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THE BEHAVIOUR OF RADIATA PINE OF DIFFERENT AGES UNDER DIFFERENT DRYING CONDITIONS

W.E. Hillis and A.N. Rozsa

ABSTRACT

The relative dimensional stability of dried radiata pine wood samples increased as the distance of the annual rings from the pith increased. The increase levelled off when material older than 10 years was examined. The pattern of stability differed between wood collected in Victoria and near Mt Gambier. The softening points of juvenile wood were less distinct than those of mature wood. Stability increased with presteaming for 2 hours, with increasing drying temperatures up to about 160°C and increasing time of drying. Green heartwood with a moisture content of 32% showed a much greater deflection under load during the initial stages of drying than did sapwood with a moisture content of 141%.

INTRODUCTION

The softening points of mature wood of *Pinus radiata* depend on the moisture content and on the previous history of heating (1). Further details of the conditions affecting the softening points are necessary in order to define the optimum conditions for treating wood during the high temperature drying process. Because of the importance of a high degree of dimensional stability of dried wood to moisture change, this work has been supported by studies of wood immediately after surface wetting and after a range of prior treatments. Furthermore, because increasing volumes of juvenile wood from different areas are now being processed, the stability and softening points of woods of different ages and from different regions have been studied.

MATERIAL AND METHODS

The strips of wood 245 x 5 x 5 mm were prepared in the same manner and the softening points were determined by the same procedure as previously reported (1). The stability after various treatments was assessed by using strips of wood of the same size, dipping them for 60 seconds in cold water, clamping one end in a frame so that the other end rests in a bearing to which is attached a circular pulley with a protractor scale of 200 mm diam. The periphery of the pulley carried a thread holding a 160 g weight. The degree of twist (deflection) of the strip of wood after 60 seconds under load is used to provide a comparison of stability on wetting.

RESULTS AND DISCUSSION

The results obtained with mature and juvenile wood may be summarized as follows:

1. MATURE WOOD

1.1 Presteaming for 2 hours before drying almost halved the instability of the dried wood when wetted in comparison with that steamed after drying. Presteaming for 2 hours lowered the softening points of green wood of 92° and 78°C to 82° and 60°C.

1.2 When wood previously dried at 100°C was heated at 100°, 135°, 160° and 180°C for 30 minutes the stability increased although there was small improvement between the samples heated at 160° and 180°C.

1.3 When green wood was heated at 100°, 120° and 135°C for 1 day and at 100°, 120° and 135°C for 2 days there was a steady improvement of stability with each of these treatment conditions. Heating under the same temperature conditions for 5 days further improved stability, but there was only a small difference between the effects of 120° and 135°C.

1.4 Increasing the wetting period of dried material decreases the stability but material dried at 135°C and soaked for one hour, is more stable than that dried at 100°C and soaked for one minute.

1.5 Stability is related to the amount of water absorbed when the dried material is immersed in water.

1.6 Following methanol extraction the stability of heartwood was considerably lower and the moisture uptake higher than that of unextracted heartwood.

1.7 Heartwood showed a much greater deflection under constant load when dried from 32 to 20% moisture than did sapwood under the same conditions for the same time when the moisture fell from 141 to 100%. From these results, the restraining forces required during the initial, critical drying stage would be less with the much drier heartwood than with sapwood.

1.8 CCA treated sticks showed a much greater stability after soaking in a liquid silicone.

2. JUVENILE WOOD

2.1 The stability of juvenile wood after drying increases steadily from that at the pith to that of wood formed about 10 years later. At that stage its behaviour is similar to the wood formed in trees of 20 or more years of age.

2.2 The stability of dried and rewetted juvenile wood from trees grown near Myrtleford has so far been found to be less than that from Mt Gambier and Mt Burr. There was a greater variation between trees near Myrtleford than near Mt Gambier.

2.3 The stability of juvenile wood from different localities is different under different drying conditions.

2.4 The softening points of juvenile wood became less distinct and more variable as the pith was approached.

3. LARGE SCALE TESTING

Experimental work has been commenced to show the relationship between the stability and softening points of samples taken from one end of a raidata pine log, the remainder of which was dried under commercial conditions and the distortion of which was measured.

Attention is drawn to a parallel study in the Division of Building Research, CSIRO (2).

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THE ANATOMICAL BASIS OF WOOD STRENGTH

R. K. Bamber

ABSTRACT

Explanations for the large amount of variation which occurs in wood strength have been sought by reference to the micro- and submicroscopic structure of wood. Consideration has been given to the anisotropic nature of wood strength, longitudinal and transverse tensile strength and longitudinal and transverse compressive strength. The relative roles of the bonding zone (middle lamella - outer secondary wall) and the whole of the cell wall in determining wood strength are discussed.

INTRODUCTION

The strength of wood arises from the properties of the individual cells and the bond between them. However simple explanations of the various strength properties are not always forthcoming when the nature of wood failure is considered. This is demonstrated by the apparent contradiction which exists between the relative roles of the bonding region of cells and the whole cell wall. While it has been shown (1), (2), (3), that wood failure occurs predominantly in the bonding zone made up of the middle lamella, primary wall, and the outer secondary wall it is evident that the strength of wood is mostly influenced by the thickness of the whole wall (as expressed by wood density). However if the strength of the bonding zone is considered to be the principal factor then total wall thickness would not be important.

Because of the importance of a fundamental understanding of the nature of wood failure an attempt has been made in this paper to analyse various strength properties in anatomical terms with particular regard to this apparent contradiction between the role of the bonding region and the whole wall. The obvious effects due to certain tissues, for example earlywood and latewood or large amounts of longitudinal parenchyma and abnormalities such as kino veins have not been considered.

THE NATURE OF THE CELL WALL

The strength properties of wood must ultimately depend on the nature and bonding of the chemical constituents, the fine structure of the wall and the gross structure of the cells. The chemical components and the fine structure of the wall are well known (4). However the way in which the cellulose,

hemicellulose and lignin are combined is not so well known although it has been suggested (5) that the cellulose crystallites are encased in hemicellulose and that the lignin is bonded to the hemicellulose thus cementing the microfibrils into a solid material. The cell wall can be divided into a number of discrete layers on the basis of the orientation of the microfibrils. These are summarised in Fig. 1.

The role of the constituents in determining the properties of wood can be demonstrated in a number of reactions for example, (a) exposure of wood to high levels of gamma radiation destroys the crystalline character of the cellulose. Although the wood is superficially unaffected it becomes extremely brittle (6), (b) removal of the lignin by chemicals allows individual cells to separate and become flexible, and (c) the formation of microscopic creases in the cell wall of fibres during compression failure removes the lignin cover from cellulose allowing it to be stained by cellulosic stains (7) (in normal wood such specific staining of cellulosic materials is difficult). This latter reaction indicates that lignin is chemically bonded to the cellulosic materials and suggest that the root cause of compression failure is the breaking of these bonds.

In the following discussion it is assumed that the wood cell wall behaves like a visco-elastic solid being formed of fibrous units (microfibrils) held together in a plastic lignin matrix. The microfibrils have been considered by some authors (8) to be much harder than the lignin matrix.

TENSION

VARIATION Like most wood properties tensile strength is anisotropic and can be more than forty times greater parallel to the grain than transversely (figures quoted are for Douglas fir (9)). Variation due to grain inclination is considerably greater than that found either between trees (intra-specific) or between species (inter-specific). Typical inter-specific variation for tensile strength parallel to grain is from about 76 MPa (density 370 kg/m^3) to about 190 MPa (density 680 kg/m^3) (10).

As cell wall thickness is not a factor in the anisotropic variation in tensile strength, the difference must be due to some other anatomical factor. An explanation may be found by reference to the previously mentioned "weak" bonding zone. As can be seen in Fig. 2 many more zones of weakness occur transversely than laterally. Considering the average dimensions of Douglas fir tracheids the difference could be in the order of fifty five times. This is not much greater than the real difference of forty times quoted for Douglas fir (9). However the model shown in Fig. 2 does not take into account the tapered and overlapping form of tracheid ends which could be expected to

reduce the above quoted theoretical value.

LONGITUDINAL The strong relationship between density (and thus average cell wall thickness) and longitudinal tensile strength appears to contradict the observed pattern of failure in the bonding zone. It is suggested that both of these factors are reconcilable by consideration of (a) the tubular form of fibres and tracheids and (b) the flexible nature of wood cells.

Because wood is flexible, a tensile force which acts initially to lengthen the cells produces a secondary force tending to reduce the cell diameter. This transforms at least part of the longitudinal tension into transverse tension between cells (Fig. 3) and thus causing failure between cells in the weak bonding zone. As this transformation of forces is obviously resisted more by cells with thicker walls than cells with thinner walls, tensile strength can be seen to be related both to cell wall thickness and the strength of the bonding zone.

TRANSVERSE While there is not a great deal of data on the relationship between density and transverse tensile strength, consideration of wood anatomy can show that, despite the predisposition of wood to fail in the bonding zone, wood density (as a measure of average cell wall thickness) is a significant factor in transverse tensile strength. As can be seen in Fig. 4 a transverse tensile force is transmitted along the portion of the wall parallel with the direction of the force. The force is transmitted from one cell to another by means of the bonding zone. It would appear likely however that the force is not transmitted evenly across the whole of the bonding zone being concentrated in the region adjacent to the force-transmitting portion of the wall. Thus it can be inferred that, as the force will be more widely distributed along the bonding zone with thick-walled cells, cell wall thickness and transverse tensile strength are related.

Bonding zone failure is not however the only mode of failure in transverse tension. Recent work (11) has shown that failure may occur either in the bonding zone or across the walls. Accepting that the bonding zone is the weaker zone in the wood it would appear that failure across the walls would be favoured more in those species with thin-walled cells. It is probable that in thin-walled cells the strength of the bonding zone is greater than the strength of the wall.

COMPRESSION

VARIATION Although compressive strength like tensile strength is anisotropic the differences in compressive strength due to grain inclination are not as large being only about seven times greater longitudinally than transversely (12). Like tensile strength the differences in compressive

strength due to grain inclination are greater than either intra- or inter-species differences. Both the anisotropic nature of compressive strength and the pattern of compression failure can be related to anatomical factors.

LONGITUDINAL Figure 5a demonstrates that longitudinal compression is transmitted fairly evenly along the whole of the cell wall. As a consequence wood is much stronger in compression parallel to the grain than transverse. The initial effect of longitudinal compression is to shorten the cells (Fig. 6). Because of the visco-elastic nature of the wall this shortening will result in transverse enlargement. Assuming that the microfibrils behave as rigid units in a plastic matrix (lignin) the increase in width can only be accommodated by re-arrangement of the lignin molecules and consequently fracture of the ligno/cellulosic bonds. That such fracture of these bonds occurs is demonstrated by the altered histochemical staining properties of those areas of the wall showing compression failure. As the ligno/cellulosic bond confers rigidity on the wall the fracture of the bond allows the microfibrils to flex or to be displaced and ultimately the wall to buckle.

Compression failure has been shown to be initiated by the formation of microscopic slip planes in the cell walls (7). These areas gradually enlarge forming kinks or creases leading ultimately to separation of the cells and wood failure. Despite observations that in compression failure, failure occurs principally in the bonding zone (1), failure in this zone does not appear to be the primary cause of compression failure. It is suggested that the primary cause of compression failure is the failure of the ligno/cellulosic bond leading to the development of the microscopic slip planes. Failure in the bonding zone between cells is a secondary effect. Longitudinal compressive strength is consequently largely determined by the strength of the ligno/cellulosic bonds within the wall and thus by thickness of the wall rather than the strength of the bonding zone.

On the basis of this hypothesis it could be argued that filling of the lumina with a hard material would prevent the transverse enlargement of the walls and the development of creases with a consequent increase in compression strength. This has been found to be the case and an increase of about 50% in longitudinal compressive strength in basswood after impregnation of the wood with methacrylate has been recorded (13). In this study (13) bending failure was characterised by an absence of compression failures. In another study (14) the longitudinal compressive strength of polymer-impregnated wood was examined. It was found that the increase in strength far exceeded the increase to be expected by the additive effect of the polymer. This increase in strength could be explained by reference to the model suggested above in which the

transverse deformation of the cell walls is minimised by the filling of the cell lumina with a hard material which in turn prevents rupture of the ligno/cellulosic bond and the consequent formation of slip planes.

TRANSVERSE The lower strength of wood in transverse compression is due to the tubular nature of wood cells and the longitudinal orientation of the cellulosic material. As can be seen in Fig. 5b transverse compression is not transmitted evenly throughout the wood; only those portions of wall which are parallel to the force initially transmit the force. Other parts of the wall are largely unsupported and readily deform. Little resistance to such deformation would be offered by the wall as the structural units of the wall, the microfibrils, are at right angles to the force and are not deformed or stressed by cell collapse in this direction. Wall thickness is clearly important as it contributes to the amount of wall available to support the force and transmit it from cell to cell (Fig. 5b).

ACKNOWLEDGEMENTS

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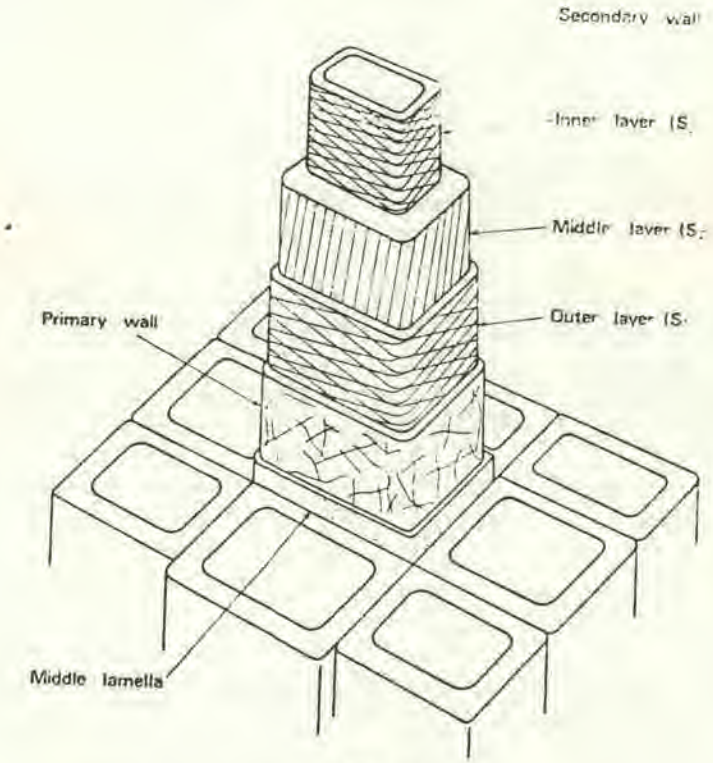

FIG. 1

Simplified structure of a wood cell wall showing orientation of the microfibrils in each of the major wall layers.

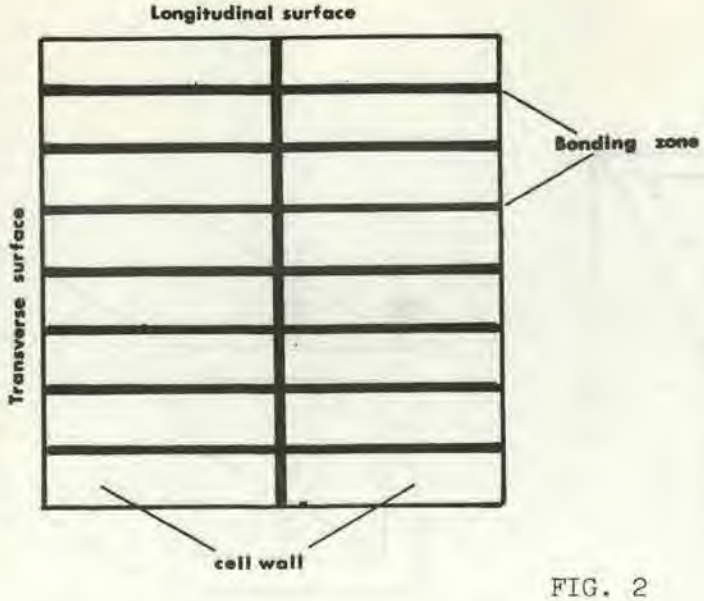

FIG. 2

Simplified model of fibres and tracheids. Cell lumina not shown.

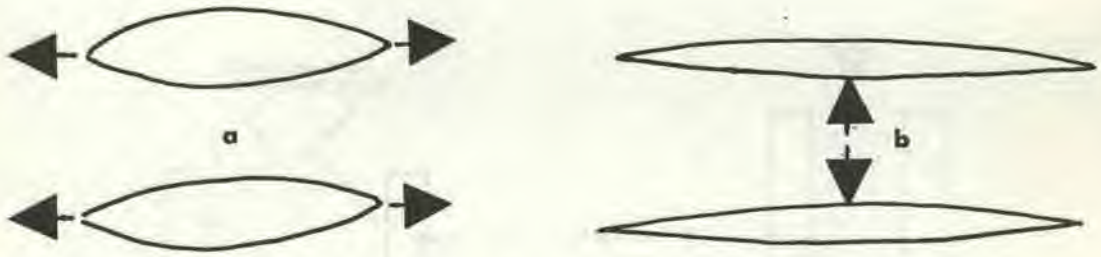

FIG. 3

Simplified diagram showing the transformation of longitudinal tension into transverse tension due to lengthening of the cells.

a) initial force b) transformed or secondary force

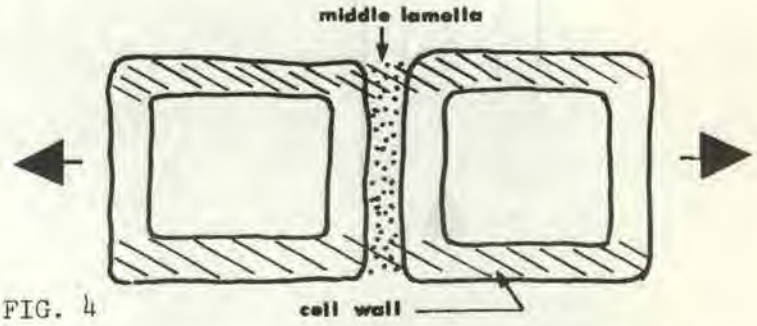

FIG. 4

Diagram showing the transmission of a transverse tensile stress in wood cell walls. Zones in which the major component of the stress are considered to occur are cross hatched.

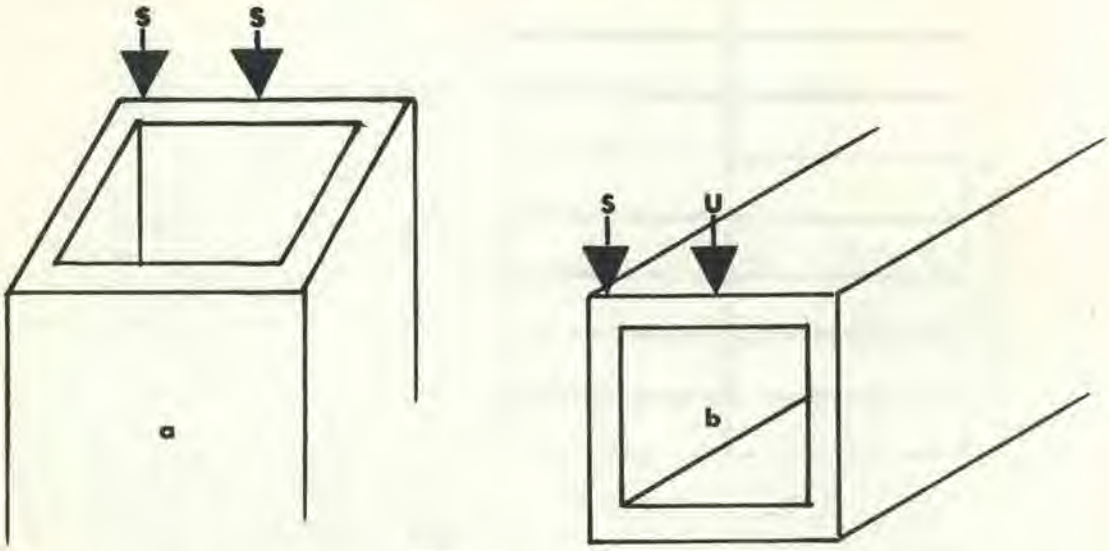

FIG. 5

Diagrams illustrating the differential distribution of compressive stress on wood cells in different directions.
a) longitudinal compression b) transverse compression
S = supported stress; U = unsupported stress

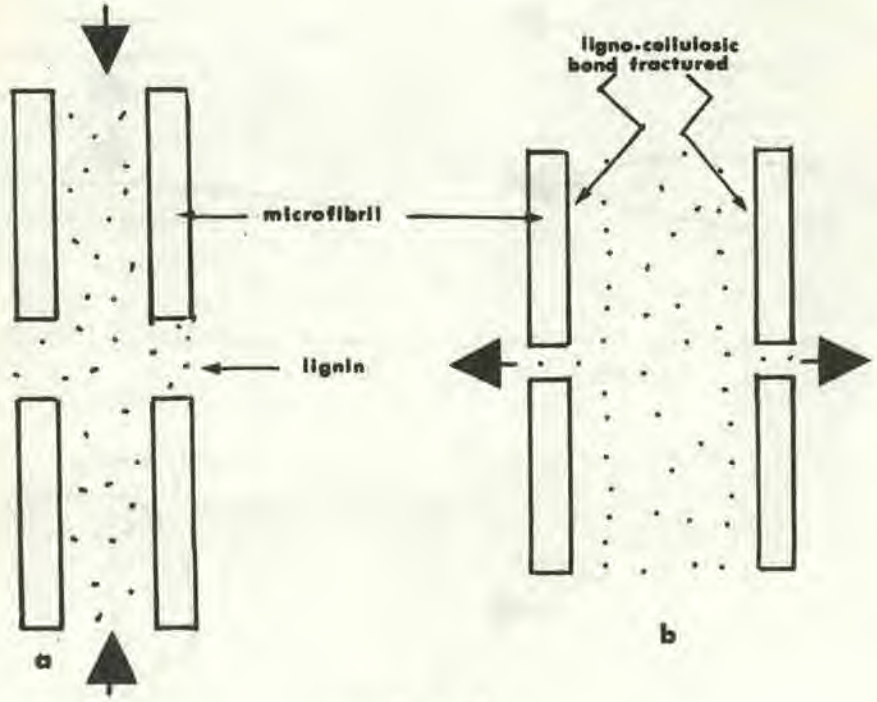

FIG. 6

Diagrams showing the postulated effect of longitudinal compression of the microfibrils and lignin matrix within the middle secondary wall. For simplification the microfibrils are drawn parallel to the direction of force.
a) initial force b) transformed force with resultant relocation of microfibrils and lignin.

