

Small Eucalypt Processing

Economic Utilisation of Thinnings from the Jarrah Forest.

by G.K. Brennan

Report No. 1
April 1988



Wood Utilisation Research Centre

Department of Conservation and Land Management

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SUMMARY

By thinning the jarrah (*Eucalyptus marginata*) forest, benefits of increased wood production on the retained trees and a likely increase in water yield in active catchments will result. At present there are no markets for the thinnings, which include suppressed trees and overmature veteran trees. Leaving this volume of wood on the forest floor creates access problems for future harvesting operations and a fire hazard, and wastes a resource that has potential use if markets are developed.

A review of some of the possible uses for thinnings from the jarrah forest is outlined in this technical report. These uses include: small sawlogs, charcoal, domestic fuelwood, reconstituted and timber jointed products, chemicals and energy, woodchips to manufacture pulp and paper, and minor forest produce.

CHAPTER 1 INTRODUCTION

Jarrah (*Eucalyptus marginata*) grows in the south-west of Western Australia. The jarrah forest extends in a long belt 30-50 km wide, along the Darling Range from near Mundaring (some 50 km east of Perth) southward to the vicinity of Albany. This belt is bounded by the Darling escarpment on the western side and approximately by the 650 mm isohyet on the eastern side (Hall *et al.* 1975) (Fig 1.1).

Jarrah is a large tree, attaining under optimum conditions a height of 30-40 m, with a straight bole up to 15-18 m, and diameters exceeding 2 m (Hall *et al.* 1975). The timber has a wide range of purposes due to its strength, durability, attractive appearance and availability. The uses include piles, bridge and wharf construction, general purpose house construction, railway sleepers, fencing, furniture, and transmission utility poles.

Cutting of the jarrah forest in the past has resulted in some groups of even-aged regrowth forest which are well stocked with saplings and poles. The regrowth stands are often in a state of stagnation, experiencing decline in vigour and diameter increment (Podger 1959; Abbott and Loneragan 1983). Stagnation is caused by regrowth jarrah trees persisting in large numbers per hectare, while under strong competition for available water and soil nutrients.

Thinning these stands will stimulate growth and vigour of the retained trees. In addition, in healthy forest with low levels of stored salt in the soil it may be possible to selectively thin forest, with the objective of increasing the water yield as well as timber production (Ritson and Shea 1980). Thinning will also provide wood for possible utilisation if markets are available for the thinnings, creating employment opportunities. Thinning reduces the amount of fuel in subsequent prescribed burning, thus lowering protection costs and improving access in subsequent harvesting operations.

The aim of this technical report is to review the possible economically viable uses of thinnings from the jarrah forest.

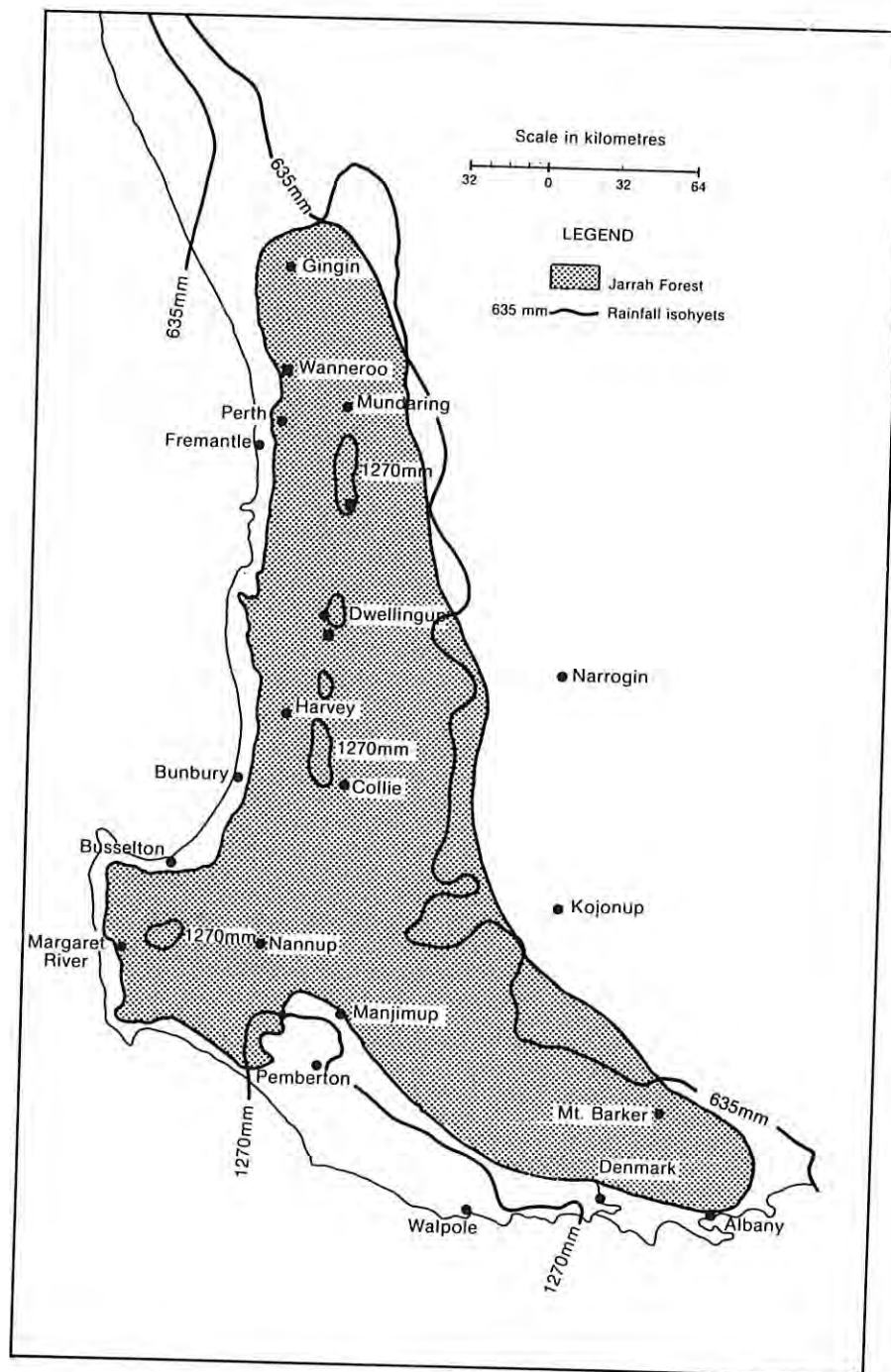


Figure 1.1
Distribution of the jarrah forest in the south-west
of Western Australia.

CHAPTER 2

THE WOOD RESOURCE AVAILABLE FROM THINNING THE JARRAH FOREST

2.1 Introduction

The State Forests of Western Australia are managed on a multiple land use basis. Land uses include wood production, water production, catchment protection, recreation, mining, scientific study and conservation. Wood production is compatible with most other uses and can proceed without adverse effects on the other management priorities. However, in some areas wood production is regarded as incompatible with the designated land use e.g. in conservation management priority areas (Forests Department 1984).

The areas of jarrah forest available for thinning are in management priority areas where wood production is the primary land use, or where wood production is compatible with other land uses. The areas thinned must be of good quality forest, with adequate stocking of regrowth trees suitable for retention as crop trees, and substantially free of dieback (caused by *Phytophthora cinnamomi*) and mining constraints.

2.2 Area of jarrah forest available for thinning

A significant proportion of the jarrah resource is available for silvicultural treatment when the constraints of mining, dieback and incompatible land uses are taken into account. This area is several times that of pine plantations or regenerated karri stands (Havel 1983).

It has been estimated that 250 000 ha of high quality forest is available for thinning, and a further 500 000 ha (currently within disease risk areas) is potentially available (Havel 1983). Williamson (1983) estimated about 10 per cent of the jarrah forest or 137 000 ha was available for thinning and regeneration. Stoneman (1983) considered that at least 100 000 ha was available for thinning and regeneration, which would benefit both wood and water production in the northern jarrah forest.

These authors did not refer to land use constraints or outline the criteria used to arrive at these broad estimations. For example, what percentage of the broad estimate is high quality T and ST Havel site types, how much of the area is silviculturally treatable regrowth stands, and what percentage is unaffected by dieback disease? Using the total area of jarrah forest in the northern jarrah forest (north of the Collie River) and these criteria (and land use constraints mentioned above) were accounted for, the area available for thinning and regeneration should be substantially less than the above estimates.

Bradshaw (1985) included the following criteria in his estimation of the area of high quality jarrah forest suitable for intensive management for wood production:

- (i) State forest or timber reserve;
- (ii) designated land use of timber production, water production, catchment protection or protection of forest values;
- (iii) not to be mined in the next 20 years;
- (iv) free of dieback according to existing maps;
- (v) in the Dwellingup high rainfall area, Bridgetown medium to high rainfall area or Murray vegetation complexes (see Heddle *et al.* 1980).

These preliminary estimates indicated a total area of 80 000 ha in the high rainfall, high quality forest. In addition to the high rainfall area, Bradshaw has estimated in the Dwellingup medium rainfall complex north of the Murray River an area of 30 000 ha. Both estimates are total areas, not just areas of pole stands (Bradshaw¹, personal communication).

2.3 Cutting history of the jarrah forest

Prior to the 1920s uncontrolled timber cutting occurred in the jarrah forest (which was then virgin bush), resulting in drastic reductions in growing stock and canopy cover. Following the State's first Forest Act (1918) and the establishment of the Forests Department, effective control of cutting based on forestry principles was introduced (Podger 1959).

The Forests Department initially introduced a group selection system of harvesting jarrah which resulted in even-aged patches of regrowth. During the 1930s ringbarking of large over-mature trees occurred, which produced some of the present patches of regrowth. Culling between 1870 and 1930 also resulted in patches of regrowth within the jarrah forest.

The group selection system of timber harvesting continued until 1965, when there was a return to the felling of all large trees suitable for sawmilling (Forests Department 1982). The return to this system was on dieback hygiene grounds. By allowing the sawmills to take all large trees suitable for sawmilling, the yield per hectare increased, the area required to be covered decreased, and the potential to spread dieback was reduced (J. Bradshaw², personal communication).

The areas silviculturally treated during the depression (1930-1940) are well stocked with poles and piles. Areas cut after 1940 were not culled and are generally irregular stands not heavily stocked with high quality regrowth suitable for thinning.

1 J. Bradshaw, Department of Conservation and Land Management, Manjimup.

2 " " " " " " " "

Cutting of the jarrah forest in the past has resulted in the formation of different stand structures. Bradshaw (1983) classified the jarrah forest into three broad categories:

- (i) regrowth forests - resulting from the uncontrolled cutting prior to the 1920s and silvicultural treatment in the 1930s;
- (ii) grouped (or two-tiered) forests - resulting from the group selection cut and cull treatment - these forests consist of groups of old growth and groups of second growth in patches of one tenth of a hectare or larger;
- (iii) mature forest - these stands are virgin or lightly cut forests on a uniform (rather than a grouped) basis.

Each of these types of forest has different silvicultural treatment and protection requirements.

2.4 Past inventories of the jarrah forest

Inventories of the jarrah forest to provide broadscale information on our hardwood resource have been carried out several times in the past (Campbell and Lush 1979). In the mid 1950s assessment for mining timbers in the Collie area was carried out (Grace 1966); the Resource Level Inventory (R.L.I.) began in 1967 and went on to 1972; and since 1974 a Management Level Inventory (M.L.I.) system has been used (Campbell and Lush 1979). R.L.I. is a broad assessment carried out for all products, e.g. sawlogs, poles, crop trees and standing dead trees, using a sample size of less than one per cent per stratum. M.L.I. is an assessment carried out for all commercial products, e.g. poles, chipwood, sawlogs and mining timber, using a sample size of 2.5 per cent per forest block. The mining timber assessment and R.L.I. have assessed small trees down to 10 cm diameter at breast height over bark (d.b.h.o.b.). However, the present M.L.I. system has concentrated on assessing current marketable sizes (see section 2.4(b)), and regrowth jarrah trees below market sizes would have been excluded in the assessments. Some of the inventory systems and assessments are summarised below.

2.4.1 Resource Level Inventory (R.L.I.)

The R.L.I. data were used to provide an accurate assessment of the wood resource over a large area of forest e.g. a sawmilling permit. It was designed to be accurate within $\pm$ 20 per cent for each forest block assessed. The R.L.I. data cannot be used reliably for portions of a forest block, unless it is a complete stratum (J. Bradshaw³, personal communication). Assessment plots in this system were located randomly in each stratum. In the R.L.I. system four marketability classes were assessed:

- (i) Marketability Class 1 - crop trees;

3 J. Bradshaw, Department of Conservation and Land Management, Manjimup.

- (ii) Marketability Class 2 - sawlog trees;
- (iii) Marketability Class 3 - standing green - live trees not containing sawlog quality material. Chipwood and green firewood commonly come from this class of tree;
- (iv) Marketability Class 4 - standing dead - depending on species, material from Marketability Class 4 is generally suitable for firewood

Within each marketability class the minimum diameter size recorded was 25 cm d.b.h.o.b. ranging in 10 cm classes up to 100 cm, then there were two larger diameter classes of 100-150 cm and over 150 cm. The forest was stratified by dieback categories, cutting history or structural classes.

The R.L.I. assessment plots were last measured 12 to 16 years ago, therefore the volume of timber recorded could have changed due to growth, mining or cutting. An inventory of small regrowth trees in a particular forest block can be obtained by using the R.L.I. data but the accuracy will depend on the number of assessment plots in each stratum (J. Williamson⁴, personal communication).

2.4.2 Management Level Inventory (M.L.I.)

The M.L.I. is an assessment carried out for all commercial products e.g. poles, chipwood, sawlogs or mining timbers: minor forest produce is not assessed. The details recorded are species, marketability class, d.b.h.o.b. and estimated bole height. The minimum diameter recorded is 40 cm d.b.h.o.b. (diameters down to 38 cm are recorded if the bole is straight) (R. Hearn⁵, personal communication). The mining timber assessment is discussed in 2.4.4.

2.4.3 Native hardwood growth and increment plots

Hardwood growth and increment plots are within all strata of the major forest types. The plots are 20 m wide and of varying lengths up to a maximum of 400 m (Campbell and Lush 1979).

Information on the regrowth sawlog resource is available from the growth and increment plots. However, there are insufficient plots to give an accurate assessment over large areas.

2.4.4 Mining timber assessment

Mining timber assessment began in the Collie area in the mid 1950s. In 1983 assessments were carried out in Hamilton, Arcadia, Arklow and Bristol Blocks in the Collie

⁴ J. Williamson, Department of Conservation and Land Management, Canning Bridge.

⁵ R. Hearn, Department of Conservation and Land Management, Wanneroo.

District, to take into account the change in mining timber standards and specifications. Products presently taken include:

- (i) split timber
 - pit props
 - slabs
 - lids
- (ii) round timber
 - pit props
 - bars
 - legs

(Cransberg 1984)

Round timbers (pit props only assessed) were assessed from 25 cm d.b.h.o.b. down to a minimum small end diameter under bark (s.e.d.u.b.) of 10 cm. Up to 10 per cent of smaller trees were assessed to 9 cm under bark (Cransberg 1984). The trees over 25 cm d.b.h.o.b. had the butt log recorded as split pit props or slabs and the remaining log as a round pit prop.

Assessment lines were oriented north-south, approximately 1000 m apart, and poles and mining timber only were recorded. Where a tree contained both poles and mining timber it was recorded as a pole.

The assessment sheet for Arklow block showed large variations in the number of poles and round pit props per hectare, over the four assessment lines recorded. The variation ranged from 0 to 15 poles/ha and 0.54 to 9.08 m³/ha for round props (Cransberg 1984).

Extrapolating these data to provide an assessment of the amount of regrowth sawlogs available in the jarrah forest would be unreliable, because they account for only four blocks in Collie District and the trees assessed ranged from 10 cm s.e.d.u.b. to 25 cm d.b.h.o.b. The diameter range needs to be broader if regrowth sawlogs are to be assessed.

2.4.5 The resource inventory at the Yarragil 4L subcatchment

The Yarragil subcatchment 4L (an area of 125 ha) in Dwellingup District was thinned in 1983, and the area yielded a large amount of wood which was not utilisable under existing marketing standards.

Prior to thinning an assessment was conducted, recording trees greater than 15 cm d.b.h.o.b. for a range of wood products. North-south lines 200 m apart were used as the centre lines of assessment strips. A 10 per cent sample of trees 30 cm d.b.h.o.b. or greater was taken by assessing trees within 10 m of either side of the line, and a 2.5 per cent sample of trees 15 cm d.b.h.o.b. up to 30 cm d.b.h.o.b. was taken by assessing 5 m on the right hand side of the line (Stoneman 1986). All jarrah, marri (*Eucalyptus calophylla*) and W.A. sheoak (*Allocasuarina fraseriana*) within the sample area were assessed for the following products: veneer logs, general purpose sawlogs, salvage sawlogs, poles, chipwood, minor forest produce or not utilisable.

Trees along the assessment lines were selected for retention or removal to leave a well spaced stand with a 10, 20 or 30 per cent canopy cover. Tree numbers were recorded and used to estimate volumes, basal areas and stockings for the original stand and for the thinning to 10, 20 or 30 per cent cover (Stoneman 1986). Following this theoretical exercise the catchment was actually thinned to a 20 per cent canopy cover.

In thinning to a 20 per cent canopy cover, 90 m³/ha of currently unsaleable bole wood was thinned to waste. Two thirds of the jarrah component of this was assessed as potentially usable, most of it being of good quality but under the currently accepted minimum diameter of 50 cm d.b.h.o.b.

Stoneman (1986) stated:

‘even if only 10 to 20 per cent of the 1 050 000 ha of the northern jarrah forest were suitable for thinning, a very substantial amount of wood would be produced by a thinning.’

He estimated 3.8 million m³ of potential utilisable jarrah logs less than 50 cm d.b.h.o.b. would be yielded from thinning to a 20 per cent canopy cover. This estimate was obtained from assessing a single area of 125 ha. For an accurate assessment of potentially usable thinnings from the jarrah forest, the forest needs to be stratified into different classes and an assessment done in every stratum.

2.4.6 The volume of thinnings yielded from the Holyoake thinning operation

An area of 9.5 ha adjacent to Banksiadale Road (Holyoake Block, Dwellingup District), was thinned in April/May 1984 to Bradshaw's prescription (Bradshaw 1983). Following a commercial logging of sawlogs and poles the Banksiadale Road area was thinned to a basal area of 12 m²/ha, and regrowth sawlogs (for the Wood Utilisation Research Centre (WURC) at Harvey) and minor forest produce were extracted. The specifications for regrowth sawlogs were:

- (i) straight and free of decay;
- (ii) dimensions:
 - 15 to 30 cm s.e.d.u.b.,
 - maximum butt diameter 40 cm under bark,
 - length 2.4 m, 3.6 m and 4.8 m.

The minor forest produce specifications were:

- (i) fence posts - 1.8 m to 1.85 m long and less than 15 cm diameter;
- (ii) strainers - up to 25 cm s.e.d.u.b. and 2.4 m in length;
- (iii) rails - 3.35 m to 7 m long.

The volume of regrowth logs removed from this area was 64.8 m^3 which averaged $6.8 \text{ m}^3/\text{ha}$. The majority of the regrowth logs removed came from the 15-19 cm and 20-24 cm log diameter classes (Brennan 1984).

Using Williamson's estimate of 137 000 ha of jarrah forest available for thinning, and assuming $6.8 \text{ m}^3/\text{ha}$ of regrowth sawlogs were removed from this total area, if the forest were thinned to a basal area of $12 \text{ m}^2/\text{ha}$, approximately $932\,000 \text{ m}^3$ of regrowth sawlogs would be available for utilisation. By using Kimber's estimate of 250 000 ha of jarrah forest immediately available for thinning (Havel 1983), 1.7 million m^3 of regrowth sawlogs would be available. Both estimates indicate that large volumes of wood are available for utilisation from a jarrah thinning operation.

The yield of $6.8 \text{ m}^3/\text{ha}$ was obtained from an even-aged regrowth stand. Most of the areas available for thinning and regeneration consist of groups of regrowth, surrounded by groups of old growth, therefore the yield per hectare of regrowth sawlogs will vary from area to area (J. Bradshaw⁶, personal communication). The area available for thinning and regeneration has a large bearing on the volume of regrowth sawlogs produced.

Bradshaw (1985) indicated that 80 000 ha of high quality jarrah forest from Dwellingup high rainfall area and an additional 30 000 ha of high quality forest from Dwellingup medium rainfall area should be available for thinning. This estimate has taken a number of constraints into consideration (referred to in section 2.2). If $6.8 \text{ m}^3/\text{ha}$ of regrowth sawlogs are removed from both the Dwellingup high and medium rainfall areas then $544\,000 \text{ m}^3$ and $204\,000 \text{ m}^3$ respectively of regrowth sawlogs will be available for utilisation following silvicultural treatment. This is only an estimate, as the yield per hectare varies from area to area.

2.5 Proposed milling studies at Harvey WURC

The jarrah regrowth logs extracted from the Holyoake area were milled at the Department's WURC at Harvey. Trials indicated which log sizes (diameters and lengths) could be milled economically on a commercial basis. Recoveries are the basis for specifications for these millable regrowth sawlogs, and resource assessments can be based on this information.

2.6 Conclusions

- 2.6.1 In selecting areas to be thinned, consideration should be given to land use priorities, condition of the growing stock, site type, dieback and mining constraints.
- 2.6.2 Cutting of the jarrah forest in the past has resulted in the formation of different stand structures, with each of these stands requiring different silvicultural treatments and protection requirements.

