9 mm, experiments with drying indicate that internal and surface checking can be effectively eliminated. A preliminary analysis of exposed closed internal checks subject to a 9% EMC treatment indicated that closed checks will open and extend radially. However, the treatment may not worsen checking to

unacceptable Australian Standard grading levels. Further larger scale work is required to confirm these results. However, this situation appears to be supported by product development steps that are occurring in Chile. In the longer term it will be possible to reduce internal checking in *E. nitens* by selective tree breeding.

Results from CRC for Forestry research also indicated that there was no appreciable effect of thinning treatment on processing performance for back-sawing and quarter-sawing strategies. This suggested that with the processing methods employed, commercial pulpwood thinnings could be obtained from *E. nitens* plantations without compromising the solid wood processing performance of the final sawlog crop. However, a non-commercial thinning at an earlier age would increase diameter growth of the retained “sawlog” trees, enabling target log diameters to be reached over a shorter rotation.

There is considerable scope for improving sawmilling efficiency for both back-sawing and quarter-sawing. Application of linear sawmills or improvements in material flow in more conventional eucalypt sawmills can result in large reductions in sawmilling costs that have potential to improve the profitability of processing and growing plantation eucalypts. Some processing systems that are suitable for both back-sawing and quarter-sawing all of the species of interest to Australia are discussed. These are:

- (i) Twin-saw systems with reciprocating wood flow, overhead end dogging and multi-rip resaws. These mills have been used successfully in trials to process plantation grown *E. globulus*, *Corymbia* spp and *E. saligna*. One mill has incorporated a chipper reducer in front of the twin-saws. The mills have an estimated capacity of 36,000-45,000 m³ log input per year with 2 shifts processing logs from 14-43 cm sed and 17-63 sed using back-sawing strategies.
- (ii) A single operator sawmill equipped with chipper reducer, a twin-saw system with parallel chains and feed rollers and a board edger. It will apply back-sawing strategies for logs 14-40 cm sed. It has a capacity of approximately 115,000 m³ per year with 2 shifts. It is a system that has been proposed to process *E. nitens* in Chile and has potential application for all species of interest to Australia.
- (iii) Close coupled linear sawmills used either commercially to process *E. nitens*, or in trials to process *E. nitens*, *E. pilularis*, *E. dunnii* and *CCV*. For the two mills discussed log diameter ranges are 14–34 cm sed and 14–25 cm sed. They have capacity of approximately 200,000-260,000 m³ log input per year with 2 shifts, producing back-sawn and quarter-sawn boards.
- (iv) Sawing lines capable of processing logs from 10- 40 cm sed with capacity up to 400,000 m³ per year with 2 shifts, producing back-sawn boards.
- (v) A proposed modified conventional quarter-sawing mill with a high throughput multi-rip machine installed to improve material flow to quarter-saw large diameter pruned *E. nitens* and *E. globulus* and suitable native forest logs. It is based on an existing ash mill in Tasmania. Log diameter range is 40-60 cm sed and log intake is estimated to be 100,000 m³ per year with 2 shifts. Modelling suggest that it would be viable to process pruned and thinned *E. nitens* and *E. globulus* while paying growers an acceptable log price.

Such systems require access to suitable volumes of plantation logs. Alternatively, suitably configured mills set up to process softwoods might be able to accept a proportion of plantation eucalypt sawlogs in a similar model to the former FEA mill at Bell Bay, Tasmania.

Peeled and sliced veneer production is a good option for both *E. globulus* and *E. nitens* and peeled veneer a good option for *E. dunnii* and CCV. However, in the case of *E. nitens* wood stiffness is lower than obtained from native forest eucalypts limiting its application as peeled veneer for downstream products.

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