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Technical Report No. 1

The Drying of Hardwood Veneers in New South Wales

Jamie Hartley

N.S.W. TIMBER ADVISORY COUNCIL
Sydney 1984
THE DRYING OF HARDWOOD VENEERS IN NEW SOUTH WALES

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Abstract

Information about the drying of hardwood veneers in New South Wales is reviewed. Sources were published and unpublished reports, and N.S.W. industrial experience. Aspects discussed are types of drier, drying rates, shrinkage, collapse, dried quality, control and measurement of dried veneer moisture content, and aspects of drier operation. Information is given about the drying of some particular species, and aspects for further investigation are discussed.
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Abbreviations

- Moisture content: MC
- Dry bulb temperature: DBT
- Wet bulb temperature: WBT
- Wet bulb depression (DBT - WBT): WBD
- Fibre saturation point: FSP
1. OBJECT

At a series of meetings held during August 1982, involving various parties concerned with the production of veneer and plywood, it was agreed that, as part of a research and development programme, there was a need for a review of current drying technology for eucalypt veneers. It was further agreed that this review should have the following objectives:

- Obtain and collate existing information on drying eucalypt veneers from published material, information available in research organisations, and from practical industrial experience - particularly in the N.S.W. veneer and plywood industry. The information should include types of driers used, drying conditions and times, final moisture content (MC), and limiting drying conditions and their effect on drying degrade.

- Assess the potential performance of available commercial driers to provide veneer producers with a basis for selecting the drier appropriate to their needs. Relevant aspects to include drying rates for different species and thicknesses, to enable them to be compared with rates quoted by drier manufacturers, and energy consumption, particularly steam used for heating.

- Compare the operating characteristics of different types of driers, including the performance of the transport systems of continuous driers (mesh or roller), particularly maintenance costs and down-time, and possible problems caused by build-up of kino.

Information was obtained from a literature survey, published and unpublished reports, and discussions with staff at eight N.S.W. plants with experience of drying eucalypt veneers. It covered most of the agreed objectives, and is the basis of this report.

2. DRIER TYPES

Three types of drier are currently in use in N.S.W. for hardwood or rainforest veneers. They are all used for drying veneers that have been clipped to width. The types are:

1. batch (screened) driers, and

2. continuous driers, further subdivided into -
   (a) "parallel" air flow, and
   (b) "jet" or "impingement" air flow.

2.1 Batch (screened) driers

These are used to dry whole or part charges as individual batches. A green charge is assembled on trucks outside the inlet end of the drier. When the previous charge is dried and removed from the drier, the green
charge is moved in, the doors closed, and the charge dried. While each charge is drying, the previous charge is unloaded from its trucks outside the drier outlet, and the trucks returned to the drier inlet end for loading with the next green charge. The veneer sheets stand vertically on the trucks, separated by "fingers" mounted in a frame.

The air is circulated in a vertical plane parallel to the veneer sheets. Circulating fans and air heaters are located in the return air circulation space above the charge. Moist air is expelled and replaced by ambient air through roof vents located to use the pressure differences across the fans or heaters. The air circulation is normally reversed mid-way through drying each charge. Drying temperatures are usually below 100°C.

All driers in use are of the type described by Gottstein and Cullity (1955). They will be referred to in this report as screened driers.

2.2 Continuous driers

In these, the veneer sheets are continuously loaded into one end of the drier, transported horizontally through it, and unloaded (usually after passing through a cooling section) at the other end. The sheets are oriented so their grain direction is parallel to their movement.

All the driers used roller transport, i.e. the sheets move between pairs of horizontal driven rollers mounted perpendicularly to the direction of travel. They are constructed so the veneer is transported in a number of parallel layers, or decks, separated vertically from each other. The transport systems have a continuously variable speed drive which, when related to the length of the drier, provides control of drying time.

The driers are constructed of a number of similar sections, mounted side by side along their length. Each section contains a heating unit and an air circulation fan, and some contain inlet and/or outlet air vents. Drying temperatures are normally over 100°C.

The general air circulation is in a vertical plane perpendicular to the length of the drier. Plenum chambers are located each side of the drier. Air flows from the inlet plenum, through the drying chamber, to the outlet plenum, then returns over the top of the chamber.

The principal difference between 2(a) and 2(b) is in the flow within the drying chamber:

2(a) In parallel flow driers, the air flows from plenum to plenum parallel to the surface of the veneer.

2(b) In jet, or impingement flow driers the air passes from the inlet plenum into "jet boxes" located above and below each veneer layer, and extending across the width of the drying chamber. It emerges through slots or holes (jets) in the boxes and impinges perpendicularly onto the faces of the veneer before passing to the outlet plenum.

Impingement flow provides substantially greater heat transfer from the air to the veneer (and correspondingly faster drying) than parallel flow.
3. **SUMMARY OF PUBLISHED AND OTHER REPORTS**

Experimental data collected over a number of years were collated by Watson and Higgins (1950). Information is given about 46 Australian-grown species, which include some hardwoods of interest for potential veneer production in N.S.W. The veneers were dried to 10% moisture content using relatively low temperatures, so the conditions and results are not directly comparable with more recent drying practice. The main types of drying degrade reported were checking and buckling. These were generally worse in the lower density "ash" eucalypts than in species such as blackbutt and spotted gum. This paper also contains information on other aspects such as peeling, recovery, and veneer quality and uses.

Ellwood (1952) investigated the drying of 1.6 mm rotary peeled mountain ash veneer. The most important forms of degrade were buckling, and checking in the earlywood on the tight side. These were found to be due to the stresses caused by the greater gross shrinkage (including collapse) of the earlywood, compared to the latewood. This, with accelerated drying from the end grain, was also the cause of end splitting. Collapse occurred early in drying, when the veneer temperature remained close to the wet bulb temperature (WBT). It could be minimised by using low WBT's, combined with large wet bulb depressions (WBD's) which increased drying rate, and shortened the exposure time of the veneer to elevated temperature. Ellwood's explanation of the development of drying degrade in collapse-susceptible veneer with distinct earlywood and latewood is still relevant, and his findings can be applied (at least partially) to the operation of screened driers. The much higher temperatures (particularly WBT) used in continuous driers tend to aggravate collapse and its effects.

Gottstein (1956) found that collapse in alpine ash and messmate veneer increased with the temperature used in preheating the peeler blocks. The uneven exposure to temperature within the blocks also caused uneven collapse in the veneer sheets, with consequent buckling and splitting.

A report on the use of mature eucalypts for veneer and plywood by McCombe and Gottstein (1967) emphasised the importance of differential collapse shrinkage of earlywood and latewood, or unevenly heated material, on drying degrade (face checking, buckling, curling of long grain edges, splitting, and thickness irregularity) in peeled veneers of the lower density eucalypts. Gross volumetric shrinkage of 30% was reported for bad logs of Tasmanian messmate. Collapse degrade was minor in the dense eucalypts, but transverse shrinkage was still high - commonly around 10%. In studies with regrowth eucalypt (mainly mountain ash) veneer dried to 12% MC using moderate temperature, high drying rate conditions, shrinkage was never more than 7%, indicating little or no collapse.

A considerable amount of information is contained in the series of Plywood Technical Notes, prepared for the Australian Plywood Industry, and similar publications by the Division of Forest Products, CSIRO. Notes of particular relevance are those by Wright and Gottstein (1957), Edwards (1958), Gottstein (1958a, 1958b, 1965), Gottstein and Stashevski (1958, undated), and Hirst (1970). The subjects covered include -

- Factors affecting dried quality.
- Minimisation of drying degrade.
- Variations in MC, and the control of final MC.
- Post-drying conditioning for MC equalization.
- Measurement of MC of dried veneer.
- Brittleness and surface inactivation of dried veneer.
- Operation and control of driers.
- Determination of the drying end point.
- Hardwood structural plywood.