6 Mr J. Bradshaw, Department of Conservation and Land Management, Manjimup.

- 2.6.3 Several estimates have been made of the area available for thinning. These estimates vary considerably and need re-defining in terms of land use, site type, dieback status, mining requirements and stand structure. Bradshaw (1985) has provided figures on the area available for silvicultural treatment, when a number of constraints are taken into consideration. His estimate is 80 000 ha of high quality forest from high rainfall area, with an additional area of 30 000 ha of medium rainfall high quality forest.
- 2.6.4 A number of inventories and assessments have been conducted to estimate the quantity of the wood resource available from the jarrah forest. A broad assessment of the volume of regrowth trees by diameter classes is available from the R.L.I. data.
- 2.6.5 To obtain an accurate estimate of the volume of regrowth sawlogs available from the areas where thinning would be appropriate, an M.L.I. assessment would be required.
- 2.6.6 The productivity and recovery trials to be conducted at the Harvey WURC should establish the regrowth sawlog size (diameter and lengths) that can be milled economically in a commercial sawmill. Inventories of the regrowth resource can be directed from these results.

CHAPTER 3

USING JARRAH THINNINGS AS SMALL SAWLOGS

3.1 Introduction

In the late 1960s most Australian sawmillers regarded eucalypt sawlogs of 50 cm mid diameter as too small and unprofitable for conversion to general sawn products (Page 1978).

The timber industry in Western Australia is already becoming increasingly dependent on smaller logs, therefore current research is directed at investigating methods of sawing small sawlogs and seasoning of the sawn timber. The Department of Conservation and Land Management have upgraded their Wood Utilisation Research Centre (WURC) at Harvey to conduct this type of research on jarrah thinnings.

3.2 Definition of a small sawlog

The definition of a small sawlog in terms of log diameter differs throughout the world (Williston 1981). In Australia the definition is based on the log size milled in specific sawmilling trials. For example, in a jarrah sawmilling trial Hadlow and Kippo (1984) milled regrowth logs within the diameter range of 15-27.5 cm s.e.d.u.b., and in another jarrah regrowth trial Loneragan (1957) investigated recovery of logs as small as 15 cm mid diameter. In Victoria Lhuede and Waugh (1980) did sawmilling trials on regrowth logs ranging from 15-45 cm s.e.d.u.b., presumably using ash-type eucalypts.

For the purpose of this report, a small sawlog will have a diameter range from 15-30 cm s.e.d.u.b. with a maximum butt diameter under bark (d.u.b.) of 40 cm. This is the diameter specification for the small jarrah sawlogs to be milled at the WURC.

3.3 Growth stresses experienced by small sawlogs

A tree trunk is subjected to a variety of internal forces or 'growth stresses' which cause distortion on or within the trunk as the tree grows. The forces along the longitudinal axis of a stem are 'longitudinal growth stresses', and those at right angles to the longitudinal axis are 'lateral growth stresses' (Jacobs 1955).

Growth stresses influence the sawing quality of the wood significantly, especially in the case of small sized and rapidly grown eucalypts. When small sawlogs are cut, the growth stresses present in the log are released, producing excessive end splitting (when cross cut) and bow or spring (when sawn to length). These defects may be double the severity of those experienced with mature trees (Bootle 1983).

An example of end splitting is shown in Figure 3.1 and diagrammatic representations of spring and bow in Figures 3.2 and 3.3.



Figure 3.1

A small jarrah sawlog with excessive end splitting as a result of cross cutting and storing in a dry stockpile for four months.

Bow and spring are deviations from the straightness of a piece of timber, due either to growth stresses present in the tree or to those which develop during the seasoning process (Bootle 1983)

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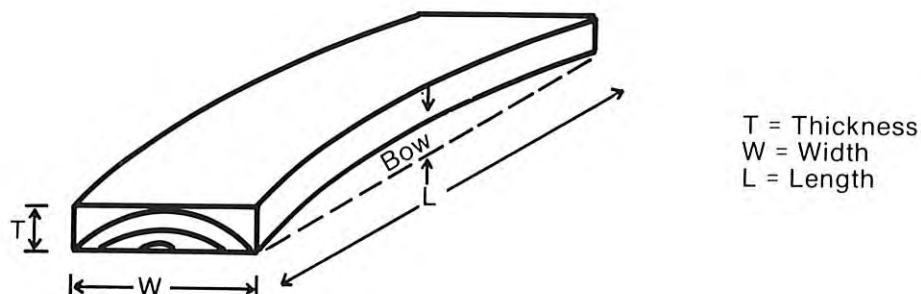


Figure 3.2

The defect of bow: bow is a deviation from the plane of the width of a piece of timber (Bootle 1983). A short kink is not bow.

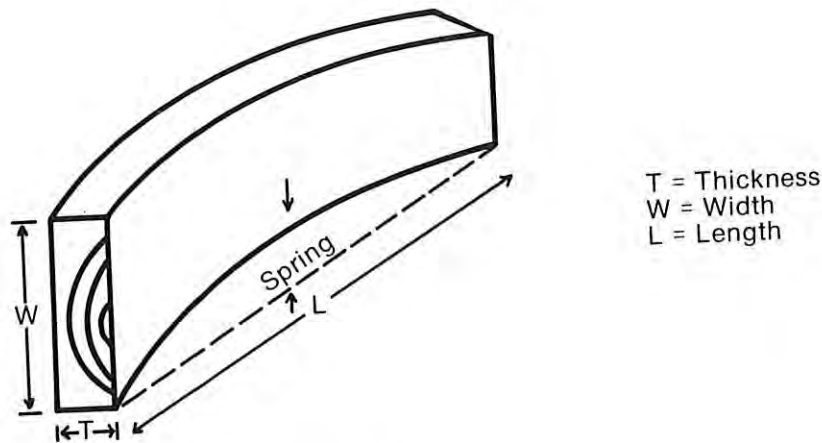


Figure 3.3

The defect of spring: spring is a deviation from the plane of the edge of a piece of timber (Bootle 1983).

3.3.1 Spring

Growth stresses within the trunk cause the log and flitches to bend longitudinally when sawn. This longitudinal bending or 'spring' is caused by the outside portion of the log being in longitudinal tension (Page 1978). When this stability is upset by quarter sawing the outer portion of the log shortens and the core increases in length. This results in longitudinal bending towards the outside of the log.

3.3.2 Shakes

Shakes occur on the ends of logs with high growth stresses and appear as star patterned splits. For higher sawn recovery from these logs the breaking down cuts need to be located predominantly along the major shakes so that the flitches produced for resawing have the shakes on their edges rather than across their cross section (Page 1978). Shakes are common in some West Australian eucalypts e.g. marri, and result in fine hair line cracks when a flitch is sawn.

3.3.3 Brittle heart

Brittle heart arises from cells in the centre of the log failing in compression (Humphreys 1981). This defect is caused by the stresses placed on the core of the tree by the development of high tensile stresses in the outer layer of the tree.

Brittle heart can occur in two forms: firstly, where the heart is excessively decayed and eaten away by termites, and is called 'pipe'; and secondly, in the much less obvious form, where the area of brittle wood is found around the decayed heart or, in the absence of decay or pipe, in the centre of the tree (Page 1978). An example of brittle heart is shown in Figure 3.4.

Small sawlogs contain a large proportion of brittle heart, therefore it is necessary to 'grade saw' them in order to optimise recovery (Page 1978).

Any timber which contains brittle heart has reduced strength, and therefore should not be used in any critical load carrying capacity (Page 1978).

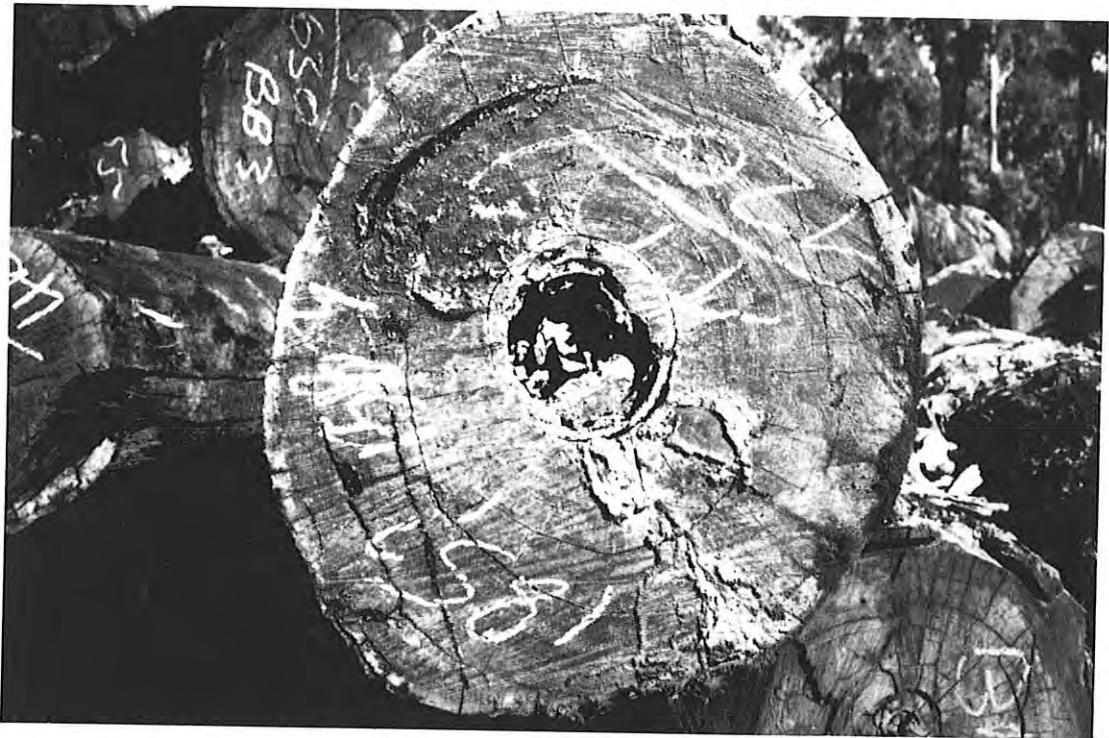


Figure 3.4

An example of brittle heart, where the heart has decayed to form a 'pipe'.

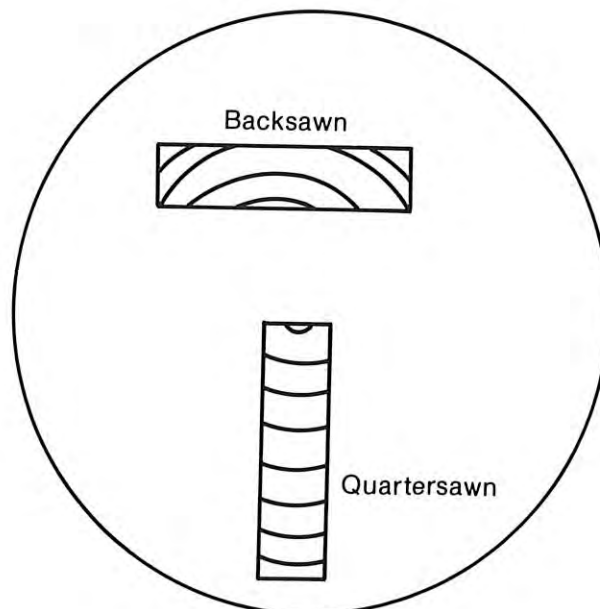


Figure 3.5

Quartersawn and backsawn boards.

3.4 Other defects affecting wood quality and recovery

3.4.1 Kino veins and pockets

When eucalypts are damaged by machinery or by agencies such as insects, fire or drought, 'gum' or kino may form over the injured tissues. Sometimes it exudes from the surface of the tree. The presence of kino is regarded as inevitable in some eucalypts and during conversion it is revealed as pockets, veins or rings within the wood. The presence of these defects downgrade the timber making it less suitable for furniture, panelling or feature flooring (Page 1978).

3.4.2 Bumps

When a branch is shed from young jarrah trees it leaves a stub cavity, which is subsequently overgrown. Before this stub cavity is occluded with wood, the area is often invaded by insects and fungi, resulting in the formation of pockets of rot and associated extended areas of discoloured tissue. The presence of this rot downgrades the timber visually and structurally, and the overgrowth produces a bump on the surface of the trunk.

3.4.3 Borer attack to small sawlogs

Jarrah trees and logs are attacked by a number of borers e.g. the pinhole borer (*Atracacerus kreuslerae*), the bardee larvae (*Phoracantha semipunctata*), *Coptocercus* spp. and the bullseye borer (*Tryphocaria acanthocera*) (Abbott 1985). If attack is severe, significant economic loss through downgrading of high grade timber will occur.

Shedley and Challis (1984a) investigated the effect of *P. semipunctata* on wood quality, using logs stored under water spray and dry stockpiled. They found from a milling trial that a significant loss of select grade jarrah was due to *P. semipunctata* damage. Over 50 per cent of select grade timber from the dry stockpile logs was downgraded when insect damage was included in grade defects, and up to 15 per cent of graded structural timber was downgraded to firewood.

3.5 Relief of growth stresses

Many methods have been used in an attempt to relieve growth stresses within a regrowth ash eucalypt log: ringbarking of the tree prior to felling, storage of the log in the forest or mill yard, and storage under water for several months at the mill landing, have all been tried. Other potentially useful methods include binding of the log ends with wire or steel, attaching nail plates to the log ends, cutting circumferential grooves near the log ends, and heat treatments with steam before milling (Bootle 1983).

The effect on product and volume recovery of log storage both in the forest and under water spray at the mill landing has been monitored in jarrah sawmilling trials at the WURC at Harvey.

Bootle (1983) believed that the amount of improvement through increased recovery is not enough to justify the extra expense of these various pre-treatments. The practical

methods to relieve growth stresses are in the sawmilling processes. Jacobs (1955) suggested the use of short length logs as a method of relieving spring when sawing small sawlogs. Back-sawing the log rather than quarter-sawing (Figure 3.5) reduces spring, but the distortion then manifests as bow. Bowed flitches are easier to resaw than sprung flitches (K. White⁷, personal communication), however, where appearance of a piece is important the log often has to be quartersawn (Page 1978).

Another method of reducing the amount of spring is by simultaneously cutting either side of the log thus producing two parallel well balanced cuts (Lew 1974). This can be done by using a Canadian carriage bandsaw or a log twin edger.

The use of mechanical equipment to force the flitch straight while it is sawn has been used to reduce spring. Experiments have shown that the dogging of logs or flitches within 60 cm of their ends to a heavily constructed carriage can sometimes restrain the log or flitch against spring (Page 1978).

3.6 Choosing the correct equipment to saw small sawlogs

In Europe and North America techniques for converting small sawlogs (mainly softwoods) have been well developed and high production rates have been reported. However, these systems often lack the flexibility for 'grade sawing', which is considered necessary for sawing small diameter eucalypts (Lhuede and Waugh 1980).

Grade sawing, or sawing around the log, is a method for breaking down logs to cut out defects such as brittle heart and kino veins. By rotating the log, defects can sometimes be excluded from the sawn flitches, for example, boxing out the defective heart of a log as shown in Figure 3.6.

In selecting sawmilling equipment, consideration must be given to the species to be cut, the product required, and the equipment that will give maximum recovery. The main decision in sawing small sawlogs is in choosing the correct log breakdown equipment because this will influence the quality of the flitches for resawing. If these flitches are sprung, they will require face cutting at the resaw to straighten them, therefore recovery will be reduced. The breakdown saw must aim to reduce spring.

Some of the equipment available for breaking down logs is described below.

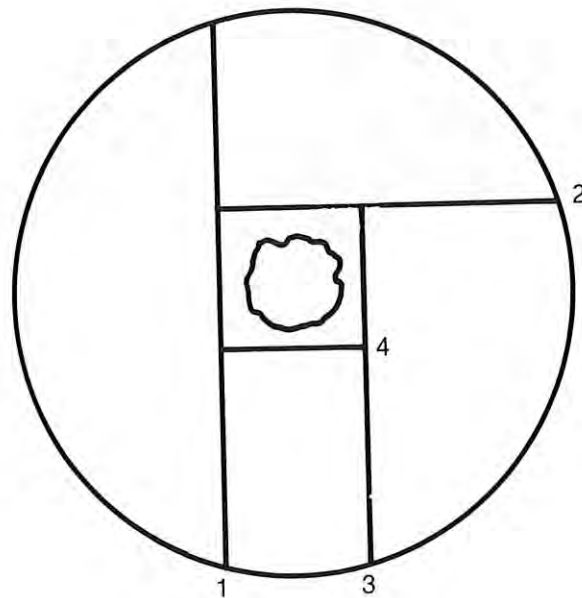
3.6.1 The log breakdown saws

(i) The gangsaw

The gangsaw consists of either a number of circular saws mounted side by side on a common spindle or a number of framed saws hung vertically (Page 1978). This saw is used for cutting large quantities of small, reasonably straight logs, e.g. plantation softwoods.

7 K. White, Department of Conservation and Land Management, Bunbury.

Gangsaws are inflexible with no log turning possibility to compensate for defects, no flexibility to change log sizes as required, and no possibility of changing cutting systems (Sylvester 1976). For these reasons, the gangsaw would be inappropriate for sawing small eucalypt sawlogs because it is necessary to 'grade saw' to gain optimum recovery and high grade products.



In this example, the log is rotated to produce four flitches (four breakdown cuts) with the defected heart excluded from the sawn flitches.

Figure 3.6

Boxing out the defective heart of a log by grade sawing.

(ii) The bandsaw

A bandsaw has a relatively thin blade and fast cutting speed. It consists of a continuous band of steel, toothed on one or both edges, which passes over two wheels mounted one above the other (Bootle 1983). This saw produces a low kerf (width of cut), has a large depth of cut, and has the ability to cut at high feed rates compared with other saws.

The bandsaw has the disadvantage of not tolerating grit or log defect abuse and compared with other saws is more prone to damage from harder woods. It also requires regular tensioning.

Bandsaws can be incorporated with small, fast log carriages operating in conjunction with rapid loading and turning gear. This system has a low cutting rate and the need for loading and turning becomes excessive compared with other systems. For this reason this breakdown system is suited more for logs larger than about 40 cm s.e.d.u.b. (Page 1978).

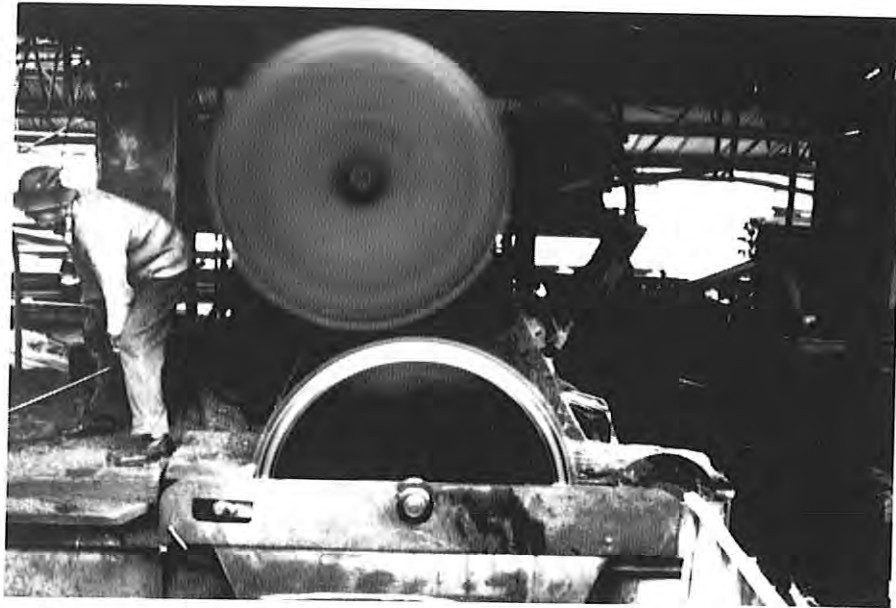


Figure 3.7

A Canadian twin saw, consisting of two overlapping circular saws. This saw is used to break down large diameter logs.

Bandsaws can be used to break down small eucalypt sawlogs. However, they are not as robust as circular saws, and sawmillers generally prefer to use the latter.

(iii) Circular saws

Circular saws are generally thicker than bandsaws because the saw must be sufficiently stiff to withstand the working forces without any support other than that provided by the central shaft and collars (Burrige 1973). This increased thickness results in larger kerf and lower recovery. This saw is restricted to a small range of log diameter sizes which it can break down unless a Canadian twin is used. A Canadian twin saw consists of two overlapping circular saws, one mounted above the other, with an adjustable distance between the two saws (Figure 3.7).

Circular saws are less susceptible to damage caused by grit and by growth defects in the timber than bandsaws and are therefore more suitable to cut logs with large growth stresses and hard wood. Circular saws have been incorporated into twin edgers with movable blades, and have been used successfully to cut small sawlogs. Like the bandsaw the single circular saw can also be used with a small, fast log carriage, with rapid loading and turning gear. This system is more suited to cutting logs larger than 40 cm s.e.d.u.b. (Page 1978).

(iv) The log edger

The log edger can comprise both twin circular or twin band log edgers and triple-and-quad band headsaw rigs, with logs fed on either a chain, a beam carriage or by overhead end clamps (Page 1978).

In the case of the twin log edger the spacing between the saws can be adjusted rapidly and the edger can make two parallel cuts at a predetermined spacing. This method of sawing can reduce the tendency of the flitch or log to spring, therefore would be suited to cutting small jarrah sawlogs, which are prone to spring. With a reduction in spring the number of face cuts required to straighten the flitch is reduced. The twin edger can also permit the log to be 'grade sawn'.

The slabs produced from the two parallel cuts that are not resawn can be directed to a slab chipper to produce chips which can be used as fuel in seasoning kilns, sold for utilisation in landscape gardening or, in the case of marri and karri, sold for woodchips.

(v) The chipper canter

This breakdown machine is similar to the log edger, both making two parallel cuts at predetermined spaces along the log edge. The main difference between the chipper canter and the log edger is that the log slabs are chipped off the log with the former.

The chipper canter operates by having the logs fed into a chipping disc producing two opposite flat faces, then the log is turned through 90 degrees and fed into the chipper again to reduce the cross section to a square or rectangle (Burridge 1973).