ALLEVIATION OF GROWTH STRESS IN LOGS EXPOSED TO VARYING MOISTURE CONDITIONS

S.C. Chafe

INTRODUCTION

The presence of growth stresses in logs can cause serious difficulties during sawing and can significantly reduce the yield of solid wood products; their importance for the genus *Eucalyptus* has recently been highlighted (1). Reduction of such stresses is desirable and a number of attempts of growth stress alleviation in logs has been made (2). A majority of these have involved water treatments in some form, e.g. soaking, spraying, boiling or steaming, and while some success in the reduction of stress has been reported, some disagreement on the effectiveness of various treatments remains (2). Recently Nicholson (3) measured a 20% reduction in growth stress both in logs stored under water sprays and in logs stored in the open (but with restricted moisture loss) for some 300 days.

The present study has examined the stress reduction in logs exposed to varying moisture conditions. Logs have been water-sprayed, allowed to air-dry or have been moisture-cycled. Investigation of these effects was prompted by the reported increased deformation of wood under constant load when subjected to changing moisture content (4). By comparison with wood maintained at constant moisture content, creep is dramatically increased in tests for bending and in compression and tension parallel to the grain (4). Internal stress relaxation also occurs during changing moisture content under conditions of constant deformation (5). It was thus postulated that reduction of the overall level of growth stress might be greater in logs air dried or moisture cycled than in logs stored under water spray.

MATERIALS AND METHODS

Five trees of 39 year old mountain ash (*Eucalyptus regnans* F.Muell.) regrowth from Powelltown, Victoria, were used in the study. Following felling, three logs, each 2.5 m in length, were cut from the bottom portion of each stem. Prior to cross-cutting, the stem was banded with Gerrard Super Strapping at points where cross-cuts were to be made. Banding was carried out to minimize the release of growth stress near cross-cut faces and so lessen the likelihood of formation of growth-stress-derived checking.

The 15 logs, each banded on both ends, were transported to Melbourne where they were debarked, randomly divided (within trees) into three groups of five

logs each such that each tree was represented in each group, and placed on separate log decks under cover for protection against sun and rain, but allowing for free movement of air. Group I was allowed to dry according to prevailing weather conditions and Group III was kept wet by a recirculating water spray. Group II was alternately allowed to dry or was water-sprayed according to Table 1. Measurements of peripheral growth strain, using the technique of Nicholson (6), were made prior to the beginning of treatments, i.e. when the logs were green, and at 2, 5, 8 and 12 months following this time (Table 1). Four measurements, equally spaced around the circumference at the approximate middle of each log were made on each measuring occasion. All samples were retained for moisture content and density determinations and small blocks (ca. 30 mm long and 10 mm square) prepared from the samples were machine tested in the green condition in compression parallel to the grain for determination of modulus of elasticity values. Where applicable, strain values were adjusted to green condition using the appropriate formula (7) (p.516) assuming a fibre saturation point of 28%. After the initial measurement, subsequent values for strain and stress were also adjusted to allow for the effect of previous sample removal from the log.

TABLE 1

Moisture Treatment of Log Groups over Testing Period

Group	Period										
	1st Measurement	2 mths Feb-Mar'78	2nd Measurement	3 mths Apr-June'78	3rd Measurement	3 mths July-Sept'78	4th Measurement	4 mths Oct'78-Jan'79	5th Measurement	
I		Drying		Drying		Drying		Drying		
II		Drying		Water Spray		Drying		Water Spray		
III		Water Spray		Water Spray		Water Spray		Water Srpay		

RESULTS AND DISCUSSION

Average changes in growth strain and growth stress for each of the three log groups over the 12 month period of measurement are graphically illustrated in Fig. 1. In all three groups there was a definite downward trend in values with time and comparison of initial and final figures showed highly significant reductions (0.1% level) in strain and stress. However, the pattern of change differed considerably from one group to the next.

In group I, under continual air drying, the trend showed a more or less regular decline throughout the measurement period. However Group III, under continual water spray, showed a significant fall (1% level) at the second measurement (two months) but thereafter displayed little appreciable change. Group II described an unusual pattern in that an initial significant decline (1% level) after drying was followed by a significant increase (for stress, 5% level) after water spray and thereafter behaved somewhat similarly to Group I.

Overall per cent reduction in growth strain and stress indicated that Group I (53% and 47% respectively) showed greatest change, Group II was second (36% and 37%) and Group III showed the least change (33% and 26%). However, because of high variability in individual measurements, statistical significance (5% level) was demonstrated only for growth stress between Group I and Group III at the final (5th) measurement. Although this indicates that drying logs to reduce stress may be more desirable than storage under water sprays, the effects of shrinkage during drying must be considered. Fig. 2 shows the end faces of logs from each group. Whereas the Group III log displays only narrow heart-contained, growth-stress-derived checks, formed during cross-cutting, logs from Groups I and II show large diametral cracks together with numerous smaller checks. These large cracks develop because, despite banding, the reduction in diameter during drying causes the bands to loosen and thereby allow relief of growth stress through transverse expansion, with the associated widening of checks. It would seem that prevention of crack development during drying could be achieved only by a banding device which continually supplied an even pressure at the log ends.

In final assessment of the treatments, it would seem that no advantage is gained from moisture cycling, at least on the time scale employed here. However, it is recognized that an even moisture conditioning of the logs probably was not achieved over the intervals involved and this may have contributed to the variability of values measured at different stages (Fig. 1). It is likely, for example, that at the end of the initial two month drying period there would be considerable difference in moisture content between the outside and inside of logs. The generally regular decline in strain and stress values for logs of Group I may suggest a progressive drying of the log heart. In the case of the water-sprayed logs (Group III), while relatively little further change occurred beyond the second measurement, a reduction of the order of 20% after two months suggests that significant stress alleviation may be achieved by storage under water sprays for relatively short intervals.

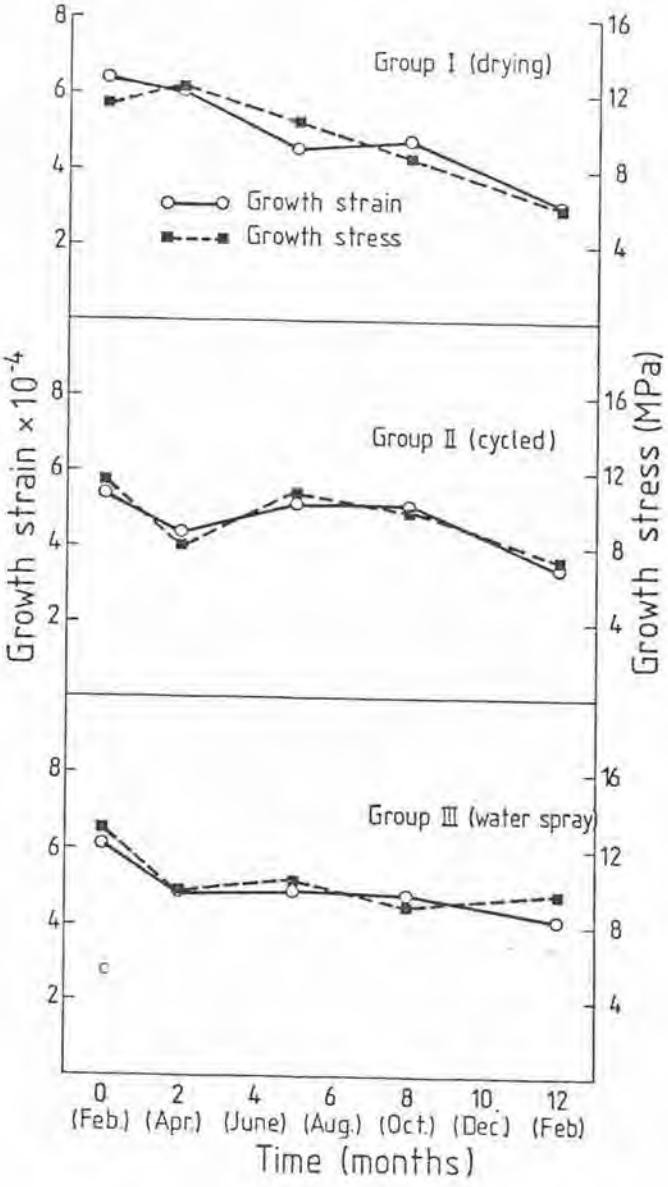

Fig. 1. Average change in growth strain and growth stress over 12 month period.

Fig. 2. End faces of logs from the same tree as represented in each of the three groups: (a) Group I, (b) Group II, (c) Group III.

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THE RELATIONSHIP OF ANATOMICAL CHARACTERISTICS WITH WOOD PROPERTIES

W.E. Hillis, J. Ilic and P. Soenardi

ABSTRACT

Two examples in the development of the use of anatomical data for indirect determination of wood properties are presented. Initial manual methods demonstrated positive correlations between cell wall area and a range of mechanical properties. The degree of correlation was not considered sufficiently high for accurate prediction of such properties, however, and development of an electronic image processor for more accurate and extensive anatomical data collection was undertaken. Initial results using this instrument have been very promising and a first experiment has shown that timbers susceptible to collapse can be predicted with great accuracy on the basis of fibre wall to lumen area ratio. Other anatomical characteristics were also shown to be different between collapse-prone and collapse-resistant material.

INTRODUCTION

The forest resource and particularly that of tropical forests must increasingly be used more completely, in a more precise manner and for the best application commensurate with quality. In addition, logs, and parts thereof, from fast-grown short-rotation plantations also require maximum conversion to high valued products. Apart from the need to explain the properties of new timbers to the end-user, there is a need for techniques that can be readily applied to classify the properties of timbers without large scale or destructive testing. These tests would facilitate modifications of routine operations and assist the increase in efficiency of integrated operations.

Density has been suggested as the most useful single parameter in the first stages of assessing little-known species (1,2). Ultimately, large scale testing of mechanical and pulping properties is also required together with the determination of the response to secondary treatments such as preservation, machining, etc. However, these tests and measurements can be impractical in defining the variations in a species, or the causes of the unsatisfactory nature of certain properties. The development of simple tests related to basic properties are clearly preferable.

Ultimately the properties of wood are dependent on the anatomy, fine structure and chemical composition of wood. An early study of 11 different

Eucalyptus species reported a "connection" between physico-mechanical properties and anatomical structure (3). Another study (4), however, failed to show statistical significance between such properties and total percentage volume of fibre, vessel and parenchyma cell walls. The present paper first describes attempts made to formulate a predictive relationship between quantitative fibre characteristics and wood properties in 10 tropical species. Partly as a consequence of limited success attained in this experiment using manual methods, the development of an electronic image processor for collection of anatomical data was undertaken. The second part of the paper describes success achieved using this instrument, in predicting collapse, a perennial problem in ash-type eucalypts (5), on the basis of wood anatomical data.

MATERIAL AND METHODS

PART I.

Samples were taken from single trees of *Myristica maxima, Dehaasia caesia, Dacryodes rostrata, Tarrietia javanica, Aquilaria malaccensis, Dillenia reticulata, Payena endertii, Diospyros* sp., *Polyathia* sp., *Artocarpus* sp. growing inland from Balikpapan, East Kalimantan. Samples 50 cm long and 7 x 3.5 cm were cut at 25% and 50% of the stem radius at the outer heartwood and sapwood of the butt, mid-position and top of the main stems of the trees.

Anatomical and physical measurements were made on specimens taken from one end of the sample. Wood structural properties determined were fibre length, fibre wall thickness, lumen diameter and the percentage of rays, vessels, fibres, parenchyma and cell wall by volume. An assessment was also made of the extent of tension wood, brittle heart, tyloses and wood extractives. Following an examination of the various methods available for the determination of anatomical features at the time, measurements were made optically with an integrating eyepiece attached to a dual linear micrometer on intact wood surfaces after cutting and immersion in water.

Mechanical tests determined by standard methods were MOE on bending, fibre stress at proportional limit in static bending, MOE in compression parallel to the grain, fibre stress at proportional limit parallel to the grain, MOR, maximum crushing strength, and hardness (radial and tangential). Basic density was also determined.

PART II

Experimental material of *E. regnans* was collected from Powelltown, Victoria, and green boards representative of ten trees were selected. A small sample of approximately 5 cm along the grain was removed from each 1 m long board for sectioning and the remainder used for conventional kiln drying. One cm cube

blocks were prepared and microscope sections cut in the usual way.

The sections were stained with 1% methyl violet, mounted permanently and then scanned radially using the image processor. Fibre area and lumen area for about 100 fields across the section were determined and fibre wall to lumen ratio was calculated (see Fig. 1). After arranging the ratios of each slide in numerical order from largest to smallest, the 10 percentile value (LW_{10}) was calculated with LW_{10} being taken as that value just above 90% of the lowest measured ratios.

On the basis of the LW_{10} values obtained the potential susceptibility of a sample to collapse was assessed. Subsequently the remaining portion of the sample boards were kiln dried and graded with the generous co-operation of Mr G.S. Campbell.

RESULTS AND DISCUSSION

PART I.

Regression analysis between both cell wall volume and density and physico-mechanical properties demonstrated positive relationships. However, the correlation coefficients did not suggest a sufficiently high level of significance in the case of cell wall volume, to allow accurate prediction of mechanical properties. Considerable variation in individual mechanical properties doubtlessly reduced this level of significance. However, the laborious nature of measurements of cell wall area by optical methods precluded an exhaustive examination and such variables as cell wall porosity and texture could not be considered. From this study density was shown as still the best indication of the strength properties of wood and its value would be extended with the additional test for toughness by means of the Izod test.

PART II.

Prior to this investigation of collapse susceptibility in green boards a reference point was determined for the image processor as follows:

Boards obtained from 20 trees had been dried under commercial conditions and 12 of these had collapsed. Samples from these dried boards were boiled in water in order to return them to a condition approximating that of green boards. It was found (unpublished work) that those samples with LW_{10} below 3-4 for the fibre wall to lumen area ratio had been taken from boards which collapsed.

Analysis of all samples taken from green boards is shown in Table 1. It was proposed that those samples with the majority of LW_{10} values above 4 (Fig. 2) would not collapse and that those samples with most of the LW_{10} values below 3 would collapse. These conclusions coincided completely with the subsequent assessments of dried boards by Mr G.S. Campbell. It will be observed from the

TABLE 1

THE RELATIONSHIP BETWEEN COLLAPSE AND 10 PERCENTILE VALUE (LW_{10}) OF FIBRE WALL TO LUMEN AREA RATIO

Tree Number	No. of microscopic sections examined	Range of LW_{10} value	Collapse predicted,	observed
MA-1	6	5.7 - 7.6	none	none
MA-2	9	2.2 - 4.3	✓	✓
MA-3	6	2.0 - 3.0	✓	✓
MA-4	9	6.9 -21.0	none	none
MA-5	7	2.6 - 3.6	✓	✓
MA-6	7	6.0 -11.1	none	none
MA-7	6	7.4 -13.8	none	none
MA-8	7	5.1 - 8.3	none	none
MA-9	6	1.8 - 4.8	✓	✓
MA-10	9	4.0 -15.3 (one at 3.0)	none	none

representative graphs in Fig. 2 that there is a more frequent and regular marked contrast between LW_{10} values in the collapsed than in non-collapsed samples. These and other features are receiving further attention so as to enable an industrial selection of collapse-prone wood.

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CHARACTERISTICS OF BARK EXTRACTS FOR COMMERCIAL PURPOSES

Y. Yazaki and W.E. Hillis

The barks of some commercially important trees contain components with potential for industrial application. The components are usually polyhydroxy phenols and some are used for converting hides and skins to leather. Some of the phenols are polyflavonoid in nature and can form condensation products with formaldehyde to act as bases for adhesives for wood. Wattle *(Acacia mearnsii)* bark extracts have been used in this way for several years and are still being developed.

The large volume of radiata pine *(Pinus radiata)* grown in Australia produces annually 80 000 tons of bark which contains considerable amounts of water soluble polyflavonoids (1). One of the most important potential uses of the radiata pine bark is the production of wood adhesives (2) as a substitute for synthetic phenolic resins and imported wattle tannin extracts.

The A ring of the C_6-C_3-C_6 flavonoid molecule can be a substituted resorcinol or phloroglucinol moiety and the B ring can be a para-substituted phenol, catechol or pyrogallol substituted ring. Compounds based on a phloroglucinol moiety are more reactive than those based on resorcinol and this accounts for the greater reactivity of radiata pine bark extracts compared with wattle bark extracts. The difficulties encountered with radiata pine bark polyflavonoids include their sensitivity to heat, oxygen, and light. These can result in variations in quality (3) and an excessively high viscosity of the hot water extract (2).

Hot (100°C) water extracts of radiata pine bark contain more than 15 constituents including catechin, procyanidins and their oligomers and polymers. The catechin-based compounds reactive with formaldehyde form the basis for adhesives. Fractionation of the extracts by Sephadex column chromatography and liquid-liquid extraction revealed that more than 70% of the extracts consist of these compounds.

Various aqueous extracts from the radiata pine bark were separated into five fractions by ultrafiltration on the basis of molecular size using Millipore filters (Table 1). The most noticeable difference between the 100°C, 60°C and 20°C aqueous extracts was found in the proportion of the fraction with a molecular size larger than that of a 10^6 molecular weight Dextran. A commercial wattle tannin and the ethanol soluble portion of it were fractionated by ultrafiltration under the same conditions used for the radiata bark extracts to

TABLE 1

Molecular Size Distribution of the Aqueous Extracts from *P. radiata* Bark Prepared at Different Temperatures

Fraction*	100°C Aqueous extract	60°C Aqueous extract	20°C Aqueous extract
More than 10^6	22.4%	11.1%	6.6%
10^5 - 10^6	5.5	11.7	13.8
10^4 - 10^5	29.2	30.8	32.9
10^3 - 10^4	11.5	11.1	9.7
Less than 10^3	31.4	35.3	37.0

* Containing compounds which have a molecular size of the corresponding number molecular weight Dextran.

TABLE 2

Molecular Size Distribution of the Wattle Tannin and its Ethanol Solubles

Fraction*	Wattle tannin	Ethanol solubles
More than 10^6	16.5	1.2
10^5 - 10^6	3.9	0.1
10^4 - 10^5	23.6	20.9
10^3 - 10^4	6.6	9.0
Less than 10^3	49.4	68.8

* Containing compounds with a molecular size of the correspondening number molecular weight Dextran.

provide a basis for comparison (Table 2). The wattle tannin contained a large amount of ethanol insolubles (31.2%), a portion of which may be high molecular weight gums. The molecular size of wattle tannin components is distributed over as wide a range as those of the radiata bark extracts but the lowest molecular size fraction was larger in the wattle tannin. Furthermore, after removal of the ethanol insolubles from the wattle tannin, the amounts of fractions containing compounds with molecular size larger than that of a 10^5 molecular weight Dextran decreased markedly from 16.5 and 3.9% to 1.2 and 0.1%, respectively.

100°C aqueous extracts were separated into methanol soluble (87%) and insoluble fractions. The viscosity of 5 poise of the methanol solubles was very much lower than the viscosity (about 85 poise) of the original 100°C aqueous extracts. Ultrafiltration of the 100°C aqueous extract gave a 77.6% yield of

filtrate with a molecular size smaller than that of a 10^6 molecular weight Dextran and a remarkably low viscosity. Consequently, both the methanol insolubles and the retentate obtained by ultrafiltration behave as complete or partial viscosity control factors of the aqueous solution of the extracts.

The amount of formaldehyde precipitate provides a reliable estimate of the total polyphenols which react with formaldehyde in adhesive formation. The lowest molecular weight fraction of the 100°C aqueous extracts from the radiata pine bark gave only 40.5% yield of the precipitate indicating the presence of impurities. Other fractions gave much higher yields of the precipitate (82.5 - 91.5%).

These results indicated that ultrafiltration and reverse osmosis as practised in some industries could be used for purification. Ultrafiltration with a commercial membrane (Nominal Molecular Weight Limit; 10^6 or more than 10^6) can be used for the removal of highly polymerised material, which is the main viscosity control factor, from the extracts. The viscosity of the filtrate from such a trial was low so that it becomes more useful for the formulation of wood adhesives.

Higher yields of the filtrate are obtained by ultrafiltration and using large quantities of water. It then becomes necessary to remove a large quantity of water from the ultrafiltrate. It has been found that a second ultrafiltration with membranes (N.M.W.L.; 10^3) removes much of this large quantity of water as well as low molecular weight materials which tend to decrease the adhesive quality.

Reverse osmosis is being studied to separate the water and the low molecular weight compounds of potential use in the second filtrate.

The drying of tannin extracts on an industrial scale is carried out by spray-drying or vacuum evaporation in which the extracts may be changed by thermal degradation. Ultrafiltration and reverse osmosis avoid those deleterious effects associated with normal dewatering processing. The process is athermal and permits removal of up to 90% of the water at ambient temperature, avoiding thermal and oxidative degradation of the product. The absence of any phase change also results in lower energy costs.

Based on these findings, a provisional patent specification by Y. Yazaki, W.E. Hillis and P.J. Collins entitled "purification of bark and wood extracts for wood adhesives" has been filed.

Because of the potential availability of polyflavonoids of defined molecular size, a study has been made of the possible shapes of the polymers and their possible involvement in the adhesive-wood interaction.

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We thank P.J. Collins for his close collaboration in establishing a pilot plant scale ultrafiltration system.

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PHYTOTOXICITY OF DIFFERENT BARKS AND WOODS

Y. Yazaki and D. Nichols

INTRODUCTION

Hardwood and softwood barks have been in common use in the American horticulture and nurseries for the past two decades and the phytotoxic effects of barks as well as leaves and sawdusts of woody plants have been studied by several workers (1), (2) and (3). Allison (4) tested 28 kinds of woods and barks on the early growth of garden peas and found that the effects of phytotoxicity varied considerably according to the original tree species. *Pinus sylvestris* bark has been used for growing nursery stock in England without any sign of phytotoxicity (5).

Significant amounts of *Pinus radiata* bark are used in horticulture and with the scarcity of good quality soil and the high price of imported peatmoss there is also increasing use of radiata pine bark as a medium for growing nursery plants in the southern States of Australia. Most of the radiata pine bark used in Australia is obtained from trees aged 15 to 35 years. This study was undertaken to determine whether radiata pine bark contains any phytotoxic components and if so, to identify the phytotoxic components.

MATERIAL AND TEST PROCEDURE

(i) RADIATA PINE BARK

Working with A.P.M., fresh barks were taken from the top and bottom parts of a 15-yr old and a 35-yr old radiata tree. Illustrations will be presented to show that:

(a) All the fresh bark samples inhibited the seedling growth of tomato, lettuce and turnip, but the inhibition effect was noticeably less in the 15-yr old bottom bark than in the other barks.

(b) The growth of radish seedlings, which had been grown in punnets for two weeks, was inhibited severely on 35-yr old bottom bark but fairly good growth in 15-yr old top and bottom barks.

(c) A remarkable growth of turnip seedlings was observed on 15-yr old top bark leached with hot water but the other barks (particularly 35-yr old bottom bark) considerably inhibited the growth.