These publications are available from the Division of Chemical and Wood Technology, CSIRO, Australia, and the notes cited form part of this summary.

A comprehensive review of cell collapse in wood was produced by Kauman (1964). Aspects particularly relevant to the drying of hardwood veneer are:

- Severe collapse is more prevalent in wood laid down early in the life of a tree, than in the younger wood of mature trees.

- The thin-walled cells of early wood generally collapse much more than the thicker-walled, stronger late wood fibres. This effect is responsible for the buckling of collapsed veneer, and for the greater collapse in fast-grown timber.

- Collapse is usually 1.5 to 3 times greater tangentially than in the radial direction.

- Collapse takes a finite time to develop. Veneer can be dried so rapidly that collapse may not have time to reach its potential maximum. This was observed in 1.5 mm "ash" eucalypt veneer, where collapse was proportional to drying time from green to fibre saturation point (FSP).

- Optimum conditions for drying 1 to 1.5 mm thick collapsing eucalypt veneer are 140 to 160°C dry bulb temperature (DBT), with the lowest possible WBT. (Author's underlining.)

- Sustained exposure of wood to elevated temperatures (either in pre-heating or drying) increases the severity of collapse, and reduces the recovery on reconditioning.

- Best recovery of collapse in reconditioning is achieved by exposure to saturated (or wet) steam at 100°C, at MC's of 15 to 20%. Recovery is incomplete at MC's below about 15%.

A trial of the production of plywood from even aged, plantation grown flooded gum was reported by H. E. Booth (unpublished, c. 1970). 1.6 mm veneer was dried in a screened drier at c. 80°C DBT. Width shrinkage in veneer from freshly peeled logs was 8.5%. It was lower in veneer from stored logs, in which it also decreased significantly with increasing diameter class. As the logs were peeled to similar core sizes, the veneer from the larger diameter blocks probably contained more juvenile wood, and had a correspondingly lower mean density (Bamber et al., 1969). The lower shrinkage of this material, and the relatively low general shrinkages, indicate that collapse in drying was not appreciable.

Ghali and Dowden (1982) reported trials with regrowth blackbutt thinnings. 2.5 mm veneer was dried without difficulty to 10 to 12% MC in a continuous jet drier. The reported feed speed was 1 m/min, giving a drying time of 10 mins (excluding cooling).
A general review of the causes of buckling in veneer, and possible ways to minimise it, was given by Lutz (1970). He considered that all buckling is caused by uneven stresses in the veneer sheets. Possible causes are growth stress, reaction wood, irregular grain, improper lathe settings (particularly if causing thickness variations within the sheets), and non-uniform drying causing non-uniform shrinkage and the development of sets in parts of the sheets. The last, with the added contribution of collapse, is probably the most important cause in eucalypts, with irregular grain important in some species.

Methods of controlling buckling include retarding the end-grain drying at the ends of the sheets, holding the sheets flat (without restraining shrinkage) during drying and cooling, and equalising the MC distributions within sheets as far as possible during drying. The last can be done to a certain extent in screened driers, but is impractical in most continuous driers, due to the severe conditions used. Buckle in dried sheets could be reduced by stacking them in thin bundles, and giving them a short hot pressing treatment.

Bethel and Hader (1952) discussed hardwood veneer drying, and presented results of drying experiments with veneers of North American hardwoods. Their paper mainly applied to drying at temperatures over 100°C in continuous driers, with the air flow parallel to the veneer sheets, and is most applicable to driers type 2(a).

They discussed the probable mechanism of moisture movement through drying veneer, and the importance of the rate of application of heat (i.e. temperature and air velocity) on the drying rate. They emphasised the impracticality of equalising MC's at the end of drying, and the need to sort green veneer into batches having similar drying characteristics to get maximum uniformity in the final MC's. The spread of final MC's was greater for higher target mean MC's, and was increased by variations in veneer thickness.

In their experiments they found an initial period of constant drying rate (i.e. MC change/time change during drying), followed by one or two zones of falling rate in which the logarithm of drying rate was proportional to the logarithm of MC. Drying could be fully described once the following parameters had been determined -

- Initial MC.
- Drying rate in the constant rate period.
- Critical MC, marking the change from constant to falling rate.
- MC separating the zones (if more than one) in the falling rate period.
- Proportionality and independent constants in the falling rate period(s).

Other findings included -

- Differences in the drying rate, and in the number of zones in the falling rate period, between sapwood and heartwood of the same species.

- Graphed results for drying rate against veneer thickness indicated that the relationship between drying time and thickness could be described by -
where $T_2$ is drying time for veneer thickness $L_2$, $T_1$ for $L_1$, and the value of $p$ was about 1.3.

- Case hardening (i.e. residual compressive stress) occurred on the tight side of some thicker veneers.
- Collapse was observed in the heartwood, but not the sapwood, of one species.

Bati and Jaramilla (1965) investigated the effect of drier temperature and veneer thickness on drying time for the heartwood of a number of medium density Philippine hardwoods. Veneers of three thicknesses (1.27, 2.54 and 4.23 mm) were dried at temperatures of 121, 141 and 160°C to final MC's of 6 to 10%. Initial MC's ranged from 55 to 145%. The air flow was 6 m/s, parallel to the veneer sheets, so the results are most applicable to driers type 2(a).

The proportional reduction in drying time with increase in temperature was virtually independent of the other variables. The results show that the logarithm of drying time decreased linearly with increasing temperature. Relative drying times at different temperatures were:

<table>
<thead>
<tr>
<th>Temperature °C</th>
<th>Relative drying time</th>
</tr>
</thead>
<tbody>
<tr>
<td>120</td>
<td>1.00</td>
</tr>
<tr>
<td>140</td>
<td>0.74</td>
</tr>
<tr>
<td>160</td>
<td>0.55</td>
</tr>
</tbody>
</table>

This is a reduction in drying time of 26% for each 20°C increase in temperature, in the range investigated.

The increase in drying time with increasing veneer thickness was also independent of the other variables. The results show that the relationship could be described by Equation (1), with a value of $p$ of about 1.5.

Comstock (1971) investigated jet veneer drying, using temperatures from 120 to 290°C and jet velocities of 10 to 40 m/s in drying veneer of different species, density, thickness, type (sapwood or heartwood), and initial MC. Two softwoods and one hardwood, with basic densities of 0.36 to 0.58 g/cm³ were used. Initial MC's varied from 35% to about 160%, and veneer thickness ranged from 1.0 to 4.76 mm. The equipment variables - jet type and area, pitching distance, etc. - were kept constant.

He reviewed previous reports, mostly on parallel flow drying, and concluded that their findings did not adequately describe his results. The best description of drying, applying to the full range of factors investigated, was drying rate decreasing linearly with MC in two falling rate periods, with no initial period of constant drying rate. This is illustrated in Figure 1.

The breakpoint, $C$, between the two periods was a transition, rather than a sharp break, and was independent of temperature, jet velocity, veneer thickness, or wood density. It ranged from 13 to 20% MC for softwoods, and appeared to be the point where free water was no longer present.
Moisture content ($M$)

For $M > C$ \[-dM/dt = A + BM\]

For $M < C$ \[-dM/dt = (A/C + B)M\]

Where $M$ is moisture content, $t$ is time, $-dM/dt$ is drying rate, and $A$, $B$ and $C$ are constants

Figure 1. Relationship between drying rate and moisture content. (After Comstock).

The constant, $A$, increased with both jet velocity and the amount the temperature exceeded 100°C. It fell to zero at 100°C, and he concluded that at, or below, 100°C, drying could be described as a single period in which drying rate decreased linearly with MC. The slope, $B$, of the early part of the drying rate curve was independent of temperature, but increased linearly with increasing jet velocity.