One of the problems with the chipper canter is that the outside slabs cut off the log are immediately chipped and not assessed for resawing. When sawing small eucalypt sawlogs containing brittle heart, the usable wood is on the outside of the log and as markets exist in Australia for small sizes (such as tile battens) it makes good financial sense to maximise sawn recovery from the outside portion of the log (Page 1978). In any case, jarrah chips are currently virtually unsaleable.

(vi) Which breakdown system to use

When cutting small eucalypt sawlogs it is desirable to relieve the growth stresses by making two well balanced parallel cuts on either side of the log, therefore a log edger or a chipper canter would be used. The choice between the log edger and the chipper canter would depend on the recovery aimed for and the availability of a woodchip market. For example, if it were more desirable to produce large volumes of chips, compared with sawn timber, a chipper canter is possibly a better choice.

If the sawmiller selects the log edger the option is available to resaw the slab edges to increase recovery. Sawn timber that can be used in furniture manufacturing and structural purposes is of higher market value than chips. For this reason the sawmiller may favour the log edger, possibly a circular saw because it is more suited to break down hard eucalypt wood.

3.6.2 The resaw

The function of the headsaw or log breakdown saw is to cut mainly back-sawn flitches in multiple thicknesses of the finished products. The purpose of the resaw is to concentrate on further log breakdown by cutting further flitches, to cut timber which is pre-cut on four sides, and to do automatic centre cutting (Sylvester 1976). The resaw can be a table bandsaw or a circular saw. The bandsaw may be preferred because of the accurate cutting and reduced kerf or the circular saw because of its strength and rigidity.

3.6.3 The edger or docker

At the docker boards are trimmed to the required lengths and any major defects e.g. brittle heart, rot, large gum pockets and splits are removed. The edger is generally a circular saw mounted on a swing arm, swinging in an arc across the board edge.

3.7 **The mill layout for sawing small sawlogs**

The sawmiller must realize that small sawlogs will yield poor returns when sawn in mills designed for large mature logs. If small sawlogs are to be milled economically these mills must be redesigned.

The main problem with cutting small sawlogs is that the sawing time per unit volume is appreciably greater than that for large logs. To justify cutting large volumes of small sawlogs the mill must be efficiently laid out, with efficient conveyor systems between saws, saws must be highly efficient and utilised to their maximum. Good log loading and turning equipment must also be incorporated into the mill (Sylvester 1976).

3.8 **Recovery and productivity of cutting small sawlogs**

Lhuede and Waugh (1980), using three different mill designs, carried out a study on the performance or suitability of sawmilling equipment to handle small eucalypt logs. They found that structural grade sawn products were obtainable from small diameter regrowth ash eucalypt logs despite the recognised inherent defects. Production rates for each of the milling systems studied (in terms of minutes/m³ of log input and man hours/m³ of sawn timber) on all but the smallest logs of less than 25 cm diameter were comparable with production rates of most modern Australian sawmills handling bigger logs from mature trees.

Lhuede and Waugh (1980) concluded that the reduced value and recovery of sawn products and the increased production time for milling logs smaller than 25 cm s.e.d.u.b. would adversely affect the profitability of converting such logs in the three sawmills studied.

Although profitability declined for logs less than 25 cm s.e.d.u.b. recovery was still high due to increased production time, ranging from 30 per cent (logs 15 cm s.e.d.u.b.) to 53 per cent (logs 45 cm s.e.d.u.b.) for all three mills.

Loneragan (1957) and Hadlow and Kippo (1984) carried out sawmilling studies on regrowth jarrah. Loneragan (1957) obtained a recovery of 34 per cent for the four largest logs (mid diameter 29-38 cm d.u.b.), and for the six smallest logs the recovery was 33.5 per cent (mid diameter 13.5-17.5 cm d.u.b.). These recoveries are comparable with mills cutting bigger logs from mature trees, however, only a small sample was milled.

Hadlow and Kippo's results were not as promising as those of Loneragan. They found recoveries low by normal milling standards, averaging 15.4 per cent for logs ranging from 15-27 cm s.e.d.u.b., because the study was not done in a mill designed to cut small sawlogs. The high recoveries obtained by Lhuede and Waugh (1980), were obtained from small sawlogs cut in three mills designed to cut small logs.

Lhuede and Waugh (1980) did not identify recovery in terms of sawn products. The profitability of sawing small sawlogs depends on the availability of suitable markets and not on produce sawn. For example, tile battens and pallet material can be produced from edgings presently cut from mature logs.

3.9 The sawn products produced from small sawlogs

Sherwen (1981) found that back-sawn timber from small sawlogs (presumably ash type eucalypts) can be utilised as structural timber graded F8 or F11. Hadlow and Kippo (1984) recovered jarrah timber of structural grade F8 (green sawn recovery) and when a sample of this material was seasoned 65 per cent was graded into select appearance grade (free of defects along more than 90 per cent of the length), and 22 per cent was graded into F14 merchantable grade (containing heart, wane and want along part of the length). Machin (1981) stated that:

'150 x 25 mm is an ideal section to produce out of small logs. It has some general use in the market, plus the advantage that short ends and poor quality pieces can go into pallet material. Select material should be stripped and seasoned for panelling and weatherboards.'

Not many of these boards will come from the smaller log diameter classes (15-20 cm s.e.d.u.b.) if the log has brittle heart and needs two flitches removed to relieve the growth stresses. Flooring sections of 100 x 25 mm can be cut and with the use of finger jointing greater lengths can be obtained. Other methods of reconstituting sawn timber can be used to increase the value of the material.

Scantling can be produced from small sawlogs, provided it is not longer than 4.8 m, nor thicker than 50 mm, as square sections are very difficult to produce (Machin 1981).

Other uses include: tile battens, palings, housing studs, outdoor furniture, wood turning and fruit casing material. With the use of appropriate seasoning techniques the structural timber can be upgraded and furniture timber can be stabilised. The aim of sawing small sawlogs is to maximise product recovery into the highest possible value timbers. Therefore, the sawmiller must try to produce as much appearance grade and select grade as possible, and the highest structural grades.

New markets need to be developed to sell the sawn timber produced from small sawlogs. Wood turning and craft industries which are labour intensive need to be developed. The furniture market is expanding locally, interstate and in south-east Asia. These industries need to be encouraged, as they produce high value appearance products which can return financial benefits to the State's economy. They are specialised industries which employ a large labour force and could create more jobs if they were to expand.

3.10 Conclusions

The sawmillers must take up the challenge of sawing small sawlogs as the resource of mature and medium size logs is diminishing. This will require redesigning sawmills to handle small sawlogs and improve productivity. New markets need to be developed for selling the sawn products. Some sawn timber may be suitable for furniture and wood turning whereas some will be low-grade, suitable only for pallets and tile battens. Some products will be produced from trees currently considered unutilisable.

CHAPTER 4

UPGRADING JARRAH TIMBER BY SEASONING

4.1 Introduction

The purpose of seasoning timber is to improve the strength of the timber, increase its stability and lightness, increase its hardness and make it easier to glue and paint. Seasoning also reduces the potential for decay due to fungal and insect attack, increases the electrical resistance, and increases the heat content or calorific value of wood. To achieve these ends timber may be air dried or kiln dried. The choice depends upon the environmental conditions suitable for air drying, the time required to air dry and the most economical and practical method available at that time.

The seasoning of eucalypts is not easy, compared with seasoning softwoods and many non-eucalypt hardwoods (Campbell 1978). Some of the problems encountered while seasoning include: collapse, surface checking of back-sawn faces, high shrinkage, steep moisture gradients and pronounced drying stresses and sets (Campbell and Hartley 1978).

4.2 Moisture contained in wood

The moisture content (M.C.) of a piece of timber is the weight of water contained in a piece of timber compared with the weight of actual woody substance in the same piece (Lamond and Hartley 1979). This ratio is usually expressed as a percentage.

i.e.

$$\text{Moisture content \%} = \frac{(\text{green weight of timber} - \text{oven dry weight})}{\text{oven dry weight}} \times 100$$

The moisture contained in a freshly felled tree can be conveniently divided into two parts, the free water (which is held in the cell cavities) and the bound water (which is absorbed in the cell walls) (Johnston 1970).

As timber dries the free water evaporates first and the effect produced is principally a loss of weight. As the bound water is removed the timber properties change noticeably, and if it is removed too rapidly it can result in timber degrade.

As the free moisture leaves the cell cavity, it eventually becomes empty, leaving the cell wall still saturated. This is the 'fibre saturation point' (f.s.p.) and for most timbers the moisture content at f.s.p. lies between 21-33 per cent (Lamond and Hartley 1979). For jarrah the f.s.p. ranged from 25.5-32 per cent with an average of 28.5 per cent in a sample assessed by Siemon (1983).

Timber dries from the outside (case) to the centre (core), setting up a moisture gradient. It is important to control this gradient when seasoning timber to prevent degrade.

The moisture content of timber in service depends on the relative humidity of the surrounding air: humidity changes are followed by moisture content changes but at a much slower rate (Lamond and Hartley 1979). When timber has dried to a state where it is in equilibrium with the atmospheric conditions it is at 'equilibrium moisture content' (e.m.c.) and is fully seasoned. The average e.m.c. for coastal Australia is 12 per cent, while timber in an air-conditioned room would have an e.m.c. ranging from 8 to 10 per cent.

4.3 Drying processes for seasoning timber

Seasoning is the process of removing moisture from wood until it reaches a level approximately in equilibrium with the normal humidity levels of the surrounding atmosphere (Bootle 1983).

The drying process starts at the surface and gradually proceeds inwards. As the surface dries below f.s.p. the cell walls begin to shrink, but the core of the timber still contains free water and has not started to dry or shrink. This leads to tension stress in the surface layers, since the surface cells are prevented from shrinking by those in the core. If the relative drying rates of the case are too high, the tension stress may be sufficient to rupture the bonding between cells, causing surface checking (Marshall 1983).

When the case is under tension stress the core is under compression stress. If the compression stress is great enough the cells within the core will collapse. Collapse is the irregular and abnormally large shrinkage caused by 'crumpling' of the wood cells (Johnston 1970). The evidence of collapse in a piece of timber can be seen in the radial surface, which may have an undulating or corrugated appearance (Bootle 1983).

A steaming treatment (reconditioning) after the drying period will usually restore the cross section of the timber to the shape which it would have reached if collapse had not occurred. However, there is the possibility that some internal checking, or honeycombing (internal splitting), may remain as evidence of collapse (Bootle 1983).

Eventually the case dries, becomes hard and sets in tension. When the core has completed drying it reaches a stage of compression set. This condition is known as 'case hardening' and results in the surface layer becoming stretched without cracking the case of the timber (Johnston 1970). In severe instances, case hardening can lead to internal splitting (Johnston 1973). The condition of case hardening can be overcome by high humidity reconditioning. Timbers that are case hardened can be susceptible to distortions when the timber is re-sawn or heavily machined (Johnston 1973).

Reverse case hardening can occur if too much reconditioning treatment is applied. This results in timber absorbing too much moisture, the case expands and this results in differential stresses occurring between the case and the core.

The establishment of moisture gradients within the wood during seasoning is unavoidable. In a particular piece of wood (at a given temperature) the rate of movement of moisture to the surface is proportional to the angle of the moisture gradient. The skill in drying lies in allowing the gradient to become as steep as the wood will

withstand to reduce the time needed, without suffering timber degradation (Johnston 1970).

4.4 Some methods of seasoning timber

A number of methods are available for drying sawn timber, for example: air drying, high temperature kiln drying, conventional kiln drying, dehumidified kiln drying, microwave drying, freeze drying and solar kiln drying. These methods can have different drying schedules applied to them, and in some cases two methods are combined, e.g. air drying followed by kiln drying.

Choice of drying method and schedule is critical. Rapid drying at high temperature and low humidity may result in degraded timber. However, drying at lower temperatures and higher air moisture contents slows the drying processes, but could make the operation more economic by producing more high grade timber.

Some methods of seasoning jarrah are outlined below.

4.4.1 Air drying

Air drying of timber involves the free circulation of air between strip-stacked boards of timber. To help this natural circulation, stacks should not be too wide (approximately 1 m), foundations should be level, of durable material and high enough (at least 400 mm) from the ground to permit rapid discharge of the descending moisture laden air (Bootle 1983). Sealing the ground reduces the incidence of weeds, which restrict air flow. There should be a good air current moving through the timber yard, with stacks of timber oriented at right angles to the prevailing wind.

To provide efficient circulation of air to all parts of the material being dried in the stack the layers of boards are separated from each other by suitable small sections of timber, called strips or stickers (Lamond and Hartley 1979). The strips need to be seasoned, of uniform dimensions, and spaced correctly to produce satisfactory results. The thickness of the strips varies from 12-25 mm, and width can be equal to, or up to, 50 per cent more than the thickness. Thinner strips are easily broken and also result in slower drying rates because they leave smaller air gaps between the boards. Morgan (1983) used strips 25 mm thick in an air-seasoning jarrah trial because this thickness is commonly used when strip-stacking jarrah.

Good stacking is necessary to reduce the amount of timber degradation in air drying. This requires the stacks to be constructed with both ends square, because overhanging boards bend and are prone to end checks and splits. Covering the stack with a roof, with open or closed sides, or with plastic sheeting, will give protection from the sun, rain and exposure to hot dry winds. This will reduce surface checking and warping.

Campbell (1971a) carried out a jarrah seasoning trial using 150 x 50 mm joinery stock. He concluded that a vast improvement in drying behaviour was possible for jarrah, even under summer drying conditions, provided that drying was carried out in an enclosed shed with very little air movement through the stacks. He also found that the rate of drying timber in the open was only slightly faster than that dried in the enclosed

shed. Even without chemical assistance surface checking can be considerably reduced by drying in enclosed sheds, but early protection would need to be given to the stacks while they were being built, and up to the time they were placed in the sheds.

Chemicals, for example microcrystalline wax, emulsified with water and applied by spraying, dipping or brushing, have also been used to protect the timber in the early stages of drying (Bootle 1983). Weights on top of a timber stack assist noticeably in preventing excessive warping but are more important in high temperature drying pine than in air drying hardwoods.

4.4.2 Advantages and disadvantages of air drying

Air drying is relatively inexpensive, requires no special equipment and can be practised whenever space is available (Johnston 1973). Another advantage is that when timber stacks are held for lengthy periods, after they have reached equilibrium with atmospheric conditions the stresses set up in the wood during drying tend to dissipate.

Some of the disadvantages are:

- (i) The drying rate cannot be closely controlled, being almost entirely dependent on the prevailing weather. If cold and wet, the drying is unnecessarily slow and may cease altogether for a time. If high temperature and low humidity conditions occur, little can be done to retard the drying and protect the timber against the risk of splitting and checking (Johnston 1973).
- (ii) When air drying is carried out on a large scale it involves holding large stacks for long periods and requires a large amount of space.

4.4.3 Chemical seasoning

Soaking timber in a chemical which is hygroscopic (i.e. moisture attracting) will slow the rate of water loss, and thus reduce the risk of a high moisture gradient with its accompanying increase in drying stresses (Bootle 1983). The chemical must be applied immediately after the green timber is cut, by soaking the timber in an aqueous solution of moderate concentration, or by a momentary dip in a saturated solution. The timber is set aside in a drying shed and well protected from rain and strong breezes.

Dry chemicals can be spread on green timber which is then stacked until all the chemical has been absorbed (Johnston 1970). Chemicals commonly used are urea, polyethylene glycol and sodium chloride (common salt). The first two chemicals replace some of the bound water in the cell walls and prevent the wood shrinking to its normal extent. This 'anti shrink' property is undesirable with species susceptible to collapse, as it is likely to increase the tension stresses in such timber (Bootle 1983). Common salt is preferred in these cases. Although it has the problem of corroding metal fittings applied to the timber, salt can be applied with corrosion inhibitors (Johnston 1970).

Campbell (1971a) conducted a trial to determine the value of 24-hour soak treatments in four different chemical solutions to control seasoning degradation in jarrah joinery. The treatments were:

- (i) upper faces sprinkled with sodium chloride (NaCl) during stacking;
- (ii) NaCl sandwiched between boards when forming a block pile - the boards remained block stacked for one week before being stripped out for air drying;
- (iii) soaked for 24 hours in a saturated NaCl solution;
- (iv) soaked for 24 hours in a saturated urea solution;
- (v) soaked for 24 hours in a 50/50 solution of saturated urea and saturated ammonium nitrate (NH_4NO_3);
- (vi) soaked for 8 hours in a 25 per cent solution of calcium chloride (CaCl_2);
- (vii) no treatment.

At the request of the local industry, the treatments were applied to timber from normal and dieback-affected trees. Timber used in each treatment was stacked for air drying in an exposed position in direct sunlight, or in a large enclosed building.

The results of the experiment were:

- (i) in general, timber from dieback-affected trees had more extensive checking, more severe in the face nearer the sapwood than nearer the heart;
- (ii) surface checking could be considerably reduced by drying in sheltered conditions rather than in an exposed outdoor site;
- (iii) chemical seasoning using common salt (soaked in solution) was most effective;
- (iv) sprinkling of salt on one face reduced checking in normal jarrah stored under shelter, but was not effective on timber in dieback-affected trees dried in either situation.

Campbell (1971a) did not attempt to explain why timber from dieback-affected trees should behave differently during seasoning, as dieback is caused by the pathogen *Phytophthora cinnamomi* which attacks the roots.

The use of surface coatings e.g. microcrystalline wax, can also be used to control the rate of air drying. Campbell (1971b) found that microcrystalline wax reduced, but did not eliminate, surface checking in jarrah joinery. If coating one face only it was better to coat the sapwood face.

Morgan (1983) investigated air seasoning of jarrah grown in the southern and northern jarrah forests, and dried in different geographic locations. These trials monitored the

effects of using sodium chloride, applied as a dry spread with or without a covering layer of sawdust, to both sapwood and heart faces of joinery stock. Block stacking the timber, with sodium chloride sandwiched between boards, then strip stacking for air drying, was also assessed. Another trial was designed to determine the effect of seasoning mature and juvenile timber using material stacked with the sapwood or heart faces on the upper side.

4.4.4 Progressive (tunnel) kiln drying

The CSIRO progressive kiln operates when ambient air is drawn into the kiln through a large inlet vent at the unloading or dry end where a heater raises the temperature of the entering air by 10-13°C; the heated air is drawn through the whole length of the kiln, being directed with the aid of baffles through the stacks in a sinuous path to the wet or loading end where it is exhausted by the fan (Campbell 1978).

By the time the air has reached the wet end it is almost saturated. These conditions make it very suitable for drying check-susceptible timber e.g. ash type eucalypts. The timber is stacked parallel to the kiln, and is moved progressively on trucks (trolleys) against the counter flow of warm air towards the dry end where it is removed (Campbell 1978).

This type of kiln is an effective way of drying timber from green down to below f.s.p. before drying to final moisture content. The reduction in drying time made by kiln drying hardwoods from green, compared with partly air drying and then kiln drying, gives the bonuses of reduced interest payments and required working capital. Timber degradation is also likely to be less than with preliminary air-drying in the open (Fricke 1983).

The CSIRO-designed progressive kiln has been operated successfully on a commercial scale at Leongatha, Victoria and in Tasmania; the Victorian kiln has successfully dried a wide variety of species, ranging from salt-treated, ash-type hardwoods to radiata pine, and in timber thickness from 20-70 mm (Fricke 1983). Throughput is 20 m³/week. Using L.P. gas for kiln heating and electricity for the fan motor, costs at January 1982 tariffs were \$16/m³ to operate. Fricke (1983) estimated that a progressive kiln holding 120-130 m³, with all fittings and trucks (trolleys), would have cost a timber miller between \$25 000 and \$30 000 to build himself in 1982.

4.4.5 Progressive kiln operating at the WURC

The progressive kiln constructed by the Department at the WURC is based on the CSIRO's model described above (Figures 4.1, 4.2). Some of the modifications of the WURC kiln are:

- (i) the drying source is a centrifugal fan which blows dry air over the timber stacks. There is no added heat;
- (ii) the timber is stacked on to trolleys with its length at right angles and not parallel to the kiln length;



Figure 4.1

The progressive tunnel kiln at the WURC: the sliding doors on the side of the kiln enable sample boards to be removed for assessment.

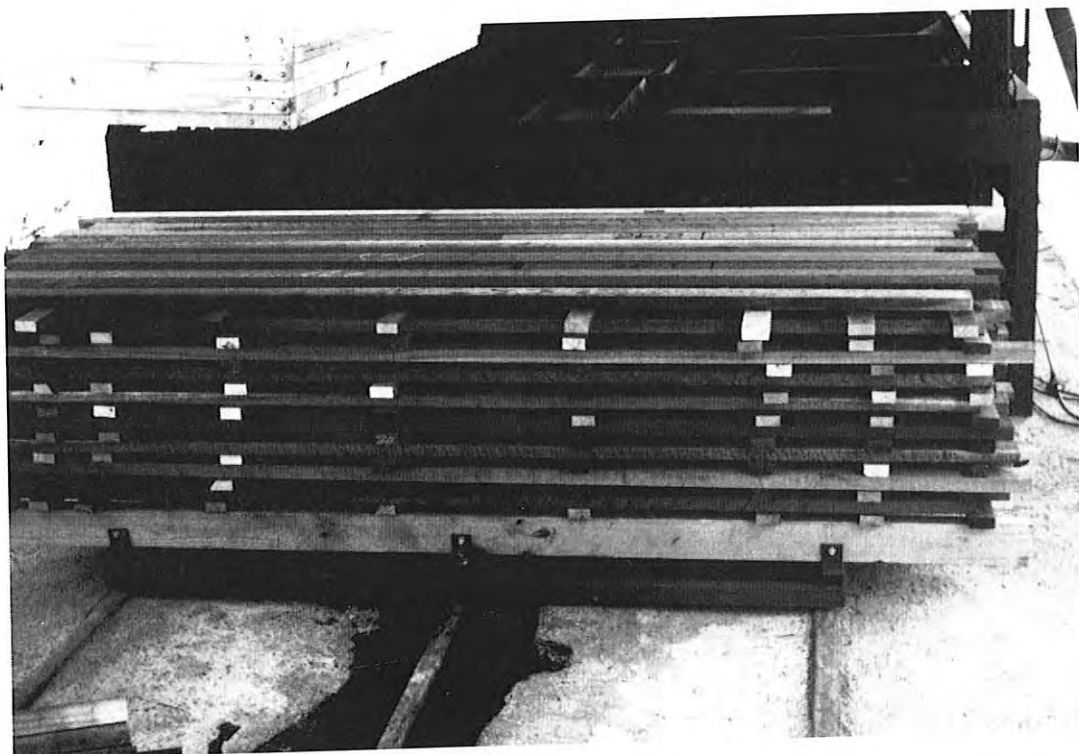


Figure 4.2

The loading bay of the progressive tunnel kiln at the WURC.