These situations indicate that 15-yr old top bark may contain water soluble phytotoxic components and 35-yr old bottom bark may contain water insoluble phytotoxic omponents.

The phytotoxicity of the bark was easily removed by extraction with methanol. The amount of the methanol solubles increased with the age of the bark (15-yr old top 12.9% and 35-yr old bottom 20.1%). However, the amount of the methanol solubles from the aged commercial bark was considerably less (only 2.5%). The methanol solubles were fractionated into diethyl ether soluble, ethyl acetate soluble, aqueous soluble and insoluble fractions. It was found that the phytotoxic effects were concentrated in the diethyl ether soluble and ethyl acetate soluble fractions. The major components of the diethyl ether soluble fraction were identified as catechin, quercetin, dihydroquercetin and 3,5,3',4'-tetrahydroxystilbene. Procyanidins B-1 and B-3 and 3,5,3',4'-tetrahydroxystilbene 4'-glucoside were major compounds of the ethyl acetate soluble fraction.

Bioassays with pure compounds revealed that catechin, and 3,5,3',4'-tetrahydroxystilbene were most toxic, procyanidins B-1 and B-3 were moderately effective, the stilbene glucoside was weakly effective and quercetin and dihydroquercetin were not effective at all. Consequently, it would be concluded that a water soluble phytotoxic compound is catechin and a water insoluble phytotoxic compound is 3,5,3',4'-tetrahydroxystilbene.

The effects on phytotoxicity of aging and composting the barks and of adding lime were examined. It was found that aging the barks by keeping in a moist condition for 40 days, decreased remarkably the phytotoxicity except for 35-yr old bottom bark which still showed strong phytotoxicity. Effect of liming on phytotoxicity was almost negligible. While moist aging was ineffective on 35-yr old bottom bark, composting as suggested by Gartner *et al.* (6) did eliminate the toxicity after 42 days. Consequently, aging barks from the 15-yr old tree and composting barks from the 35-yr old tree were very effective ways of removing phytotoxicity from barks.

(ii) RIVER RED GUM AND MOUNTAIN ASH SAWDUST

Eucalyptus camaldulensis (red river gum) and *E. regnans* (mountain ash) sawdusts have been used by Victorian Nurserymen as amendments for potting soil (7). One of the difficulties with growing plants results from phytotoxicity. Consequently, it was necessary to determine whether any phytotoxic compounds exist in sawdusts of both species and it was needed to find how they could be easily removed.

Fresh sawdusts of *E. camaldulensis* and *E. regnans* severely inhibited the growth rate of radish seedlings. Aging the sawdusts was not effective for decreasing phytotoxicity. The phytotoxicity of *E. camaldulensis*, but not

E. regnans, was removed by liming the sawdust for seven weeks. Amending the sawdust with fertilizers and keeping it for six weeks was an effective way of removing the toxicity from *E. camaldulensis* and *E. regnans* sawdusts.

The amount of the methanol solubles from the amended sawdusts was considerably less than that of the methanol solubles from the fresh sawdust. The composition of the mehtanol solubles of both species was very similar. Ellagic acid, 8 ellagitannins, 4 methyl ellagic acids, 3 methyl ellagic acid glycosides, gallic acid, catechin and procyanidin polymers were identified. Fresh sawdusts of both the species contained larger amounts of ellagitannins but there were no ellagitannins in the amended sawdusts. This result indicated that ellagitannins would be responsible for the phytotoxicity of the sawdusts.

The phytotoxic bioassays with pure ellagitannins found as major compounds in the sawdusts of both species revealed that the ellagitannins were very toxic and responsible for the phytotoxicity of the sawdusts.

CONCLUSIONS

Catechin and 3,5,3',4'-tetrahydroxystilbene were identified as the phytotoxic components in radiata pine bark and ellagitannins as responsible in red river gum and mountain ash sawdusts. Composting or amending with fertilizers was found to be the most effective way of removing the phytotoxicity.

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THE DESIGN BUCKLING STRENGTH OF TIMBER STRUCTURES

R. H. Leicester and L. Pham

ABSTRACT

Basic concepts for the derivation of design rules for the buckling strength of timber structures are discussed and the buckling strength characteristics of some of the structures considered in the Australian Timber Engineering Code are described.

INTRODUCTION

The effects of slenderness on strength are frequently important for timber structures. However, it is usually difficult to specify effective design rules to cope with these effects, because while these rules must be simple for practical purposes, the number of practical applications to which they are applied is extremely varied and extensive. In addition, these difficulties are often compounded by the lack of both theoretical and experimental information. In the following, the procedure used to formulate design rules for AS 1720, the SAA Timber Engineering Code (Standards Association of Australia 1975) is described, and some discussion is given on the characteristics of four types of structures considered by the Code.

METHODOLOGY

A great number of parameters affect the buckling strength of timber structures. These can be divided roughly into two classes. The first contains those parameters that are specified as input parameters in a design process. These include the applied load system, the geometrical parameters of the structure and the basic properties of the structural material. The latter usually refer only to ultimate strength and linear elastic deformation parameters. Typical unspecified parameters that affect buckling strength include member crookedness, material non-homogeneity and non-linear material characteristics. Also secondary structural effects that are usually neglected in the usual types of design analysis may be considered to act effectively as unspecified buckling strength parameters. An example of this is the influence of the membrane action of plywood webs.

A convenient method of normalising the information on buckling strength is to combine all the specified parameters into two composite parameters, the

theoretical elastic critical buckling load of the system and the squash or stable load capacity of the structure. The influence of these unspecified parameters on buckling strength is then obtained by an empirical fit with experimental data.

These two basic parameters are used to define two further parameters, as stability factor k_u and a slenderness factor Q, defined as follows,

$$F_u = k_u F_{u(s)} \tag{1}$$

and

$$Q = \sqrt{F_{u(s)}/F_e} \tag{2}$$

where F_u denotes the ultimate value of the nominal applied stress on the structural system, $F_{u(s)}$ is value of F_u for a completely stable system and F_e is the elastic critical buckling stress of the system.

These definitions serve to normalise the description of buckling strength, because for <u>all</u> structural systems the reference strengths $F_u = F_{u(s)}$ and $F_u = F_e$ are now described by

$$k_u = 1 \tag{3}$$

$$k_u = 1/Q^2 \tag{4}$$

Equations (3) and (4) are illustrated in Fig. 1a.

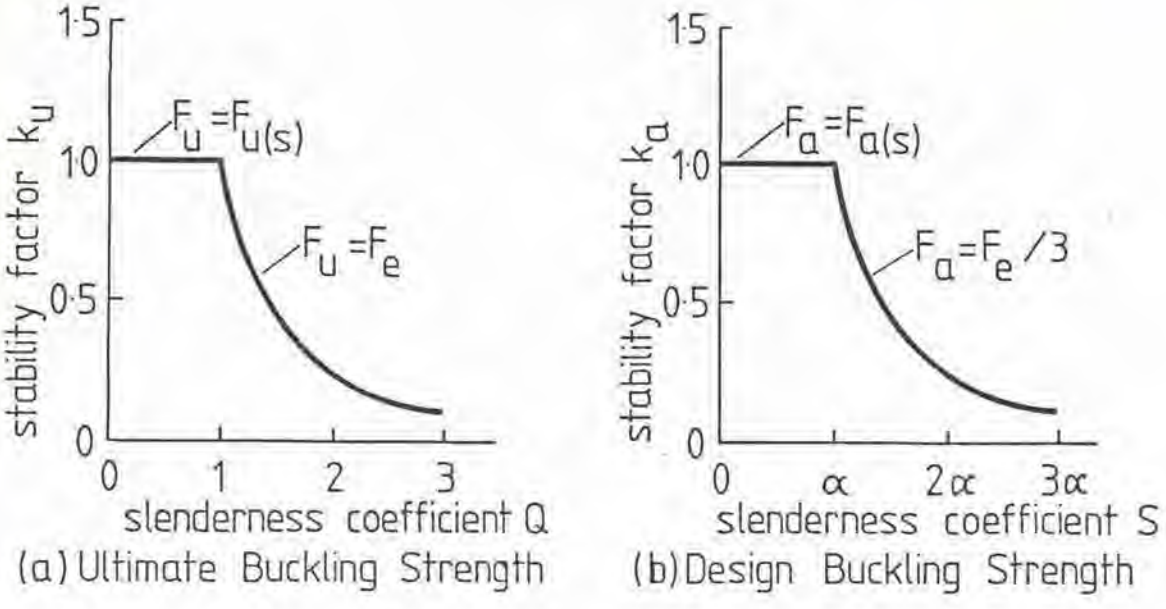

FIG. 1 NORMALISATION PARAMETERS FOR BUCKLING STRENGTH

A similar, but not identical, approach is useful for normalising parameters for the design buckling strength.

First the effect of instability on design strength is described by means of a stability parameter k_a, defined by

$$F_a = k_a F_{a(s)} \tag{5}$$

where F_a is the allowable design value of nominal stress, and $F_{a(s)}$ is the value of F_a for a stable structure. The definition of a slenderness coefficient is then chosen so as to conform with design tradition in that it is solely a function of structural geometry, and that for the particular case of a pin-ended rectangular column it is L/D, the length to depth ratio of the column. Such a slenderness coefficient, denoted by S, is defined by

$$S = \sqrt{(\pi^2/12)(E/F_e)(F_{a(s)}/F_{ca(s)})} \tag{6}$$

where E is the design modulus of elasticity for the material and $F_{ca(s)}$ is the value of $F_{a(s)}$ for the particular case of compression stresses.

With this definition of slenderness, the reference design strengths $F_a = F_{a(s)}$ and $F_a = F_e/3$ can be written

$$k_a = 1 \tag{7}$$

$$k_a = (\alpha/S)^2 \tag{8}$$

where α is given by

$$\alpha = \sqrt{(\pi^2/36)(E/F_{ca(s)})} \tag{9}$$

These equations are illustrated in Fig. 1(b). It is to be noted that the parameter α does not depend on the type of structure or loading condition. However, it does depend on material properties. This is unfortunate because design rules in timber must be written to cover a wide range of material properties. A more useful slenderness coefficient would be a universal coefficient such as Q defined in equation (2). A possible compromise is to describe instability effects in terms of a slenderness parameter S_o defined by

$$S_o = S\sqrt{F_{a(s)}/E} \tag{10}$$

It is to be noted that equations (2), (6) and (10) leads to

$$S_o = \beta Q \tag{11}$$

where $\beta = \sqrt{(\pi^2/12)(F_{a(s)}/F_{ca(s)})(F_{a(s)}/F_{u(s)})}$ is roughly independent of the timber stress grade.

Equations (8), (9) and (10) lead to the normalised equation of $F_a = F_e/3$ as follows:

$$k_a = (\gamma/S_o)^2 \qquad (12)$$

where $\gamma = \sqrt{(\pi^2/36)(F_{a(s)}//F_{ca(s)})}$ is independent of the timber stress grade.

Finally, for the purposes of relating experimental data to design specifications, it is useful to note that for any particular structure the relationship between the slenderness parameters S and Q can be derived from equations (2) and (6) and is

$$S = Q\sqrt{(\pi^2/12)(F_{a(s)}/F_{ca(s)})(E/F_{u(s)})}. \qquad (13)$$

EXAMPLES OF BUCKLING STRENGTH

It is outside the scope of this paper to discuss in detail the derivation of design rules for the buckling strength of specific structures. However, it is of interest to indicate some buckling strength characteristics of the types of structures considered in AS 1720.

Figs. 2-5 show normalised plots of experimental data for four types of structural systems. Also plotted in each figure are the reference lines $F_u = F_{u(s)}$ and $F_u = F_e$ shown in Fig. 1(b). The effects of crookedness and non-linear material characteristics tend to pull the data point below these reference lines; similarly some non-linear geometrical effects tend to pull the data points above the reference lines.

Fig. 2 and 3 include curves of buckling strength derived theoretically by assuming an effective member crookedness and then applying an analysis similar to that used in the well-known Perry Robertson formula for steel columns. Fig. 4 shows a theoretical strength curve derived from an assumption that the plywood web can develop a full diagonal membrane tension field. For the case of a point load on a beam with an unstiffened web there is no satisfactory buckling strength theory, although the elastic critical buckling load can be computed. In this type of situation an empirical curve may be fitted to the data as shown in Fig. 5 and design rules derived through use of the assumption $k_a = k_u$.

CONCLUSIONS

The difficulties associated with writing design rules for buckling strength arise from the large number of specified and unspecified design parameters that influence buckling strength. These difficulties can be minimised by normalising the concept of buckling strength through combining the specified parameters in terms of two single parameters, the stability factor k_u and slenderness Q, and then using test data to determine empirically the influence of unspecified parameters.

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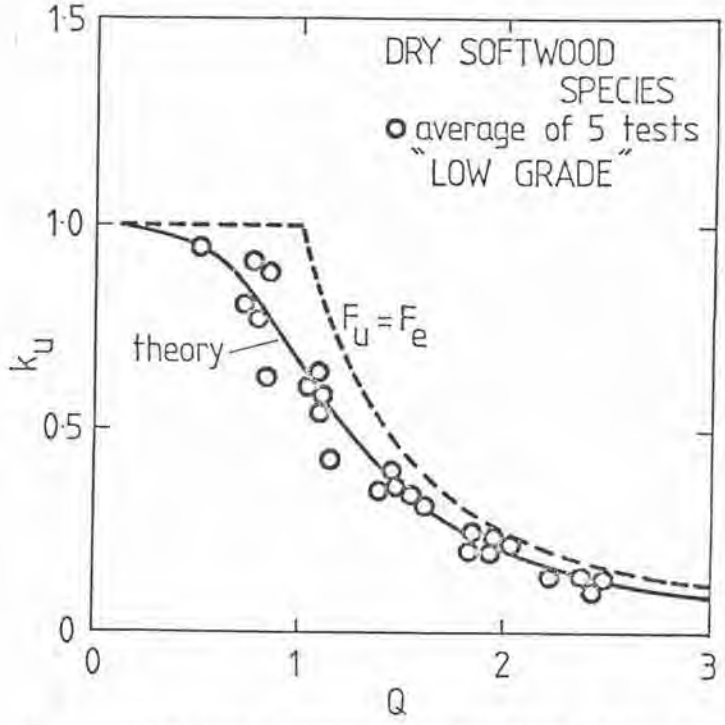

FIG. 2 BUCKLING STRENGTH OF COLUMNS (DATA FROM SUNLEY 1955)

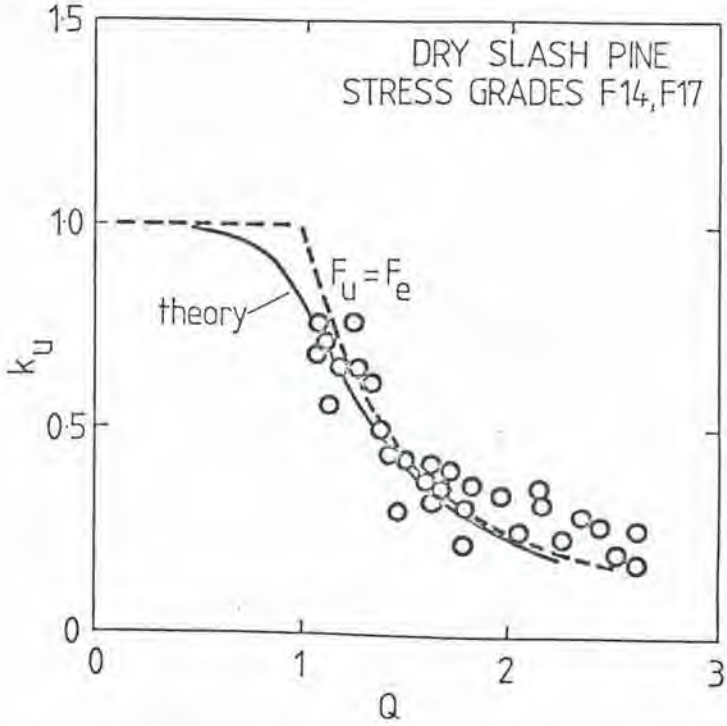

FIG. 3 BUCKLING STRENGTH OF BEAMS (CSIRO DATA)

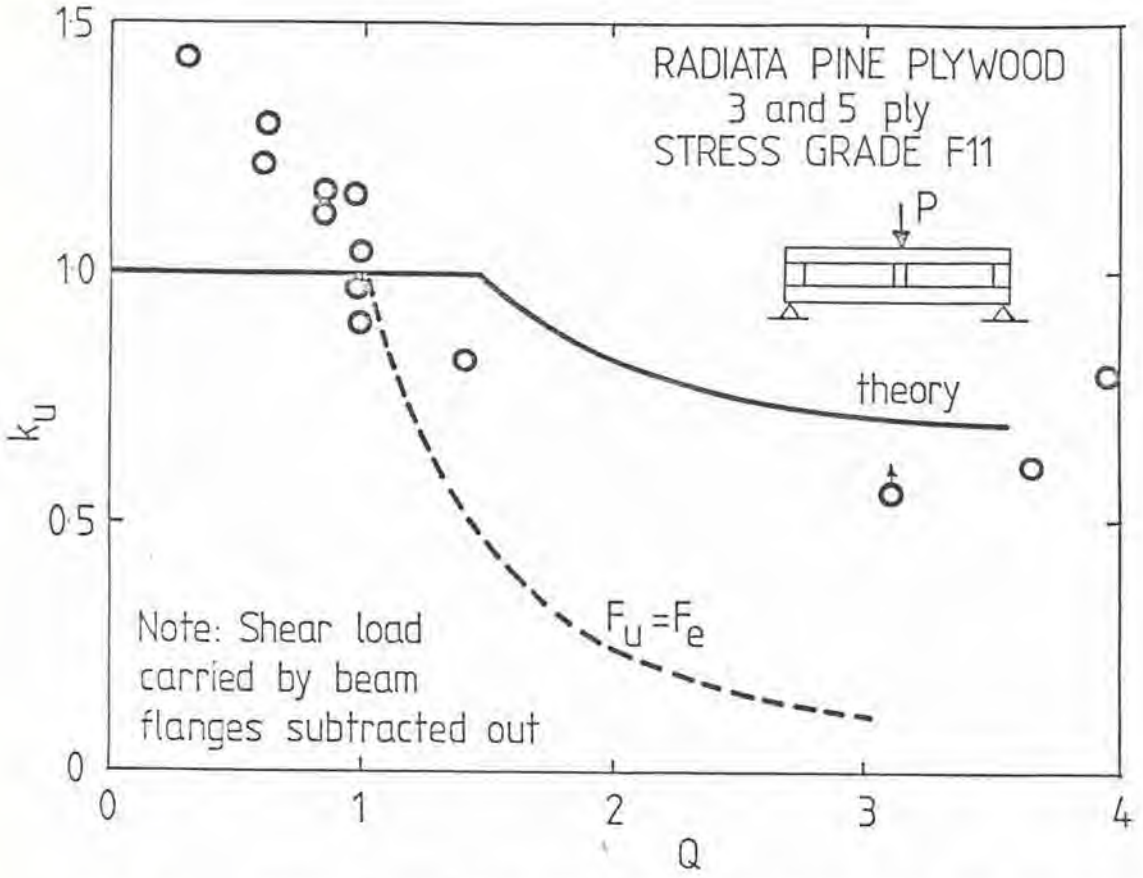

FIG. 4 BUCKLING STRENGTH IN SHEAR OF PLYWOOD WEBS (CSIRO DATA)

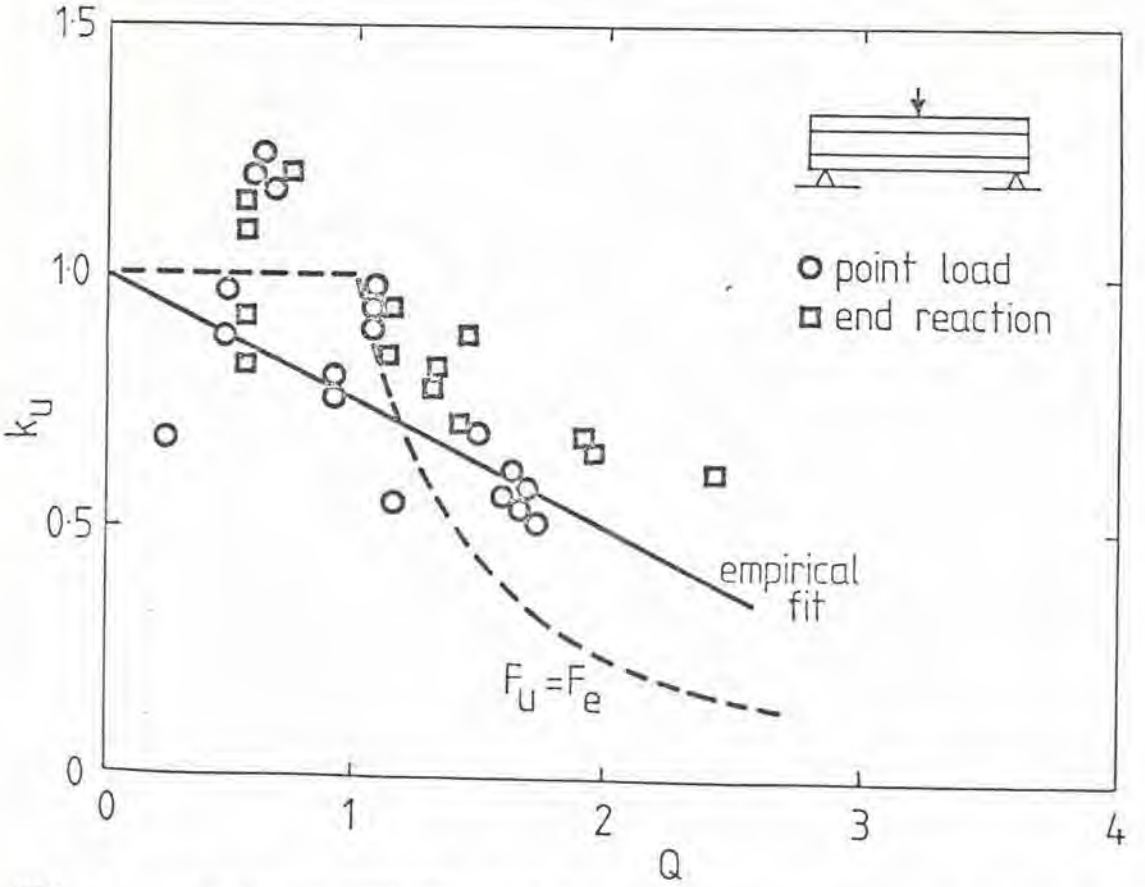

FIG. 5 BUCKLING STRENGTH OF I-BEAMS WITH UNSTIFFENED WEBS AND SUBJECTED TO FLANGE POINT LOADS (CSIRO DATA)

THE MECHANICAL STRESS GRADING OF CYPRESS PINE

D. J. Grant

INTRODUCTION

In early 1977 a sawmill at Warialda, N.S.W. owned by Cypine Pty. Ltd. installed a Computermatic timber grading machine* so that the machine grading of cypress pine could be investigated.