$A$ and $B$ were both independent of species and wood type, but were functions of veneer thickness and wood density. The effect of this on drying time could be expressed as -

$$\frac{T_2}{T_1} = \left(\frac{L_2}{L_1}\right)^p \left(\frac{D_2}{D_1}\right)^q$$

where $T_2$, $L_2$ and $D_2$ are drying time, thickness and density respectively of veneer 2,

$T_1$, $L_1$ and $D_1$ are drying time, thickness and density respectively of veneer 1,

and $p = 1.19$ and $q = 0.87$. 
This value of p is lower than the values of c. 1.3 and 1.5 obtained from the results of Bethel and Hader (1952), and Bati and Jaramilla (1965), respectively, for parallel flow drying.

These findings should have practical application in quantifying the performance of jet veneer driers. They indicate that, for a given drier with fixed equipment variables (including jet velocity), temperature, and veneer thickness, drying time depends principally on wood density and initial MC. These are the major factors to be considered in sorting green veneer into batches having similar drying characteristics.

The factors affecting heat transfer from impinging air jets were reviewed by Arganbright and Resch (1971), and studied by Arganbright et al. (1978, 1979) and Wedel (1980). However these papers are of more direct relevance to designers of jet driers than to commercial firms drying veneer.

4. INFORMATION FROM N.S.W. VENEER PRODUCERS, WITH DISCUSSION

Eight N.S.W. veneer plants were visited. Seven had previous experience with hardwood. The eighth was visited during a trial with two hardwood species. These were all the known current, or recent past, N.S.W. plants with relevant experience. They are listed in Appendix A, together with their drier types and hardwood species used. Appendix B is a listing of the species, or species groups, mentioned in this report.

Most experience with hardwood was of either 2.5 (or 2.54) or 3.2 mm veneers for structural plywood, dried in either screened, or continuous jet driers. There was also some experience of thinner veneers from a few species, and one plant had dried hardwood veneer in a continuous parallel flow drier. Various aspects of the information obtained are discussed below.

4.1 Drying Rates

There were large differences in drying rate between the drier types, and comparative information between species also differed, so each type has been considered separately.

Where possible, comparative information was obtained between hardwood and "traditional" rain forest veneer species, typically coachwood and/or white birch, representing "medium" and "fast" drying species respectively. Most hardwood veneer is dried to lower final MC's than is normal for rain forest species. This would increase drying times, even if all other factors were the same.

4.1.1 Screened driers

Drying times were taken to be the actual time the drier was operating, excluding final conditioning (if any). They did not include the time taken for fan reversal, or loading and unloading the drier. The total additional time would normally not exceed 10 minutes per charge.

Drying times reported for hardwoods were generally comparable with, or only a little longer than, times for coachwood of the same thickness. The
exception was one plant which reported an approximate doubling of its drying times when it changed from rain forest species to hardwood. The reason for this was not obvious, but was most likely related to the performance or operation of that particular drier.

Most hardwoods had similar drying times, indicating that there was no general effect of species or density. Minor species effects reported were that scribbly gum probably dries a little faster, and messmate may dry a little slower than hardwoods generally. The one major species effect was with white gum, which dried comparatively slowly, and with patchy MC's. This was not marked in 1.6 mm veneer, but increased progressively through thicknesses of 2.1, 2.5 and 3.2 mm. This species group also dries slowly and unevenly in sawn timber sizes.

Reports indicated that sapwood dries faster than truewood. There also was one report of 1.6 mm white gum sapwood narrows drying in only 25 to 30% of the normal drying time for truewood full sheets of the same thickness. Veneer from heated billets were reported to dry faster than veneer from billets peeled cold.

Drying times differed between plants, due to the different drying temperatures used. They probably were also affected by the performance characteristics and state of repair of the driers. Information from a plant with a drier in good repair, that normally reached DBTs of about 77 ± 4°C before final conditioning, indicated that drying time increased approximately linearly with veneer thickness, i.e. the exponent, p, in Equation (1) (page 12) was about 1.0. Drying time was about 35 minutes per mm of thickness.

One plant reported using lower temperatures than normal (with consequent slower drying) for scribbly gum, to reduce buckling and end splitting.

Some information about the effect of temperature on the drying time of 3.2 mm hardwood veneer was obtained in laboratory experiments (J. Hartley, unpublished). Veneer was dried in a laboratory kiln simulation of a screened drier, with the air flow parallel to the sheets. DBT's, ranging from 80 to 140°C, were maintained after the initial heating period. Each increase of 20°C reduced the drying time by about 40% in drying silvertop stringybark from 80 to 8% MC. A similar reduction of about 35% was obtained in more limited tests drying blackbutt from 36 to 8% MC.

4.1.2 Continuous driers

Drying times were taken as the time for passage from the inlet to the outlet of the drier sections, and did not include time in the final cooling section, where some additional drying takes place.

All the continuous driers seen were loaded and unloaded manually. This limited their maximum potential output to the drying of thick veneers. With the shorter drying time required for thin veneer, production was restricted to the quantity that could be handled, and drier performance was reduced accordingly. This was done by lowering the temperature (usually by reducing the steam supply pressure), or turning off the heating in one or more sections of the drier.
4.1.2(a) Parallel flow driers

The information available was restricted to one plant. The drier was steam heated, using coils located between the veneer decks in the drying chamber, and was normally operated at 140 to 150°C DBT.

Typical drying time for 2.54 mm coachwood was 40 to 45 minutes. Messmate (peeled hot) was similar, but white gum (also peeled hot) took about 10% longer. Flooded gum (peeled cold) and scribbly gum (peeled hot) both took about 15% less time to dry than coachwood.

4.1.2(b) Jet driers

There was some variation in the comparable information obtained from different plants, but some general conclusions could be made.

Drying times for plantation grown flooded gum were generally similar to those for coachwood dried to similar final MC's, with scribbly gum taking about 10 to 15% (possibly up to 20%) longer. However, some flooded gum, probably not plantation grown, and peeled very green, had reported drying times similar to scribbly gum. For comparison, fast drying rain forest species (e.g. white birch) dried about 10 to 15% faster than coachwood. More limited information about blackbutt, and a single report on Sydney blue gum, indicated drying times similar to those for scribbly gum.

The lower density of plantation flooded gum could account for it drying faster than the other hardwoods. This was not conclusive, as there was little reported difference between the other hardwoods, although their densities differ. The effect of density could be masked by differences in green MC.

Comparative drying time data for different veneer thicknesses was only available for the range of 2.54 to 3.2 mm. Expressing the effect of thickness on drying time as in Equation (1) (page 12) gave values of the exponent, $p$, ranging from 1.0 to 1.6. A value of $p = 1.3$ would probably be adequate for preliminary estimates of the effect of thickness. This is higher than the value of 1.19 obtained by Comstock (1971) for jet drying, but is similar to the value obtained from the results of Bethel and Hader (1952) for parallel flow drying.

Operating temperatures (DBT's in the air inlet side of the central sections of the driers) varied between plants from ca. 150 to 165°C. Drying times provided by the plants indicated that this had a marked effect, with an increase in DBT from 150 to 165°C reducing drying time by about 30%. This illustrated the importance of operating the driers at the highest possible temperature in order to obtain maximum production. Higher drier temperatures can be achieved in a number of ways -

- Increasing the temperature of the heating medium (i.e. higher pressure, where steam is used).

- Reducing the temperature difference between the heating medium and the drier, by increasing the capacity of the heat exchanger.

- Reducing heat lost through venting, where possible. This increases the WBT as well as the DBT, but would probably
increase the drying rate, as the effect of WBD is negligible at the DBT's used, and the increased water vapour content in the drier should increase the rate of heat transfer to the veneer.

Estimates of probable drying times for some species and thicknesses were made from the information obtained. They are given in Table 1.

Table 1. Estimated drying times of some hardwood veneers in jet driers.