- (iii) the baffling system is different: the baffles are located between the sides of each stack and the kiln wall, thus allowing the air to flow straight through all the stacks instead of flowing on a sinuous path. The baffles also stop the air rushing down the sides of the kiln, then out the back of the kiln.

This experimental kiln at present has a capacity of approximately 6 m^3 (i.e. 10 stacks averaging $0.5\text{-}0.7 \text{ m}^3$). Wet and dry bulb thermometers are located along the kiln at every third stack to record drying conditions along the kiln. The thermometers are connected to a continuous recorder.

The results obtained to date are: in 5-6 weeks the timber was dried from 70 per cent M.C. to 28 per cent M.C. (f.s.p.) and in 11 weeks the M.C. reached 20 per cent (Fig. 4.3). No surface checking or collapse occurred. This material was dried in the winter. The drying rate will be faster in the summer, therefore moisture may need to be added to the kiln to reduce the drying rate and hence the possibility of surface checking. Timber with greater thickness will be more difficult to season.

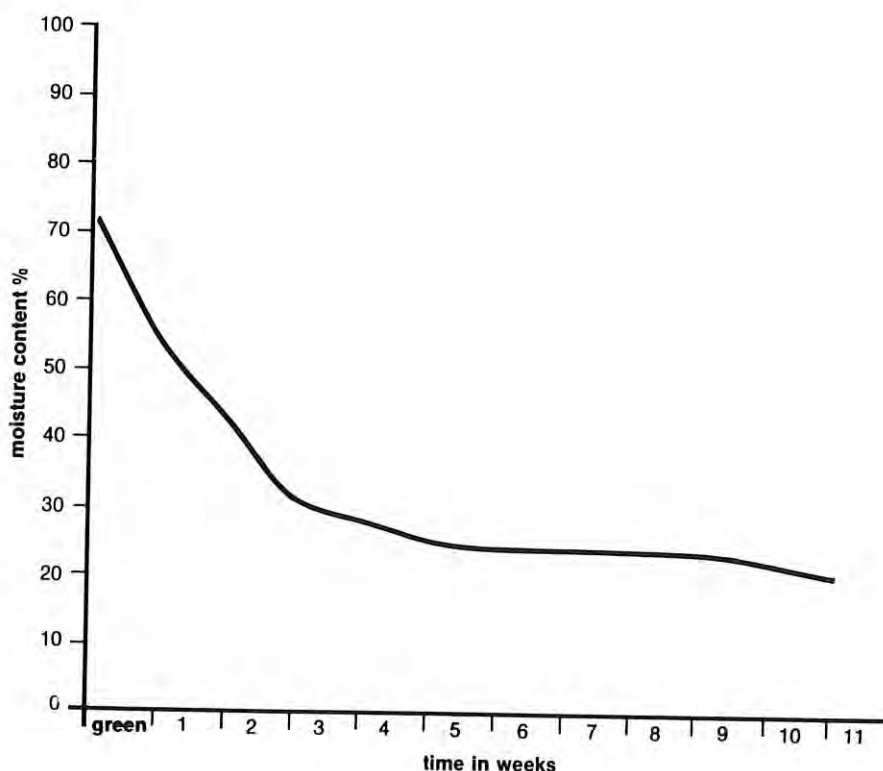


Figure 4.3

The progressive drying of a bundle of 75 x 25 mm mature jarrah, dried in the tunnel kiln during winter. The mature jarrah was provided by Bunning Bros. Pty. Ltd.

4.4.6 Pre-driers

A pre-drier consists of a large enclosure containing a number of parallel lines of timber stacks and fitted with a fan that blows air at a rate of one to two metres per second. A small amount of heat is provided on a continuous basis (Bootle 1983).

The pre-drier serves as a useful alternative to air drying in reducing the moisture content to below the f.s.p., after which the stacks are transferred to a kiln.

4.4.7 High temperature kiln drying

With high temperature kiln drying, i.e. at temperatures greater than 100°C, circulating air picks up heat as it passes over the steam coils (or other forms of heat exchange) and gives up heat as it moves through the timber stack. Most air is then re-heated and re-circulated, but some must be allowed to escape through the ventilation to rid the system of moisture evaporated from the wood. The exhausted air must then be replaced by an equal weight of cold drier air from outside (Johnston 1970). The heat and humidity required for kiln drying is provided artificially.

Air movement is required to remove the moist air adjacent to the surface of the wood and replace it with drier air. This layer of moist air is the boundary layer, and the greater the air velocity the less the boundary layer affects the rate of drying (Johnston 1970).

The temperature also controls the rate of drying. An increase in temperature increases the rate of diffusion of moisture through the wood, and the capacity of the air for holding water vapour. The amount of air that needs to be exhausted from the kiln in order to remove a definite amount of moisture is reduced (Johnston 1970). That is, at any given temperature, the rate of evaporation of moisture is inversely proportional to the relative humidity of the air. In effect the humidity controls the rate of evaporation and the temperature of the air controls the rate of transpiration.

High temperature drying is several times faster than conventional kiln drying and air drying. Prior to kiln drying, hardwoods are air dried to below f.s.p. (Bootle 1983). A problem with high temperature drying is that it can lead to internal collapse if timber above f.s.p. is dried rapidly. Drying stresses are also created, therefore at the end of kiln drying the timber is given a high humidity reconditioning treatment to relieve the stresses.

4.4.8 High temperature drying of jarrah

Fung and Campbell (1977) used a high temperature laboratory kiln to assess seasoning properties of both 25 mm and 75 mm jarrah pre-dried in a dehumidifier. The sample tested indicated that 25 mm stock could be successfully dried at high temperatures provided the initial moisture content was below 30 per cent. At higher initial moisture contents between 35 and 40 per cent high temperature seasoning was unsatisfactory because of case hardening and moderate to severe internal checks, confirming the presence of free water in the cell lumen.

The test results with 75 mm boards were inconclusive since only one board had a moisture content below 30 per cent. This board showed satisfactory drying from 27 to 13 per cent in 12 hours. There were some slight surface checks after reconditioning. At initial moisture contents greater than 30 per cent the drying was entirely unsatisfactory: the boards showed case hardening with severe to very severe internal checks (Fung and Campbell 1977).

Donnelly (1983a) successfully conducted high temperature drying on jarrah using three kiln charges, each of 11 m³ of 100 x 25 mm random length boards. The boards were air dried for five months and the moisture contents prior to high temperature drying averaged 23.3 per cent with a range of 19.5-25 per cent.

The drying schedule used was a pre-steaming period of six hours in a steam flooded chamber. This increased the wood temperature from 15-95°C. The timber was then dried in the kiln for 19 hours with dry bulb temperature maintained at 110°C and wet bulb temperature falling from 95°C to 72°C during the drying. Air speeds were approximately 8 m/s through the stacks with fans reversed every six hours. Standard 25 mm stickers were used.

After drying the timber was steamed in the reconditioning chamber for seven hours.

Final moisture content averaged 11.4 per cent, ranging from 9-14 per cent. Some degradation was expected as a result of such severe drying, however, after dressing, the timber colour was good and there was little evidence of degradation.

Donnelly (1983b) in a report on high temperature seasoning of 25 mm jarrah boards, concluded that:

- (i) high temperature kiln drying is possible, provided material to be dried is below f.s.p.;
- (ii) a random sampling method must be used to ensure that sample boards represent the whole population;
- (iii) best drying rates appeared to be when air temperature in the kiln was 120°C, wood temperature 110°C, vents at 1/8 opening;
- (iv) improved drying and a faster drying rate should result from using 25 mm thick stickers instead of 19 mm to better restrain boards and improve air flow.

4.4.9 Conventional kiln drying

Conventional kiln drying occurs at temperatures below 100°C and generally between 42-82°C (Wenger 1984). A conventional kiln operates in the same manner as a high temperature kiln (except at lower temperatures), which is described in 4.4 (g). Conventional kilns are commonly used by the timber industry of W.A.

Timber can be dried in a conventional kiln, from the green condition down to final moisture content or air dried for two to four months then kiln dried for three to seven

days, depending on the species and the timber size. Kiln drying from the green condition to e.m.c. would take between ten days and four weeks depending on species (Boas 1947).

4.4.10 Dehumidified kiln drying

The dehumidified kiln controls humidity within the kiln by condensing water vapour within the kiln, thus recovering the heat of condensation from the water vapour (Ferguson 1983). The dehumidifier is a heat pump similar to a refrigerator or air conditioner, composed of an evaporator, compressor, condenser, expansion device and a fan. The warm moist air passed across the evaporator is cooled, causing water vapour to condense and water is piped from the kiln. Dehumidifier kilns have been used in W.A. for 10 years. The early units could operate to 50°C, but the most common type of unit operating in W.A. today has an upper temperature limit of 60°C.

Ferguson (1983) reported on kiln charges of green (70 per cent M.C.) jarrah of joinery grade dried to 12 per cent M.C. in a dehumidifier. The drying time for the 50 mm jarrah was about 90 days and for 75 mm about 140 days, and with almost no drying degradation.

This kiln can be used to complete drying of already air dried material, with drying times only slightly slower than conventional low temperature kilns. Fung and Campbell (1977) suggested using dehumidifiers to replace air seasoning from green to f.s.p. because of reduced drying time and minimum degrade.

The dehumidified kiln has the advantage of conserving energy because the latent heat used to evaporate moisture from the wood is recovered and can be used to re-heat the circulating air (Johnston 1970). The cost of installation is low compared with conventional kilns and make dehumidifiers suitable for small operators e.g. joinery shops.

4.4.11 Solar kiln drying

Two types of solar kilns have been developed over the past two decades. The types are:

- (i) the 'greenhouse' type, consisting basically of a framed structure with a transparent roof and walls with an internal blackened collector;
- (ii) a solar kiln consisting of an enclosed heavily insulated drying chamber and some form of external collector (Steinman *et al.* 1980).

All solar kilns rely on solar heated air as the drying medium. Two different systems (hot air or hot water) are employed to transfer the solar heat energy from where it is collected to where it is used within the kiln.

Two solar kilns based on the glasshouse principle are operating commercially in Queensland, and one in Papua New Guinea (Gough 1981).

Gough (1981), using one of the Queensland solar kilns, found that in March drying 100 x 25 mm boards of *Eucalyptus crebra* (narrow-leaved red ironbark) took 32 days from

green (33 per cent M.C.) to 12.5 per cent M.C. A matching air drying stack dried to 20 per cent M.C. in the same time, and was down to only 18 per cent after a further 29 days. He also found in drying hoop pine (*Araucaria cunninghamii*) 25 mm thick of varying widths, that moisture contents dropped from 32.5 to 12 per cent in 16 days and reduced to 8.5 per cent after 24 days. A matching air drying stack took 32 days to dry from 28 to 15 per cent, and failed to dry below 15 per cent.

The drying time of timber in the solar kiln can be reduced by initial air drying down to 20 per cent M.C. Kiln drying time from 20 to 12.5 per cent M.C. was about three weeks for ironbark and one week for hoop pine.

Kiln temperature and the rate of drying are affected by wet and cloudy weather and by seasonal change. However, it is only under the most unfavourable weather conditions that drying is likely to cease in solar kilns, whereas an unprotected air drying stack is affected immediately by wet weather (Gough 1981).

The efficiency of solar kilns decreases with increasing distance from the equator and it is further reduced in areas of high rainfall or heavy cloud cover. Efficiency is also reduced when drying timber greater than 25 mm thick from high density species (Gough 1981).

A solar kiln takes two to three times longer than a conventional kiln to dry timber, but capital cost and operating cost of the former are much less than that for conventional kilns.

Solar kilns have limitations. However, their use for drying jarrah joinery timbers should be considered as an alternative to oil fired kilns and dehumidified kilns, because they are more economical to install and operate.

4.4.12 Minor forms of kiln drying

(i) Microwave Drying

Microwave drying is suggested by Bootle (1983) as a method of drying small pieces of relatively thick timber, as used by the wood turner and sculptor. This technique has not yet been fully investigated, but it appears to give a very quick and satisfactory result with little degradation, except in collapse-prone species.

(ii) Freeze Drying

A freeze drying technique for timbers including jarrah was investigated by the Western Australian Maritime Museum (P. Shedley⁸, personal communication). It involved pre-freezing the wood, sublimation (i.e. changing water within the wood from a solid to a vapour without going through the liquid phase), drying under vacuum and desorption of water vapour.

8 P. Shedley, Department of Conservation and Land Management, Como.

Some of the results of preliminary tests were:

- checking that occurred was not the result of collapsed cells.
- checking was caused by the rapid expansion of volatiles (and air) when the vacuum was first applied. Jarrah has a very high content of volatile chemicals, and is therefore difficult to season by this method.
- temperature in the sublimation chamber must not be below freezing point. The good insulating properties of timber result in differential vapour pressure between the wood and the sublimation chamber walls. This causes rapid surface drying and further tendency to check.
- application of the vacuum should be slow for jarrah, because of the nature and quantity of volatile chemicals.
- application of microwave heat, initially to disturb the volatile chemicals, may assist in making their distribution more uniform throughout the wood section. This could reduce degradation.

4.5 Drying characteristics of regrowth jarrah

Campbell and Hartley (1978) outlined some of the drying characteristics of wood from plantation and young regrowth ash-type eucalypts:

- (i) collapse in low density species is generally higher than in high density species;
- (ii) shrinkage before reconditioning is generally higher in young than mature material, especially in the tangential direction: this is not a problem if the timber is reconditioned before being used in service;
- (iii) greater tangential shrinkage also indicates that collapse is greater in the younger material;
- (iv) wood sawn close to the pith may collapse, check and split irrespective of the drying conditions;
- (v) warp (bow, twist or spring) is caused by the relief of growth stresses and is greater in younger than mature wood: this is a problem in drying and conversion;
- (vi) internal checks caused by collapse are more often associated with young than mature material, particularly in wood from near the pith.
- (vii) reconditioning closes the checks, but subsequent machining can expose them and give them the appearance of surface checks.

There are exceptions to these characteristics, because variations can occur due to diverse factors such as species, tree maturity, position in the tree, thickness, width and

direction of cut of the sawn timber, and environmental factors such as site, climate and latitude (Campbell and Hartley 1978).

Despite the adverse drying characteristics of regrowth or plantation eucalypt, good seasoning practice can control the amount of degradation to an acceptable level.

The knowledge required to season regrowth jarrah is emerging. Fricke and Northway (1982) did seasoning trials on regrowth jarrah (seedling and coppice) with boards sawn from:

- (i) small butt logs 15-17 cm small end diameter (s.e.d.);
- (ii) butt logs 20-22 cm s.e.d.;
- (iii) small head logs from large trees of 33-35 cm d.b.h.o.b.;
- (iv) near pith of butt logs of large stems;
- (v) near bark of butt logs of large stems.

Thirty boards were cut into four 600 mm long samples and four samples from each board were randomly allocated to four drying runs. The drying conditions were:

- Run 1. air dry to 24 per cent M.C., then low temperature kiln dry;
- Run 2. pre-dry to 21 per cent M.C., low temperature kiln dry using the conventional jarrah schedule, then recondition and finally kiln dry to 13 per cent M.C.;
- Run 3. kiln dry from green at very low temperature, simulating conditions in a progressive tunnel kiln;
- Run 4. simulate a schedule possible in a dehumidified kiln.

Fricke and Northway (1982) concluded from the seasoning tests that the best method of producing the least degradation with regrowth jarrah material was to air-dry under cover and then kiln dry as in Run 1. Reconditioning was of doubtful advantage because for a small advantage of increased dimensions there was a high risk of re-opening surface checks.

Small butt logs produced the worst seasoning problems, followed by small head logs. The remaining three types of logs tested produced boards with similar levels of seasoning degradation.

Seedling and coppice material appeared to have similar degradation with any of the drying schedules used.

The results indicated that regrowth jarrah timber should be seasoned like mature jarrah, that is, air-dry to f.s.p. and then kiln-dry using a conventional kiln.

Fung (1976) further confirmed the need to air dry to about f.s.p. before high temperature drying of regrowth eucalypts. He seasoned 25 mm thick regrowth *Eucalyptus regnans* (mountain ash) from 30 to 15 per cent M.C. with negligible degradation. The drying conditions used were two hours at 130°C dry bulb temperature, 52°C wet bulb temperature and 10 m/s air velocity. The quality of this material compared well with that of regrowth material seasoned in a conventional kiln.

When Fung (1976) dried the same type of material at higher initial moisture contents of 40-50 per cent high temperature drying was not satisfactory, resulting in honey-combing (internal splitting), excessive shrinkage due to collapse and increased discolouration.

The research done by Fung (1976), Fung and Campbell (1977), Fricke and Northway (1982) and Donnelly (1983a and 1983b) is being extended to improve methods and schedules for drying regrowth jarrah.

4.6 Conclusions

- 4.6.1 The challenge faced to economically and efficiently convert small jarrah sawlogs is again faced with seasoning the resulting sawn timber. A number of authors (Donnelly 1983a; Fung 1976; Fricke and Northway 1982) emphasised the need to pre-dry to f.s.p. prior to kiln drying. Fricke and Northway (1982) suggested regrowth jarrah should be seasoned using the same methods and schedules as mature jarrah.
- 4.6.2 Timber can be upgraded by seasoning e.g. increased strength and stability and reduced weight. Methods and schedules need to be developed to increase the value of timber and allow its utilisation range to be extended, such as upgrading structural grade timber to joinery grade.
- 4.6.3 These methods for seasoning must be economical, quick and with minimum degradation, for example pre-drying to f.s.p. in a tunnel kiln followed by high temperature kiln drying. This method was tested at the WURC on 75 x 25 mm mature jarrah. Different timber sizes, seasoning schedules, and regrowth material need to be tested in the tunnel kiln/high temperature kiln.
- 4.6.4 The seasoning of regrowth jarrah needs to be researched using alternative methods.

CHAPTER 5

USING JARRAH THINNINGS AS A CHARCOAL RESOURCE

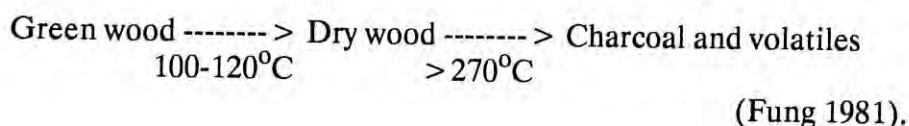
5.1 Introduction

Charcoal is a form of carbon obtained by the incomplete combustion of wood. It has a considerably higher calorific value than wood and similar to that of other high carbon fuels. Its calorific value is in the range of 29-37 kJ/kg, while coal is 28-33 kJ/kg, coke 28-30 kJ/kg, and kerosene 46 kJ/kg (Bootle 1983).

5.2 The charcoal production process

Charcoal is manufactured in 'kilns' in which wood is heated with a limited supply of air, sufficient to effect the removal of volatile gases and tars, but not enough to oxidise large amounts of carbon (Bootle 1983).

The carbonisation process can be outlined by the following equation:



In this process the wood is heated and at temperatures ranging from 100-120°C loss of free and bound water occurs. An exothermic reaction (carbonisation) begins at about 270°C and from this point no further external heat is required.

The carbon content and yield of charcoal are dependent on the final carbonisation temperature. That is, the higher the final temperature the higher the carbon content and the lower the charcoal yield. At temperatures ranging from 400-800°C the carbon content ranges between 75-96 per cent with a maximum possible charcoal yield of between 28-44 per cent, based on dried wood mass (Fung 1981). If oxidation of charcoal and other losses occur in the carbonisation process this yield of charcoal is reduced.

By-products resulting from the carbonisation process are pyroligneous acid, wood tar (which contains the distillation products insoluble in water) and the wood gases. These products can be broken up into components:

- (i) pyroligneous acid:
 - acetic and other homologous acids
 - methanol
 - acetone and esters
- (ii) wood tar:
 - oils
 - phenols
 - creosote
 - pitch

- (iii) wood gases:
- carbon monoxide
 - carbon dioxide
 - hydrogen
 - methane

(Fung and Liversidge 1981).

The composition of products obtained from the carbonisation of jarrah is shown in Table 5.1.

Table 5.1

Carbonisation Products of Jarrah

Charcoal (10 per cent volatile matter)	=	37.0%
Wood gases	=	20.5%
Pyroligneous acid	=	42.5%
i.e. acetic and homologous acids	=	2.8%
methanol and acetone	=	1.7%
tar	=	9.8%
water of decomposition	=	28.2%

(After Fung (1981))

5.3 Methods of carbonisation

Charcoal has been produced with very unsophisticated methods, such as the controlled burning of wood in a pile covered with earth or in simple kilns fitted with vents and chimneys (Fung 1981). These systems are generally labour intensive, requiring only a small degree of operator skill thus making a uniform product quality difficult to maintain. The energy utilisation of wood is inefficient.

Modern techniques and appliances have been researched and developed to improve the efficiency of wood carbonisation. Some of these include: the fluidised bed system, and the Herreshoff and BSP/Envirotech large continuous vertical carbonising furnaces developed in the U.S.A. (Harris 1981). Some of the common appliances in use today include: kilns, retorts, continuous kilns, and furnaces.

5.3.1 Kilns

The production of charcoal in a kiln depends on the combustion of part of a pile of wood until it reaches sufficient heat to react exothermically in a limited air supply. Kilns can range from earth covered pits to those constructed of brick, concrete or metal. For forest operations portable steel kilns have been developed which can be used to manufacture charcoal at specific sites in the forest (Earl 1975).