Cypine Pty. Ltd., timber grading machine (Photo. A. Garbellini)

A strength evaluation was carried out in late 1976 on a sample of cypress pine from Queensland supplied by Swansbel Sawmilling Pty. Ltd. In this evaluation the sample was divided randomly into two groups - one tested green and the other air dried to 12% before testing. It was found that the average M or R of the dry sample was below the average M of R of the green one - a result one does not expect in timber.

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* Computermatic timber grader manufactured under licence from the Forestry Commission of N.S.W.

The objectives of this investigation were as follows:

1. To determine the effect of drying on the stiffness and strength of cypress pine scantling.
2. To establish a program suitable for the machine grading of cypress pine.
3. To evaluate operational difficulties in machine grading cypress pine.

MATERIAL

Samples taken from mechanically graded cypress pine were to be sent from Warialda to the Forestry Commission of N.S.W. Wood Technology and Forest Research Division for testing and altogether eighty samples were received. Forty of the samples were 35 mm x 97 mm and the others were 47 mm x 96 mm.

The initial intention was for the operator to regularly sample from machine graded stock with the result that after some months, material from various areas would have been sampled. The depressed state of the building industry has prevented this from happening and so far the 80 samples received represent the sampling from only 2 days grading.

OPERATIONAL DIFFICULTIES

No major difficulties were encountered. Green cypress pine does not contain enough water to be a problem during grading. Dye colours were not as clear as when they are applied to pinus species but this is not a great problem. A careful control will need to be exercised however on the size accuracy and surface finish of material to be graded.

Cypine were passing their stock through a moulder and the final product was excellent in respect of both size and finish.

EXPERIMENTAL PROCEDURE

It was decided to use the normal softwood programs (1), modified so that F5 and F4 would be the only grades. This was a precautionary measure until more was known about the strength of the species in the dry state.

Samples were separated in the laboratory into two groups, the odd numbers being tested green and the even numbers air dried in the controlled laboratory conditions (22 ± 1°C, 65 ± 10% R.H.) until E.M.C. was reached. M of E green was also determined for the samples that were air dried.

The testing was in accordance with AS 1749, rules for mechanical stress grading of timber (2). The following tests were performed on all samples - M of E, M of R and moisture content using a resistance type moisture meter. A record was also made of the visual defect, if any, at the point of initiation of failure.

RESULTS

Table 1 is a summary of the analysis of the results for the Warialda and Swansbel material. Each size and source is analysed separately because of the large variations in the results. Table 2 shows the results for small clear sample tests on the Swansbel material. These were tested in accordance with BS373 (3).

THE EFFECT OF DRYING ON SOME PROPERTIES OF CYPRESS PINE

1. Apparent Modulus of Elasticity

   M of E showed an increase for all the sizes tested with the average being 18% for Warialda (W) and 17% for the Swansbel (S) material. This result is important when it is considered that cypress pine is sold and generally used in the green state. Figure 1 shows the distributions of M of Es in both the green and the dry states.

2. Modulus of Rupture

   The mean M of R of the dry (12%) samples were lower than the mean M of R of the green samples in each group tested as can be seen from Table 1. Figure 2 shows the distribution of M of R for each group. The percentage of samples in the lower 10-20 MPa range can be seen to be greater in the dry group over the green group for each size tested except for the 47 x 96 mm material from Warialda i.e. groups W3 and W4.

3. Compression Parallel to the Grain and Izod values

   Some small clear specimens were taken from the Swansbel material. The mean compressive strength of the dry samples was 47% higher than that of the samples tested in the green state.

   The mean Izod value of the dry sample was 41% lower than that of the green samples.

   Figure 4 shows the distributions of the results for the small clears.

MODULUS OF ELASTICITY (GREEN) AND MODULUS OF RUPTURE (12%)

Figure 5 is a plot of the M of E (green) Vs M of R (12%). The correlation coefficient for all the data was found to be 0.47 for n = 81 and is significant at the 1% level.

The M of R (12%) values for all samples with M of E (green) within the normal softwood grade M of E boundaries were separated into groups and the frequency distribution of the M of R values is shown in Figure 6. Some statistics of the three populations is included in table 3. There is a difference in the strength distribution for each grade with an obvious increase in strength as the stiffness range becomes higher.

TABLE 3

Population statistics of Modulus of Rupture for samples with Modulus of Elasticity (green) values within the stated ranges.

M of E (green) range	> 8.02 GPa	8.02 - 5.52	5.52 - 4.14
No. of samples	12	47	21
Mean M of R (MPa)	41.15	33.17	22.08
Standard deviation	11.35	14.49	7.94
Standard skewness*	0.95	0.79	0.75
Standard kurtosis*	2.47	3.86	2.49

* Hahn & Shapiro (4)

GRADE RECOVERY

The grade breakdown using the softwood programs was:

F8 - 15%
F5 - 58%
F4 - 25%
Reject - 2%

FURTHER WORK

It will be necessary to test at least 150-200 samples in each grade from various areas before working stresses can be accurately assigned. Any further testing would involve:

1. Measuring M of E in the green state.
2. Air drying all the samples to 12%.
3. Measuring M of E in the dry state.
4. Determine M of R.

If further work is to be done in investigating the effect of drying on strength then it should be based on *closely matched* samples of *various sizes* from *different areas*. This investigation could also include tests of samples at lower moisture contents (say 8%).

CONCLUSION

It has been shown that cypress pine does not, like most timber species, become stronger in bending as it dries, in fact there is a general tendency towards a decrease in bending strength. Despite this the strength of the dry timber appears adequate when compared to softwoods like radiata pine.

Not enough samples have been tested so far to enable positive assignment of working stresses to the various M of E ranges. At least 150-200 randomly selected samples would have to be tested in each grade before this could be done.

TABLE 1

Means and standard deviations of Modulus of Elasticity and Modulus of Rupture for each group.

Group	Green Size (mm^2)	Mean M.C. (%)	No in group	M of E		M of R	
				Mean (GPa)	S.D.	Mean (MPa)	S.D.
W1	35x97	43	20	6.61	1.07	36.25	11.94
W2	35x97	42	20	6.23	1.35	-	-
W2	35x97	12	20	7.54	1.41	30.79	13.68
W3	47x96	29	20	6.29	1.16	35.51	12.94
W4	47x96	30	20	6.46	0.91	-	-
W4	47x96	12	20	7.45	1.02	35.30	15.26
S5	34x71	38	20	6.50	1.18	38.06	9.46
S6	34x71	38	21	6.32	1.38	-	-
S6	34x71	11	21	7.57	1.47	28.36	10.94
S7	34x96	37	20	7.42	1.05	44.52	10.33
S8	34x96	33	20	6.96	1.81	-	-
S8	34x96	12	20	7.96	1.97	33.16	15.18

Source W - Warialda S - Swansbel

TABLE 2

Means and standard deviations of Compression strength parallel to the grain and Izod values for small clear samples selected from the Swansbel material.

Group	Green Size (mm^2)	Mean M.C. (%)	Comp Parallel			Izod		
			N	Mean (MPa)	S.D.	N	Mean (J)	S.D.
S5	34x71	38	18	36.82	3.86	20	3.9	1.4
S6	34x71	11	21	55.24	5.60	21	2.3	0.3
S7	34x96	37	19	38.03	5.28	20	4.3	1.1
S8	34x96	12	20	54.91	7.33	20	2.3	0.8

Source S - Swansbel

It appears, however, that an F8 grade can be successfully extracted from cypress pine using machine grading and that the 8.02 GPa softwood cutoff level is perhaps conservative. The number of samples tested in this grade however is very small and no definite conclusion can be drawn. The theoretical F5 and F4 grades appear to be of adequate strength but again the sample is too small for the 1/40 low probability value to be estimated accurately.

There is therefore a good chance that F8, F5 and F4 grades can be extracted from cypress pine scantling by machine grading. Grading would have to be carried out in the green state however for the normal programs to be applicable. Another program would have to be designed if the species was to be graded dry.

The grade breakdown of the tested material was F8-15%, F5-58%, F4-25%, Reject 2%.

ACKNOWLEDGEMENT

The author would like to thank Mr. A. Garbellini for carrying out much of the testing.

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SILVERTOP STRINGYBARK: POTENTIAL USE BASED ON MECHANICAL AND PHYSICAL CHARACTERISTICS

M. Ghali

SUMMARY

Twenty trees of Silvertop stringybark collected from two different districts of the state of New South Wales were tested to evaluate the mechanical and physical properties. The test results provide an estimation of gluability, physical and strength characteristics based on small clear specimens.

There were no significant differences in seasoned strength between the two districts.

The average basic, air dry, and green densities obtained were 665, 860, 1030 kg/m^3 respectively. Maximum fibre stress (MOR) in static bending is 143 MPa at 12% m.c. and 87 MPa green. Modulus of elasticity (MOE) in bending was 18 GPa at 12% m.c. and 15 GPa green. Maximum crushing stress in compression parallel to grain is 73 MPa at 12% m.c. and 38 MPa green.

The mechanical and physical properties of Silvertop stringybark are discussed in relation to a variety of end uses.

INTRODUCTION

Silvertop stringybark (*Eucalyptus laevopinea* R. T. Baker) occurs mainly on the northern tablelands of New South Wales at altitudes between 700 and 1200 m. It grows between latitudes 29°-33°S and east of longitude 151°. This species rarely occurs in pure stands but typically is a co-dominant in species mixtures which may include Tallowwood (*E. microcorys* F. Muell), Sydney blue gum (*E. saligna* Sm), New England blackbutt (*E. andrewsii* Maid., subsp. *campanulata* (R. T. Bak and H. G. Sm.) L. Johnston and D. Blaxell), messmate (*E. obliqua* L'Herit), brownbarrel (*E. fastigata* Deane et Maiden) and manna gum (*E. viminalis* Labill).

In the forest this species develops a straight, slightly tapered bole which may extend to more than half the total height of the tree, which may be up to 35 m and a diameter of 100 cm. The bark is more or less rough, fibrous dark reddish-brown, 2-3 cm thick separating into long shallow, narrow shreds. This species, like many other eucalypts may produce growth stresses which tend to cause brittle heart and log-end splits immediately upon felling.

Although Silvertop stringybark has a relatively compact distribution and occurs in mixed species forests, it is a popular sawlog species of typically good quality. The total annual cut was approximately 36,000 m^3 in 1976/77 which is nearly 5% of the N.S.W. total for hardwood production. Silvertop stringybark ranks as the eighth most important hardwood species being cut in the coastal and tableland districts of N.S.W.

Silvertop stringybark has proved to be a reliable plantation species in the cooler, southern sites of the north coast of N.S.W. An active plantation programme has been underway in Chichester State Forest; near Dungog since 1966. The planting rate is about 150 ha per year and mean annual increments in excess of 20 m^3/ha have been recorded.

Despite the importance of this species in N.S.W. and its ready acceptance in the market place, information on its mechanical and physical properties were quite sparse. This study was undertaken to provide a good estimate of these properties based on small clear specimens for trees growing in natural stands.

EXPERIMENTAL MATERIAL AND PROCEDURE

Tree sampling points were selected from lists of potential locations provided by the foresters familiar with the areas concerned.

Nine trees were taken from the Glen Innes and eleven from the Newcastle Forestry districts. They were subjectively considered to be representative of the commercial tree population and collected from 12 different State Forests scattered over the two districts and distributed within the entire growing range. Within the selected sample, the average merchantable height was 15 m and log diameter ranged between 33 cm to 91 cm measured at breast height. Trees that had excessive lean, spiral grain, decay or other pronounced abnormalities, such as poor crown class, were rejected.

Two flitches 15 cm thick, representing the full diameter of the log including pith, were taken from two billets cut from each tree at heights of 1.2 m and 6 m above the ground. Since the trees were felled several weeks before testing began, the flitches were wrapped in polythene sheets, and thus preserved in an unseasoned condition.

These flitches were cut into matched paired sample sticks 65 x 65 x 1300 mm to provide material for green and air-dry tests. The green material was machined to size, packed in polythene bags and stored in a refrigerated room at freezing temperature to prevent water loss.

The air-dry material was left undressed, stacked and air-dried under shade and load for 14 months to minimise drying defects.

Standards (1, 2, 3) for evaluating the mechanical and physical properties of small clear specimens were used. Testing covered density, elasticity, gluability, hardness impact, shrinkage and strength.

The gluing properties of Silvertop stringybark with phenolic adhesive resin were evaluated using standard procedures of the British Standard BS 1204 Part 2 (4). Lap close joints were made from Silvertop stringybark slips 114 x 25 x 3 mm, glued with 25 mm overlap, using a room temperature setting resorcinol phenol (Cascophen RS 240 M) mixed with 20% (by weight) of dry powder hardener (Fm-124).

Silvertop stringybark veneers were obtained from G. L. Briggs & Sons Pty. Ltd. and made into sample sheets of 3 ply-plywood in the laboratory. The bond quality of the plywood was examined in accordance with Australian Standard AS 2098.2 - Chisel test (5). The green veneers 3 mm thick, were kiln dried from an initial moisture content of 88.6% to 11.8% prior to manufacturing the plywood. The same mixture of adhesive resin used in the lap joints were brushed on the veneer and cured at 120°C, and 1 MPa for six minutes.

RESULTS AND DISCUSSION

The wood of Silvertop stringybark is odourless, relatively hard, of uniform medium texture and is diffuse - porous. The grain is usually straight although some interlocked grain may occur. There is only fair distinction between sapwood and heartwood. The sapwood is 3-5 cm in thickness and slightly paler in colour than the heartwood. The colour of the heartwood varies considerably from pale yellowish brown to pale pinkish brown. The growth rings are narrow, indistinct and hard to distinguish.

Some of the samples showed serious cross checks and collapsed badly during air-drying, indicating that such samples were brash and fissile. No large gum pockets or veins were observed in the sample. Insect and fungal attack of the type often associated with the timber borer *Platypus incompertus* Schedl. (*Coleoptera: Platypodidae*), were present.

Prior to this study, the only known data related to the properties of Silvertop stringybark were those reported by Lanyon and Bamber (6) and Bootle (7). Lanyon indicated the basic density to be 625 kg/m^3 while Bootle reported 530 kg/m^3. His value for air-dry density at 12% moisture content was 880 kg/m^3.

The data on physical properties of this species are provided in Table 1 whilst those covering the mechanical test results from green material are given in Table 3. Results for the air-dry material after being corrected to 12% moisture content, (exponential formula - USDA), (8) are given in Table 4.

The average basic, air-dry and green densities obtained were 665, 860 and

1030 kg/m^3 respectively (Table 1). There is a minor variation between the head and butt logs.

The data in Table 1 also suggest that there are greater density variations between sites than between trees within sites. Samples from trees grown in the Glen Innes district were lower in density than those from the Newcastle area. The largest difference (11.2%) was in basic density. Shrinkage values measured on Glen Innes samples were higher than those from the Newcastle.

Shrinkage and density values for Silvertop stringybark are compared to messmate (*E. obliqua* L'Herit), blackbutt (*E. pilularis* Sm), turpentine (*Syncarpia glomulifera* (Sm.) Niedenzu), and some other species in Table 2. Despite the diversity of the shrinkage values, the Silvertop stringybark stability ratio (T/R) under both tests conditions (green to air-dry, and green to oven dry) were lower than most of the other species.

The green moisture content was 60% and varied between 35% and 85%.

Tables 3 and 4 suggest that the Newcastle samples had higher strength values than the Glen Innes material which may be due to the increase in density. However a comparison of the strength properties of seasoned material from the two sites indicates that there is no statistically significant differences, at the 5% confidence level, between the strength of timber obtained from either district. This analysis was carried out by using a Wilcoxon-Mann-Whitney rank sum test (9).

Table 5 provides the data of test results taken from previous publications (10, 11), and shows a comparison between the mechanical strength properties of Silvertop stringybark and other species, based on tests of small clear seasoned (12% m.c.) specimens treated in accordance with standard laboratory testing procedures. On this evidence Silvertop stringybark may be rated as a strong hardwood of the same strength as blackbutt, messmate and turpentine.

Gluing properties test results of lap close joints, shear failing load and percentage of wood failure are given in Table 6. This table also contains results of lap joints made from Coachwood (*Ceratopetalum apetalum* D. Don) slips, assembled under the same conditions for comparative purposes.

The average bond quality values for glueline failure of the laboratory's manufactured plywood were:

Result	Dry test (as cut condition)	Bond type A (boiling for 72 hours)	Bond type B (cold water for 20 hours)
No. of gluelines	6	6	6
Average scale measured	6.5	6.0	5.5
Min. scale measured	4	2	3
Max. scale measured	8	9	7
Coefficient of variation %	23.3	52.7	31.5

The results for shear failing load and bond quality tests indicate that Silvertop stringybark can be glued satisfactorily with phenolic resin, and therefore has a good potential for the production of a water resistant, low cost plywood for construction purposes.

UTILIZATION

Silvertop stringybark wood has found many local uses in building and construction as beams, columns, joists, fencing posts and pilings. Penfold and Willis (12) stated that Silvertop stringybark wood is moderately durable. Blakely (13), Hall *et al.* (14) and Bootle (7) accept this opinion. The Forestry Commission of N.S.W. (15) has classified this material as durability class 2-3.

Silvertop stringybark is straight-grained and has moderate weight and strength. It is well suited for a large range of applications in the building industry. Poles have been treated experimentally with preservative and it compares favourably with blackbutt in preservative penetration and splitting characteristics (R. S. Johnstone, personal communication).

The density and hardness values obtained for Silvertop stringybark are sufficiently high to recommend this species for application where resistance to abrasion is required, i.e. flooring, bridges, decking and other types of heavy construction.

The moderate shrinkage and density, straight uniform texture and high moisture content of the green logs are adequate for use in veneer producing industries. Its good gluability with waterproof adhesives (phenolic type) suggests that it may be useful for manufacturing structural phywood and glue-laminated structural members.

In general Silvertop stringybark is a most useful hardwood species which should continue to find a good market for a variety of uses.

This species should be further investigated for its possible use for pulp, other fibre products and particleboard.

ACKNOWLEDGEMENT

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G. L. Briggs and Sons Pty. Ltd. and Borden Chemical Company (Australia) Pty. Ltd. supplied the veneers and adhesive respectively.

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Table 1. Physical properties of *Eucalyptus laevopinea* R. T. Baker

		Head log					Butt log					Whole tree				
		n	$\bar{x}$	cv	min	max	n	$\bar{x}$	cv	min	max	n	$\bar{x}$	cv	min	max
Density (kg/m^3)																
	G	9	960	*9.4*	810	1065	9	1040	*12.8*	815	1180	9	1005	*10.9*	830	1105
Green	N	11	1030	*5.2*	970	1115	11	1065	*6.9*	960	1175	11	1050	*4.9*	970	1120
	G + N	20	1000	*7.9*	810	1115	20	1055	*9.7*	815	1180	20	1030	*8.0*	830	1120
	G	9	810	*6.2*	740	885	9	830	*7.6*	750	930	9	820	*6.6*	750	905
Air-dry	N	11	880	*5.7*	790	950	11	885	*4.9*	810	940	11	885	*5.2*	800	945
	G + N	20	850	*7.1*	740	950	20	860	*6.8*	750	940	20	860	*6.5*	750	945
	G	9	620	*7.4*	530	680	9	630	*8.5*	580	735	9	625	*7.6*	560	710
Basic	N	11	685	*5.4*	620	740	11	710	*4.5*	640	750	11	695	*4.8*	635	745
	G + N	20	655	*8.2*	530	740	20	675	*8.6*	580	750	20	665	*8.1*	560	745
Shrinkage (%)																
Green - Airdry																
	G	9	5.8	*26.7*	3.7	9.4	9	5.7	*24.8*	3.9	8.5	9	5.6	*20.4*	3.8	8.1
Radial	N	11	4.4	*19.3*	3.4	5.8	11	4.2	*16.5*	3.2	5.7	11	4.3	*11.9*	3.5	5.3
	G + N	20	5.1	*27.5*	3.4	9.4	20	4.9	*26.3*	3.2	8.5	20	4.9	*22.2*	3.5	8.1
	G	9	8.0	*29.1*	3.8	11.0	9	8.4	*23.6*	3.6	10.1	9	8.3	*23.7*	3.7	10.3
Tangential	N	11	6.8	*15.8*	4.8	8.7	11	6.9	*20.3*	4.2	8.7	11	6.9	*13.9*	5.6	8.2
	G + N	20	7.3	*24.5*	3.8	11.0	20	7.6	*23.9*	3.6	10.1	20	7.5	*21.3*	3.7	10.3
Green - Ovendry																
	G	9	9.0	*20.3*	6.3	11.3	9	9.1	*22.6*	6.1	12.6	9	9.1	*21.6*	6.2	12.2
Radial	N	11	6.8	*20.9*	3.9	8.5	11	6.7	*12.7*	5.4	7.9	11	6.6	*13.4*	5.1	7.9
	G + N	20	7.8	*24.8*	3.9	11.3	20	7.8	*24.4*	5.4	12.6	20	7.7	*24.6*	5.1	12.2
	G	9	10.7	*22.7*	7.6	14.6	9	10.9	*16.9*	6.9	13.0	9	10.8	*17.8*	7.3	13.5
Tangential	N	11	10.3	*13.1*	8.6	13.3	11	10.3	*20.9*	5.6	12.6	11	10.4	*14.0*	7.8	12.3
	G + N	20	10.5	*17.8*	7.6	14.6	20	10.6	*18.8*	5.6	13.0	20	10.4	*16.7*	7.3	13.5

n ≡ number of trees $\bar{x}$ ≡ arithmetic mean cv ≡ coefficient of variation (%)

min ≡ minimum and max ≡ maximum value observed in the sample

G ≡ Glen Innes material N ≡ Newcastle material

Table 2. Comparison of the physical properties of several hardwood species.

Species		Shrinkage (percent)						Density (kg/m^3)		
		Green to air dry			Green to oven dry					
		R	T	T/R	R	T	T/R	Green	Air dry	Basic
Stringybark, silvertop	*	4.9	7.5	1.53	7.7	10.4	1.35	1030	860	665
	K	5.0	8.5	1.70	-		-	1040	880	530
Messmate	W	4.7	6.4	1.36	8.4	10.4	1.24	1075	785	665
	C	5.1	11.3	2.13	-	-	-	-	770	600
Gum, spotted	W	4.5	6.5	1.44	8.0	10.4	1.30	1125	930	735
	C	4.3	6.1	1.42	-	-	-	-	990	790
Blackbutt	W	4.5	7.5	1.67	6.9	10.8	1.57	1095	895	715
	C	4.3	7.3	1.70	-	-	-	-	880	700
Stringybark, white	W	4.5	8.1	1.80	6.9	11.1	1.61	1095	895	635
	C	5.6	10.6	1.89	-	-	-	-	855	652
Stringybark, yellow	W	3.7	6.3	1.70	5.6	9.4	1.68	1100	865	685
	C	4.3	7.5	1.74	-	-	-	-	884	697
Turpentine	W	6.7	11.8	1.76	8.6	13.9	1.62	1130	925	675
	C	6.5	13.0	2.00	-	-	-	-	945	690

* = this study K = Bootle (1971) W = Ghali (1977) C = Bolza and Kloot (1963)

Table 3. Mechanical properties of *Eucalyptus laevopinea* R. T. Baker - Green Material.