<table>
<thead>
<tr>
<th>Thickness (mm)</th>
<th>Species</th>
<th>Maximum drier DBT (°C)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>α. 150</td>
</tr>
<tr>
<td>2.54</td>
<td>Flooded gum (plantation)</td>
<td>14 - 15</td>
</tr>
<tr>
<td></td>
<td>Other*</td>
<td>16 - 17</td>
</tr>
<tr>
<td>3.2</td>
<td>Flooded gum (plantation)</td>
<td>18 - 19</td>
</tr>
<tr>
<td></td>
<td>Other*</td>
<td>20 - 22</td>
</tr>
</tbody>
</table>

* Other: scribbly gum, flooded gum (not plantation, and peeled very green), blackbutt, Sydney blue gum.

4.2 Shrinkage

Information about shrinkage, including some measurements made during trials, was obtained during the visits. Another source of data for many species was Kingston and Risdon (1961), and some data for two species was obtained in laboratory trials (J. Hartley, unpublished). The collected information indicated that large variations occur, but shrinkage is generally a more important source of volume loss in hardwood than in rain forest veneer, for several reasons -

- Hardwoods generally have a higher true shrinkage than some of the rain forest species used for veneer.

- Hardwood veneer is normally dried to lower final MC's, with consequent increased shrinkage.

- Collapse, which is more prevalent in the lower density hardwoods than in rain forest species. It can vary considerably within and between trees, between species, and probably with site. It can be a more serious source of loss in veneer than in sawn timber, as it may be exacerbated by the relatively high drying temperatures used - particularly in continuous driers - and reconditioning to recover collapse is not used in normal production drying.

The largest shrinkage in sheets of rotary peeled veneer is in their width. Producers allow for this when clipping, and this information was available. There was general agreement that width shrinkage was greater in hardwood than in rain forest veneer.

Shrinkage in thickness is also likely to cause a significant volume loss in hardwood, but less information was available from producers. However, there were indications that it may be necessary to allow an
increase in veneer thickness in some cases. Another adverse effect is thickness variations within the dried sheets, mainly due to differences in collapse shrinkage.

Reported shrinkages were generally higher for veneer dried in continuous driers than in screened driers. This was consistent with increased collapse produced by higher veneer temperatures during drying.

Information obtained about individual species, or species groups, was:

4.2.1 Flooded gum

Measurements made in trials, as well as general information from veneer producers, indicated that mean width shrinkage was probably in the range of 5 to 8.5%, but some reports were higher - up to 11.5%. There was some evidence that shrinkage in veneer dried in a screened drier (maximum DBT of c. 80°C) may be lower in juvenile wood from near the heart, than in wood from near the outside of the tree. This is consistent with the drying producing little or no collapse.

4.2.2 Scribbly gum

There were wide variations in the information obtained. Mean width shrinkage reported for veneer dried in continuous jet driers varied from a range of 6.5 to 9% in the north of N.S.W., to over 20% in material from the Hastings and Macleay Rivers region. Measurements on one batch of veneer, dried in a screened drier, indicated a mean shrinkage of about 10.5%.

A general estimate of mean width shrinkage was a range of 7 to 11%, but much higher shrinkages may occur, particularly if collapse is severe. The reported wide differences could also be due to differences between species in the scribbly gum group.

One report from the Hastings River area was that the peeled thickness of nominal 2.54 mm veneer was increased by at least 5% to allow for excessive thickness shrinkage.

4.2.3 Blackbutt

Measurements made in one trial, supported by information from a producer, indicated a mean width shrinkage in the range of 11 to 13% for veneer dried in continuous driers. In veneer dried in a jet drier, with DBT's up to c. 165°C, shrinkage was greatest in wood from near the heart. This was consistent with greater collapse occurring in the lower density juvenile wood.

One report of thickness shrinkage in a continuous parallel flow drier (DBT of c. 150°C) was a range of 7 to 16%.

In laboratory experiments with a small sample of 3.2mm veneer, using parallel flow and DBT's of 80 and 140°C, mean shrinkages to 8% MC were 6.5 to 7% in width, and c. 4% in thickness, and were similar at both DBT's. The veneer temperature probably remained at, or near, the WBT (50 or 60°C) early in drying, when collapse may occur. These shrinkages indicate that little, or no, collapse took place. This is in contrast to the information for continuous driers, in which the veneer temperatures were probably much higher. However, the sample was too small for this result to be taken as representative of the species.
4.2.4 White gum

The only information was from one trial with 1.6 and 2.1 mm Eucalyptus\n\textit{viminalis} veneer dried in a screened drier. The mean width shrinkage was\nabout 9\%. This species is known to vary considerably in its drying\ncharacteristics and susceptibility to collapse. There may also be\ndifferences between the species that may be included in the white gum\ngroup.

4.2.5 Messmate

Information provided by one producer was mean shrinkage ranges of 10.5\nto 13\% in width, and 4 to 11\% in thickness.

4.2.6 Silvertop stringybark

The only information was from laboratory experiments with 3.2 mm\nveneer, using parallel flow and DBT's ranging from 80 to 140\degree C, with\ncorresponding WBT's ranging from 50 to 60\degree C. Mean shrinkages to 8\% MC\nranged from 6.75 to 10.25\% in width, and 5 to 11\% in thickness, with the\nlarger values occurring at the higher temperatures. This indicated that\nsome collapse occurred at veneer temperatures as low as about 60\degree C early in\ndrying.

4.2.7 Tentative allowances for width shrinkage

Tentative estimates of the allowances required for width shrinkage\nwere made from the information obtained and are given in Table 2. These are\nthe shrinkages that should not be exceeded in more than 1\% of sheets dried\nto a final MC of 6\%. They are tentative because there could be con­\nsiderable variation, mainly depending on the amount of collapse that takes\nplace, and allowances as high as c. 25\% may be necessary in some cases.\nThe nominal clipping width for sheets should also include allowances for\nclipping tolerance and panel trim.

Table 2. Tentative allowances for width shrinkage in some hardwood\nveneers. *

<table>
<thead>
<tr>
<th>Species</th>
<th>Shrinkage (% of green dimension)</th>
</tr>
</thead>
<tbody>
<tr>
<td>flooded gum</td>
<td>11%</td>
</tr>
<tr>
<td>scribbly gum</td>
<td>14 - 15%</td>
</tr>
<tr>
<td>blackbutt</td>
<td>15%</td>
</tr>
<tr>
<td>white gum</td>
<td>13%</td>
</tr>
<tr>
<td>messmate</td>
<td>15%</td>
</tr>
<tr>
<td>silvertop stringybark</td>
<td>13%</td>
</tr>
</tbody>
</table>

* See text for explanation.
4.3 Dried veneer quality

The quality of dried hardwood veneer is an important constraint on its use. It is the result of many factors, from the quality of the wood in the tree, through logging and log storage, heating (if used) and billet preparation, peeling and clipping, to handling and drying.

Quality may be reduced during drying by the effects of shrinkage and/or collapse. This can occur in several ways -

- Defects resulting from stresses caused by shrinkage/collapse, e.g. checks, splits, end splits, buckle.

- Extensions of defects present in the green veneer, e.g. splits, end splits.

- Defects associated with other wood factors, e.g. buckle caused by the interaction of shrinkage/collapse with variations in grain direction, or differential collapse between earlywood and latewood.

Gum veins or pockets are also a common defect in veneers of many eucalypts. They may melt and spread during drying, reducing the veneer quality.

Another important aspect of drying is control of final MC, and variations in MC both within and between sheets. This is discussed separately.

Information about veneer quality was obtained during the visits to the veneer producers. The reports varied greatly, both between species, and within species from logs of different types and/or from different sites.

The most general drying defect was end-splitting, often originating in the log or billet and extending during drying. It was not considered serious for general structural applications and in many cases would close in pressing. However open splits may make veneer unsuitable for formply faces supporting overlays. Closed splits are permitted in all veneer grades except decorative.

Buckle was also a common drying defect, but varied in severity and importance. Excessive buckle could best be avoided by careful log selection to avoid serious irregular grain, and material known from experience to exhibit large differences in collapse between earlywood and latewood. Buckle in drying was reduced (but possibly at the cost of greater splitting) by the greater restraint provided in continuous, than in screened, driers.