5.3.2 Retorts

Retorts are containers in which wood is subjected to heat applied to the external surface of the apparatus until the charge is converted to charcoal (Earl 1975). The gases produced, if collected and condensed, may be fractionated into saleable by-products such as methanol, acetic acid and pitch. The gases may also be used as energy to carry on the distillation process (Harris 1981).

The establishment of a retorting process involves a high capital cost, therefore any advantage of retorting over kilning depends upon the existence of a market for the by-products. Today most of the wood chemicals can be more economically synthesised from oil, making it difficult to sell by-products (Fung 1981).

5.3.3 Continuous kilns

The continuous kiln usually consists of a vertical insulated steel cylinder, in which raw material enters at the top and charcoal is withdrawn from the bottom. The principle of the continuous kiln is similar to the kilns referred to in 5.3 (a) above, because energy is required from an external source to initiate the carbonisation cycle (Earl 1975).

The major difference between the continuous kilns and other kilns is that chips or sawdust have to be continuously fed into the kiln. This operation requires labour day and night to supply the continuous kiln with wood, and this can be costly.

5.3.4 Furnaces

The Herreshoff and BSP/Envirotech large continuous vertical carbonising furnaces are widely used in the U.S.A. for carbonising small wastes of all types (Harris 1981). These two furnaces are efficient and economical at producing fine charcoal, which can be briquetted into large units.

The advantages and disadvantages of the four carbonisation systems discussed in sections 5.3.1 to 5.3.4 are listed in Table 5.2.

5.3.5 The fluidised bed system of carbonisation

A fluidised bed carbonisation unit was designed by the CSIRO's Division of Chemical Technology (now Forestry and Forest Products) as an experimental unit to investigate the feasibility of this method for sawdust and mill residue carbonisation and heat recovery (Fung 1981). The unit is shown in Figure 5.1.

Table 5.2

ADVANTAGES AND DISADVANTAGES OF VARIOUS CARBONISATION SYSTEMS

Advantages

Kilns:

- Low capital costs
- No external fuel requirement
- Low technological requirement
- Labour-intensive (developing countries)
- Aid to silviculture; portable kilns provide very good regeneration sites
- Relatively large pieces of wood may be used, with moisture contents not being critical.

Retorts:

- Not labour-intensive (developed countries)
- High yield of charcoal with built-in quality controls
- By-products may be more valuable than required energy inputs.

Continuous kilns:

- Can utilise small-sized residues
- Provide continuous supplies of good quality charcoal
- Cheaper than retorts and furnaces.

Furnaces:

- Can utilise any organic material including wood chips, sawdust and bark
- Provide continuous supplies of high quality charcoal of any desired volatile content
- Not labour-intensive (developed countries).

Disadvantages

Kilns:

- Labour-intensive (developed countries)
- Quality and quantity of charcoal difficult to control
- By-products (energy) lost
- Very small material, e.g. chips, sawdust, and bark cannot easily be utilised.

Retorts:

- Capital-intensive (developing countries)
- Advanced technology needed
- Size and moisture content of wood has to be strictly controlled
- External energy source required for at least part of the process.

Continuous kilns:

- Charcoal is hot when discharged and therefore requires special handling
- Attention needed day and night
- By-products lost
- Require external energy inputs for at least part of the time.

Furnaces:

- Capital intensive
- Wood has to be chipped
- Moisture content must be below 45 per cent
- Advanced technology required
- By-products lost.

(After Earl (1975)).

The operation of the fluidised bed is as follows:

The wood source is fed continuously into a fluidised bed of hot sand at 500°C, where the wood is rapidly dried and carbonised into charcoal and volatile vapours. The volatiles produced combust upon mixing with the fluidised air, releasing considerable heat to the sand bed. The light charcoal particles formed are separated from the bed by the flue gases, leaving behind the heavier sand. A heat exchanger, consisting of a coil within the fluidised bed, recovers the useful heat (Fung 1981).

The advantages of the fluidised bed carbonisation unit are:

- (i) it can carbonise a range of particle sizes from fine sawdust to coarse chipped wood by a continuous process;
- (ii) it has the ability to handle the wide range of moisture contents normally encountered in timber residues, without resorting to expensive pre-drying methods;
- (iii) very high heat transfer rates are obtained when heat transfer tubes are immersed within the fluidised bed;
- (iv) the unit can be used by an industry to produce heat and electricity to supply the industry's own energy requirements, with the possibility of exporting surplus energy;
- (v) if the unit is used by a sawmill the unused residues could be disposed of in an environmentally acceptable manner and energy can be supplied for kiln drying.

5.4 The domestic use of charcoal

Charcoal can be utilised in domestic heating and cooking appliances and for horticultural purposes (Fung 1981). Other uses of charcoal have been in potting mediums, and applied to lawn to improve the soil structure and promote growth. Further aspects of domestic charcoal use are covered in Chapter 6.

5.5 The industrial use of charcoal

5.5.1 Fuel

Charcoal is a smokeless, clean-burning fuel with a high calorific value. It can be used in a solid, pulverised, or semi-liquid form for firing boilers (Fung 1981).

Ground charcoal can be mixed with fuel oil to form a slurry of 20 per cent by mass of charcoal, which is fired in this semi-liquid state.

The charcoal/oil slurry fuel has not yet been used on a commercial basis by industry. However, it has been burnt successfully in trials at two plants in Australia and Papua New Guinea (Fung and Liversidge 1981). One aspect which tends to limit the potential value of charcoal/oil fuels in Australia is over-abundance of coal. In Western

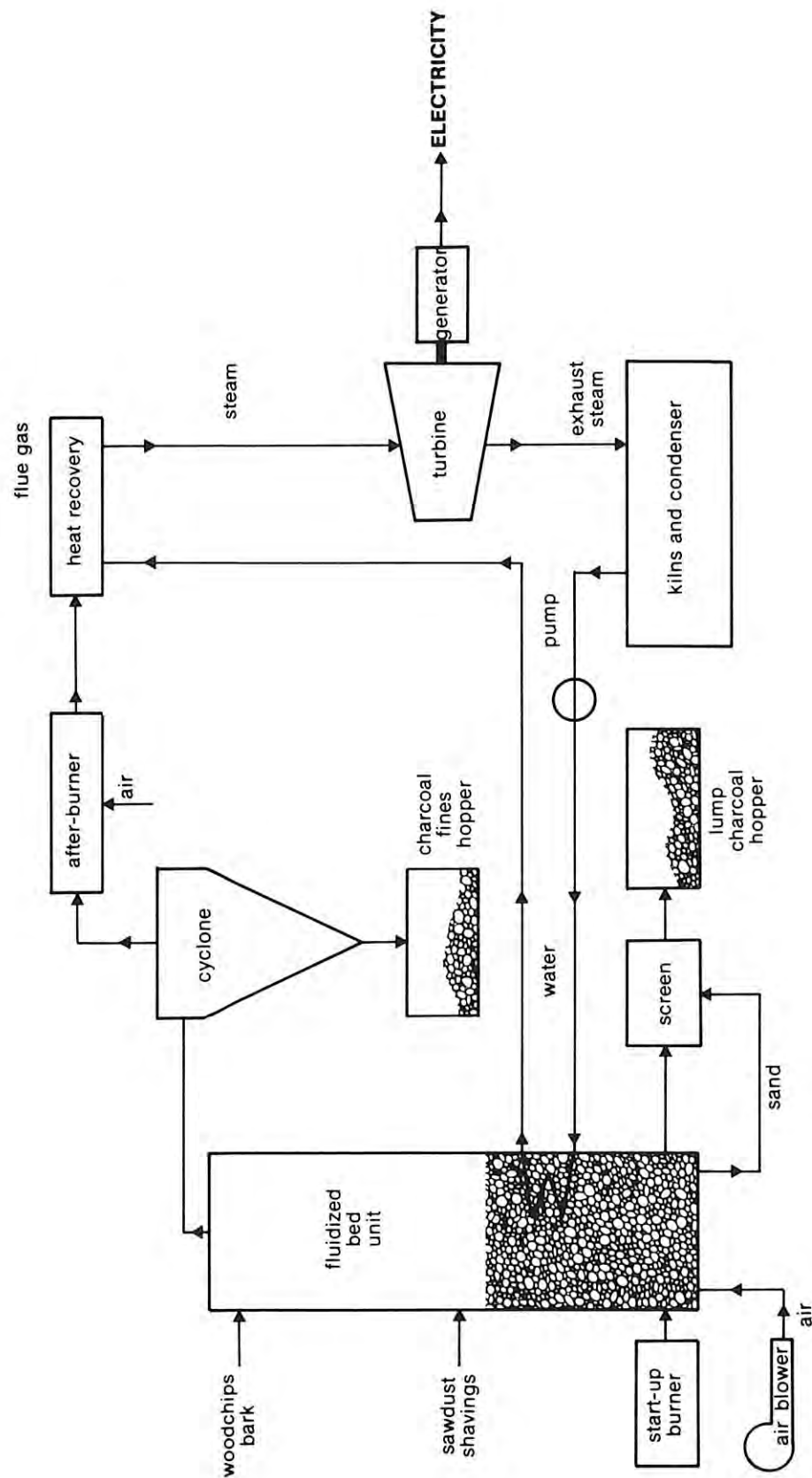


Figure 5.1

A systematic diagram of the CSIRO's fluidised bed carbonisation unit for charcoal production, heat recovery and power generation.

Australia the availability of natural gas from the north-west shelf will restrict the use of charcoal/oil fuels.

5.5.2 Gasification

Charcoal can be converted into low calorific value gas, suitable for stationary or mobile engines, in a simple gas producer similar to those used to power vehicles during war-time petrol rationing (Fung 1981). The charcoal used in gas producer units should have a low volatile content to prevent deposits forming in the engine and should be dense or briquetted to reduce volume (Earl 1975).

If charcoal were inexpensive and readily available it could be used as a transport fuel in place of petroleum fuels. As the price of petroleum fuels continue to increase, the cost of charcoal relative to petroleum fuels may become cheaper. Earl (1975) estimated that a tonne of charcoal is equivalent to 720 L of petrol under normal vehicle running conditions.

5.6 **Increasing the value of charcoal**

5.6.1 Briquetting

Lump charcoal can be powdered and mixed with charcoal fines, together with wood tar or starch (which both act as binders), to form briquettes (Earl 1975).

The advantages of briquetting are:

- (i) low wastage - the total yield of charcoal including dust can be utilised;
- (ii) cheaper transport and storage-briquettes are denser than lump charcoal and therefore have more thermal content per unit volume;
- (iii) burning quality - the burning quality of briquettes can be modified by the addition of substances chosen to suit the consumer, e.g. chemicals to produce rapid ignitable but slow burning properties;
- (iv) briquetting can provide a very good fuel for gas producer units and domestic heating appliances.

The disadvantages of briquetting are:

- (i) the briquetting process is capital intensive, therefore a good market is required to justify the capital invested (Earl 1975).

5.6.2 Activated charcoal

When charcoal is treated with steam or chemicals such as phosphoric acid and zinc chloride, the pores which are normally clogged with condensed volatiles can be opened to form activated charcoal (Fung 1981).

The activated charcoal is highly absorptive of gases and liquids and this makes it a very valuable product. It can be used in herbicidal deactivation in the soil, insecticidal deactivation in mammals, sewage treatment, air purification and water purification (Earl 1975). Activated charcoal is currently used in Western Australia to extract gold from its ore.

In the 1979-80 fiscal year Australian imports of activated charcoal amounted to 1 400 t, worth \$1.8 million at an average value of \$1 350/t (Fung and Liversidge 1981). The demand for activated charcoal has increased over recent years due to strict pollution controls.

If the local charcoal industry recommenced and increased production the amount of imported activated charcoal would decrease, employment opportunities would be generated and a market would be available for jarrah thinnings.

5.7 Other uses of charcoal

5.7.1 Charcoal as a carbon source

The carbon content of charcoal is in the range of 75-96 per cent, and could be utilised as a source of high grade carbon. Two possible uses for such carbon would be as a rubber filler and in carbon electrodes for aluminium production. These two processes currently use carbon black and petroleum coke respectively, both products derived from oil.

The use of charcoal as a substitute for carbon black in the rubber tyre industry is not as promising as utilising charcoal for carbon anodes in aluminium production, because charcoal reinforced rubber is not as strong as carbon black reinforced rubber (Fung and Liversidge 1981).

The outlook in aluminium production is more promising. About 0.5 t of carbon anode is required to produce 1 t of aluminium. The projected aluminium production for Australia is 1.3 million t/year, which would require some 650 000 t/year of carbon anodes (Fung and Liversidge 1981).

5.7.2 Using charcoal as a reducing agent

Approximately 0.5 t of carbon for each tonne of quartzite is required in the processing of quartzite into silicon metal (Fung 1981). Other sources of carbon are available e.g. brown coal, char and petroleum coke, but wood charcoal is preferred for silicon manufacture because of the reduced electricity consumption and its low level of impurities (particularly sulphur and metals with a lower oxidation/reduction potential than silicon) which would contaminate the final product (Fung 1981).

In 1983 the Wundowie charcoal and iron plant, owned by Agnew-Clough, were planning a silicon manufacturing process which would use about 130 000 t/year of fuelwood to produce charcoal as the metal reducing agent. This amount of fuelwood would increase if Wundowie decided to increase their present furnace capacity from two to four

furnaces (W. Pearce⁹, personal communication). Jarrah thinnings could provide the resource for this industry as jarrah charcoal is an excellent reducing agent.

5.8 The Wundowie charcoal and iron plant

The Wundowie charcoal and iron plant operated from 1948 to 1981 and utilised 40 000 to 50 000 t/year of charcoal to manufacture pig iron (Harris 1981). The by-products produced e.g. methanol and acetic acid, were sold in eastern states markets, but competition from chemicals produced from petroleum and high transport costs prevented the expansion of this section of the plant.

The fuelwood used in the manufacture of charcoal was from four main sources. They were:

- (i) sawmilling waste from the Wundowie mill;
- (ii) non-utilisable timber from clearance schemes on agricultural land;
- (iii) non-utilisable timber from operations involving the conversion of indigenous hardwood forest to coniferous plantations;
- (iv) undesirable trees and tops from logging in state forest.

(Earl and Mabonga-Mwisaka 1970)

The species utilised in charcoal production at Wundowie were: jarrah, wandoo (*E. wandoo*), powder bark wandoo (*E. accedens*) and W.A. sheoak. Marri was unsuitable for charcoal manufacture. The wood used to manufacture charcoal was non-millable and came from trees degraded due to fire damage, suppression, malformation or old age. These degraded trees would have remained standing in the forest because their removal would have been uneconomic if they were not used in charcoal manufacture. The charcoal industry provided a silvicultural and protection benefit to the forest by removing trees that impeded the growth of the remaining trees, presented a fire hazard and was a source of infection. If the charcoal/silicon manufacturing industry were operating at Wundowie the non-millable timber from timber production priority areas in the jarrah forest could be utilised and silvicultural benefits would result to the residual stands, as occurred with the charcoal/iron operation. In addition, the reduction in stocking density should result in an increased water yield from the treated forest. In the Perth metropolitan area the demand for water is expected to exceed supply by 50 per cent by the turn of the century (Stoneman 1982). Any increase in water yield from the catchments supplying water to the metropolitan area will be an additional benefit.

9 W. Pearce, Mill Manager, Agnew-Clough, Wundowie.

5.9 Conclusions

- 5.9.1 Charcoal is an almost smokeless, high calorific value fuel which can be manufactured in primitive kilns through to high technological furnaces and fluidised beds. It can be used to form briquettes and activated charcoal. Charcoal can be used in domestic heating and cooking appliances and has many industrial uses.
- 5.9.2 In W.A. two possible industrial uses for charcoal are the refining of silicon at the Wundowie plant and in the manufacture of carbon anodes for aluminium smelting. In the latter case, the charcoal-produced carbon anodes would be competing with carbon anodes derived from petroleum coke. The choice between the two would depend on economic viability, suitability and availability.
- 5.9.3 Using charcoal as an industrial fuel would mean competing with coal, natural gas and oil. Large supplies of coal and natural gas are available in Western Australia, therefore the future of charcoal as an industrial fuel is limited.
- 5.9.4 The development of an activated charcoal industry would decrease the amount imported into Australia, create employment and provide a valuable product to the Western Australian industries. At present large amounts are used in the gold industry.
- 5.9.5 A charcoal industry, in addition to providing social and economic benefits, would provide a market for jarrah thinnings. This would enable a viable silvicultural treatment to be conducted in the jarrah forest to promote sawlog growth. Utilising the thinnings would reduce the amount of fuel available for subsequent prescribed burning and a reduction in stand density should result in increased water yield.

CHAPTER 6

USING JARRAH THINNINGS AS DOMESTIC FUELWOOD

6.1 Introduction

Fuelwood means wood used as a fuel to produce energy. The term firewood is also used by some authors (e.g. Todd 1981a) and has the same meaning.

Wood has been an important source of fuel for nearly a million years. Only since the Industrial Revolution and the rise in the use of fossil fuels, has wood declined in its share of the energy market. However, recent increases in the price of petroleum products and consequent increases in the cost of domestic energy (energy used in the household for cooking and heating), have resulted in a resurgence of interest in wood fuels in Australia (Annandale *et al.* 1983). Thinnings from the jarrah forest are a wood resource that could be used increasingly for domestic energy.

6.2 Domestic fuelwood consumption in Australia

According to the 1976 Australian census, 8 per cent of dwellings in Australia used wood for heating (340 000 dwellings), 5 per cent used wood for cooking (206 000 dwellings), and 5 per cent used wood for heating water (223 000 dwellings). This means that well over one million people in Australia relied on wood for domestic heating or cooking needs (Todd 1983). Todd estimated that an Australian household using fuelwood would require 3 t (air dried) per year for heating purposes, and for combined cooking and water heating 15 t (air dried) per year. This suggests that over 4 million t (air dried) of fuelwood is consumed by the domestic sector of Australia each year.

It is assumed that households in Western Australia using fuelwood would consume the same amounts as the Australian households referred to above.

6.3 Trends in fuelwood use in Western Australia

Based on data from Annandale *et al.* (1983), Table 6.1 compares wood as a domestic energy source (domestic energy sources include wood, electricity, gas, charcoal, oil) between 1976 and 1980, for all the Australian capital cities. The data show domestic use of wood in the Australian cities increased by 17 per cent between 1976 and 1980, with Adelaide, Canberra, Perth and Sydney all showing substantial increases. Perth's use increased by 23.3 per cent. Also in 1980, 32 per cent of Perth's domestic energy was provided by wood. Annandale *et al.* (1983), suggested three possible reasons for the increase in domestic usage of wood in Perth. They are:

- (i) cost of alternative fuels - high and continually rising costs of traditional fuels such as electricity, gas, kerosine and heating oil, with relatively low and steady costs of wood (Fig. 6.1);
- (ii) the availability of wood - the wood supplies far exceed the Perth market requirements;

- (iii) better designed and more efficient wood burning appliances are available for domestic use.

The use of wood (and solar heating) may lead to a substantial degree of independence from non-renewable energy sources with their rapidly increasing costs (Newman 1983). If the present boom in sales of solid fuel heaters continues the demand for fuelwood over the next few years may significantly increase (Todd 1981a). Beyond that, continued increases in demand will depend on whether fuelwood can maintain its present price advantage over competing domestic heating energy sources, and whether a reliable supply can be maintained.

Table 6.1

Wood As A Domestic Energy Source In Australian Cities, 1976-1980

	Adelaide	Brisbane	Canberra	Hobart	Melbourne	Perth	Sydney	Total
Per-capita domestic wood use (GJ) (a) 1980	3.01	0.37	2.12	7.76	1.81	4.18	0.59	2.14
Total domestic wood use (PJ) (b) 1976	2.06	0.36	0.43	1.24	4.39	3.06	1.27	12.81
1980	2.82	0.38	0.52	1.32	4.28	3.77	1.90	14.99
Percentage change 1976-1980	+36.9	+5.6	+20.9	+6.5	-2.5	+23.2	+49.6	+17.0
Wood as a percentage of total domestic energy use in 1980	19	4	11	31	7	32	5	11

(a) GJ = giga joule = 10^9 J
(b) PJ = peta joule = 10^{15} J

Note: Total domestic energy is the sum of the total amount of electricity, gas, heating oil and kerosene, coke, coal and briquettes, and solar energy consumed by all Capital Cities except Darwin.

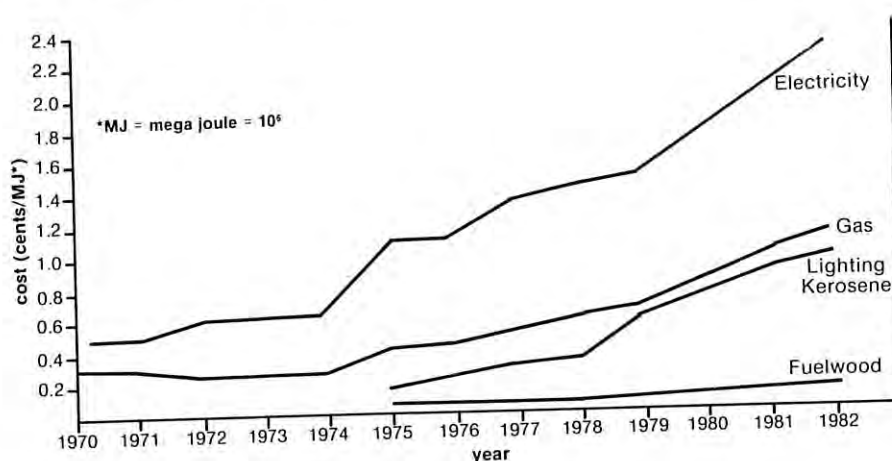


Figure 6.1

Average costs of delivered energy (cents/MJ) to domestic customers in Perth 1970-82. For comparison, the 1982 price of coal (which is little used as a domestic fuel) in Perth was between 0.4 and 0.7 cents/MJ (Annandale *et al* 1983).