PROPERTIES		Head log					Butt log					Whole tree				
		n	$\bar{x}$	cv	min	max	n	$\bar{x}$	cv	min	max	n	$\bar{x}$	cv	min	max
Static Bending																
MOR	G	9	87.6	7.1	72.9	94.1	9	85.5	7.4	76.0	95.0	9	86.6	6.7	74.5	94.6
(MPa)	N	11	88.9	12.2	68.8	107.1	11	87.3	11.1	74.5	99.1	11	87.8	9.9	71.9	99.9
	G + N	20	88.3	10.0	68.8	107.1	20	86.5	9.4	74.5	99.1	20	87.3	8.5	71.9	99.9
	G	9	15.8	9.5	13.5	18.2	9	14.3	10.0	11.5	19.7	9	15.1	9.4	13.5	17.3
MOE	N	11	14.8	16.4	9.8	18.2	11	15.2	19.2	11.8	22.5	11	15.0	16.0	10.8	20.4
(GPa)	G + N	20	15.3	13.8	9.8	18.2	20	14.8	18.5	11.5	22.5	20	15.0	13.1	10.8	20.4
Compression //																
Max. crushing	G	6	38.7	12.5	31.3	43.1	7	36.6	10.8	30.8	41.7	7	37.8	8.6	32.3	41.7
stress	N	9	38.6	14.0	31.2	47.8	10	38.6	7.7	35.2	44.2	10	38.5	10.8	32.4	44.7
(MPa)	G + N	15	38.7	13.0	31.2	47.8	17	37.8	9.1	30.8	44.2	17	38.2	9.7	32.3	44.7
Shear (MPa)																
	G	8	11.8	9.5	10.1	13.5	9	11.3	6.7	9.9	12.6	9	11.5	7.3	10.4	12.7
Radial	N	11	11.9	7.6	10.6	13.2	10	11.4	5.4	10.3	12.3	11	11.7	5.0	10.5	12.6
	G + N	19	11.9	8.3	10.1	13.5	19	11.4	5.9	9.9	12.6	20	11.6	6.0	10.4	12.7
	G	7	12.7	10.8	10.8	15.1	9	12.3	13.5	9.3	14.9	9	12.5	9.1	10.5	13.6
Tangential	N	11	13.0	13.1	9.6	15.7	10	13.3	8.3	11.8	14.9	11	13.1	9.1	11.4	14.8
	G + N	18	12.8	12.0	9.6	15.7	19	12.8	11.2	9.3	14.9	20	12.8	9.2	10.5	14.8
Compression ⊥ (MPa)																
	G	9	13.3	17.0	9.2	15.8	9	14.1	12.3	11.5	16.4	9	13.7	13.3	10.4	14.8
Radial	N	11	15.7	8.9	13.2	18.3	11	16.8	11.8	13.5	21.0	11	15.9	12.0	12.1	18.2
	G + N	20	14.6	15.2	9.2	18.3	20	15.6	14.7	11.5	21.0	20	14.9	14.3	10.4	18.2
	G	9	14.6	20.1	8.9	17.9	9	14.9	15.7	9.7	17.6	9	14.7	17.8	9.3	17.7
Tangential	N	11	14.9	13.7	10.2	18.3	11	15.4	8.0	13.4	17.7	11	15.1	7.1	13.3	17.0
	G + N	20	14.8	16.4	8.9	18.3	20	15.1	11.8	9.7	17.7	20	14.9	12.3	9.3	17.7
Impact (J)																
	G	9	14.5	22.5	7.5	19.3	8	15.6	23.9	10.6	21.8	9	14.5	18.1	11.3	18.4
Izod	N	10	17.9	17.3	13.5	24.2	10	18.8	18.6	13.3	24.2	11	18.8	14.1	14.4	23.0
	G + N	19	16.3	21.8	7.5	24.2	18	17.4	22.2	10.6	24.2	20	16.9	20.0	11.3	23.0
	G	8	21.3	25.5	16.4	30.5	9	20.9	19.1	16.4	27.4	9	20.0	22.8	13.3	27.7
Denison	N	10	22.3	17.0	17.5	30.1	10	21.2	13.9	15.7	24.3	11	22.2	16.6	16.6	30.1
	G + N	18	21.8	20.5	16.4	30.5	19	21.0	16.1	15.7	27.4	20	21.2	19.5	13.3	30.1

n ≡ number of trees $\bar{x}$ ≡ arithmetic mean cv ≡ coefficient of variation (%)

min ≡ minimum and max ≡ maximum value observed in the sample

G ≡ Glen Innes material N ≡ Newcastle material

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Table 4. Mechanical properties of *Eucalyptus laevopinea* R. T. Baker - Air dry material at 12% m.c.

PROPERTIES		Head log					Butt log					Whole tree				
		n	$\bar{x}$	cv	min	max	n	$\bar{x}$	cv	min	max	n	$\bar{x}$	cv	min	max
Static Bending:																
	G	9	141.1	*10.5*	114.8	158.1	9	140.0	*9.7*	118.5	159.5	9	141.5	*8.1*	126.4	158.7
MOR	N	11	147.8	*6.4*	133.7	162.3	11	142.5	*12.1*	106.1	172.4	11	144.8	*9.4*	114.0	162.9
(MPa)	G + N	20	144.8	*8.5*	114.8	162.3	20	141.4	*10.9*	106.1	172.4	20	143.3	*8.7*	114.0	162.9
	G	9	18.5	*12.2*	16.4	23.1	9	17.8	*7.1*	16.1	19.8	9	18.1	*8.7*	16.3	21.4
MOE	N	11	19.3	*13.5*	16.4	24.3	11	18.5	*15.6*	13.3	24.3	11	18.6	*13.7*	13.3	23.4
(GPa)	G + N	20	18.9	*12.8*	16.4	24.3	20	18.2	*12.5*	13.3	24.3	20	18.4	*11.6*	13.3	23.4
Compression //																
Max. crushing	G	8	77.1	*9.2*	69.9	90.9	8	73.2	*9.5*	65.9	86.1	8	75.2	*8.0*	69.0	87.7
stress	N	11	71.1	*7.7*	62.0	79.0	9	71.2	*11.2*	62.8	89.9	11	70.7	*7.1*	62.5	80.1
(MPa)	G + N	19	73.6	*9.2*	62.0	90.9	17	72.1	*10.2*	62.8	89.9	19	72.6	*7.9*	62.5	87.7
Shear (MPa)																
	G	9	15.1	*23.4*	9.1	18.6	9	15.7	*11.6*	12.5	18.0	9	15.6	*14.2*	10.8	18.0
Radial	N	11	16.2	*14.3*	13.7	20.4	10	15.8	*14.2*	12.2	19.7	11	16.0	*13.0*	13.5	19.7
	G + N	20	15.7	*16.4*	9.1	20.4	19	15.8	*12.7*	12.2	19.7	20	15.8	*13.2*	10.8	19.7
	G	9	18.7	*10.3*	14.6	20.8	9	19.3	*4.7*	17.8	20.5	9	18.9	*8.1*	16.5	20.5
Tangential	N	11	19.4	*16.5*	12.2	23.5	10	21.3	*9.3*	17.9	24.0	11	20.3	*9.1*	16.9	22.5
	G + N	20	19.1	*14.0*	12.2	23.5	19	20.4	*9.2*	17.8	24.0	20	19.7	*8.6*	16.5	22.5
Compression ⊥ (MPa)																
	G	9	23.2	*14.9*	18.9	28.1	9	24.1	*7.1*	20.9	26.0	9	23.7	*9.2*	20.7	27.0
Radial	N	11	26.1	*7.0*	23.7	29.6	10	26.8	*11.8*	22.6	31.4	11	26.4	*8.0*	23.7	29.6
	G + N	20	24.8	*12.1*	18.9	29.6	19	25.5	*11.3*	20.9	31.4	20	25.2	*9.9*	20.7	29.6
	G	9	20.2	*17.6*	15.7	26.0	9	19.8	*9.6*	17.5	23.3	9	19.8	*11.7*	17.8	24.7
Tangential	N	11	22.1	*12.8*	18.1	27.1	10	21.6	*13.9*	17.0	26.4	11	22.0	*12.5*	17.6	26.2
	G + N	20	21.2	*15.2*	15.7	27.1	19	20.7	*12.7*	17.0	26.4	20	21.0	*13.0*	17.6	26.2
Hardness (kN)																
	G	9	7.5	*11.8*	6.1	8.7	9	7.4	*13.1*	6.3	9.5	9	7.4	*11.3*	6.3	9.1
Radial	N	11	9.7	*13.3*	8.2	12.0	10	9.8	*13.7*	7.9	11.7	11	9.9	*12.9*	8.4	12.0
	G + N	20	8.7	*18.0*	6.1	12.0	19	8.7	*19.3*	6.3	11.7	20	8.7	*18.9*	6.3	12.0
	G	9	7.7	*17.7*	5.2	9.3	9	7.4	*18.9*	5.6	10.2	9	7.5	*16.1*	5.8	9.5
Tangential	N	11	10.1	*9.8*	8.7	12.5	10	9.7	*17.0*	7.1	12.4	11	10.0	*13.1*	8.2	12.5
	G + N	20	9.0	*18.5*	5.2	12.5	19	8.6	*21.9*	5.6	12.4	20	8.9	*19.8*	5.8	12.5
	G	9	9.0	*13.8*	7.4	11.0	9	8.8	*7.8*	7.9	9.9	9	8.9	*9.5*	7.9	10.0
End	N	11	11.0	*10.4*	9.5	12.9	10	10.8	*11.9*	8.6	12.5	11	11.0	*9.9*	9.2	12.2
	G + N	20	10.1	*15.0*	7.4	12.9	19	9.8	*14.8*	7.9	12.5	20	10.0	*14.3*	7.9	12.2
Impact (J)																
	G	9	15.7	*20.8*	11.7	20.4	8	16.2	*13.9*	12.2	18.2	9	16.1	*13.9*	13.5	19.1
Izod	N	10	20.2	*16.0*	15.8	25.7	11	18.8	*18.9*	13.3	22.8	11	19.3	*13.2*	14.6	22.9
	G + N	19	18.0	*21.7*	11.7	25.7	19	17.7	*18.6*	12.2	22.8	20	17.9	*16.1*	13.5	22.9
	G	9	19.3	*19.6*	10.2	23.4	9	17.8	*16.5*	13.6	21.4	9	18.7	*13.0*	14.8	21.7
Denison	N	10	21.5	*26.5*	9.3	29.1	10	20.5	*28.9*	11.3	27.6	11	21.2	*14.7*	15.3	26.8
	G + N	19	20.4	*23.8*	9.3	29.1	19	19.2	*21.3*	11.3	27.6	20	20.1	*15.2*	14.8	26.8

n = number of trees $\bar{x}$ = arithmetic mean cv = coefficient of variation (%)

min = minimum and max = maximum value observed in the sample

G = Glen Innes material N = Newcastle material

Table 5. Comparison of the strength properties of several hardwood species - Air dry material (12% mc).

Species		Stat. bending		Comp //	Shear		Impact		Janka hardness		
		MOR	MOE	Crush stress	R	T	Izod	Denison	R	T	E
Stringybark, silvertop	*	143	18	73	16	20	18	20	9	9	10
Messmate	W	93	14	59	17	17	-	-	6	6	9
	C	118	15	64	13	14	16	17	7	7	8
Blackbutt	W	144	20	76	16	19	22	24	9	9	10
	C	144	19	77	15	16	20	22	9	9	10
Stringybark, white	W	131	17	65	16	19	14	19	8	9	10
	C	136	17	75	15	18	18	22	9	9	10
Stringybark, yellow	W	131	18	68	16	20	14	18	9	8	9
	C	132	17	76	14	18	15	19	9	9	9
Turpentine	W	144	16	74	16	21	9	16	11	12	14
	C	136	15	79	18	21	10	15	12	12	14

* = this study W = Ghali (1977) C = Bolza and Kloot (1963)

TABLE 6

Lap joints shear test result

Test condition	Silvertop stringybark	Coachwood	B.S. 1204 minimum limit
Slips moisture content %	10.7	11.2	12 ± 2.5
A - Dry test			
1. mean failing load kN	2.69	-	
2. average wood failure %	52	-	
B - Cold water (20 hrs test)			
1. mean failing load kN	2.79	2.36	2.22
2. joints in excess of min. limit %	100	80	-
3. average wood failure %	53	100	-
C - Boiling water (6 hrs test)			
1. mean failing load kN	2.66	2.7	1.45
2. joints in excess of min. limit %	100	100	-
3. average wood failure %	84	93	-

TOOTHED-PLATE CONNECTOR JOINTS SUBJECTED TO LONG DURATION LOADS

R.H. Leicester, G.F. Reardon and K.B. Schuster

ABSTRACT

The strength and deformation characteristics of connector joints, fabricated with toothed-plate connectors and subjected to long duration loads, are described and compared with the design recommendations of the Australian Standard AS:1720.

INTRODUCTION

Although toothed-plate connectors are commonly used in domestic construction in Australia, there is little data available on their characteristics under long duration loads.

The following represents a brief summary of data obtained in tests on tension joints constructed with toothed-plate connectors, in which loads were applied for periods of up to 10 years.

EXPERIMENTAL ASPECTS

It is outside the scope of this paper to present details of the experimental method. The toothed-plate connectors were all from the one manufacturer and will be denoted by the following terms;

(i) 14-gauge (old) - this type of plate was in use when the tests commenced, but has since been discontinued

(ii) 14-gauge (modified) - these are geometrically similar to the old 14-gauge plates, but contain a modification in the metal used. This modification was introduced after CSIRO tests indicated a brittle failure mode through shear at the root of the teeth of the earlier plates. These plates are no longer in production.

(iii) 14-gauge (current) - this is the 14-gauge plate currently in use.

(iv) 18-gauge - this 18-gauge plate is also still currently in use.

Each plate contained roughly 40-50 teeth per plate. The timber used included initially green messmate (*Eucalyptus obliqua*), initially green blackbutt (*Eucalyptus pilularis*), dry radiata pine (*Pinus radiata*) and dry Douglas fir (*Pseudotsuga Menziesii*). Four replications were made of each test specimen.

The loaded specimens were located under cover in a shed which had two ends open to the weather. Thus the joints were subjected to the full range of temperatures and humidity likely to be encountered in practice

TEST RESULTS

In the following, the loads are expressed as a per cent of the initial joint strength. For the purpose of this paper, the initial strength and stiffness will be defined as the values obtained from a set of matched joints loaded to failure in a standard three minute test. Typical basic design loads specified in structural codes are roughly 25 per cent of the initial strength.

The time to failure of joints under sustained loads are shown in Figs. 1-3. As a reference, the duration effect specified for the design of joints according to the Australian Standard 1720-1975, the SAA Timber Engineering Code (Standards Association of Australia 1975) is also shown on the graphs. This effect appears to be roughly correct for the current 14-gauge plates, but inadequate for the 18-gauge plates.

Fig. 4 shows the residual strength of joints that have been loaded for roughly 4000 days without failing, and are then unloaded for 35 days prior to reloading to failure. Contrary to the implications of the design method used in the Australian Standard 1720-1975, the sustained load is seen to have had detrimental effect on the residual strength, particularly for green timber. It was also found that the sustained load had reduced the stiffness of the joints to about half their initial value.

Figs. 5-8 show examples of the long term deformation characteristics of joints loaded to roughly 25 per cent of their initial strength. In these figures the total joint deformation Δ is expressed relative to the initial deformation Δ_o obtained three minutes after loading. It is seen that these deformations are as large as those specified in AS 1720 for the design of nailed joints.

The graphs show that an increase in deformation occurs each spring, and that for the initially green timber there is also a slight recovery in winter. This behaviour reflects the influence of moisture movements into and out of the

timber. Fig. 8 shows that for these tests the initially green blackbutt and the dry radiata pine show very different relative deformations after a few months under load but it appears that they would be roughly identical after a load duration of 20 years. The collapse prone, green messmate shows considerably greater deformation than both of these species. It is outside the scope of this paper to discuss reasons for these deformation characteristics.

CONCLUSIONS

The effects of load duration on the deformation and strength characteristics of toothed-plate connectors appear to be more severe than is implied by the design recommendations of the Australian Standard 1720-1975.

REFERENCES

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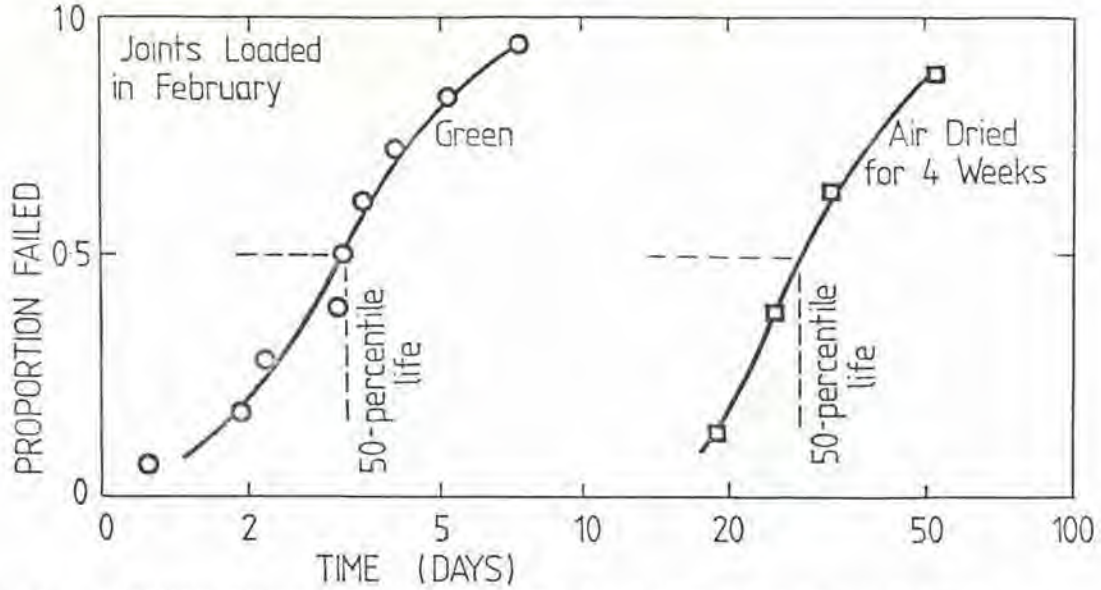