Dried hardwood veneer was generally more fissile and difficult to handle without splitting or tearing than veneer from many rain forest species.

Information obtained about individual species, or species groups was:
4.3.1 Flooded gum

This was usually peeled cold, and was reported to generally peel and dry well. Veneer quality was better from logs that had been stored under water sprays to reduce the effects of growth stresses. Some minor buckling occurred in drying, but it was not considered serious. The principal drying defect was end splitting, or the extension and opening of end splits present in the green veneer. The veneer was generally suitable for structural plywood centres, and some was reported to be suitable for faces. One report indicated that carefully selected 1.27 mm veneer was suitable for formply faces, as the end splits closed in pressing.

4.3.2 Scribbly gum

The reported quality varied considerably. Factors that could be involved included species, site, log size, log storage and preheating before peeling.

The majority reporting was of severe irregular and interlocked grain interacting with shrinkage and/or collapse to produce localised buckling and ridging in the dried sheets. (One report was that "you can see through the sheets between the ridges"). General buckling was also common, probably caused by shrinkage and/or collapse. One firm used low drying temperatures to reduce buckling and splitting. However, there were also reports of veneer drying with little buckle or collapse distortion.

Reports of end splitting varied, ranging from moderate to excessive, particularly where the splits were an extension and widening of splits in the billets.

Gum veins were reported to be a problem, requiring careful log selection. Dried veneer was brittle and difficult to handle, and tended to split or tear at the gum veins and pockets. One firm reported that log size had a marked effect on veneer quality, with small logs being much better than large.

There was agreement that logs must be stored under water sprays to prevent excessive splitting, but conflicting information about the optimum length of storage for best veneer quality. Pre-heating before peeling was generally considered to improve veneer quality, but may not produce sufficient increase in recovery to justify its cost. Pre-heating also produced more severe end splitting in billets, and hence in the dried veneer. Acceptable veneer could be obtained from some carefully selected logs peeled cold.

One report was much more promising. Scribbly gum from Kempsey peeled hot, and dried immediately, produced good, smooth, flat, straight veneer with a "rubbery" texture and only minor end splitting.

The range of experience indicated that veneer suitable for some purposes can be obtained from scribbly gum, but logs must be carefully selected. There was general agreement that the species group is only suitable for inner longbands in structural plywood. It is not suitable for faces, and is unlikely to be acceptable for glue-carrying crossbands.
4.3.3 Blackbutt

Experience was more limited than for the previous two species, and was mainly confined to regrowth trees. Billets were usually peeled hot, no problems were experienced in drying, and dried quality was generally good. Some collapse and buckle occurred, and some end splitting - mostly originating in the billets and extending during drying.

Blackbutt was considered very good for structural plywood, and some veneer would be suitable for faces. One problem was the splintery nature of the veneer, particularly when dried.

4.3.4 White gum

Reports were varied and dried quality appeared to depend on the type and quality of the logs. One report indicated more degrade than in blackbutt or messmate, particularly that associated with gum veins in larger logs. This material was peeled hot, and would not be suitable for faces.

*E. viminalis* was peeled cold in one plant and dried in a screened drier. The veneer showed some washboarding due to differential shrinkage and/or collapse between earlywood and latwood, but it was not sufficiently severe to affect its utilization. End splits from the billets did not extend or open appreciably in drying, and would close in pressing. Some of the material produced could be used for decorative faces.

This species group could provide veneer ranging in quality from structural centres to faces, and even decorative veneer, depending on wood quality.

4.3.5 Messmate

Again reports were varied. Some veneer sheets had considerable buckle, caused by differential shrinkage and/or collapse, and end splitting, but were adequate for structural centres. Another report indicated good dried quality, with the veneer suitable for glue-carrying cross bands. Billets were normally peeled hot.

4.3.6 Other species

Brief comments on other species were -
- Sydney blue gum: "Very clean veneer"; normally peeled hot.
- Brush box: "too brittle".
- Tallowwood: "too greasy".

4.3.7 Effect of temperature on quality in laboratory experiments

In the laboratory experiments referred to previously there was no apparent reduction in dried veneer quality with increasing DBT from 80 to 140°C in 3.2 mm blackbutt or silvertop stringybark veneer. However, the sampling was too limited to be fully representative of these species.
4.4 Moisture content control

Control of final MC is an important aspect of veneer drying. There was general agreement that hardwood veneer should be dried to mean final MC's of about 5 to 6% - lower than usual for rain forest species. This is necessary to reduce MC variations within, and between sheets, and was supported by reports of patchy MC's in scribbly gum veneer unless it was dried to a mean MC of less than 5%. It was also considered desirable to hold veneer in a block stack for a MC equalising period of at least one week after drying.

Problems of patchy and uneven MC's are likely to be worse in white gum than most hardwoods, due to its relatively slow and uneven drying. They will probably increase with increasing veneer thickness.

The methods of controlling the final mean MC, and minimising MC variations, differ in screened and continuous driers:

4.4.1 Screened driers

These have a number of aspects that assist, and provide flexibility, in MC control -

- Individual trucks of veneer can be removed when dry, leaving trucks of wetter veneer for further drying.

- Trucks of inadequately dried veneer can be returned to the drier for a supplementary drying period.

- With experience, the completion of drying can be determined from the conditions in the drier. Two possible methods are from the temperature drop across the drier, as suggested by Gottstein and Stashefski (1958), or from the ratio of the WBT to the DBT of the air in the inlet side of the drier. The latter was used in one N.S.W. plant.

- Some MC equalising can be achieved by closing the vents for a short conditioning period at the end of drying.

However, it would still be desirable to ensure that the material in each charge (or at least on each truck) was similar in drying characteristics, in order to minimise variations in MC.

4.4.2 Continuous driers

These have much less flexibility than screened driers. Temperatures are maintained approximately constant in each section during each run, and the only adjustable control is of the speed of the transport system, i.e. of the drying time. Speed control operates from the infeed end, i.e. it is set before the veneer is dried, but the information required for setting the speed - the final MC - comes from the outfeed end, after the veneer has been dried, and when any deficiencies have already occurred. Inadequate final MC's may be difficult, or at least inconvenient, to rectify.

In these driers it is essential to sort the green veneer on the basis of similar drying time, and only dry similar material in each run. The
runs should be as long as possible to reduce the effect of MC variations during start-up and while establishing the optimum transport speed.

It is usually not possible to provide any equalising in continuous driers, due to the high temperatures, and correspondingly low equilibrium moisture content conditions, used. An exception could be when the heating is reduced for drying thin veneer. If this is done by turning off the heating in the drier sections at the outfeed end, some MC equalising of the dried veneer may occur.

4.5 Moisture content measurement

Most firms monitored the MC of their dried veneers with electrical resistance meters. These are not suitable for true production quality control, as they usually have a minimum reading of 5 or 6%, so many readings are "off the bottom of the scale" and provide no measurement of the actual MC. However, they are useful for detecting under-dried veneer, or wet patches in sheets.

An alternative, used by one firm, is the use of capacitance or power-loss meters. These give readings down to zero MC. Their main disadvantage is that they respond to the absolute amount of water present, rather than the ratio of water to wood, which is the normal expression of MC. This causes variations in meter reading with variations in density, as well as MC. The readings may also vary with veneer thickness, and may be affected by surface roughness.

The calibrations for capacitance or power-loss meters must be established for each application, and routinely checked. This is done by taking readings on representative samples of veneer, which are then oven dried to determine their MC. Even with proper calibration these meters may be less accurate than resistance meters. However, they are used for routine production quality control testing in the softwood veneer industry and, as they provide readings over the whole final MC range, their application to hardwood veneers, necessary calibration procedures, etc. should be evaluated.