6.4 The available supplies of fuelwood to the Perth area

Despite its significant contribution (32 per cent) to the domestic energy supply (Annan-dale *et al.* 1983), wood is rarely considered as a fuel, or included in energy planning forecasts by state energy authorities (Newman *et al.* 1983). This is because it is a decentralised energy source, and most energy authorities are concerned primarily with centralised energy.

The Department of Conservation and Land Management is responsible for managing the wood resource on State forest in Western Australia, and issuing licences for the collection of fuelwood. In 1981, only 14 046 t of firewood was officially collected from State forest by licensed cutters, compared with 200 000 t estimated to have been used by households in Perth (Newman *et al.* 1983). Newman *et al.* (1983) assumed the difference between the two figures would have been collected from millends, urban wood waste, and by individuals without licences collecting from State forest.

The extent of the fuelwood resource for Perth is difficult to quantify, as collectors tend to suggest that there is little market potential for anything that is not dry jarrah without charring or rot.

Newman *et al.* (1983) stated that against the 0.2 million t estimated for Perth's wood consumption, approximate annual quantities of readily available wood within 120 km of Perth consist of:

- (i) 5 million t of dry wood;
- (ii) 6 million t of green wood (unused for timber purposes i.e. tops and unused bolewood);
- (iii) 18 million t of deformed trees and thinnings from the jarrah forest.

In addition there are fuelwood resources available from areas cleared for bauxite mining, from the Forest Improvement Rehabilitation Scheme (FIRS) operations, and thinnings and pruned branches from pine plantations.

The availability of large amounts of fuelwood within 120 km of Perth indicates that fuelwood usage in Perth can expand without utilising timber set aside for higher value products e.g. sawn timber. However, if State forests are to be extensively used for fuelwood, additional management constraints need to be enforced.

6.5 Managing the forest for fuelwood collection

The majority of fuelwood comes from unplanned, unco-ordinated private collection, either from urban waste or State forest (Annan-dale *et al.* 1983). One of the big problems associated with the unplanned, unco-ordinated collection of fuelwood from State forest is the increased potential to spread jarrah dieback (caused by the fungus *Phytophthora cinnamomi*). This fungus can be spread by soil attached to the collector's vehicle, particularly in wet soil conditions. This activity is far more of a threat to the

forest than the damage that could be caused to the forest crop by cutting for domestic fuelwood.

Most fuelwood is collected in winter when the risk of spreading dieback is high. Therefore, efforts should be made to induce operators and private collectors to gather wood in summer from areas of low disease impact. A major problem faced by the Department of Conservation and Land Management is to economically thin overstocked jarrah regrowth stands. Contractors could be employed to thin these stands and utilise the low grade material for fuelwood. The fuelwood could be either taken to Perth for distribution, or extracted to roadside landings for collection by the end-user, although security may be a problem.

The use of contractors would have the advantage of establishing a good relationship between fuelwood collection and forest management. Having a few contractors to deal with, compared with numerous individuals collecting firewood on the weekends, would give forest officers more control and power to implement dieback hygiene policies.

6.6 Promoting a fuelwood industry

To satisfy the demand for fuelwood and to manage the jarrah forest economically, the fuelwood industry needs to be better organised in the Perth area. As wood has a relatively low heat output per volume, it is most sensibly used as near as possible to its point of origin, otherwise the energy required to provide fuelwood for household use would exceed the energy output from the wood (Newman *et al.* 1983). For this reason the industry should be located near both the resource and the market.

Todd (1981a) investigated the Tasmanian fuelwood industry. He found that commercial fuelwood suppliers fall into two main categories: the solid fuel merchants and the small part-time operators. Table 6.2 summarises the costs associated with the small part-time operators, operating on an average 100 km round trip. Fuelwood supplies on this scale of collection were found to be marginally profitable.

The larger-scale fuelwood merchants, supplying 1 000 to 3 000 t per year, can reduce some costs because of the higher volume of wood handled (enabling increased economies of scale), but have additional overhead costs, such as the wood yard and firewood in stock (Todd 1981a).

The following cost structure has been estimated for the larger-scale operators:

-	cutting	\$ 5/t
-	splitting, loading and royalty	\$ 7/t
-	delivery to wood yard	\$ 4/t
-	delivery to household	\$ 5/t
-	overheads and profit	\$11/t
	Total	\$32/t

Table 6.2

Cost Structure of Firewood Supplied by Small Operators in Hobart

OPERATION:

- 1 or 2 person operation.
- cut split, load and deliver 4 t per day per person.
- 100 days operation.
- average round trip 100 km.

COSTS:

4 t load tray truck (about 15 years old) (replace every 5 years)	\$3 000.00
Chainsaw (replace every 3 years)	\$600.00
<u>Cost per tonne of wood:</u>	
Chainsaw operation - fuel, maintenance (including new chain) and depreciation.	\$5.00/t
Truck maintenance and depreciation.	\$4.00/t
Truck registration.	\$0.75/t
Truck running costs (fuel and service).	\$5.00/t
Royalty (private land).	\$1.00/t
Labour cost (\$4/hour, 10-hour day).	\$10.00/t
	\$25.75/t

Fuelwood from these merchants sells for \$30 to \$35 in Hobart, compared to \$20/t to \$30/t for small operations (Todd 1981a). These costs would have increased substantially since 1981. Todd (1981a) stated that

‘the small operator and people cutting their own wood, will not be able to change their mode of operation very much because of the lack of capital. Their ability to stay in the industry will depend on the availability of accessible fuelwood close to urban areas’.

If this is the case in W.A., the small-scale operators may slowly be squeezed out of the fuelwood industry by the larger-scale merchants, as the supply of fuelwood diminishes near the markets. If they are to stay in the industry, they will have to invest in new capital equipment for snagging, loading, splitting and haulage.

As petrol prices rise, the economics of private wood collection will become less obvious and the nearest sections of forest will come under excessive pressure from private collectors (Newman *et al.* 1983). If both the small and large-scale fuelwood merchants could be encouraged to distribute their products from specific collection points, preferably within each local government area, the private collectors would be able to collect their fuelwood from these points. This would release some of the pressure on the forest adjacent to urban areas and would minimise transport costs. This would enhance the overall economics of wood usage, as private collectors would only need to travel to central distribution points. The cost of wood can also be kept low by collec-

tors promoting the use of cheap non-jarrah alternatives, most of which can be collected much closer to the city (Newman *et al.* 1983).

Large-scale fuelwood merchants have the advantage over the small-scale operators and private collectors, by having capital equipment that can extract large and small dead trees to a landing for cutting, splitting and loading. This enables optimum utilisation of available fuelwood. The small-scale operator would only have equipment to extract smaller logs and sections of the larger logs.

The large-scale merchants could be employed to do silvicultural operations and utilise more of the fuelwood resource presently available from areas cleared for bauxite mining. Dieback hygiene policies would be easier to implement, as the Department of Conservation and Land Management would only need to control a few operators compared with a large number of small-scale operators and private collectors. The large-scale merchants could stockpile fuelwood during dry soil conditions and sell this resource during the winter.

One disadvantage of encouraging large-scale merchants or integrating the small-scale operators into large-scale organisations, is that the price of fuelwood would probably increase significantly (Todd 1983). This could be avoided by eliminating excessive administrative barriers, by snagging large dead logs to accessible areas for small operators to collect, and by granting exclusive fuelwood rights to single companies over only small areas of forest (Todd 1983).

Training and employment relief schemes could also promote the fuelwood industry. Unemployed people could be employed to do silvicultural work and at the same time utilise the low grade thinnings for fuelwood.

Another source of wood for the fuelwood industry is from urban wood wastes. At present, most of the 90 000 t of wood waste each year in Perth is burnt or buried at rubbish tip sites (Newman *et al.* 1983). This resource could be used to supplement the fuelwood collected from State forest.

Fuelwood could be converted into charcoal (which has a higher heat content and is cleaner burning than wood), at the centrally located distribution points in each local government area. The charcoal could be sold to the domestic sector as a substitute for fuelwood, or for industrial use.

6.7 The problem of atmospheric pollution from fuelwood combustion

The pollution that stems from using wood fuels must be balanced against the serious problems caused by burning fossil fuels. Coal and petroleum contain sulphur in varying amounts, and when burnt they release it as sulphur dioxide (Smith 1981). Sulphur dioxide (which is a pollutant in its own right) can combine with rain to form dilute sulphurous acid, or can transform in the atmosphere into other potentially dangerous compounds (Tillman 1978).

Tillman (1978) did a chemical and ash analysis on eight different fuelwoods (eight species), and found that the mean sulphur content is 0.013 per cent (by dry weight) and

the mean ash content is 1.12 per cent. These values demonstrate that wood is essentially pollution free, although wood combustion requires some particulate control measures. In Australia, most states rely on the 'National Emission Standard for Air Pollution', developed and revised by the National Health and Medical Research Panel, as a guide in measuring pollutants. However, there are no defined limits on emission from domestic appliances (Annandale *et al.* 1983). If particulate emission from wood-fired domestic appliances is a problem, control devices need to be enforced in the domestic sector. Dr John Todd of the University of Tasmania is presently monitoring particulates and organic compounds in emissions from domestic wood stoves (Todd 1981b).

From the point of view of controlling formation of sulphur dioxide and prohibiting the release of particulate matter, wood is a more desirable fuel than any of the other solid fuels (Tillman 1978). With improved appliances and correct operation, air pollution from domestic fuelwood combustion can be further reduced.

6.8 Conclusions

- 6.8.1 The domestic use of fuelwood in the Perth metropolitan area is increasing. The continued increase in domestic fuelwood use will depend on the availability of fuelwood, and its ability to maintain its present price advantage over other domestic energy sources.
- 6.8.2 Thinnings from the jarrah forest are available to supply the Perth fuelwood market. The low quality thinnings (deformed trees and sub-standard logs) could be used for domestic fuelwood.
- 6.8.3 A fuelwood industry should be encouraged to satisfy this demand. This would have the following advantages over private collections:
 - (i) Contractors could be employed by the Department of Conservation and Land Management to do silvicultural work in the jarrah forest and utilise the low grade thinnings for domestic fuelwood. This would reduce the amount of fuel on the ground when prescribed burning;
 - (ii) By restricting the number of private vehicles entering the forest, the potential to spread dieback is reduced;
 - (iii) Unemployed people could be employed in the collection and distribution of fuelwood;
 - (iv) The State forest adjacent to Perth may become severely exploited for fuelwood as petrol prices increase and the supplies of fuelwood get further from Perth. This practice would affect the condition of the forest in these areas. A fuelwood industry may encourage the private collector to buy fuelwood from operators within the industry;

- (v) The net energy of fuelwood (the difference between the energy produced in heating or cooking, and the energy involved in fuelwood collection) may be enhanced if an industry were developed.
- 6.8.3 The fuelwood industry should have a number of operators because with a small number of large-scale merchants, the price of fuelwood may increase significantly. However, the number of operators should be maintained at a level which can be effectively managed by the Department of Conservation and Land Management.
- 6.8.4 Fuelwood can be further upgraded to charcoal (a higher energy fuel), and used by the domestic sector or by other industries e.g. the iron and steel industry or the aluminium industry.
- 6.8.5 Further study is required to determine the amount of particulate emission from wood combustion, and then after establishing the amount of emission, develop the necessary regulations for burning wood.

CHAPTER 7

RECONSTITUTED WOOD AND TIMBER JOINTED PRODUCTS

7.1 Introduction

The main uses of eucalypts in Australia for reconstituted wood products are concentrated primarily in the hardboard industry, with smaller amounts used in plywood and particleboard (MacMillan 1978). From these three basic products, different varieties and innovations can be developed. Some of the reconstituted wood products that can be produced include: hardboard, softboard, medium density fibreboard, particleboard, wood-composite products, Scrimber, plywood and parallel laminated veneer.

End jointing and edge jointing facilities are available to lengthen or widen sawn timber and to exclude timber defects.

The types of reconstituted wood products and timber joining processes available, and their application to using small diameter eucalypts, particularly jarrah, as the raw material are outlined below.

7.2 Fibreboard

The process involved in manufacturing fibreboard is basically the reduction of wood to its individual fibres, followed by a reconstitution into flat sheets. The sheets are sometimes left uncompressed to form fibre insulating board (softboard), or else compressed to form hardboard (Raynham 1970). The type of raw materials for fibreboard manufacture are less critical than that for particleboard. For example, more bark can be tolerated in fibreboard.

7.2.1 Hardboard

Hardboard is a panel product manufactured from interfelted ligno-cellulosic fibres, which are consolidated under heat and pressure in a hot press to a density from 500 kg/m³ to 1 000 kg/m³ (standard hardboard has a density of between 800 to 1 000 kg/m³) (Wilcock and Lyngcoln 1983). Other materials may be added to improve properties such as stiffness, hardness, resistance to abrasion and moisture, as well as to increase strength, durability and utility. The addition of adhesives is not necessary, because the ligno-cellulosic material is consolidated under heat and pressure.

The raw material for hardboard manufacture is converted into chips, which are either heated with steam and ground up in an Asplund defibrator, or heated under pressure and disintegrated by blowing them through a Mason gun. The former process is called the Defibrator process and the latter the Mason process (MacMillan 1978).

Following the initial fibre separation, the suspension of fibres is passed through refiners to achieve a particular distribution of size of fibre and fibre bundles. The water in suspension is removed by suction. Then the formed bed is cut into desired

lengths and stacked in a multi-opening hot press to complete the bonding process (Bootle 1983).

The hardboard industry has developed the ability to utilise material that otherwise would have little or no commercial value. In Australia this raw material is derived from eucalypt fibre, from either forest thinnings or sawmill residues (MacMillan 1978). One mill in Australia has used plantation grown *Eucalyptus grandis*, *E. saligna*, *E. pilularis* and *E. cloeziana*. In South Africa and Brazil, hardboard producers use predominantly 8-10 year old *E. grandis* and *E. saligna*.

MacMillan (1978) believes that forest thinnings and sawmill residues will continue to provide the bulk of the wood fibre for hardboard mills in Australia at least in the near future. Thinnings from the jarrah forest are a wood resource that could be utilised for hardboard manufacture in the future.

Hardboard can be manufactured into many different forms and some of the end uses of hardboard include: pre-finished panelling, sheet floor underlay, cladding, door facings, perforated display boards, eave linings, television cabinet backs, automotive components, concrete framework and roof shingles (Bootle 1983).

7.2.2 Softboard (low density fibreboard)

'Softboard' or 'Insulation board' is in most cases made from pine, and notably *Pinus radiata* in Australia (MacMillan 1978). This type of fibreboard is made by a wet-forming process, followed by drying in a multi-deck dryer. No heat or pressure is used for consolidation (Bootle 1983).

There have been only minor uses made of eucalypts in softboard manufacture in Australia, and then only to make a specific product (MacMillan 1978). Overseas, notably in South Africa and Brazil, eucalypts are used to manufacture softboard. In Australia the technology is available to use eucalypts, but MacMillan (1978), believes there is no cost advantage in using eucalypts, compared with *P. radiata*.

Lower density softboard can be used for ceiling tiles and higher density softboard for structural insulation board for under-sidings in frame construction (Haygreen and Bowyer 1982).

7.2.3 Medium-density fibreboard (M.D.F.)

Medium-density fibreboard (M.D.F.) is similar to both hardboard and particleboard. Like hardboard, M.D.F. is made from wood fibre, but the fibres are bonded together with resin or adhesive, thus resembling the manufacture of particleboard (Haygreen and Bowyer 1982). The adhesive used in M.D.F. manufacture is usually urea formaldehyde, however, in structural applications phenolic or tannin based binders are used (Wilcock and Lyngcoln 1983).

The most significant use of M.D.F. is in furniture manufacture, where it is used in much the same way as particleboard. Some of the advantages of M.D.F. over particleboard are:

- (i) M.D.F. can hold screws intact;
- (ii) M.D.F. has increased internal bonding strength and modulus of rupture;
- (iii) M.D.F. can be machined almost like solid wood, eliminating the need for the edge banding, often necessary if particleboard is machined.

The raw material for fibreboard can come from eucalypts or radiata pine. Pine M.D.F. produces very smooth surfaces and is easy to work, therefore it is the preferred raw material. With the ready availability of pine thinnings in Australia, the pine resource is likely to continue to be used to manufacture M.D.F.

7.3 Particleboard

Particleboard is a panel product made from relatively large particles, instead of fibres, and is dependent for its strength and durability on the type and quantity of adhesive used to bond the particles (Bootle 1983). There are many types of particleboard, which differ in the size and geometry of the particle, the amount of adhesive used, and the density to which the panel is pressed. The properties and potential uses of particleboard differ with these variables.

7.3.1 The manufacture of particleboard

The manufacturing process of particleboard involves the drying of particles to a pre-determined and uniform moisture content and then screening to remove oversized and fine particles. The particles are then blended with a calculated amount of adhesive (urea, phenol or tannin formaldehyde) and other additives, and in a flat press process are formed into a mat which is bonded under heat (150-160°C) and pressure (MacMillan 1978). Most of the particleboard currently produced has a layered structure, consisting of particles of different size and shape, which is designed to give better properties.

7.3.2 The raw material for particleboard

The traditional raw material for Australian particleboard manufacturers has been the wood of exotic *Pinus* species, particularly *P. radiata*. Several attempts have been made, with varying degrees of success, to produce boards either partly or entirely from the available eucalypt species (MacMillan 1978). Eucalypt raw material produces flakes of inferior form compared with pines. In addition, the production of small-sized material ('fines'), at both the green and dry stages of processing, is markedly higher than with pine wood and hence recovery is lower (MacMillan 1978).

In Western Australia there are large volumes of pine thinnings readily available for particleboard manufacture, and there are increasing volumes of pine sawmill residue becoming available. It is very unlikely that jarrah thinnings would be used to manufacture this product.

7.4 Wood composite products

Wood composite products are produced from a combination of veneer and particleboard, often called 'Comply' (Haygreen and Bowyer 1982). Comply can be used to manufacture panel products and framing timbers. The veneer component is used for the surface layers of a panel (edges or faces), where bending stresses are greatest, whereas the particleboard component is used in the core where bending stresses are lower, but where maximum shear occurs. The veneer surface also limits dimensional changes that may be caused by changes in equilibrium moisture content (e.m.c.).

Composite products were developed in the U.S.A. to more efficiently utilise small-diameter softwood logs. This was achieved by cutting veneers from the outer portion of the logs, and using the inner portions and logging and mill residues for the particleboard core (Blomquist *et al.* 1975). This process is expected to use half as many trees to produce a given number of studs, compared with conventional sawmilling practice.

Although softwoods are generally used to manufacture Comply, particleboard cores could be made from low-grade hardwoods that are not being fully utilised, and the edge strips could be made from hardwood veneers (Blomquist *et al.* 1975). A disadvantage with using dense hardwoods is that the weight of the stud would be increased. The combination of hardwood veneer with softwood particleboard cores is another possibility.

The trials with Comply-studs have been active in the U.S.A. for more than a decade, but Comply has not yet reached commercial fruition (Coleman 1981). Until this product has been fully developed in the U.S.A., it is unlikely that Australian companies will venture into manufacturing Comply. Other reasons for Australia not producing wood composite products in the short term are:

- (i) lack of availability of suitable low cost raw material;
- (ii) wood composite products are unlikely to compete with plywood or particleboard, which has a superior performance/cost ratio (Wilcock and Lyngcoln 1983).

7.5 Other wood composite products

7.5.1 Wood-cement products

Mineral binders e.g. cement, are used in several types of wood-based particle products. One of these products is the porous low-density product called wood excelsior (wood-wool) boards (Haygreen and Bowyer 1982). Wood-wool boards are about one-quarter to one-third wood by weight, the remainder being cement or other mineral binders.

Cement-bonded particleboard has excellent resistance to decay, insect attack and fire. This makes it well suited for both interior and exterior wall surfaces and decking for public and commercial buildings (Haygreen and Bowyer 1982). Wood cement products are difficult to cut and fasten compared with plywood and this may deter its continued use.

The selection of the species as raw material for this product is extremely important, because some wood sugars and extractives can retard or inhibit the curing of the cement (Haygreen and Bowyer 1982). If wood-cement products are to be produced from jarrah, the effect of the extractives on curing the cement needs to be closely examined.

7.5.2 Wood fibres to replace asbestos fibres in cement sheet products

Flat and corrugated cement sheet products have in the past been reinforced with asbestos fibre (CSIRO 1981). The future of asbestos fibres in building materials is uncertain, due to the health risks associated with their use, and their increased production cost.

The CSIRO's Division of Forestry and Forest Products has investigated the use of wood fibres to substitute completely for the asbestos fibres in cement sheet products (since the 1960's cellulosic fibres have been used in asbestos fibre.) The Division had experienced significant problems with chemical bonding between the wood fibre and the cement matrix when only wood fibres are used. They studied the use of chemical coupling agents to enhance the chemical bonding between the wood fibre and the matrix (CSIRO 1981). Two wood fibre cement products, Hardiflex II and Hardiplank II, have been manufactured by James Hardie and Co. Pty Ltd. In these two products the wood-fibre is refined mechanically before it is combined with the matrix and this improves the mechanical properties.

On health grounds alone, wood fibre-cement products are an improvement on asbestos-cement products, therefore the development of wood fibre-cement products should be encouraged.

7.5.3 Structural particleboard - reinforced with glass fibre

Particleboard has a relatively weak flexible bending strength (Saucier and Holman 1975). This product can be incorporated with strands of high tensile strength, e.g. glass fibre or aluminium wire, to increase its strength. By increasing the strength of particleboard, this product will have a wider range of uses, particularly in construction work.

Reinforced particleboard has been developed in the U.S.A., where a number of species and particle sizes have been tested. The development and promotion of this product in Australia will depend on its cost/performance criteria compared with plywood and other structural reconstituted products.