FIG. 1 FAILURE TIMES FOR JOINTS WITH 14 GAUGE (CURRENT) PLATES IN GREEN MESSMATE, LOADED TO 70 PER CENT INITIAL STRENGTH

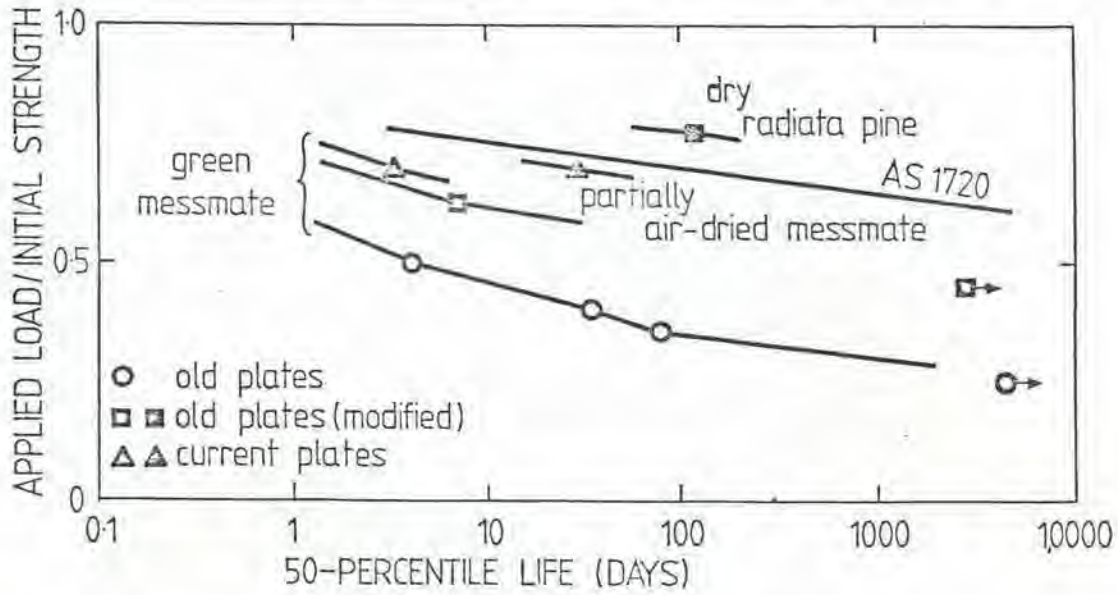

FIG. 2 50-PERCENTILE LIFE OF JOINTS WITH 14 GAUGE PLATES

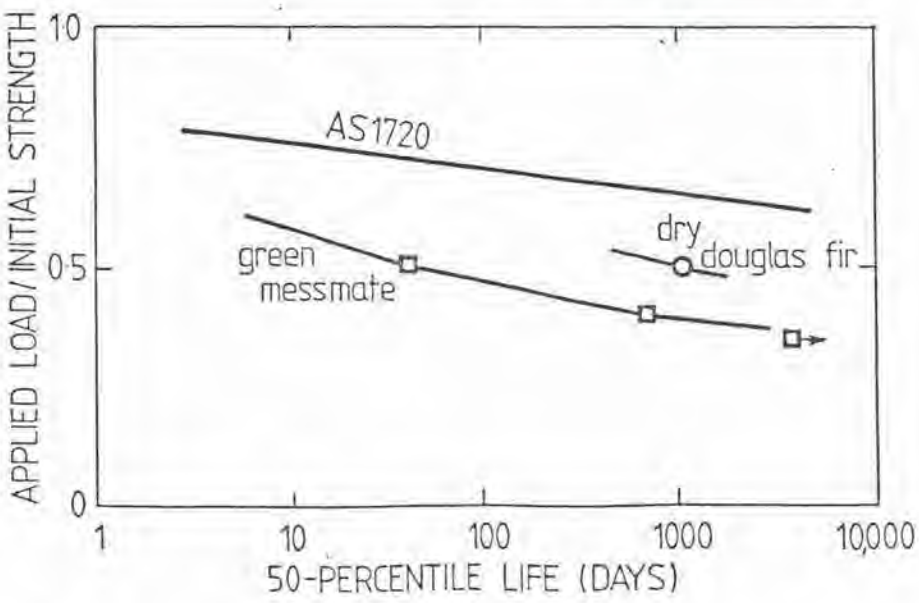

FIG. 3 50-PERCENTILE LIFE OF JOINTS WITH 18 GAUGE PLATES

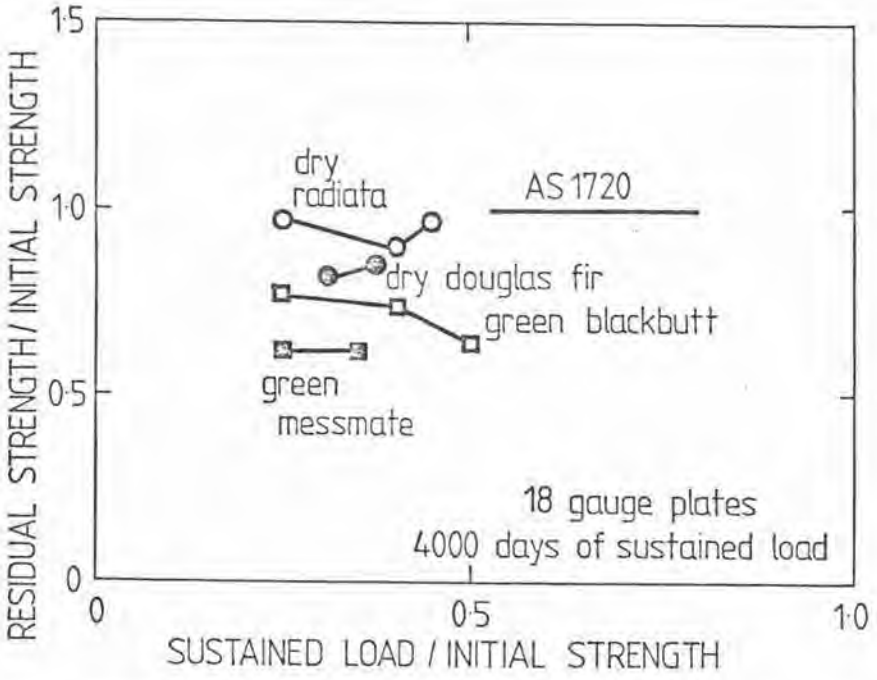

FIG. 4 RESIDUAL STRENGTH OF JOINTS WITH 18 GAUGE PLATES

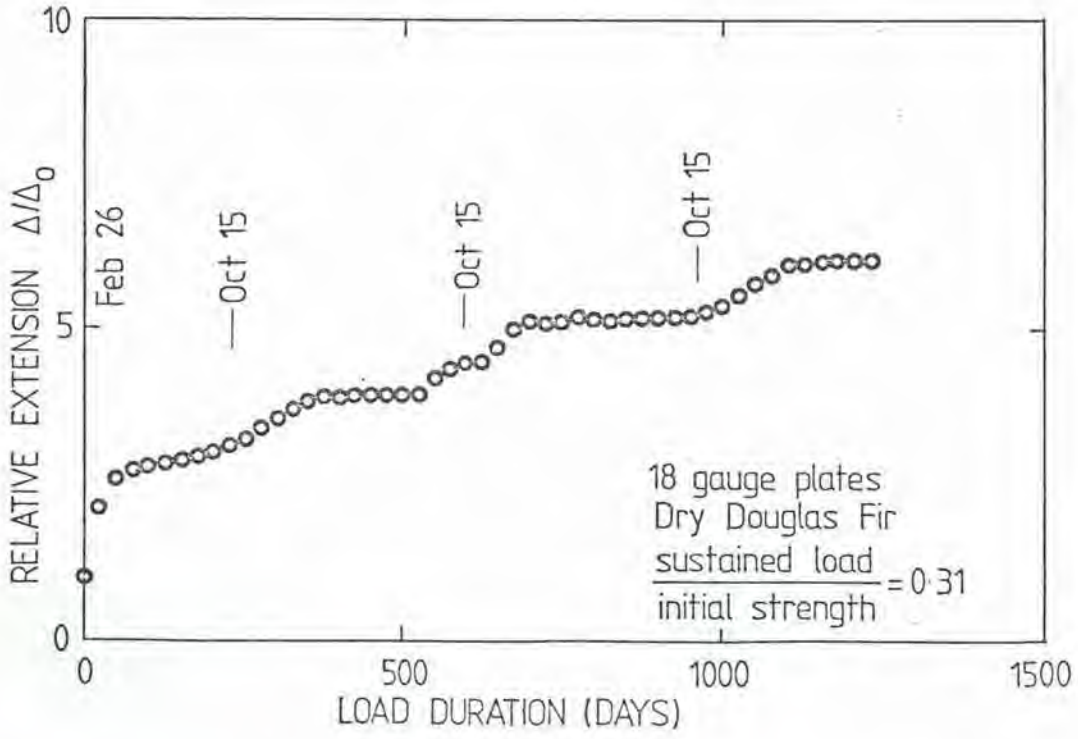

FIG. 5 DEFORMATION OF JOINTS WITH 18 GAUGE PLATES IN DRY DOUGLAS FIR.

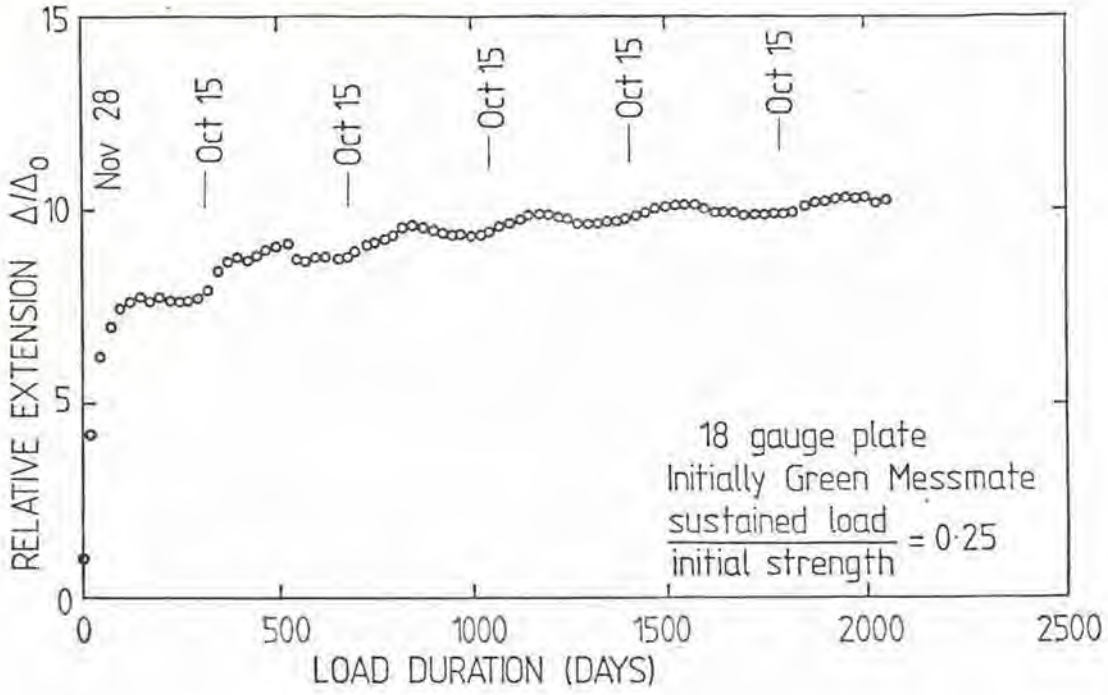

FIG. 6 DEFORMATION OF JOINTS WITH 18 GAUGE PLATES IN INITIALLY GREEN MESSMATE

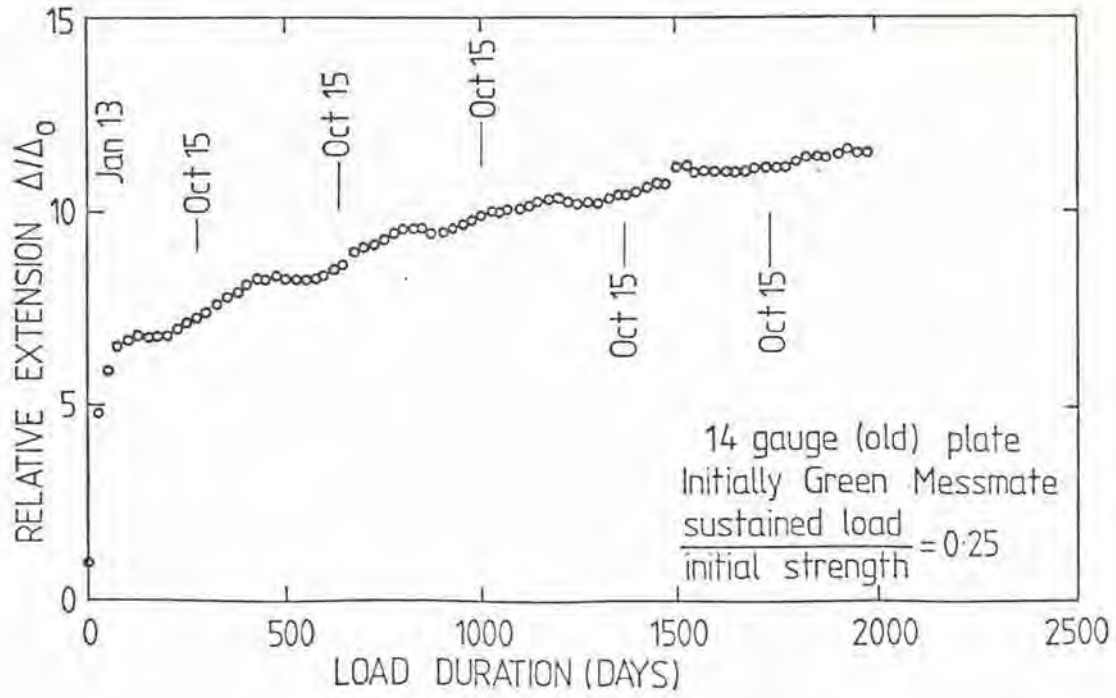

FIG. 7 DEFORMATION OF JOINTS WITH 14 GAUGE PLATES IN INITIALLY GREEN MESSMATE

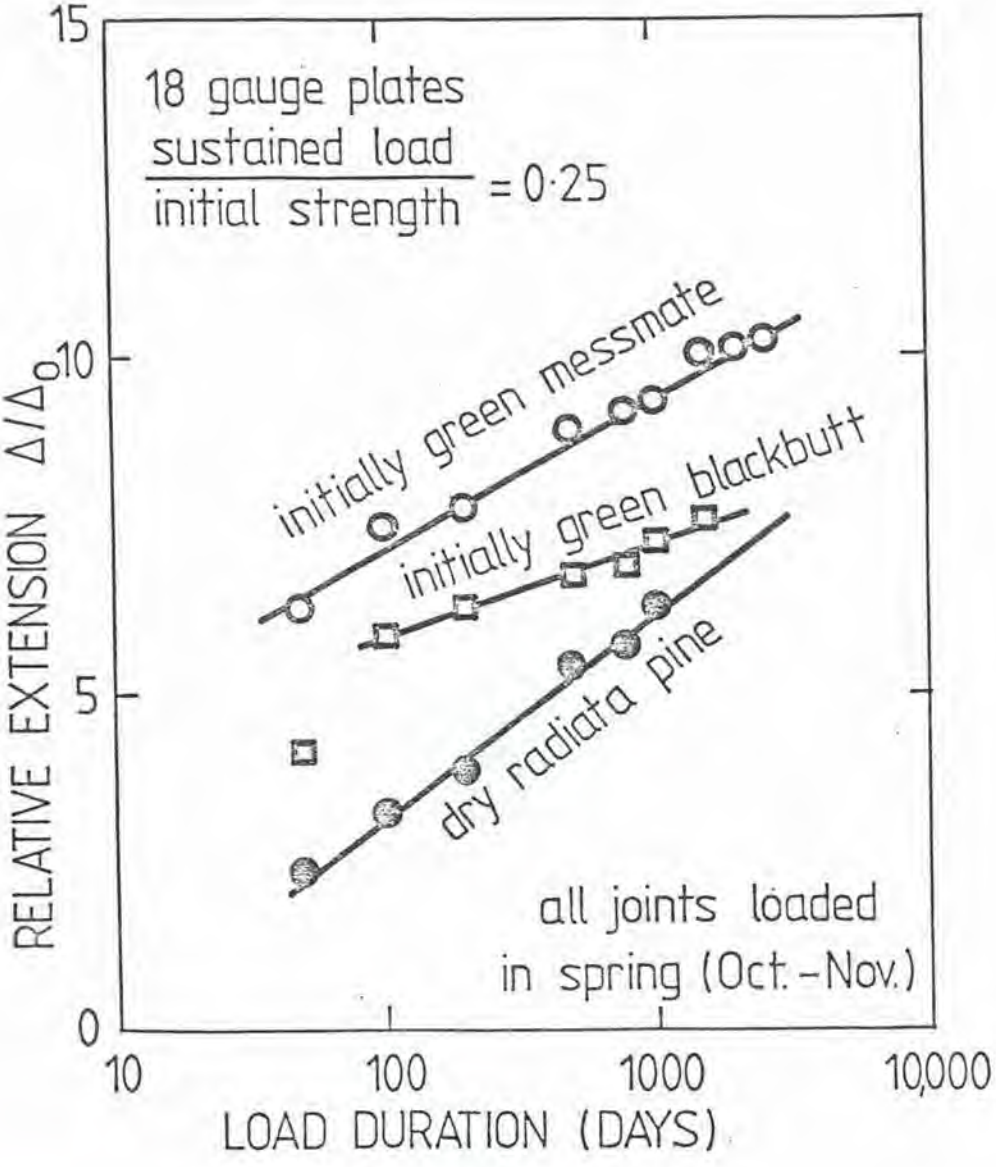

FIG. 8 COMPARISON OF THE DEFORMATIONS OF JOINTS WITH VARIOUS TIMBERS

THE FIRE RESISTANCE OF METAL CONNECTORS

R. H. Leicester, C. A. Seath and L. Pham

ABSTRACT

Standard tests indicated that the fire resistance of timber joints fabricated with metal connectors is poor. An attempt was made to devise a less severe fire test and to devise fire resistant connectors.

INTRODUCTION

It is fairly well known that solid timber structures of reasonable cross-section have an excellent fire resistance. However, there is little information available on the fire resistance of exposed joints fabricated with metal connectors. To obtain this information tests were made on typical timber tension joints in accordance with the Australian Standard 1530, Part 4-1975 (Standards Association of Australia 1975).

EXPERIMENTAL ASPECTS

The timber of the test specimens was a hardwood, blackbutt (*Eucalyptus pilularis*), seasoned to 12 per cent moisture content and of 90 x 50 mm cross-section. Each joint was formed with a double lap splice. Where these splice plates were of timber, each was of the same material and cross-sectional dimension as the primary tension member. The four basic types of joints tested were the following:

(i) A nailed joint, with 36 nails, each 4.5 mm diameter and 90 mm long,

(ii) A toothed-plate connector joint, with two 14 gauge plates, each 230 x 75 mm in size,

(iii) A bolted joint, with six 12 mm diameter bolts, and

(iv) A split ring connector joint, fabricated with four 64 mm diameter rings.

Some additional details of the test joint are shown in Fig. 1.

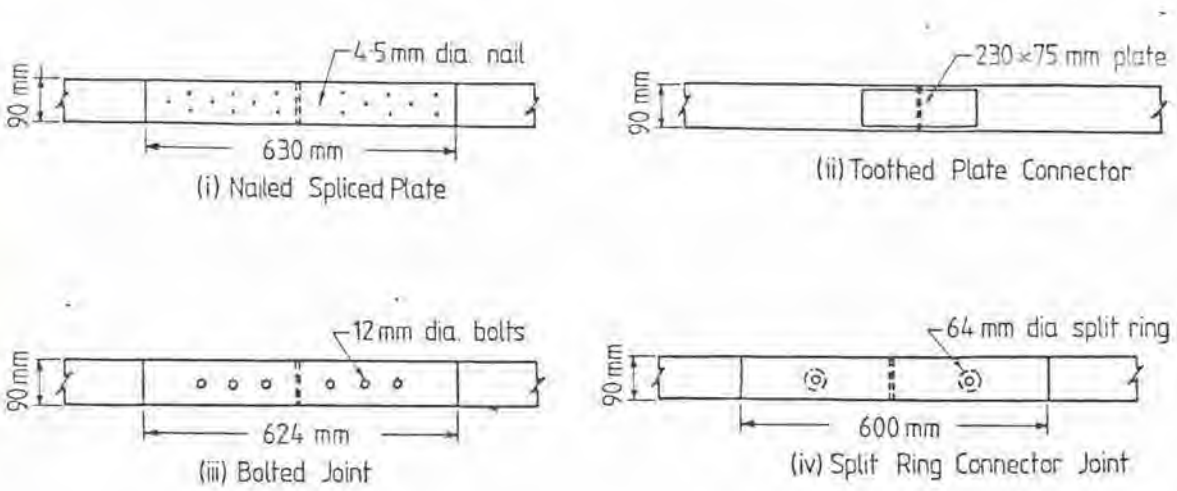

FIG. 1 DETAILS OF THE TEST JOINTS

The furnace used for the fire tests is lined with bricks having the thermal properties required in the draft of the revised Australian Standard 1530, Part IV. Each joint was first placed in the furnace and loaded in tension to the design working load specified in the Australian Standard 1720, the SAA Timber Engineering Code, (Standards Association of Australia, 1975a). The furnace temperature was then raised in accordance with the Australian Standard 1530 and the joint extension recorded. Two replicates of each joint were tested.

TEST RESULTS

Typical examples of the measured extension-time relationship of the four types of joints tested are shown in Fig. 2.

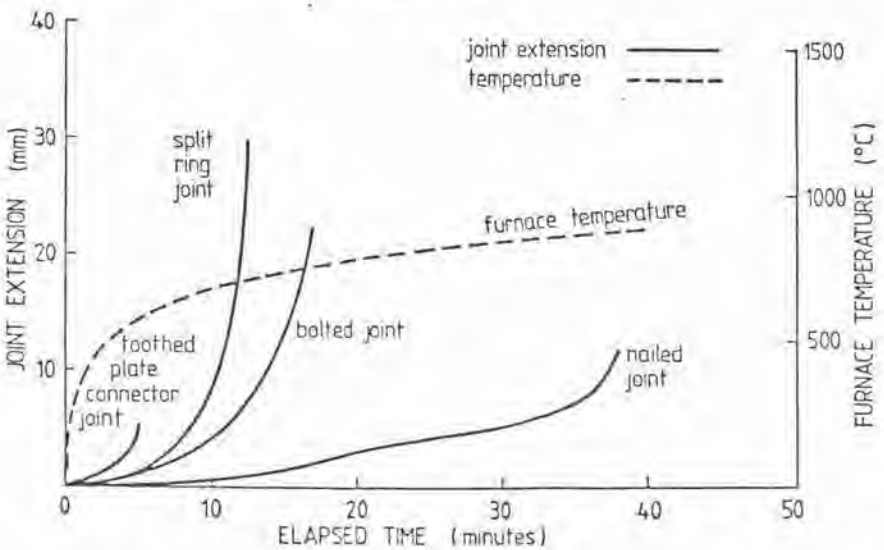

FIG. 2 JOINT PERFORMANCE IN STANDARD TEST

The time to reach a joint extension of 10 mm, the chosen criterion of failure, was found to be as following:

(i) toothed-plate connector joint . . . . . 4 min.
(ii) split ring connector joint . . . . . 11 min.
(iii) bolted joint . . . . . 14 min.
(iv) nailed joint . . . . . 33 min.

ASSESSMENT OF THE TEST RESULTS

The poor performance of the split ring connector joint came as a surprise, particularly when it was noted that the temperature of the protected rings was only 120°C when failure occurred. However, it was later realised that although wood at 120°C does not char, it can become very soft (Hillis and Rozsa, 1978) and would then lose its resistance to high bearing stresses. This was borne out by observations of the failed test specimens which showed the gross deformation of the wood at the bearing edge of the split rings.

It is probable that the nailed joints performed well because the deformation of the nails resulted in the faces of the timber being pressed tightly together, thus protecting the highly stressed portions of the wood and nails. Furthermore, because nails are thin compared with their length, heat is not easily transferred along them to the stressed portions.

ADDITIONAL TESTS

Because of the poor performance of some of the joints, two additional sets of tests were undertaken. In the first set several attempts were made to devise an effective fire resistant joint. None of these were successful. In one test a set of 64 mm diameter ceramic ring connectors was used, together with stitch bolts intended to prevent the splice plates from opening out. The time for these joints to reach an extension of 10 mm was 14 minutes, exactly the same as that obtained in the tests with the metal split rings.

In a second set of tests an attempt was made to assess the performance of joints under typical, rather than extreme fire conditions. To do this the test load on the joints was reduced by 30 per cent and the furnace was controlled so as to produce the time-temperature relationship shown in Fig. 3. This time-temperature curve was intended to simulate the temperatures measured by Rodak and Ingberg (Gross 1977) for a typical fire in a residential building. As indicated in Fig. 3, only two out of the four types of joint tested survived this relatively mild test and of these two the bolted joint appeared to have

only a small margin of safety. However, in assessing the fire risk it should be borne in mind that only about 10 per cent of all fire ignitions reach the point of flashover (Baldwin 1974).

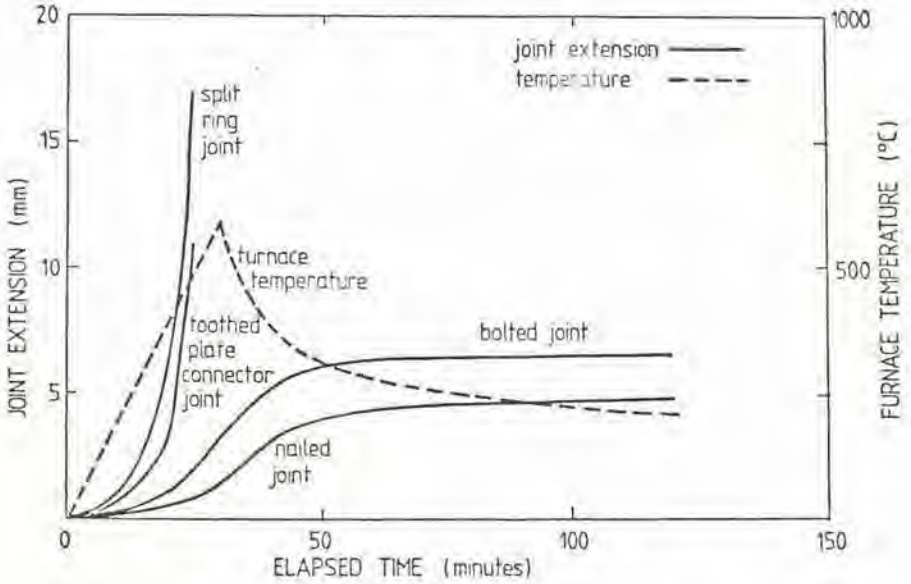

FIG. 3 JOINT PERFORMANCE IN MILD FIRE TEST

CONCLUSIONS

Of the four types of joints tested, only the nailed joint showed satisfactory fire resistance characteristics. The mechanism for the poor characteristics of the other joints has been identified and using this information it may be possible to devise a joint with good fire resistance characteristics.