It is possible that the actual amount of water present in veneer when it is glued may be more important than its MC as conventionally expressed. Capacitance or power-loss meters may provide a direct means of measuring this.

4.6 Aspects of drier maintenance, performance, and operation

4.6.1 Maintenance

No firms reported extra maintenance problems that could be attributed to drying hardwood, rather than rain forest, veneer. No significant kino buildup on the transport systems of continuous driers were reported.

All the continuous driers had roller transport systems. These appeared to be quite suitable for hardwood veneer in the thicknesses peeled most frequently, i.e. 2.5 to 3.2 mm, and probably for veneer down to 1.27/1.3 mm. Some blockages occurred, but their incidence was similar for hardwood and rain forest veneers. Blockage in roller transport driers is primarily a function of veneer thickness, with the frequency of occurrence increasing as thickness decreases. This system is unsuitable for very thin
veneers, which require the continuous support provided by a mesh transport, or similar.

The most common maintenance requirement, apart from routine lubrication, was regular cleaning to remove accumulated slivers, etc. that collected in the driers. These rapidly become bone dry, and constitute a fire hazard.

4.6.2 Energy consumption

The only specific information obtained was from a firm operating a 3-deck, 4-section continuous jet drier (8 m long, plus cooler), at a maximum DBT of \( \sim 160°C \). Steam was used to heat the drier, at a supply pressure of 160 p.s.i. (1.1 MPa) gauge. The consumption was reported to be 2800 lb/hour (1270 kg/hour) when drying 2.54 mm veneer.

4.6.3 General

A practice observed was stopping the transport system of a continuous drier during work breaks, with veneer left inside the drier. This veneer would inevitably be over-dried, and the practice should be discouraged.

5. COLLAPSE AND RECONDITIONING

5.1 Collapse

Collapse is an important cause of economic loss in veneers of many hardwoods. It is most prevalent in lower density species, or in regions of relatively low density wood. Its principal adverse effects are its contribution to drying degrade, and loss of volume. The latter may be as high as 20%, or even greater, if collapse is severe.

Aspects of collapse and reconditioning are summarised in Section 3. Further information is contained in the cited references, particularly Kauman (1964).

Collapse mainly occurs early in drying, as the MC falls to FSP. The two aspects of the drying conditions during this period that most affect its severity are -

- When the MC is above FSP, the veneer temperature remains close to the WBT. Maintaining this below \( \sim 60°C \) (or even as low as 40 to 45°C for "difficult" material) minimises collapse.

- Rapid drying may prevent collapse reaching its potential maximum.

Temperature probably has a greater effect than drying rate, particularly for thicker veneers.

5.1.1 Screened driers

Screened driers can be operated to provide low WBT's and relatively fast early drying rates (within the capacity of the drier) by appropriate control of venting, combined with maximum heat input. This should produce the lowest collapse achievable from commercial accelerated drying methods. However, significant energy is lost in venting, and drying rates are slow compared with jet driers.
5.1.2 Continuous driers

Temperatures in continuous driers are normally much higher than in screened driers, and they are operated to produce the fastest drying possible, with high thermal efficiency. The DBT is usually the highest that can be maintained continuously, and there is little inlet venting. WBT's are high (often approaching 100°C) and conditions may approximate drying in superheated steam. Fast drying is achieved by the high DBT (giving a large WBD) and, in jet driers, by the high heat transfer from the air impinging on the veneer.

Veneer temperatures are high early in drying, when they approximate the WBT, increasing the severity of collapse in susceptible material. The rapid drying in jet driers may tend to prevent collapse from developing fully, but this effect will decrease as veneer thickness increases, due to the increase in drying time. Collapse in susceptible veneers is likely to be greater than in material dried in screened driers. This is supported by the information on shrinkage reported in Section 4.2.

Continuous parallel flow driers have the high temperatures of jet driers, but substantially longer drying times, and are likely to maximise collapse.

5.2 Reconditioning

The excessive shrinkage caused by collapse can be recovered by reconditioning (steaming) the collapsed wood when its MC is below the FSP. Best recovery is obtained using saturated, or wet, steam at 100°C. Other important factors are -

- The duration of reconditioning. Ellwood (1952) found that 30 minutes was sufficient to produce maximum recovery in 1.6 mm mountain ash veneer. Thicker material will probably take longer. This is about half the drying time in a screened drier, but much longer than the total drying time in a jet drier.

- MC at the time of reconditioning. Complete recovery does not occur at MC's below 15%. As hardwood veneers are dried to target final MC's of 5 to 6%, only partial recovery can be expected from reconditioning after drying. Reconditioning at this stage also will probably increase the MC of the veneer, so a final re-drying may be necessary.

- Previous exposure conditions can affect the recovery of collapse in subsequent reconditioning. Recovery can be reduced by the combined effects of elevated wood temperature and exposure time, particularly at MC's above the FSP. The size of the reduction probably varies with the type of veneer drier used. It is likely to be least for screened driers, and greatest for continuous parallel flow driers.

- The wood temperature should be appreciably below 100°C at the start of steaming, for reconditioning to be effective. Veneer temperatures in continuous driers are usually well above 100°C late in drying, so the material must be cooled before reconditioning. Some cooling may also be necessary for veneer from screened driers.

These factors must be considered in any proposal for incorporating practical and effective reconditioning in a production drying process. An
additional constraint is the need to avoid double-handling of veneer, i.e. veneer must only be loaded onto, and unloaded from, the trucks for screened driers, or the transport system of continuous driers, once.

5.2.1 Screened driers

It may be possible to incorporate reconditioning into the production drying of veneer in a screened drier. Figure 2 shows a flow chart for -

- Including reconditioning, either
  I. in the screened drier, or
  II. in a separate reconditioner.

- Normal drying, without reconditioning.
Figure 2. Flow chart for veneer drying in a screened drier with and without reconditioning.
The relative merits of the two reconditioning regimes are -

I. Reconditioning in the screened drier:

Advantages -
- Avoids double handling of trucks.

Disadvantages -
- Existing driers are not designed for reconditioning conditions, and the structure, cladding, screens, fans, heaters, fittings, etc. may deteriorate rapidly. A drier constructed to withstand the conditions would probably cost considerably more than the established design.
- A large reduction in drier productivity, due to the time taken in reconditioning. Additional drying time will be lost if cooling before reconditioning is necessary.

II. Reconditioning in a separate chamber:

Advantages -
- Less deterioration of plant. Reconditioning done in a chamber constructed to withstand the conditions.
- Less reduction in drier production.
- Greater operational flexibility, as the breaks between the drier and reconditioner can provide production buffers.
- Drier charges can be mixed, with only the trucks containing collapsing material being reconditioned.

Disadvantages -
- Double handling of the veneer trucks.
- Time lost in extra loading and unloading of the drier.
- Cost of, and space required for, the reconditioner, and its associated areas for veneer trucks.
- Additional veneer trucks may be required.
- Greater steam demand, if the reconditioner and steam-heated drier are operated simultaneously.

Regime II appears preferable, but both involve a reduction in drier productivity, and a significant increase in total drying costs. The increased cost may outweigh the savings gained from decreased degrade and reduced shrinkage losses, particularly if the driers are operated to minimise collapse.
5.2.2 Continuous driers

Incorporating effective reconditioning within the transport system of a continuous drier would involve adding a cooling section and reconditioning sections within the length of the drier. The configuration of the drier would become -

veneer loading
drying sections (drying to, say, 15 to 20% MC)
cooling section
reconditioning sections
final drying section(s) (drying to 5 to 6% MC)
cooling section
veneer unloading

instead of the normal arrangement of -

veneer loading
drying sections (drying to 5 to 6% MC)
cooling section
veneer unloading

Including reconditioning is unlikely to be both practical and economical for two principal reasons -

- Reconditioning to obtain maximum recovery may take longer than drying, particularly in jet driers. This would more than double the length of the drier, and substantially increase its cost.