7.6 'Scrimber' process

In the Scrimber process, slender wood stems are crushed and rendered to a point where the resulting mass of inter-connected strands can be conveniently dried. Then a resin is applied before collating and pressing to a final form (Coleman 1981). The raw materials used are long slender stems, (stems 8 to 16 cm in diameter are readily processed), preferably of equal length to the final product. This produces zero 'grain' angle and minimises the presence of air pockets in the product. The wood resource used in the Scrimber process could be harvested from coppice, or thinnings could be

utilised. Most eucalypts will respond to scrimming, although some may be too soft e.g. *E. globulus*. Both jarrah and marri have been successfully processed in trials of the Scrimber process (P. Shedley¹⁰, personal communication).

7.6.1 The properties and characteristics of Scrimber

Coleman (1981) outlined some of the properties and characteristics of Scrimber as follows:

- (i) imperfections which would otherwise prevent the attainment of specific strength values in commercial timber are diminished and randomised during processing, and it is possible to achieve some 70 per cent of the bending strength of clear quality mature parent timber;
- (ii) full size structural sections have been tested and given excellent stiffness and good compression properties. The resin bond strength is greater than required and failure occurs by tensile fracture of the wood strands;
- (iii) the surface finish and density are determined by strand size, forming pressure and wood species;
- (iv) Scrimber can be sawn, planed and sanded with standard machinery and will retain fastenings strongly. For all intents, the structure responds in the same manner as if part of the parent stemwood;
- (v) fillers, colours and chemicals, such as fire retardants or fungicides can be incorporated into Scrimber during manufacture;
- (vi) satisfactory means of reducing the wood stem to a stranded 'scrim' form in commercial quantities have been developed, and the reconsolidation process has been demonstrated to be workable to the prototype stage, producing finished 200 x 80 mm sections.

The South Australian Timber Corporation now holds the franchise for the Scrimber process, using it with radiata pine. However, the scope of the Scrimber process to produce structural and speciality products is enormous and the process would be able to utilise low grade thinnings from native eucalypt forests.

7.7 Plywood

Plywood is defined as a panel consisting of an assembly of veneers, bonded together with the grain in most of the alternative plies at right angles to each other (Wilcock and Lyngcoln 1983).

10 P. Shedley, Department of Conservation and Land Management, Como.

Plywood is manufactured from veneers which are either rotary peeled or sliced from flitches. In Western Australia, jarrah is sliced from flitches. The veneers are then dried, edge-glued and taped together in sheets of the required size, coated with adhesive, then assembled to provide the required thickness and pressed in large heated hydraulic presses. The plywood sheets are trimmed to size, sanded and then distributed to the end-user (Bootle 1983).

A small proportion, less than 10 per cent of the Australian plywood production, is from eucalypts derived from mature native forests. The majority of eucalypt plywood is a structural grade, which shows significant strength advantages over similar grades of softwood plywood. Furniture grade veneers can be made from some species (MacMillan 1978).

The manufacture of eucalypt plywood is very difficult. The main characteristics of eucalypts that make them difficult to handle are:

- (i) relatively high density and high undried moisture contents, which cause glueing and peeling problems;
- (ii) free splitting of log ends on cross cutting;
- (iii) susceptibility to collapse during drying, which adversely affects veneer quality and yield;
- (iv) drying degradation results in face checking, buckling, curling of long edges, splitting and irregularities in thickness.

(MacMillan 1978).

These problems are often more severe in regrowth and plantation grown eucalypts, which have pronounced growth stresses. A study was done on the suitability of regrowth *E. regnans* for veneer and plywood manufacture, and it showed a relatively low recovery due to high shrinkage losses and a prevalence of end splits and kino defects (MacMillan 1978). The storage of veneer log and flitches under water, or subjecting them to heat treatments may reduce some of these problems.

7.7.1 Jarrah veneer trials

In 1980 a jarrah veneer trial was undertaken between the Forests Department and Wesply (now Wesfi), with the aim of producing high value veneer products from regrowth jarrah trees. Some of the conclusions were:

- (i) quality of 'log veneer' was not significantly different from the veneer produced from mature flitches. This was despite the fact that 'log veneer' involved slicing across the heartwood and in some cases close to the pith.
- (ii) recovery of veneer from veneer logs is strongly related to log size, therefore any log less than 30 cm diameter was considered uneconomical to slice and was rejected from the trial. In earlier trials, logs ranging from 15 to 30 cm

diameter were processed. Some of these logs gave recoveries greater than 30 per cent.

- (iii) presence of large amounts of sapwood in regrowth logs reduced recoveries.
- (iv) processing of small logs for veneer involves additional expenditure, principally because of the extra handling involved.
- (v) additional 'waste' produced by slicing small logs may be utilised for energy production at the plywood mill.
- (vi) veneer logs need to be of good quality and have a straight bole.

(Shea 1980).

Plywood is a high value product that has many uses both structurally and for decorative purposes. Although eucalypts are very difficult to use in plywood manufacture, they have significant advantages over softwood plywood. The development of plywood and veneer products from both regrowth and mature jarrah trees should be encouraged. This would enable high grade products to be manufactured from the jarrah.

7.8 Glue-laminated products

Timber of large cross-sections, as required for large spans, has the disadvantage that such material is very slow to dry and thus expensive to obtain in the seasoned state. There is also the difficulty of obtaining it in long lengths (Bootle 1983). The use of seasoned small sections, end jointed and glued together in layers or laminae can overcome this problem.

Glue-laminated beams are constructed from laminae, dried to a moisture content of 8-12 per cent, and glued with a waterproof glue e.g. resorcinol formaldehyde. The end joints are staggered within the bonded member to prevent a concentration of stress. The glue is cured under controlled conditions, and the beam can be formed in a jig to produce camber. Material of lower quality can be used for the inner laminae without affecting the strength of the beam (Bootle 1983).

While glue-laminated construction has been used to a considerable extent overseas, it has not made much progress in Australia, except for window heads, stair treads and exposed decorative beams (Bootle 1983). MacMillan (1978) reports of high-quality glue-laminated products made from finger-jointed short lengths of sawn material from fast grown *E. grandis* and *E. saligna*. Seasoned timber from regrowth jarrah trees may be used in the construction of glue laminated products.

7.9 End jointing timber

Both glue jointing and nail plates can be employed to fasten timber ends together. The type of glue joints available are butt joints, scarf joints and finger joints. Numerous types of nail plates are available to join timber. Timber jointing can be used to exclude defective sections in a length of timber and re-join the pieces of clear wood, or to lengthen short pieces of timber.

7.9.1 Glue joints

Butt jointing involves glueing squared ends of two pieces of timber. This joint has a strength of less than 10 per cent of that of clear wood, therefore it is excluded from structural uses (Bootle 1983).

Where strength is required, the overlapping scarf joint is favoured, but this joint results in considerable wastage of timber (Bootle 1983). The flatter the slope of the scarf the stronger the joint e.g. a slope of 1 in 12 could give a joint strength of 85-90 per cent that of clear timber.

Finger joints are a form of interlocking wedge, and intermediate between scarf and butt joints in strength (Bootle 1983). Jekerst (1981) stated, 'there are no practical economic alternatives to finger joints for jointing wood end grain to end grain'. Finger joints are not restricted to end-grain bonding, but may be used for other types of joints.

7.9.2 Nail plates

Nail plates are rectangular plates of galvanised steel, usually with prongs extending from the plate (toothed plate connectors) or plates with holes for nails (gusset plates) (Bootle 1983). A wide range of sizes is available and most are commonly used to fasten roof truss components together.

7.10 **Edge jointing timber**

A system in the U.S.A. called EGAR (Edge Glue and Rip) was developed in recognition of the fact that much of the available timber consists of second growth small diameter trees that are inherently low in lumber recovery, and yield limited quantities of wide boards (Williston 1981).

The EGAR process involved live-sawing the log to a desired dimension, drying the un-edged flitches, edging to the maximum width obtainable, and edge-glueing to produce a wide panel. This panel in turn is ripped to the desired standard widths and then planed (Williston 1981).

Some of the advantages of EGAR are:

- (i) it can produce wide boards from small sawlogs;
- (ii) it can improve dimensional stability;
- (iii) it can be adapted to a combination of end and edge glueing operations, thus providing complete width and length flexibility.

7.11 **Laminated veneer lumber (L.V.L.) products**

Lyngcoln (1987) discussed manufacture of laminated veneer lumber (L.V.L.) from pine in Australia. L.V.L. is manufactured in a similar manner to plywood, but the veneer lamination is parallel, compared to plywood cross grain lamination. Low grade

logs can be reconstituted into L.V.L. with knots, knot holes and other defects dispersed between the different plies of veneer, thus upgrading product quality.

Tests and structural applications have shown that the product is a compatible substitute for stress-rated solid sawn timber.

The United States Forest Products Laboratory had been interested for some time in the production of a similar product, referred to as parallel-laminated veneer (P.L.V.) for sawing by conventional means to commercial sizes (Coleman 1981). Both 'Presslam' and 'Microlam' are P.L.V. products.

Some of the products produced from P.L.V. are: structural framing, purlins, scaffold planking, cross arms, railroad sleepers, ladder rails and pallet stock (Harpole 1976).

L.V.L., like plywood, is difficult to manufacture from small diameter eucalypts and a pine raw material is more suitable.

7.12 Conclusions

- 7.12.1 There are many reconstituted wood products presently available. Research is continuing in Australia and overseas to develop new and to refine existing products.
- 7.12.2 A number of reconstituted wood products can use both eucalypts and pine as the raw material. However, pine is often preferred because of its availability, ease of reconstituting and the quality of the final product.
- 7.12.3 Hardboard in Australia utilises low grade thinnings and forest residues from native forests. Hardboard has been successfully manufactured from plantation grown eucalypts, both in Australia and overseas. This product may be manufactured from low grade jarrah thinning, and if suitable, jarrah hardboard could compete with similar products.
- 7.12.4 Plywood and veneers can be used for structural and decorative purposes. Both products are of a high value and their promotion should be encouraged.
- 7.12.5 Small jarrah veneer logs are difficult and often uneconomical to slice. A trial in 1980 established that veneer logs greater than 30 cm diameter could be economically sliced into veneer for plywood and decorative products.
- 7.12.6 The Scrimber process and the use of wood fibre to replace asbestos fibre in cement sheet products are being developed by the CSIRO. These products can utilise low grade eucalypt thinnings.
- 7.12.7 Both jarrah and marri have been successfully reconstituted into Scrimber, and if the Scrimber process were commercially implemented in Western Australia, thinnings from the jarrah forest could provide the raw material.

- 7.12.8 The use of end jointing and edge jointing facilities provides complete width and length flexibility. The edge glue and rip mills in the U.S.A. can increase the width of sawn timber from second growth small diameter trees. Both glue-ing and nail plate end jointing facilities are available in Australia.
- 7.12.9 Finger jointed pieces of timber can be used to form high value glue laminated products, e.g. laminated exposed beams. Sawn timber from regrowth jarrah trees could be utilised in the manufacture of glue laminated products.

CHAPTER 8

FOREST AND MILL RESIDUES AS A SOURCE OF CHEMICALS AND ENERGY

8.1 Introduction

The recent jump in the price of petroleum has increased the public's awareness of the finite nature of this resource and its importance to the economy (Hillis 1978b). Oil not only provides huge quantities of fuel that are indispensable for transport, but also the raw material for a vast chemical industry which manufactures a wide range of materials in common use.

With the realisation of the limited nature of crude oil stocks, interest has quickened in the value of renewable resources. Attention has been given to the possibility that the forest could provide some of the chemicals and fuels that are presently derived from petroleum (Hillis 1978b). In Australia this concern is exemplified by the development of national and state energy advisory bodies, and the expansion of petroleum, gas and coal exploration programs (Payne 1983).

This chapter will review the uses of chemicals and energy derived from forest and mill residues and their possible future uses in the Australian economy.

8.2 The chemical composition of woody plants

Woody plant material is composed of three main polymers: cellulose, hemicellulose and lignin. Other components which are more variable in structure or quantity are: extractives (the soluble compounds which are often species or genus-specific) and bark (Goldstein 1981). The woods of eucalypts have been reported to contain 40-62 per cent cellulose, 12-22 per cent hemicellulose and 15-22 per cent lignin (Hillis 1978a). The extractives content in eucalypts is strongly dependent on the species and the age of the tree. It is not unusual for old eucalypt trees to contain over 20 per cent of material that can be extracted with dilute alkali (Higgins H.G. 1978).

Most of the extractives in eucalypts are found in the heartwood and are composed of phenolic compounds, that is ellagic acid, gallic acid and ellagitannins, gallotannins, flavonoids and their polymers (Higgins H.G. 1978). The extractives from jarrah wood are mostly polyphenolic and account for about 40 per cent of the dry wood weight (Fallick 1981).

The composition of the leaf oils of eucalypts varies widely between groups of species (Hillis 1978b). The leaves of fewer than 20 eucalypt species provide the raw material for the commercial production of essential oils. The principal compounds used commercially are cineole, citronellol, piperitone and phellandrene, derived from *Eucalyptus globulus*, *E. citriodora*, *E. dives* and *E. elata* respectively (Hillis 1978b).

8.3 Some of the uses of wood chemicals

Because of the complex carbohydrate-lignin structure of wood severe reaction conditions are required to reduce it to simple chemicals such as: formaldehyde, furfural, phenols, ethanol and methanol (Maloney 1978). The production costs of these chemicals are directly related to the scale and complexity of the operation, and the cost of the raw material. The production of these chemicals from wood is a more complex process, compared with producing the same chemicals from a petro-chemical feedstock (Goldstein 1981).

8.3.1 Formaldehyde

The largest single use of formaldehyde is in urea-formaldehyde resins, used in the manufacture of plywood and particleboard (Maloney 1978). Formaldehyde is also the base for other thermosetting adhesives e.g. melamine formaldehyde and phenol formaldehyde (Bootle 1983).

8.3.2 Furfural

Furfural is a unique five membered organic ring compound, derived from pentose sugars, which can be obtained from the hemicellulose in hardwoods. Attempts have been made to produce furfural from eucalypt residues, but an economically viable process has not been developed (Hillis 1978b). Furfural is used in solvent refining of petroleum oils as an industrial solvent, for resin production, and as the starting point for the synthesis of the furan chemicals (Maloney 1978).

8.3.3 Phenols

Phenols are important chemicals used in the formation of synthetic resins, for the plywood and particleboard industries, and are mainly derived from petro-chemicals (Maloney 1978). Considerable potential exists for the polyphenols derived from the bark of *Acacia* spp., *Pinus radiata* and the wood of *Schinopsis lorentzii*, to be used for manufacturing wood adhesives (Hillis 1978b).

The bark of *E. astringens* and *E. sideroxylon* contain large amounts of tannins or polyphenols, but the constitution of the polyphenols in the bark and wood of those species is not suitable for the production of adhesives by current methods. It is likely these polyphenols will only act as extenders for phenol-formaldehyde adhesives. However, the wood extractives from jarrah, which are primarily complex polyphenols, could be used as extenders for phenol-formaldehyde adhesives (Fallick 1981).

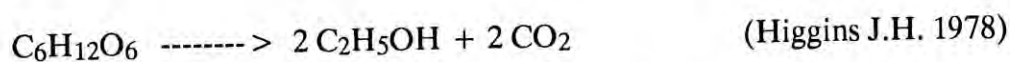
8.3.4 Essential leaf oils

The essential leaf oils of some eucalypts have commercial uses in medicine, perfumery and for industrial purposes (Hillis 1978b). For example, cineole from *E. globulus* is used in the medical field and has potential as a useful chemical intermediate. The cineole component of jarrah leaves (3.7 per cent) is considerably less than that of *E. globulus* (75 per cent), therefore it is unlikely to compete with *E. globulus* for the supply of cineole (Fallick 1981).

8.3.5 Ethanol production

Ethanol is produced by either severe acid hydrolysis of hogged or chipped wood, or by enzymatic hydrolysis of pulverised wood. These two processes convert the carbohydrate present in the wood into sugars (Maloney 1978). Both C₆ and C₅ sugars are formed but the latter cannot be fermented to ethanol.

The equation for the production of ethanol is:



The sugars generated by hydrolysis of the carbohydrate can be processed into products such as molasses for animal feed, yeast polyols (glycols) and ethanol (Maloney 1978). The lignin residue from the acid hydrolysis can be used as a fuel or converted into phenols. The yield of ethanol is dependent on the wood species, but from available data it is expected to be in the range of 230 to 320 kg/t (dry weight) of wood (Stewart *et al.* 1979).

8.3.6 The market potential for ethanol

Ethanol has been used in the past as a substitute or as an extender for petrol. During the 1920s and 1930s, many countries required the use of alcohol in blends varying up to 30 per cent with petrol (Higgins J.H. 1978). In Brazil motor vehicles are fueled by a blend of 85 per cent petrol/15 per cent ethanol. The ethanol in this case comes primarily from the sugarcane industry, with only modest amounts being produced from wood and wood residues (Tillman 1978).

Equipment for wood hydrolysis has been built only during exceptional economic circumstances. The Rheinau plant in Germany was operating in 1960 and produced specialty wood-sugars (Stewart *et al.* 1979). The cost of extracting ethanol from wood, using the Rheinau process, is estimated to be \$650/t (ethanol) (Table 8.1). This estimate is about twice the estimated cost of producing methanol from wood (Table 8.2), and is based on unpublished studies originally conducted by CSIRO, for the production of fermentable sugars from kenaf (Stewart *et al.* 1979).

Siemon (1975) undertook a major study of the potential for ethanol production from wood in Australia. He concluded that 13 million ha of plantation timber would provide half of Australia's projected liquid fuel requirements in the year 2000. Land, agronomic requirements and technology are all available, but costs are prohibitive and not competitive with other options, such as oil from coal.

There are a number of factors limiting the viability of producing ethanol from wood, to supply Australia with liquid transport fuels.

Table 8.1

Estimated Cost of Ethanol Production from Wood

Plant capacity:	115 000 t/yr of ethanol = 3.37 PJ/yr.
Days operating/year:	330
Employment/plant:	227 man-years/yr
Fixed capital cost:	\$106 million
Working Capital:	\$12 million

	\$/t ethanol	
<u>Raw Material</u>		
Wood (@ \$40/t (DW))		
- as feedstock (3.64 t (DW))	146	
- as fuel (4.8 t (DW))	<u>194</u>	340
<u>Operating Costs</u>		
Other supplies	15	
Other utilities	14	
Labour (Including supervision)	8	
Maintenance	63	
Overheads	<u>8</u>	108
Capital charges @ 20%/yr.		<u>205</u>
TOTAL		653
1 t ethanol	= 1 267 L ethanol	
Gross calorific value ethanol	= 29.3 GJ/t	
D.W.	= Dry Weight	

These include:

- (i) cost of land, fertilizer and the protection necessary to maintain production on a 13 million ha timber plantation would be very high, considering Australia has an abundance of low priced coal (Hillis 1978b).
- (ii) there is a high energy and capital cost needed for the chemical disruption of the cellulose-lignin complex to produce ethanol from wood. Although considerable progress has been made in enzymatic and modified hydrolysis methods, it is unlikely that this will lead to ethanol from wood becoming competitive with other fuel options (Payne 1983).
- (iii) estimated cost of ethanol from wood is about twice the estimated cost of producing methanol from wood (Stewart *et al.* 1979).
- (iv) liquid fuels can be obtained at a lower price by liquidification of natural gas and coal (Payne 1983).

Table 8.2

Estimated Cost of Producing Methanol from Pre-dried Wood Using Electricity

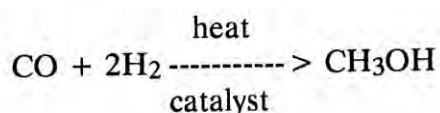
Plant capacity:	100 000 t/yr of methanol = 2.24 PJ/yr.	
Days operating/yr.:	330	
Employment/plant:	248 man-years/yr	
Fixed capital cost:	\$47.6 million	
Working capital:	\$5.0 million	
		\$/t methanol
<u>Raw Material</u>		
- feedstock (2.2 t (DW))	88	
- fuel (4.8 t (DW))	<u>16</u>	104
<u>Operating Costs</u>		
Supplies	15	
Labour	25	
Maintenance	28	
Power	<u>16</u>	77
Capital charges @ 20%/yr.		<u>105</u>
TOTAL		<u>286</u>

1 t methanol = 1 265 L methanol
 Gross calorific value methanol = 22.4 GJ/t
 D.W. = Dry Weight

With Western Australia having large reserves of coal and natural gas, it is unlikely that ethanol will be derived from wood or wood residues in the next few decades. Also, liquid fuels produced from wood residues appear unlikely to become competitive with other biomass-derived liquid fuels (Payne 1983).

8.3.7 Methanol production

Methanol production is an extension of oxygen-blown gasification, where the synthesis gas produced in wood gasification is purified and adjusted to a volumetric H₂/CO ratio of 2:1. Then in the presence of heat and a catalyst such as zinc oxide or a mixture of catalysts, the endothermic reaction



is carried out (Tillman 1978).

The hydrogen and carbon monoxide mixture, commonly known as synthesis gas or syn-gas, can be obtained from a number of sources, such as natural gas, oil, coal, coke, garbage and wood waste (Maloney 1978).

Numerous advantages are achieved by using wood in the preparation of synthesis gas. These include:

- (i) a relatively high H_2/CO ratio in the wood gas;
- (ii) the low desulphurisation costs in purifying the wood gas;
- (iii) reduced risk of catalyst poisoning due to the low sulphur content of wood (Tillman 1978).

Despite these advantages the energy efficiency (energy output, including by-products, divided by energy input) is in the range of 34-37 per cent.

Stewart *et al.* (1979) consulted a number of studies to arrive at a 'best estimate' for the cost of producing methanol from wood. They estimated the cost of producing methanol from wood (including pre-drying) as \$286/t (methanol) for a plant of 100 000 t/yr output capacity. A drop of \$50/t methanol could be obtained with five-fold increase in production. However, this would increase raw material costs because the transport distance was likely to increase.

The net production of methanol is estimated to be 284 L/t (dryweight) of wood or 5.0 GJ/t (dryweight) of wood (the major energy input, apart from biomass, is electricity, needed for oxygen production (Stewart *et al.* 1979)). The net production of ethanols is estimated to be 80 L/t (dryweight) or 1.85 GJ/t (dryweight) of wood.