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ON THE DESIGN STRENGTH OF NOTCHED BEAMS

by

R. H. Leicester and W. G. Poynter

ABSTRACT

This paper describes the results of laboratory tests undertaken to provide rules for the design of notched beams. The tests were made on seasoned timber beams and covered a practical range of notch angles and timber species.

INTRODUCTION

The Australian Timber Engineering Code AS 1720 (Standards Association of Australia, 1975) gives rules for the strength design of notched beams. These rules were based on theoretical studies combined with only limited test data. The experimental study reported herein was undertaken to provide more reliable data on the strength of notched beams.

The essential features of the problem under investigation are shown in Fig. 1. The geometrical dimensions a, d, g, B and D are indicated therein and also the sign convention of bending moment M and shear force V acting on the beam at the cross-section containing the notch root.

For the case of notch roots subjected to a single type of force action, the nominal fracture stress, denoted by f_b and f_v are defined by

$$f_b = 6M_c/Bd^2 \qquad (1)$$

$$f_v = 3V_c/2Bd \qquad (2)$$

where M_c and V_c are the values of M and V to cause fracture if each were acting on its own. The values of f_b and f_v depend on the beam depth D, the relative notch depth a/D, the notch angle parameter a/g and the timber species. For practical purposes it is convenient to describe the fracture strength of various species in terms of index properties obtained from tests on small clear specimens of timber (Mack, 1978) such as density ρ, shear block strength F_v and bending strength F_b. In the following all dimensions, stresses and densities are to be taken as stated in mm, MPa and $kg.m^{-3}$ units respectively.

EXPERIMENTAL METHOD

All measurements were made on timber beams seasoned to a moisture content in the range 10.5-12.5 per cent, having a thickness of 35 mm and a depth of 150 mm. The effect of depth on fracture stress is known (Leicester 1971, 1973) and will be discussed later. Some pilot studies failed to reveal any measureable effect of thickness on fracture stress. In each test a displacement gauge was used to measure the opening of the notch angle in order to provide a clear measurement of the onset of fracture. For most beams this occurred at or very close to their ultimate load capacity.

ASSESSMENT OF THE TEST DATA

The effect of notch depth on fracture strength can be computed theoretically with the methods of fracture mechanics (Walsh 1974). Such computations indicate that with the usual assumption of a constant stress intensity factor at fracture, the values of nominal fracture stress as defined by equations (1) and (2) have a minimum within the range a/D = 0.2-0.8, and that as a/D → 0 or a/D → 1 the stress to cause fracture theoretically rises to infinity. For these reasons and for simplicity it was decided to specify the fracture stresses as independant of notch depth in deriving expressions that are suitable for the formulation of design rules. Furthermore it was decided to use the notch depth a/D = 0.5 as a reference value in the analysis of test data.

From an examination of data of the type shown in Figs. 2 and 3, it was found that fracture stresses, denoted by $f_{b\alpha}$ and $f_{v\alpha}$ and defined as follows give a resonably conservative estimate of fracture strength,

$$f_{b\alpha} = 0.70\, f_{bo} \qquad (3)$$

$$f_{v\alpha} = 0.85\, f_{vo} \qquad (4)$$

where f_{bo} and f_{vo} are the average values of f_b and f_v for a notch depth a/D = 0.5. In Figs. 2 and 3 and in subsequent figures, the notation N is used to denote the sample size corresponding to each plotted point of experimental data.

Tests to assess the effects of notch angle on the fracture stress showed that for notch roots in the middle portion of the beam, the following relationships hold roughly;

$$f_b(x) = f_b(o)\left[1 + 0.5x\right] \qquad (5)$$

$$f_v(x) = f_v(o)\left[1 + 0.5x\right] \qquad (6)$$

where $f_b(x)$ and $f_v(x)$ denote the values of f_b and f_v for a notch angle corresponding to a/g = x. Examples of these relationships are shown in Fig. 4.

The relationship between the reference stresses f_{bo} and f_{vo} was found to be roughly

$$f_{vo} = 0.2\, f_{bo} \tag{7}$$

and the effect of timber species was given by

$$f_{bo} = 1.3\, F_v \tag{8}$$

and as an alternative

$$f_{bo} = 0.03\rho \tag{9}$$

where F_v denotes the shear block strength and ρ denotes the density. The fit of equations (5)-(9) with the experimental data is shown in Figs. 5-8. It is to be noted that this fit has been chosen to be slightly conservative.

The theoretical effect of beam depth D on fracture strength has been investigated theoretically previously and also verified by experiment (Leicester 1971, 1973). It was found that the nominal fracture stress of a beam is proportional to $D^{-0.450}$, $D^{-0.326}$ and $D^{-0.241}$ for notch angles corresponding to $g/a = 0$, 2 and 4 respectively. Combining this fact with the relationships defined by equations (3)-(9) lead to the equations in Tables 1 and 2. These give conservative predictions of the fracture stresses f_b and f_v.

In addition to the fracture stress equations given in Tables 1 and 2, it is also necessary for practical purposes, to provide interaction equations for use when both bending moments and shear forces are acting simultaneously. For this case the fracture stresses will be denoted by f_b^1 and f_v^1. A conservative failure envelope for the combined stresses is given by the following:

For $f_b^1>0$, $f_v^1>0$,

$$(f_b^1/f_b) + (f_v^1/f_v) = 1 \tag{10a}$$

For $f_b^1>0$, $f_v^1<0$,

$$f_b^1/f_b = 1 \tag{10b}$$

For $f_b^1<0$, $f_v^1>0$,

$$f_v^1/f_v = 1 \tag{10c}$$

For $f_b^1<0$, $f_v^1<0$, no failure through fracture is considered to be possible. A comparison between this failure envelope and one set of experimental data is shown in Fig. 9.

TABLE 1

BEAM FRACTURE STRESS

IN TERMS OF SHEAR STRENGTH

Strength Type	Notch Angle	Strength Equation*
Bending	g/a = 0	$f_{b\alpha} = 0.91\ F_v\ (150/D)^{0.450}$
	g/a = 2	$f_{b\alpha} = 1.82\ F_v\ (150/D)^{0.326}$
	g/a = 4	$f_{b\alpha} = 2.73\ F_v\ (150/D)^{0.241}$
Shear	g/a = 0	$f_{v\alpha} = 0.22\ F_v\ (150/D)^{0.450}$
	g/a = 2	$f_{v\alpha} = 0.44\ F_v\ (150/D)^{0.326}$
	g/a = 4	$f_{v\alpha} = 0.66\ F_v\ (150/D)^{0.241}$

* $f_{b\alpha}$, $f_{v\alpha}$, F_v to be stated in MPa.
D to be stated in mm.

TABLE 2

BEAM FRACTURE STRESS

IN TERMS OF DENSITY

Strength Type	Notch Angle	Strength Equation*
Bending	g/a = 0	$f_{b\alpha} = 0.021\rho\ (150/D)^{0.450}$
	g/a = 2	$f_{b\alpha} = 0.042\rho\ (150/D)^{0.326}$
	g/a = 4	$f_{b\alpha} = 0.063\rho\ (150/D)^{0.241}$
Shear	g/a = 0	$f_{v\alpha} = 0.005\rho\ (150/D)^{0.450}$
	g/a = 2	$f_{v\alpha} = 0.010\rho\ (150/D)^{0.326}$
	g/a = 4	$f_{v\alpha} = 0.015\rho\ (150/D)^{0.241}$

* $f_{b\alpha}$, $f_{v\alpha}$ to be stated in MPa
ρ to be stated in $Kg.m^{-3}$
D to be stated in mm.

DESIGN RULES

The fracture equations given in Table 1 represent a conservative fit to the experimental data, and consequently suitable design equations can be obtained through replacing the shear block strength F_v in these equations by F_{sj}, the design shear strength of joint details specified in AS 1720 (Standards Association of Australia 1975). A small modification to this will be required if it is considered that the margin of safety required for fracture strength is different from that inherent in the specification of design shear strength.

One possibly obvious point that may be overlooked in writing design rules is that since fracture strength increases inversely with beam size, then $f_{b\alpha} \to \infty$ and $f_{v\alpha} \to \infty$ as $D \to 0$. Consequently it is necessary to specify the additional condition that the design values of nominal bending and shear stresses do not exceed the values that would be allowed if the beam were not notched.

CONCLUDING COMMENT

Although outside the scope of this paper, it is of interest to note that the fracture measurements reported herein may be used to derive the fracture toughness of timber notches in terms of critical stress intensity factors. However, to do this it is first necessary to compute the stress intensity factors of notched beams under load by some numerical technique such as that undertaken previously by Walsh for the case $g/a = 0$ (Walsh 1974). This is difficult but would be the logical procedure to apply if it was considered necessary to examine the fracture strength of notched beams for a great range of beam geometry and loading conditions.

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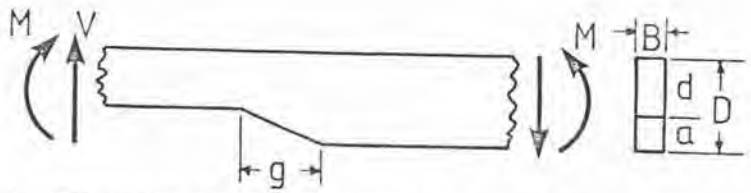