- The additional sections would be permanent installations on the drier transport system. All veneer would pass through them, even when they were not being used for reconditioning.

In addition, reconditioning is unlikely to produce complete recovery.

It appears that the adverse effects of collapse should be accepted as a consequence of drying susceptible veneers in continuous driers, and be offset against the advantages of rapid drying and high productivity.

6. COMPARATIVE MERITS OF DRIER TYPES

6.1 Continuous jet driers

These have impinging air flow, and are usually operated at the highest temperature that can be maintained continuously.

Advantages -

- Highest heat transfer and drying rate, hence greatest productivity.

- High thermal efficiency. The drying rate is virtually independent of the WBT at the DBT's normally used (substantially above 100°C). This enables the driers to be operated with little or no inlet venting, minimising the energy used in heating the incoming vent air. Under these conditions
there will be a high water vapour content in the drier. As the specific heat of water vapour (even on a volumetric basis) is greater than that of air, more heat is available for transfer to the veneer.

- The veneer is positively restrained at each pair of rollers. This should reduce buckle, but possibly at the cost of increased splitting.

- Manual loading and unloading is less laborious than for screened driers, as veneer is loaded horizontally. Veneer handling, loading and unloading can be partially, or fully, automated.

Disadvantages -

- Poorer control of, and less opportunity for adjusting, final MC than in a screened drier.

- Control of drying during a run is normally done by adjusting the transport speed. The information required for making adjustments is obtained at the outfeed end of the drier, from the MC of veneer that has already been incorrectly dried.

- Little, or no, capacity to equalise MC's in the drier.

- Any run must contain material of similar drying rate, to minimise variations in the final MC.

- Any veneer in the drier during a stoppage of the transport system is likely to be over-dried.

- Limited flexibility for drying material having widely different drying times, e.g. production of fast-drying veneer may be restricted by the capacity to load and unload the drier. This could largely be overcome, at a cost, by automating loading and unloading.

- The veneer is hotter early in drying than in a screened drier. This tends to maximise collapse, and reduce the recovery obtainable by reconditioning.

- Incorporation of reconditioning in the drying process is probably both impractical and uneconomic.

6.2 Continuous parallel flow driers

These have the disadvantages of continuous jet driers, and also have poorer heat transfer, giving slower drying rates and lower productivity.

6.3 Screened driers

These have parallel air flow and are normally operated at temperatures below 100°C.
Advantages -

- Greater flexibility for short production runs of different material.

- Can be used for mixed charges, provided all the veneer on each truck is similar, as different truckloads can be dried for different times.

- Veneer temperature can be kept low early in drying, minimising collapse and losses due to gross shrinkage.

- Including reconditioning, for the recovery of collapse, may be practical.

- More flexible control of final MC than in continuous driers.

- Drying progress can be assessed, with experience, from conditions in the drier.

- Equalising treatments can be given, by closing the vents at the end of a run.

- Operate at lower temperatures than continuous driers, so they can use a lower temperature heating medium, e.g. lower steam pressure.

- Possibly less splitting, as veneer sheets are largely unrestrained.

Disadvantages -

- Slower drying and lower productivity than continuous driers.

- Capacity is reduced unless the veneer sheet lengths are the full height of the drier, or short sheets can be arranged in separated layers to make up the full height.

- A large WBD is required to maximise the drying rate. This requires substantial inlet venting, reducing the thermal efficiency of the drier.

- Little restraint against buckle.

- Loading and unloading is relatively laborious, and is difficult with large veneer sheets.

6.4 Summary

Continuous jet driers are best suited to large volume production of similar veneer, and are probably the most suitable drier type for this purpose. However, screened driers have some important advantages, particularly for drying smaller mixed volumes of material having different drying characteristics, and for minimising collapse.
7. CONCLUSIONS

1. There is a considerable amount of reported information relevant to the drying of hardwood veneer, but little that is specific to the requirements of the N.S.W. industry.

2. The two most common drier types - batch screened driers and continuous jet driers - should be considered separately in assessing their performance, and effect on the dried veneer. Continuous parallel flow driers are unlikely to be of importance in future developments in N.S.W.

3. Drying times for hardwood veneers in both screened and continuous jet driers were generally similar to, or a little longer than, those for "medium drying" rainforest species (e.g. coachwood) veneers of the same thickness. Some between species variations occurred, the most marked being the relatively slow and uneven drying of white gum - particularly in thicker veneers.

4. There was little clear evidence of wood density affecting drying time.

5. Increased drying temperatures produced marked reductions in drying time, without generally reducing the quality of the dried veneer.

6. The effect of veneer thickness on drying time could be described by Equation (1) (page 12). Estimates of the values of the exponent, p, were 1.0 for screened driers, and a mean of about 1.3 for jet driers.

7. Shrinkage of hardwood veneer varied greatly, and was generally greater than for rainforest veneer. It caused a significant loss of material.

8. Collapse occurred in many hardwood veneers. There was evidence that it was greater in veneer dried in jet driers than in screened driers, which was consistent with it being more severe in veneers exposed to higher WBT's early in drying.

9. Incorporating reconditioning for the recovery of collapse may be practical in screened drying, but the additional drying cost and loss of production may outweigh the benefits. Reconditioning in continuous drying processes is probably both impractical and uneconomic.

10. Dried veneer quality varied greatly, and was related to wood characteristics, such as interlocked grain, differences in susceptibility to collapse between earlywood and latewood, and the presence of kino veins, the storage of logs, and degrade in the billets. Some material was only suitable for inner longbands in structural plywood. However, selected material from some species may be suitable for formply faces, or even decorative veneer.

11. The most widespread drying defect was end splitting - often originating in the billet. This was not considered serious for general structural plywood, but could make veneer unsuitable for faces.

12. Hardwood veneer was generally more brittle, fissile, and difficult to handle than rain forest veneer.

13. Species could be grouped according to the number of plants that had dried them:
most: flooded gum, scribbly gum, blackbutt; then: white gum, messmate.

Of these, plantation grown flooded gum was generally considered the most suitable for veneer, followed by blackbutt (mostly regrowth). Veneer suitable for some purposes could be obtained from selected logs of the other three species.

Veneer had also been produced from other hardwood species. Experience was more limited, but the general indication was that many species could be used, but careful selection of logs may be necessary.

14. Control of final MC was important, and more difficult in continuous driers than in screened driers. An equalising period after drying was desirable.

15. Resistance meters were inadequate for routine production quality control monitoring of the MC of dried hardwood veneer. Capacitance or power-loss meters may be more suitable.

16. Continuous jet driers and screened driers had comparative advantages and disadvantages. The more suitable type depended on the requirements of the particular situation.

8. ASPECTS FOR FURTHER INVESTIGATION

A number of aspects may warrant further investigation. One - end splitting - could also be improved by the more rigorous application of existing knowledge. These are discussed further.

8.1 Measurement of the MC of dried veneer

A quick, reliable method of measuring final MC's is necessary for proper production quality control. Oven drying is destructive, labour intensive, and too slow. However, it is the reference for other methods. Electrical resistance meters are widely used in the veneer industry. They are non-destructive, quick, and convenient, but cannot read sufficiently low MC's.

Capacitance (or power-loss) meters have the advantages of resistance meters, and read down to zero MC. They may be less accurate than resistance meters, as their readings are affected by factors other than MC - particularly density. They also must be calibrated, with routine checking, for each application. However, they are potentially the most suitable instrument available. Their accuracy, reliability, and the calibration procedures required, should be determined.

Another aspect of capacitance meters is that they measure the absolute amount of water present. A. Anton (pers. comm.) has advised that this may be of more importance in gluing than the MC as normally expressed, i.e. the ratio of water to wood. It appears possible that the meters could be used for direct assessment of the suitability of veneer for gluing.
8.2 Collapse and reconditioning

There is little quantitative information available about collapse in veneers from the hardwood species of greatest importance to N.S.W. veneer producers, and none about the recovery produced by reconditioning. Many factors are probably involved, particularly -

- Species.
- Site factors, including age and growth rate.
- Position in the tree.
- The history of wood temperature during log or billet heating.
- The drying method used - particularly the temperature/MC/time history of the veneer.
- Veneer MC at the time of reconditioning.
- The length of reconditioning.