Wood can possibly be used in conjunction with natural gas as a co-feedstock to produce methanol (Payne 1983). In this process the natural gas produces hydrogen rich gases, while the wood produces a large quantity of carbon oxides. The combination of both streams in the appropriate quantities avoids a wasteful intermediate reaction. Similar advantages would be seen by combining a gas and a coal co-feedstock (Payne 1983).

Methanol can be used in blends up to 15 per cent as a petrol extender, but ethanol appears more suited for this purpose (Higgins J.H. 1978). Like ethanol, methanol from wood is unlikely to become competitive in the next few decades in Western Australia, while natural gas and coal liquidification options remain open (Payne 1983).

8.4 Wood as a source of energy

In section 8.3.5, 8.3.6 and 8.3.7 the uses of ethanol and methanol as forms of chemical energy were discussed. In this section they are excluded from the discussion, and comment concentrates on the use of wood residues as a source of energy, from either direct combustion or conversion into producer gas (CO , H_2 , CH_4 , C_xH_x) followed by combustion.

8.4.1 Introduction

Wood has a long history as a fuel in Australia, although its use has been dwarfed by the fossil fuels (oil, natural gas and coal). It is nevertheless still a viable energy source today in a number of industries. As a solid fuel it is regarded by many of its users as a cheap clean-burning source of energy, low in ash and sulphur (Fung and Liversidge 1981). The increasing cost of energy from fossil fuels has directed attention to the need to make better use of wood residues.

In the hardwood industry, residues are generally disposed of by incineration, landfill or dumping, with no financial return (Fung *et al.* 1978). These residues could be utilised by the sawmilling and other industries as a source of energy, and any excess energy could be exported as electricity to the community or sold as charcoal. In the case of the sawmilling industry, the energy could be used to run the mill and to fire seasoning kilns. In addition the wood residues would be disposed of in a cheap and environmentally sound manner.

8.4.2 Direct combustion of wood residues

Recovering the energy value from wood involves either direct combustion or conversion to gaseous or solid fuels, followed by combustion of those energy products (Tillman 1978).

There are three general types of wood-fired combustors, classified on the way the wood is burnt - fixed bed systems, fluidised bed systems, and suspension systems (Fung 1984).

- (i) Fixed bed systems: In the fixed bed systems, the fuel moves vertically downwards towards the combustion zone. As it drops the fuel goes through the stages of drying, pyrolysis and carbonisation. Air or oxygen is added at the top (in downdraft versions) or at the bottom (in updraft versions) (Todd and Elliffe 1983).
- (ii) Fluidised bed systems: In the fluidised bed systems, combustion of the wood residue occurs in a pneumatically agitated bed of sand (Todd and Elliffe 1983). This system has excellent heat transfer between the sand, the wood and the gases. It has the capacity to handle wet, low heating value fuels and the capability of placing heat transfer tubes within the bed, thereby utilising very high heat transfer rates (Fung 1984).
- (iii) Suspension systems: The suspension systems operate by having fine wood material (e.g. sander dust and sawdust) pneumatically conveyed into the combustion chamber where high temperatures and high turbulence are encountered in the burner. This leads to a very short carbonisation and combustion time for the individual wood particles (Fung 1984).

Suspension burners have the highest heat release rate per unit volume of combustion chamber, and are the most compact of the three systems. One problem with the suspension burner is that there are upper limits to the moisture content and particle size that they can handle (Fung 1984).

8.4.3 Size of the wood fired combustor for a sawmill

The sawmiller's choice of a wood fired combustor is determined by the heat requirement of the mill, and the wood residue available. In most sawmills, the residue availability far exceeds the heat requirements (Fung 1984). If the energy requirements of the sawmill exceed the available wood residue fuel, as is the case of sawmills integrated with particleboard plants, then supplementary fueling with oil, gas or coal may be required.

Of the various forest products industries, sawmilling uses the least energy in the form of heat and electricity to produce a unit product. Estimates have shown that a sawmill producing seasoned timber can provide its own electricity and heat requirements by burning between 20-45 per cent of its total residue production (Fung 1984). In integrated forestry complexes, surplus sawmill residues could be used as fuel by other more energy intensive sectors. Where there is a surplus of wood residues above that required for a timber mill's energy needs, partial combustion of the residue into a charcoal by-product could be considered.

8.4.4 Use of wood fuels in non-forest-based industries

There is a limited number of industries, not forest-based, which use wood residues as a fuel. These industries are limited by the availability of mill residues in their area, and the distance that the residues must be transported (Fung and Liversidge 1981).

In Perth a wool scouring factory (burning green jarrah and pine sawdust), a large hospital (burning 10 000 t/yr of green jarrah sawdust) and a number of brickworks, all use wood residues. A number of brick factories have recently converted from oil to wood fired kilns and this has increased competition for wood fuels in Perth (Fung and Liversidge 1981).

8.4.5 Gasification of wood residues

During the 1940s, gas producers which were fired on charcoal, or to a lesser extent on wood, were used in motor vehicles to supplement war-time shortages of petrol and diesel fuels. When petrol and diesel supplies became unrestricted, the gas producers were abandoned.

However, the recent petroleum price rises have generated an upsurge of interest in industrial wood-fired gas producers for the generation of gas to replace fuel oil (Fung and Liversidge 1981).

In wood gasification, partial combustion of wood occurs in a limited amount of air or oxygen to produce a combustible mixture of gases. The wood initially passes through stages of drying and carbonisation, followed by gasification of the charcoal (Fung and Liversidge 1981). The calorific value of the cleaned gas from an air-blast system is in the range 3 700 to 5 600 kJ/m³, which is low compared with coal gas (20 000 kJ/m³) and natural gas (39 000 kJ/m³). However, oxygen-blast systems which eliminate nitrogen produce gas of a higher calorific value within the range 11 000 to 14 000 kJ/m³ (Fung and Liversidge 1981).

Fixed bed and fluidised bed systems can be used as gasifiers. The fluidised bed has the advantage of being able to handle smaller particles and materials of relatively high moisture content, and has a greater throughput per unit volume of bed.

The combustible gas can be used to either directly fire kilns with a gas burner or be used in conjunction with a heat recovery unit, such as a boiler, to provide the necessary heat transfer medium (Fung 1984). At the CSIRO's Division of Forestry and Forest Products, a close-coupled wood gasifier was developed for retrofitting into oil or gas fired boilers. This enables the wood gas to augment the fossil fuels, thereby reducing the consumption of these expensive fuels (Fung 1984).

8.4.6 The fluidised bed gasifier on trial at the WURC

A fluidised bed pilot plant was on trial at the WURC during November and December 1984. This unit is designed to perform various thermal processes, such as mineral calcination or roasting, toxic waste incineration, and wood combustion. The principal objective of using the plant at Harvey was to produce wood gases from a range of wood wastes at different moisture contents. These gases replaced the fuel oil, currently used to fire the high temperature seasoning kiln (Van Doornum and Shedley 1985).

While on trial at Harvey this pilot plant carried out many tests, including combustion, gasification and charcoal production using sawdust, woodchips, bark and shavings, from both hardwoods and softwoods. A gas analysis was performed on the wood gases produced from the different wood fuels.

8.4.7 Economics of using wood fuels

Payne (1983), in his investigation of the biomass energy potential for Western Australia, compared the cost of combustion and gasification of wood, coal and fuel oil. Oil, coal and wood residues are costed at the refinery, the colliery and the mill respectively, while pyrolysis gas, plantation wood and forest residues are costed at a central processing point.

Payne found that while mill residues are the most competitive if used in-situ or in close proximity, the higher energy density of coal makes it more attractive if long haul distances are involved (coal breaking even at 450 km, assuming a haulage cost of 5.52 cents/t/km). Forest or plantation wastes do not appear competitive with coal on a cost per giga joule basis (this imbalance may be corrected if simultaneous chemical extractions were executed).

The gasification of woodchips as a boiler fuel is an option that shows potential, particularly as existing oil burners can be re-fitted to handle producer gas to fire boilers (Payne 1983).

In the case of the sawmilling industry, the use of wood residues as an energy source and the possibility of producing the by-product charcoal is an attractive option. This would make the mill self-sufficient in heat and electricity, and the sawmiller would not have the problem of residue disposal. The conversion of non-forest-based industries to

using wood gases to fire existing boilers depends on the price of oil, their ability to obtain natural gas, and the price of natural gas compared with wood or coal gas.

8.5 Conclusions

- 8.5.1 It is technically feasible to meet our organic chemical and synthetic polymer needs in Australia from wood residues, but it is currently uneconomic to use these residues when options of chemicals from oil, coal and natural gas are available.
- 8.5.2 The decision to use wood and wood residues as chemical (including liquid transport fuels) feedstocks will depend on: the future availability and cost of fossil fuels, and the political decisions on the alternative uses of wood and wood residues e.g. for sawn timber, reconstituted wood products or pulp.
- 8.5.3. The use of mill residues by the sawmilling industry to supply energy to power the mill and heat seasoning kilns is an option that shows potential.
- 8.5.4 In the case of non-forest-based industries, the gasification of woodchips could be a viable option if existing boilers can be retrofitted to fire producer gas. This viability will depend on the availability and price of wood residues, compared with natural gas and coal.
- 8.5.5 The CSIRO's Division of Forestry and Forest Product's pilot gasifier trials and the WURC gasifier trials, will provide valuable information on the viability of utilising mill residues to produce electricity to power the mill and fire seasoning kilns. There is also the possibility of using excess residues to produce a charcoal by-product and to export electricity to the community.

CHAPTER 9

OTHER USES OF THINNINGS FROM THE JARRAH FOREST

9.1 Producing pulp from jarrah woodchips

A mixture of marri and karri woodchips, in a ratio of about 60:40 is exported by the Western Australian Chip and Pulp Company (WACAP) to Japan (C. Fallick¹¹, personal communication). The high extractive contents of jarrah has restricted its use for woodchips, although in the late 1970s and early 1980s, several shipments of jarrah woodchips were sent to Japan on a trial basis (P. George¹², personal communication).

At this time there was a high demand for hardwood woodchips, and the Japanese were accepting small quantities of jarrah. Since the early 1980s, the market for jarrah woodchips has been very unfavourable, and it is now virtually impossible to sell jarrah chips to some Asian countries (Japan, Taiwan and Korea) (P. George, personal communication).

Attempts by WACAP to persuade Asian countries to accept jarrah alone, or with the marri-karri mixture, have failed because jarrah yields a poor pulp compared with the marri-karri mixture. In addition, the black liquor from jarrah is very viscous and has poor burning properties (C. Fallick, personal communication). To make the pulping operation viable, the pulping chemicals need to be recovered from the black liquor, and used as a source of energy for further pulping or sold as a chemical by-product. At present there is no pulping plant or market in Western Australia for the chemical by-product.

Phillips *et al.* (1967) assessed the pulping potential of karri, marri and jarrah.

They found:

- (i) for sulphate pulp prepared from marri, karri and jarrah thinnings, using a 14 per cent total alkali, that yields of marri and karri pulps were similar and were considerably higher than that of jarrah sulphate pulp;
- (ii) for neutral sulphite semi-chemical (NSSC) pulp from the thinnings, marri and karri had much higher strength properties than jarrah, and yield of jarrah was 3-4 per cent lower than that from marri and karri;
- (iii) yield of sulphate pulp prepared from jarrah sawmilling wastes was considerably lower than that from karri sawmilling wastes. Jarrah required additional chemical (17 per cent total alkali) to give a similar strength pulp to karri produced with 12 or 14 per cent alkali;

11 Dr C. Fallick, CSIRO, Division of Forestry and Forest Products, Floreat Park.

12 P. George, Western Australian Chip and Pulp Company (WACAP), Manjimup.

- (iv) NSSC pulp prepared from karri sawmilling wastes was higher yielding and had considerably higher strengths, than jarrah pulp prepared under the same conditions;
- (v) strength properties of karri and jarrah NSSC pulps from sawmilling wastes were inferior to those from thinnings.

Despite jarrah requiring a high chemical consumption, having a lower yielding pulp compared with marri and karri, and having the problem of a highly viscous black liquor, the CSIRO's Division of Forestry and Forest Products are researching into these problems. They are looking at combining jarrah with exotic eucalypts, e.g. *E. globulus* and *E. maculata*, to produce pulp, or combining jarrah pulp with pine pulp. The CSIRO, in association with WACAP, are testing pre-extraction of the black liquor from the jarrah woodchips and using a mechanical roller to destructure jarrah woodchips prior to pulping (C. Fallick¹³, personal communication).

Jarrah woodchips will become viable if:

- (i) an overseas country wants to buy a cheap supply of hardwood woodchips;
- (ii) Western Australia can sell to a country familiar with pulping difficult timbers (i.e. high density dark pulps) e.g. India;
- (iii) technology available to pulp jarrah improves;
- (iv) jarrah pulp can be upgraded by combining with pine pulp or an exotic eucalypt woodchip (P. George¹⁴, personal communication).

9.2 Minor forest produce from the jarrah forest

9.2.1 Bark and sawdust

In the U.S.A. composted tree bark has been used successfully for control of some soil borne diseases. The system of composted bark has been most widely adopted for production of containerised nursery stock; it has eliminated the need for sterilisation of media and reduced the need for application of soil fungicides (Hoitink 1980).

Apart from a report from New South Wales showing the potential of *Pinus radiata* bark to prevent *Phytophthora cinnamomi* attack, there are very little published data on the potential of Australian hardwood and softwood barks and sawdust for reducing root rots of plants grown in nurseries (Sivasithamparam 1981a).

Sivasithamparam (1981b) tested sawdust and composted bark from some trees grown in Western Australia for their ability to suppress sporangial production, zoospore

13 Dr C. Fallick, CSIRO, Division of Chemical and Wood Technology, Floreat Park.

14 P. George, Western Australian Chip and Pulp Company (WACAP), Manjimup.

release and survival of *P. cinnamomi*. He found that jarrah bark and sawdust, and bark from *Pinus* spp., karri and wandoo did not give protection from the disease. Further tests indicated that karri and marri barks gave significant protection, even though they were not the best medium for plant propagation.

A number of nurseries in the Perth area use jarrah sawdust, because it is relatively cheap (\$3-\$4/m³) compared with other materials such as peat (\$21/m³). Currently jarrah sawdust (5-6 t/yr) is used in the soil mixture at the Department's Manjimup nursery (R. Edmiston¹⁵, personal communication). Nurseries need to apply strict nursery hygiene to prevent the entry of root rot fungi.

The Department's Hamel nursery used pine bark, as they had a ready cheap supply from the Wesfi particleboard mill at Dardanup (K. Tiedemann¹⁶, personal communication). Fresh pine bark is known to be phytotoxic (Sivasithamparam 1981a), therefore care must be taken when preparing the soil mix.

Other advantages of using bark and sawdust as a potting medium are:

- (i) the non-coherence and resilience of the bark ensures free drainage and good aeration;
- (ii) it does not condense into a dense 'paste', which would resist penetration by roots (Bootle 1983).

Bark and sawdust can be used as a mulch, which is good for weed suppression, prevents the loss of soil moisture by evaporation, resists the downward percolation of rain, and it buffers the root system against abrupt changes in temperature (Bootle 1983). Care must be taken to ensure that all the polyphenolic extractives (which are phytotoxic) are leached out of the bark and sawdust before adding to the soil mix.

Edible mushrooms have been grown in a pulverised pine bark medium, in place of peat, without affecting the yield (Aaron 1973). Fukuzumi and Macrae (1983) tested *Banksia grandis* sawdust for suitability to grow the edible mushroom *Pleurotus ostreatus*, and found *B. grandis* supplemented with wheat bran meal or corn bran meal was a favourable medium for *P. ostreatus* cultivation.

Along with woodchips, bark can be used in landscape gardening. In Perth pine bark is commonly used for landscaping but is expensive and often hard to obtain (K. Sivasithamparam¹⁷, personal communication). The popularity of woodchips for landscaping is increasing in Perth and further increases would provide a market for jarrah woodchips.

15 R. Edmiston, Department of Conservation and Land Management, Como.

16 K. Tiedeman, Department of Conservation and Land Management, Esperance.

17 Dr. K. Sivasithamparam, Department of Soil Science and Plant Nutrition, University of Western Australia, Nedlands.

Bark has been successfully used as a deep litter, for both beef and dairy cattle, where it serves as a substitute for straw (Aaron 1973). It can be used in building boards in a number of ways. In the manufacture of fibre board (i.e. hardboard and insulation board) bark is frequently included in the raw material in the form of unbarked small thinnings and sawmill residues (Aaron 1973). Sawdust can only be used to a small extent in particleboard because its large surface area requires more adhesive than do flakes and the product obtained is much weaker (Bootle 1983).

9.2.2 Round timbers (poles, posts, strainers, rails and mining timbers)

Round timbers can be used for housing supports, pole-framed buildings, fencing, underground mining, playground equipment, landscape gardening, retaining walls, vine trellis and hop poles (Dale 1978).

Round timbers from jarrah thinnings contain a large proportion of sapwood. In the structural use of round timbers there is little or no difference in strength between heartwood and sapwood, but sapwood is far more susceptible to attack by insects and fungi due to its higher starch content. Sapwood is far less durable than heartwood, because of the toxicity of extractives in the heartwood to fungi and the physical impedance by blocking vessels in the heartwood (Bamber 1979). However, sapwood can be treated with preservatives much more readily than heartwood, due to its more easily penetrable open cell structure, not blocked by tyloses and deposits (Tamblyn 1978). Sapwood, when properly treated, should last as long as the heartwood of all but the most durable 'Class 1' species (Dale 1978). Durability ratings are based on the in-ground performance of outer heartwood. Jarrah is rated as durability 'Class 2' (i.e. durable) (Shedley and Challis 1984b).

Untreated sapwood on transmission poles of durable species eventually decays. Design stresses are therefore based on heartwood diameter if sapwood is not treated, so that a comparatively larger pole is required. In practice, it is usual to remove the sapwood below the groundline to ensure a continuously firm footing in the ground (Bootle 1983). This operation is time consuming, costly and reduces the service life of the round timber. Another problem with using round eucalypt timbers is that some are prone to end splitting and barrel checking. By drying the timber in tree lengths and avoiding those species most prone to end splitting and barrel checking, as well as using preservative oils that are water repellent and protect the timber against weathering, their effects can be minimised. Splits and checks do not usually affect the life or strength of treated round timbers, but they do detract from their appearance (Dale 1978).

The sale of round timbers in Western Australia depends on local demand, which can fluctuate between areas and from time to time. For example, mining timber sales are confined to the Collie area where a number of deep underground coal mines are in operation.

9.3 Dowelled two-piece Westrail sleepers

In 1980, Westrail was approached by the Forests Department to consider the use of small section softwood sawlogs from plantation thinnings to produce railway sleepers (Syers 1984). A project was started with the following objectives:

- (i) to develop a dowelled two-piece sleeper using available locally grown plantation timbers, at an economic cost, and suitable for extensive introduction throughout the Westrail branch lines;
- (ii) to test samples of the developed sleepers, in both short term laboratory tests and longer term field trials, to establish their suitability.

Two softwood species (*Pinus radiata* and *P. pinaster*) and regrowth jarrah were selected for testing. The two-piece sleepers were preferred to the one piece sleeper (due to the limited availability of large sawlogs) and to the laminated sleeper (due to the fabrication difficulties) (Syers 1984).

The two-piece sleeper is fabricated by inserting four twisted steel dowels horizontally into pre-drilled holes before seasoning and treating with preservative. In an initial trial, fifty per cent of each species (*P. radiata* and *P. pinaster*) were then treated with 80 per cent oil / 20 per cent creosote, at 1 400 kPa (average retention: 180 kg/m³), at Koppers, Picton Junction. The remaining 50 per cent of each species was treated with 99.5 per cent oil / 0.5 per cent termiticide at 7 000 kPa (retention: 175-350 kg/m³), at Buntings, Pemberton (Syers 1984).

These test sleepers were placed on the relatively heavily trafficked railway line between Northam and Goomalling, where they be inspected at regular intervals to ascertain performance levels.

At the moment the economics of milling, kiln seasoning and assembling two-piece softwood sleepers are not acceptable, but improved technology will no doubt reduce costs (Syers 1984).

Further work is being carried out on two-piece jarrah sleepers and glue-laminated softwood sleepers are also being prepared for testing. If the two-piece jarrah sleepers prove successful, then jarrah thinnings could be used for sleepers. The use of dowelled two piece jarrah and softwood sleepers would reduce the quantity of sleepers milled from mature jarrah, thus extending the mature jarrah resource and possibly directing mature jarrah into producing higher value products, e.g. furniture and joinery timber.

9.4 Conclusions

- 9.4.1 At present there is no market for jarrah woodchips for pulp production. Research is being undertaken by the CSIRO's Division of Forestry and Forest Products to increase the yield and viability of jarrah woodchips. Additional markets need to be investigated e.g. India and Europe.

- 9.4.2 The market for round timbers depends on local demand. For example, jarrah thinnings can be sold for mining timbers in the Collie area.
- 9.4.3 Use of bark and sawdust has the potential to expand further in the nursery industry. However, strict hygiene is required if jarrah bark and sawdust are used to avoid spreading dieback.
- 9.4.4 Pine bark is commonly used for landscape gardening in the Perth area. Jarrah bark may substitute for pine in this use.
- 9.4.5 Trials have started with dowelled railway sleepers, using two-piece softwoods, two-piece jarrah and laminated softwoods. At the moment, the economics of producing these sleepers are not acceptable. The use of dowelled sleepers would reduce the number required from mature jarrah logs.

ACKNOWLEDGEMENTS

I thank Dr Graeme Siemon, Mr Jack Bradshaw, Mr Joe Havel, Mr Roger Underwood and Mr Phil Shedley for their helpful comments (especially Graeme Siemon and Jack Bradshaw). In addition, I thank the many people who provided unpublished information, and Giulia Maranta, Terri Boyes, Toni Jones and Colleen Clements for typing the manuscript.

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