A comprehensive investigation into all these would be impractical. However, if reconditioning is considered to be a serious commercial option, information providing some guidelines could probably be obtained from a study restricted to a few, selected factors.

8.3 Collapse in jet driers

The normal operation of jet driers - maximum DBT, little inlet air venting, and high WBT - tends to increase the severity of collapse. It may be possible to operate these driers with sufficient inlet venting to provide a low WBT (and veneer temperature) early in drying, combined with a relatively high DBT to give fast drying. The drier operation would be less efficient, and drying times would probably be increased, but collapse in susceptible veneers may be significantly reduced.

8.4 End splitting

This was the most widespread form of degrade. In some cases it originated in the peeled veneer, probably due to stresses caused by accelerated drying from the end grain, either during drying, or in the storage period after peeling. Methods of minimising this are given in some of the references cited, particularly Wright and Gottstein (1957). Relevant extracts are reprinted in Appendix C.

Many end splits originated before peeling, from stress or splits in the billets, probably caused by end-grain drying and/or the effects of growth stress. End-grain drying can easily be prevented. Growth stress, and its effects, is outside the scope of this report, but an assessment of its contribution to veneer degrade would be valuable. If it is found to be commercially significant, determining ways to minimise its effects would be desirable.

8.5 Log selection

The selection of logs suitable for peeling was largely subjective, based on experience. The important criteria (apart from the gross physical features of form, shakes, soundness of heart, etc.) probably were irregular grain, potential large differences in collapse between earlywood and latewood, and kino veins and pockets. An objective method of measuring these in the log, with the measurements related to subsequent veneer recovery and quality, would assist both the selection and the marketing of veneer logs.
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10. REFERENCES


APPENDIX A: N.S.W. VENEER PRODUCERS VISITED

Veneer driers, and hardwood species.

Big River Timber (Veneer) Pty. Ltd.,
Junction Hill.
Drier: continuous jet.
Species: blackbutt, flooded gum, scribbly gum group, Sydney blue gum, stringybark.

G. L. Briggs and Sons,
Briggsvale.
Drier: screened.
Species: blackbutt, New England blackbutt, brush box, flooded gum, round-leaved gum, scribbly gum group, Sydney blue gum, white gum group, messmate, diehard stringybark, silvertop stringybark, white stringybark, tallowwood, turpentine.

Coffs Harbour Plywood,
Coffs Harbour.
Drier: screened.
Species: flooded gum, white gum group.

Hanbro Plywoods (Hancock Bros. Pty. Ltd.),
Wauchope.
Drier: continuous jet.
Species: blackbutt, flooded gum, scribbly gum group, messmate.

Bruce Roper Pty. Ltd.,
Armidale.
Drier: screened.
Species: scribbly gum group, white gum group.

Veneer and Timber Products Pty. Ltd.,
Wauchope.
Driers: 2 screened, 1 continuous parallel flow.
Species: blackbutt, flooded gum, scribbly gum group, white gum group, messmate.

Venlay Plywood,
Grevillea.
Drier: continuous jet.
Species: trial with blackbutt and flooded gum.

Wood Products (Yarras) Pty. Ltd.,
Yarras and Wauchope.
Drier: continuous jet.
Species: blackbutt, brush box, flooded gum, scribbly gum group, messmate, tallowwood.
APPENDIX B: SPECIES AND SPECIES GROUPS MENTIONED IN THE REPORT.

alpine ash: *Eucalyptus delegatensis* R.T. Bak.
mountain ash: *E. regnans* F. Muell.
white birch: *Schizomeria ovata* D. Don.
blackbutt: *E. pilularis* Sm.
brush box: *Lophostemon confertus* (R.Br.) Peter Wilson et Waterhouse.
coachwood: *Ceratopetalum apetalum* D. Don.
flooded (rose) gum: *E. grandis* W. Hill ex Maiden. Mainly plantation grown.
round-leaved (brown) gum: *E. deanei* Maiden
scribbly gum group: probably mostly *E. signata* F. Muell., possibly *E. haemastoma* Sm.
spotted gum: *E. maculata* Hook.
Sydney blue gum: *E. saligna* Sm.
white (manna) gum group: mainly *E. viminalis* Labill., possibly *E. dunnii* Maiden
messmate: *E. obliqua* L'Hérit.
stringybark. Species unspecified.
diehard stringybark: *E. cameronii* Blakely et McKie.
silvertop stringybark: *E. laevispina* R.T. Bak.
white stringybark: probably mostly *E. eugenioides* Sieb. ex Spreng.
tallowwood: *E. microcorys* F. Muell.
turpentine: *Syncarpia glomulifera* (Sm.) Niedenzu.
APPENDIX C: EXTRACTS FROM "THE DRYING OF VENEER, PART I. THE PROBLEM"
by G.W. Wright and J.W. Gottstein.¹

HANDLING AND STORAGE

Poor or careless handling can be a major cause of splitting and can initiate faults which later extend during drying. Poor storage of peeler blocks or green veneer, resulting in end drying, can also cause degrade. For example, unless kept wet or shielded there is a risk that green veneer in bulk piles will develop end splits, the cause being a combination of end drying and within-pile restraint. Alternatively, end drying may accentuate later end waviness. It is wise to avoid delay in peeling after cross-cutting from the log, and in drying after peeling. Both these measures will help to avoid end drying.

END SPLITS AND END WAVINESS

In most cases these two forms of degrade develop from the same cause, namely, differences in drying rates and, hence, in shrinkage rates between the ends and the remainder of veneer sheet.

Under conditions which cause early end shrinkage, the sheets develop transverse tension stresses at the ends. Because the elastic limit of moist wood is very low, tension set develops at the ends of the sheets very early as a result of these stresses. If the intensity of stress due to excessive end drying exceeds the transverse tensile strength of the veneer, end splitting will result. Material peeled from blocks which have been allowed to end dry, or green veneer which has end dried during storage also develops tension set, or moisture gradients which result in tension set under uniform drying conditions.

The presence of tension set at the sheet ends results in a reduced shrinkage of the ends, and later in drying they automatically wrinkle to accommodate the slightly lesser width of the bulk of the sheet.

Excessive moisture absorption at the ends of sheets during conditioning, as when exposed to excessively humid conditions, or the exposure of poorly built bulk piles of dry veneer stored under humid conditions, can also accentuate end waviness. Over-dried veneer develops severe waviness when stored under normal equilibrium moisture content conditions.

End wrinkling is more likely in tightly cut veneer than in loosely cut material, because of reduced flexibility.

Much veneer of many species is dried without end splitting or waviness when driers are properly designed and controlled, and end drying of the peeling blocks and of the veneer while in green storage is prevented. The most common and practicable steps to prevent the trouble if it is experienced are:-

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(i) Shielding the ends of sheets by baffles at right angles to the air flow is used sometimes, but has a somewhat limited application. In the screen drier, sheets placed parallel to the air flow against the veneer sheet ends, thus forming a boundary layer barrier, are effective in minimizing end drying, and may be required if end gradients are present.

(ii) Pasting kraft paper about 1 in. (25mm) wide across the surface at the ends or wrapping the ends with polyethylene-coated kraft paper about ½ in. (12mm) wide may be justified for specially valuable stock.

(iii) Lapping the ends of sheets by about ¼ to ½ in. (6 to 12mm) is a very effective method in mechanical driers, but calls for extreme care in loading. Excessive end lapping gives a lot of trouble due to wet sheet ends.

(iv) Wetting the ends of sheets just before and, where possible, during drying is effective if excessive end drying makes such a measure necessary.