FIG. 1 NOTATION OF DIMENSIONS AND LOAD ACTIONS OF A NOTCHED BEAM

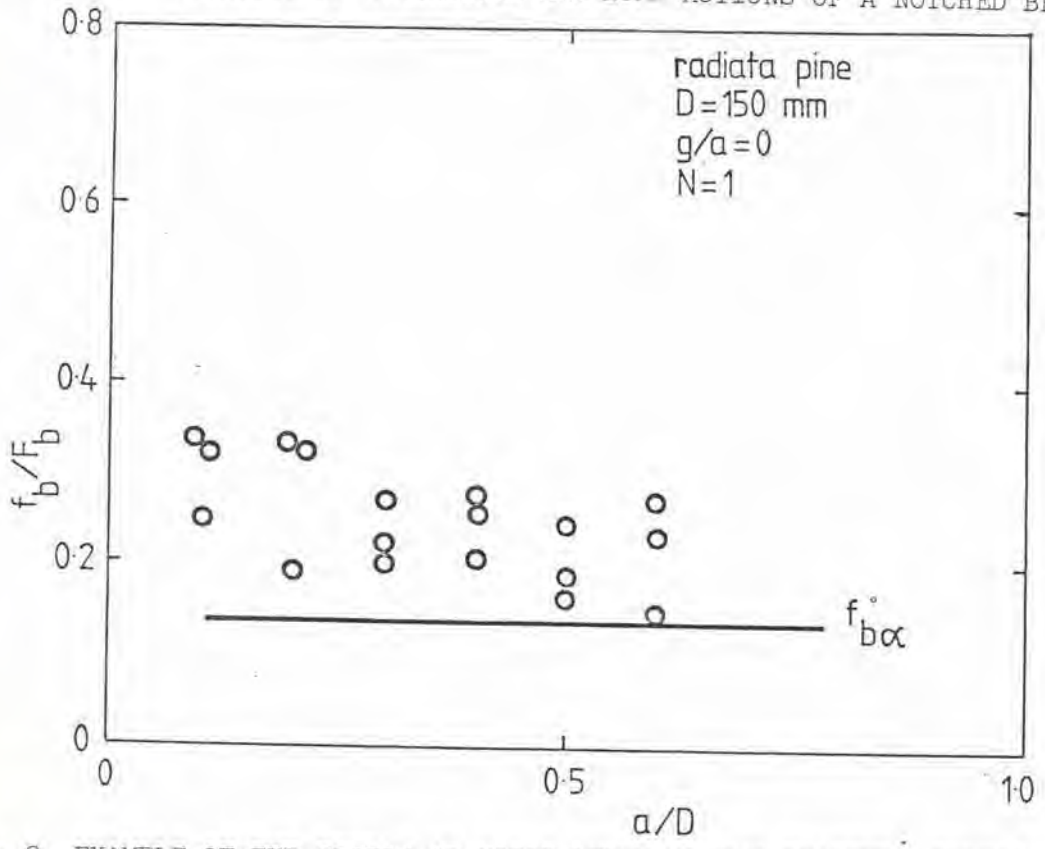

FIG. 2 EXAMPLE OF THE EFFECT OF NOTCH DEPTH ON THE FRACTURE STRESS IN BENDING

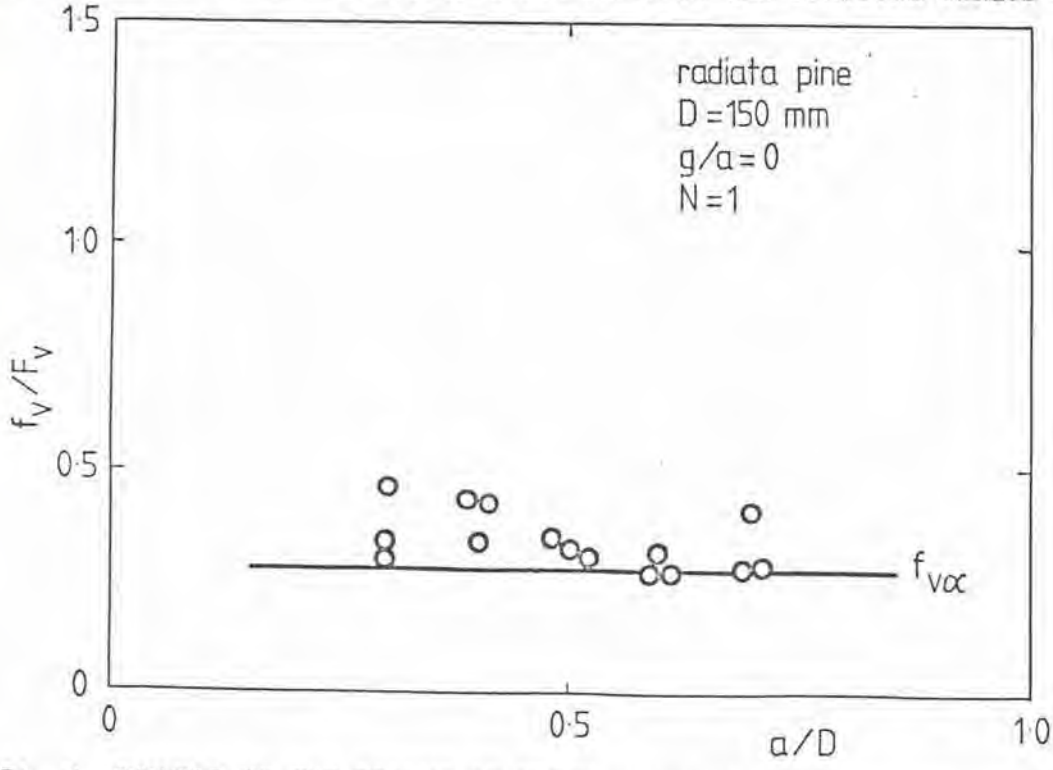

FIG. 3 EXAMPLE OF THE EFFECT OF NOTCH DEPTH ON THE FRACTURE STRESS IN SHEAR

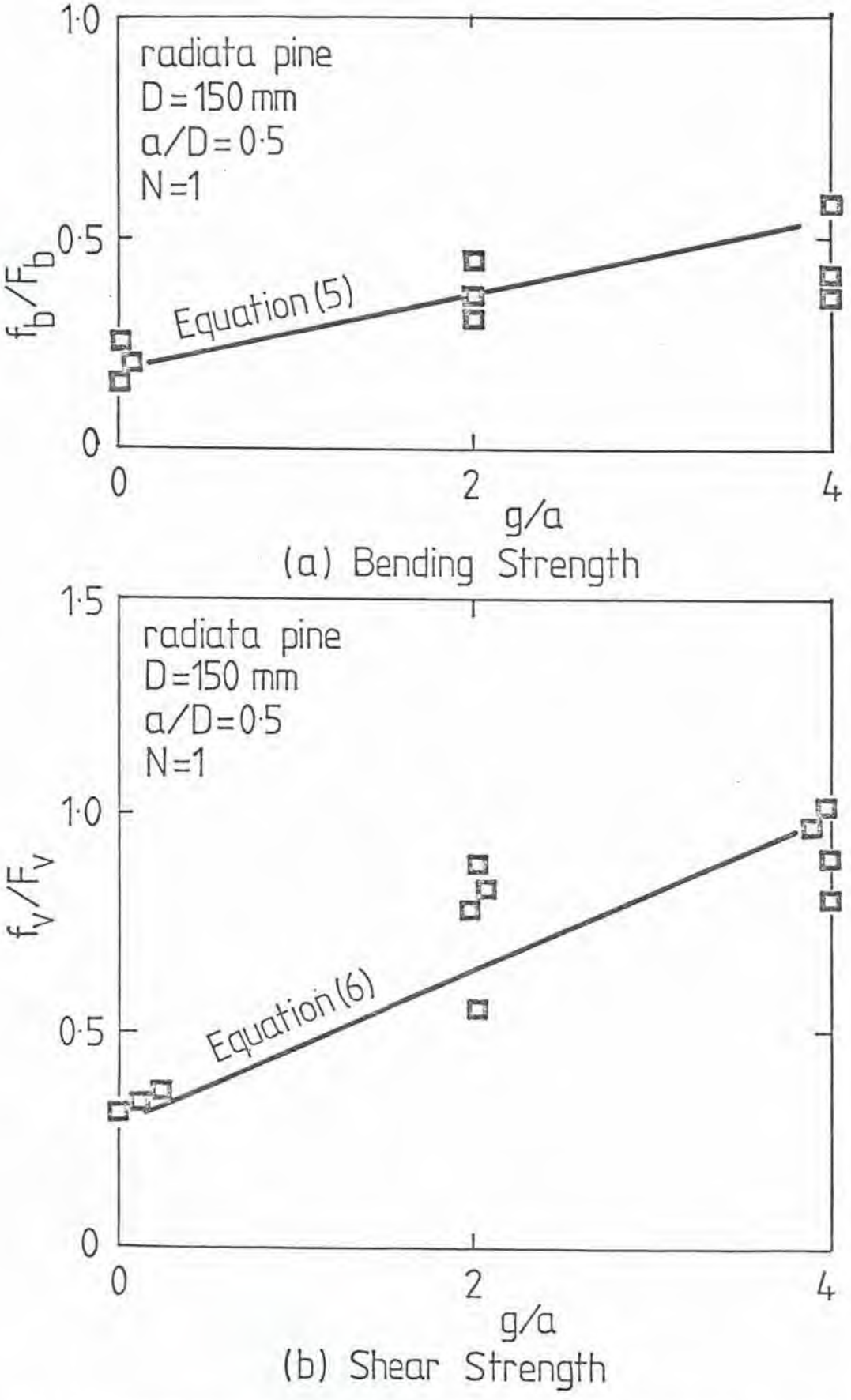

FIG. 4 EXAMPLES OF THE EFFECT OF NOTCH ANGLE ON FRACTURE STRESS

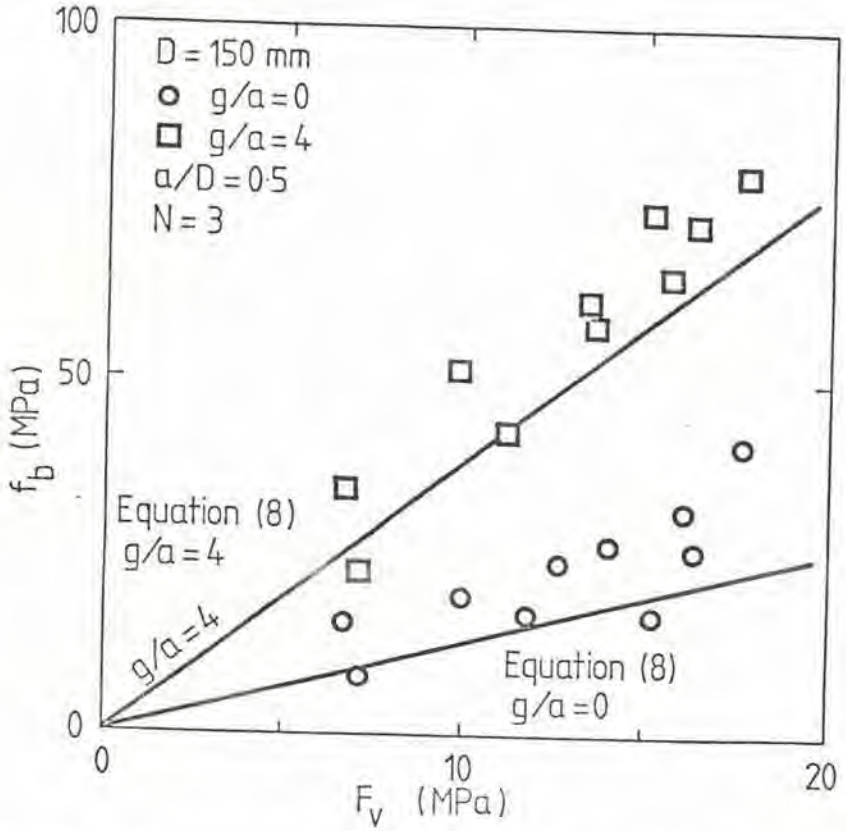

FIG. 5 EFFECT OF SPECIES SHEAR STRENGTH ON THE FRACTURE STRESS IN BENDING

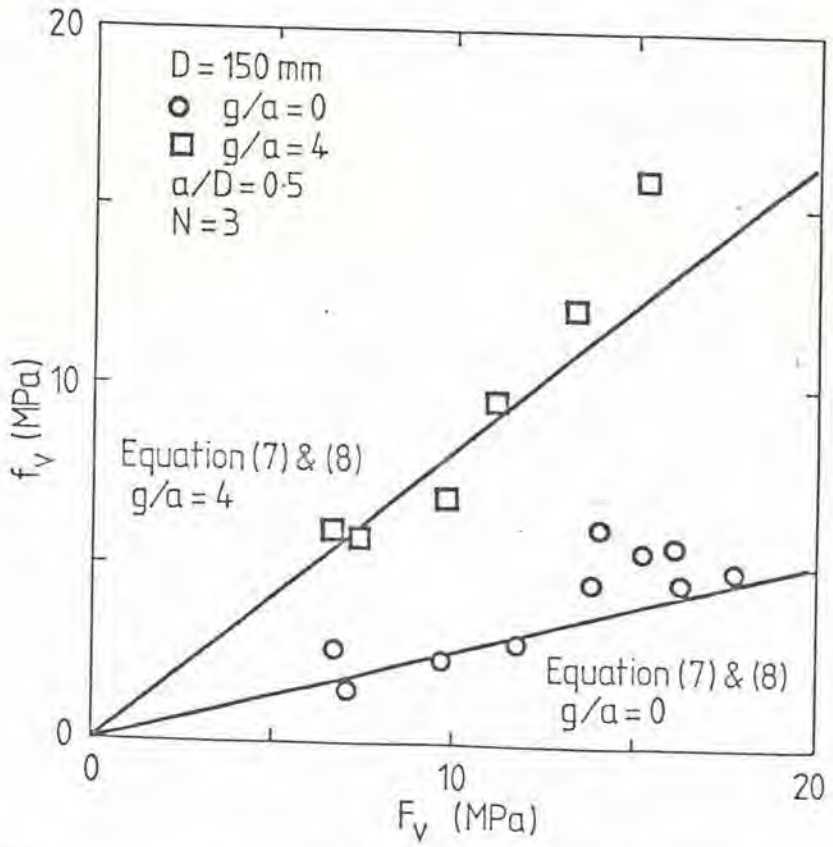

FIG. 6 EFFECT OF SPECIES SHEAR STRENGTH ON THE FRACTURE STRESS IN SHEAR

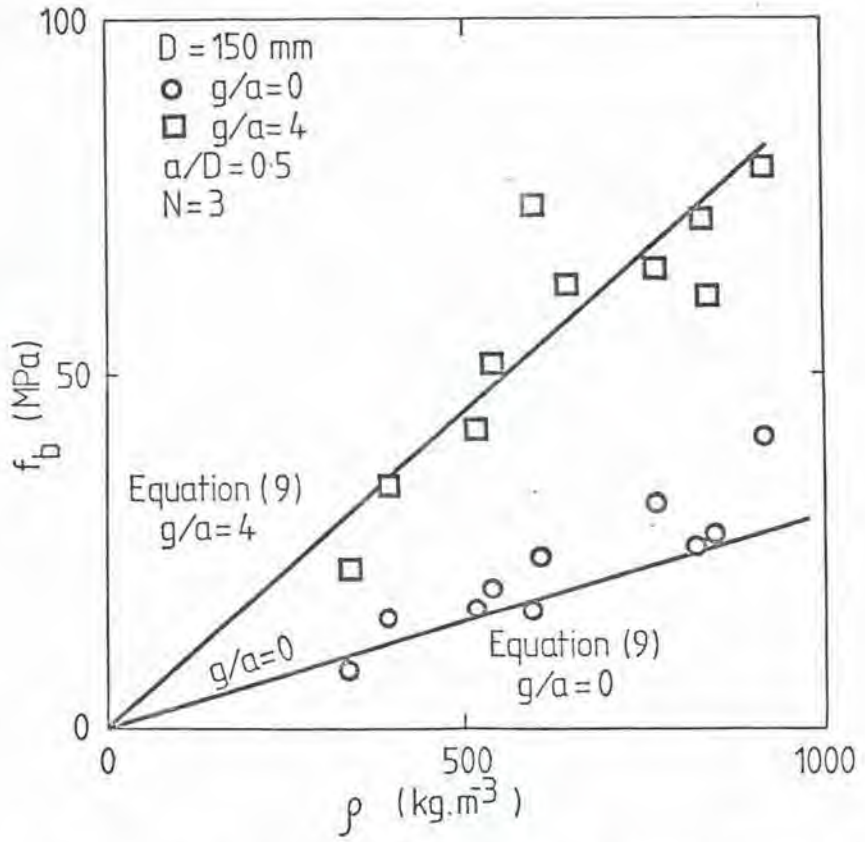

FIG. 7 EFFECT OF SPECIES DENSITY ON THE FRACTURE STRESS IN BENDING

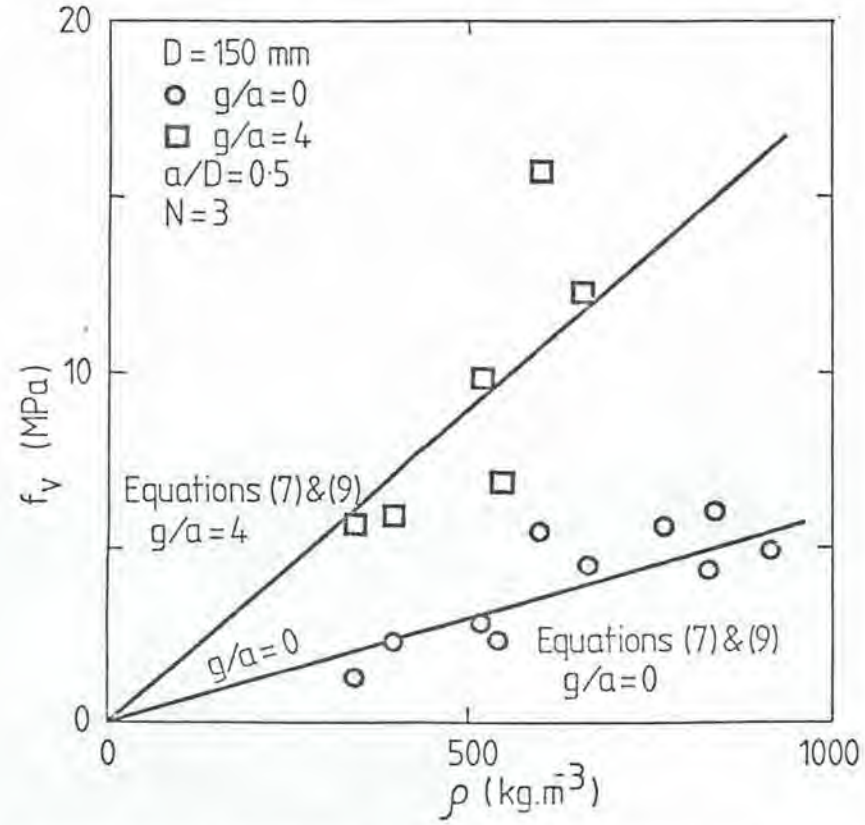

FIG. 8 EFFECT OF SPECIES DENSITY ON THE FRACTURE STRESS IN SHEAR

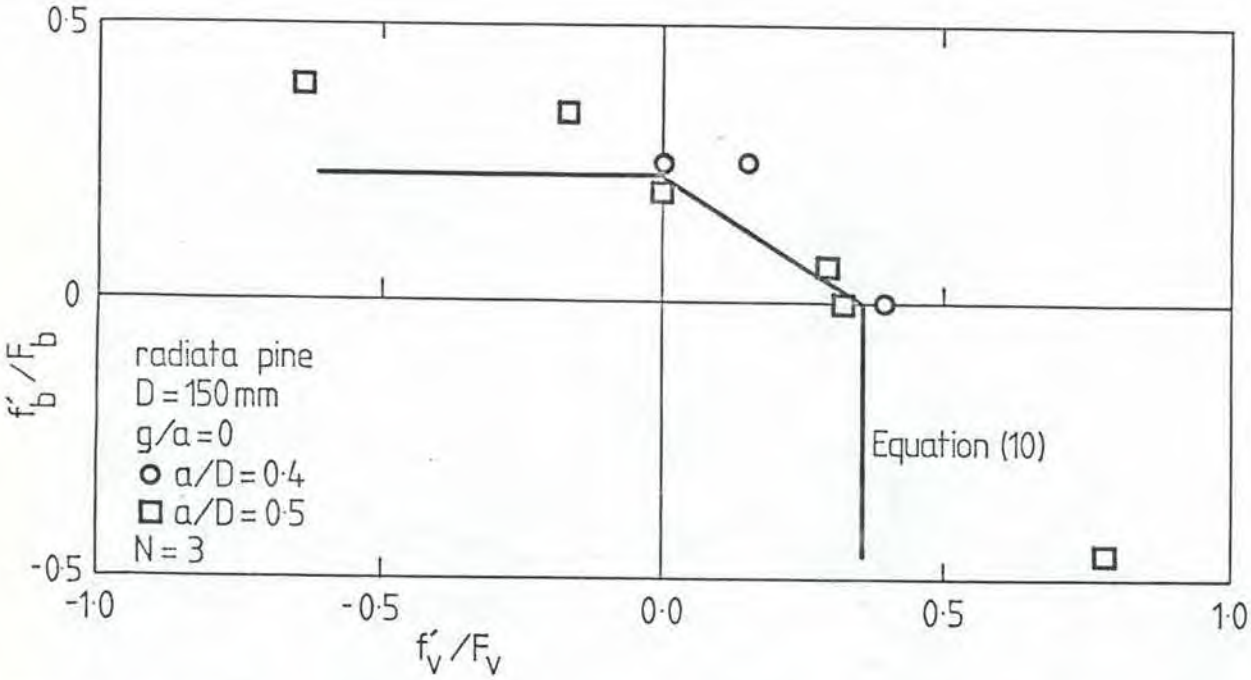

FIG. 9 EXAMPLE OF THE INTERACTION BETWEEN THE FRACTURE STRESS IN BENDING AND SHEAR.

IN-GRADE STRUCTURAL PROPERTIES OF SOME AUSTRALIAN TIMBERS

R. H. Leicester

ABSTRACT

The measured structural properties of three Australian timbers, graded both visually and mechanically, are compared with the required values of design strength and stiffness specified in the Australian Standard AS 1720. The study indicates that some modification in the specified design values may be necessary.

INTRODUCTION

Values for the design stresses and stiffness of structural timber have evolved over several decades through modifications and extrapolations of existing concepts, usually without direct experimental verification. In recent years a considerable amount of data from tests on structural-size timbers have become available and it is therefore timely to use these data to assess the effectiveness of the Australian structural timber Standards, particularly the Standard 1720-1975 (Standards Association of Australia 1975), the SAA Timber Engineering Code.

The information from similar studies in other countries cannot be used directly for this purpose, as the correct design values depend not only on the properties of the structural timber concerned, but also on many related Standards, such as for example the Loading Codes. The following is an example of the type of rational procedure that should be used in an assessment of design values. Because there will always be limited data for such an assessment, rational procedures should be considered primarily as a framework for linking the various design concepts with the available data.

TEST DATA

The assessment to be described is based on data obtained from three common types of Australian timbers which have quite different structural characteristics. These are a green hardwood, messmate (*Eucalyptus obliqua*), a green

softwood with unusual knot characteristics, cypress pine (*Callitris glauca*), and a typical dry softwood, radiata pine (*Pinus radiata*). The test lengths of the sticks were 3.6 metres and the cross-sections were roughly 90 mm x 35 mm. The four structural properties measured were the following:

(a) the bending strength, denoted by B, measured at the weakest defect with the defect strength located on the tension edge,

(b) the tension strength, denoted by T,

(c) the average modulus of elasticity, denoted by E, and

(d) the local modulus of elasticity, measured on the flat over a span of 900 mm and denoted by E_o.

Data obtained from these tests are given in Table 1 and 2.

LOAD FACTORS

In an earlier study on the reliability of structural timber (Leicester 1979) it was shown that with the assumption of a lognormal distribution of strength a reasonable load factor is obtained by relating the design strength R* and 5-percentile strength $R_{0.05}$ through $R^* = R_{0.05}/(1.2 + 1.4V_R)$, where V_R is the coefficient of variation of R. This is similar to the recommendations of the Nordic building code (Nordic Committee on Building Regulations 1978) when the consequences of structural failure are not serious. In order to translate this to basic design values it is also necessary to include a factor of 1.75, the factor used to relate basic and three minute strength values in AS 1720, a factor used to account for the increase in bending strength when the weakest defect in a stick of wood occurs at a random location, and a contingency factor of 0.9 to allow for the possibility of weaker timber occurring in specific mill outputs. Hence the basic design bending, tension and stiffness values for visually stress graded timber, denoted by B*, T* and E* respectively, can be taken to be given by

$$B^* = \frac{(0.9)(1.15)B_{0.05}}{(1.75)(1.2 + 1.4\ V_B)} \qquad (1)$$

$$T^* = \frac{0.9\ T_{0.05}}{1.75(1.2 + 1.4\ V_T)} \qquad (2)$$

$$E^* = 0.9\ \bar{E} \qquad (3)$$

where $B_{0.05}$ and $T_{0.05}$ are the 5-percentile values of B and T, $\bar{E}$ is the mean value of E, and V_B and V_T are the coefficients of variation of B and T. For mechanically stress graded timber, equations (1)-(3) are again applicable. However, because regional effects are reflected in the grading modulus E_o, the contingency factor of 0.9 is not required in this case.

ASSESSMENT OF VISUAL STRESS GRADES

Table 1 shows some measured properties of graded timber together with the corresponding basic design values derived from equations (1)-(3) and with the assumption of lognormal strength distributions. It is seen that in comparison with the values specified in AS 1720, the derived design bending strengths with one exception, are roughly correct; the derived design tension strengths, particularly the Radiata pine are far too low; and the derived design stiffnesses are about correct for the Messmate, conservative for Radiata pine and inadequate for the Cypress pine.

ASSESSMENT OF MECHANICAL STRESS GRADES

The properties of mechanically stress-graded timber were obtained through computer simulations with parent populations having parameters similar to the measured ones shown in Table 2. From each population three populations were obtained by selecting members having local stiffnesses in the ranges $0.7\text{-}1.0\overline{E}_o$, $0.8\text{-}1.2\overline{E}_o$ and $1.0\text{-}1.4\overline{E}_o$. For each of these selected populations, basic design values B*, T* and E* were obtained through application of the modified form of equations (1)-(3) and are shown in Figs. 1-3. The grading modulus E_o shown in these figures refers to the lower bound value of E_o used in selecting the mechanically stress-graded population. For reference purposes specified design values for specific stress grades and the DWT grading line (Forestry Commission of NSW 1974) are also indicated.

The most obvious features to be seen in the Figures are the differences between the grading lines of the three species, the differences between the required grading modulus E_o for each design property and, as for visually graded timber, the low tension strengths relative to the bending strengths.

CONCLUSIONS

The design properties of structurally graded timber do not fit in completely with the strength classifications given in AS 1720. Some of the difficulties arise as would be expected from strength grouping effects. Others are due to the selection characteristics of the grading process. For example, the measured ratio of T*/B* was about 0.56 for mechanical stress grades but only 0.47 for visual stress grades. The apparent understrength in tension noted for both methods of grading is accepted in AS 1720 because the duration effect corresponding to the factor 1.75 does not occur for structural timber (Madsen 1973). However, in designing for short duration loads, this factor is removed and the resulting design could well be unsafe.

TABLE 1

PROPERTIES OF VISUALLY GRADED TIMBER

TIMBER	STRESS GRADE	MIN. SAMPLE SIZE	MEASURED STRUCTURAL PROPERTIES					B* (MPa)		T* (MPa)		E* (GPa)	
			$\overline{B}$ (MPa)	$\overline{T}$ (MPa)	$\overline{E}$ (GPa)	V_B	V_T	derived	AS1720	derived	AS1720	derived	AS1720
Messmate	F11	8	48	37	12.0	.25	.30	11.9	11.0	6.9	8.6	10.8	10.5
	F14	24	58	51	14.1	.25	.30	14.3	14.0	9.6	11.0	12.7	12.2
	F17	20	56	52	15.3	.25	.30	13.8	17.0	9.8	14.0	13.8	14.0
Cypress pine	F5	21	29	21	6.7	.25	.30	7.2	5.5	3.9	4.3	6.0	6.9
Radiata pine	F7	29	34	23	13.4	.35	.40	6.4	6.9	3.3	5.5	12.1	7.9
	F11	16	60	33	15.6	.35	.45	11.3	11.0	4.2	8.6	14.0	10.5

TABLE 2

MEASURED PROPERTIES OF SOME PARENT POPULATIONS

TIMBER	MIN. SAMPLE SIZE	MEAN				COEFF. OF VARIATION				CORRELATION COEFF.		
		$\overline{B}$ (MPa)	$\overline{T}$ (MPa)	$\overline{E}$ (GPa)	$\overline{E_o}$ (GPa)	V_B	V_T	V_E	V_{E_o}	r_{E_oB}	r_{E_oT}	r_{E_oE}
Messmate	117	49	39	13.4	11.3	.30	.45	.20	.25	.85	.70	.75
Cypress pine	30	31	21	6.7	5.9	.25	.35	.25	.25	.55	.60	.85
Radiata pine	74	39	23	13.3	10.2	.45	.50	.25	.30	.80	.80	.85

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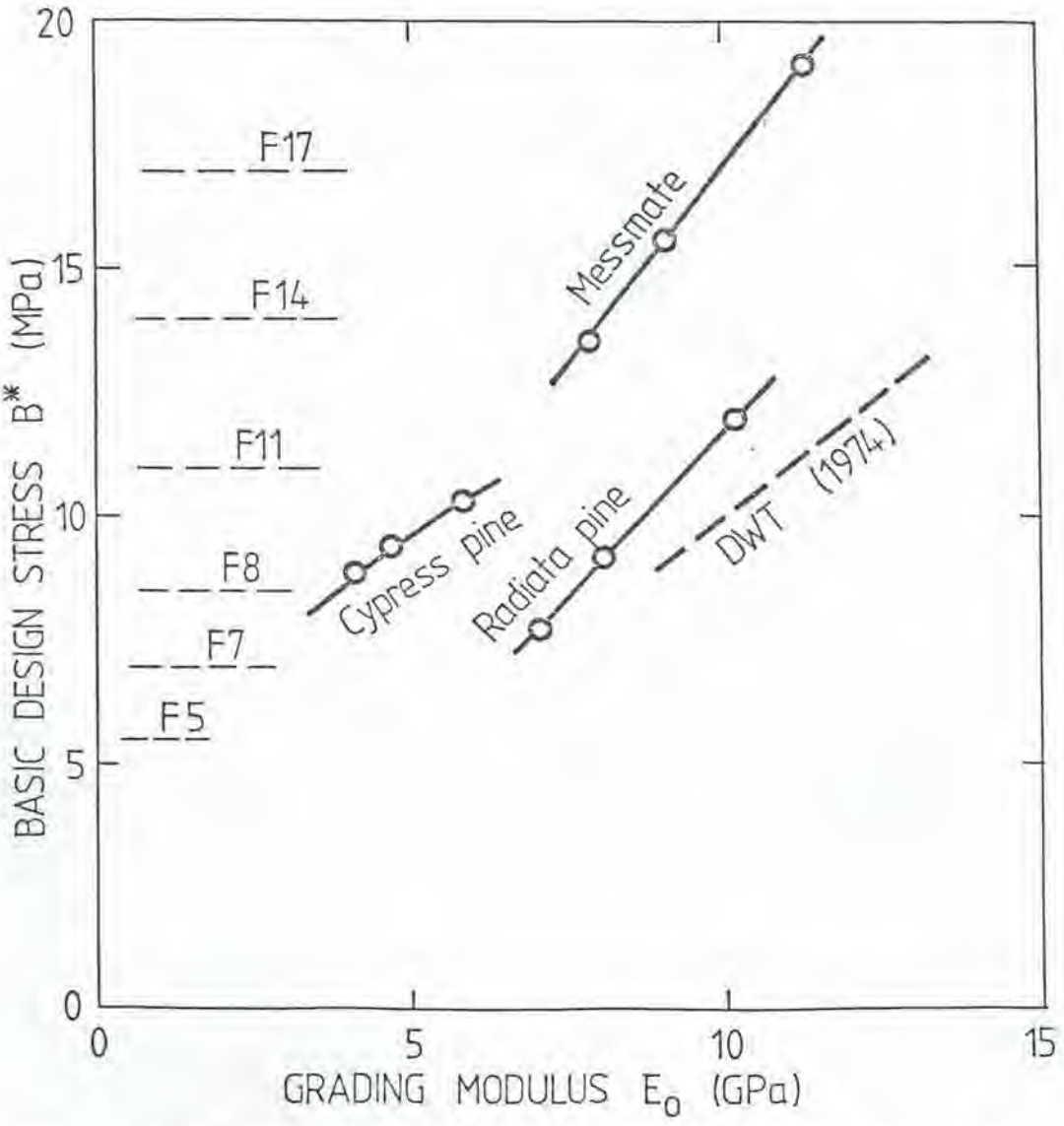

FIG. 1 BASIC DESIGN STRESS IN BENDING OF MECHANICALLY STRESS GRADED TIMBER

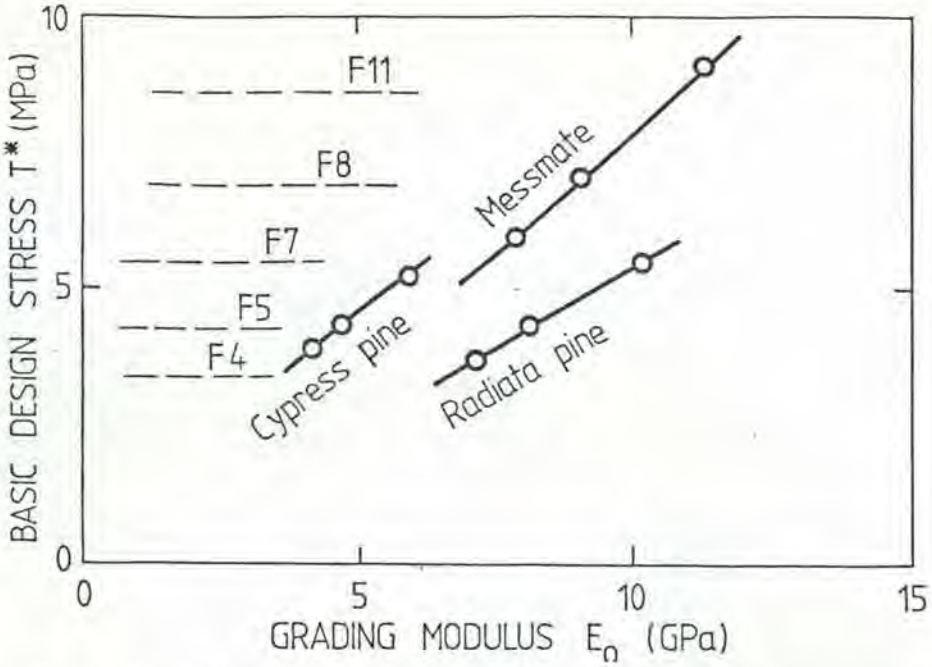

FIG. 2 BASIC DESIGN STRESS IN TENSION OF MECHANICALLY STRESS GRADED TIMBER

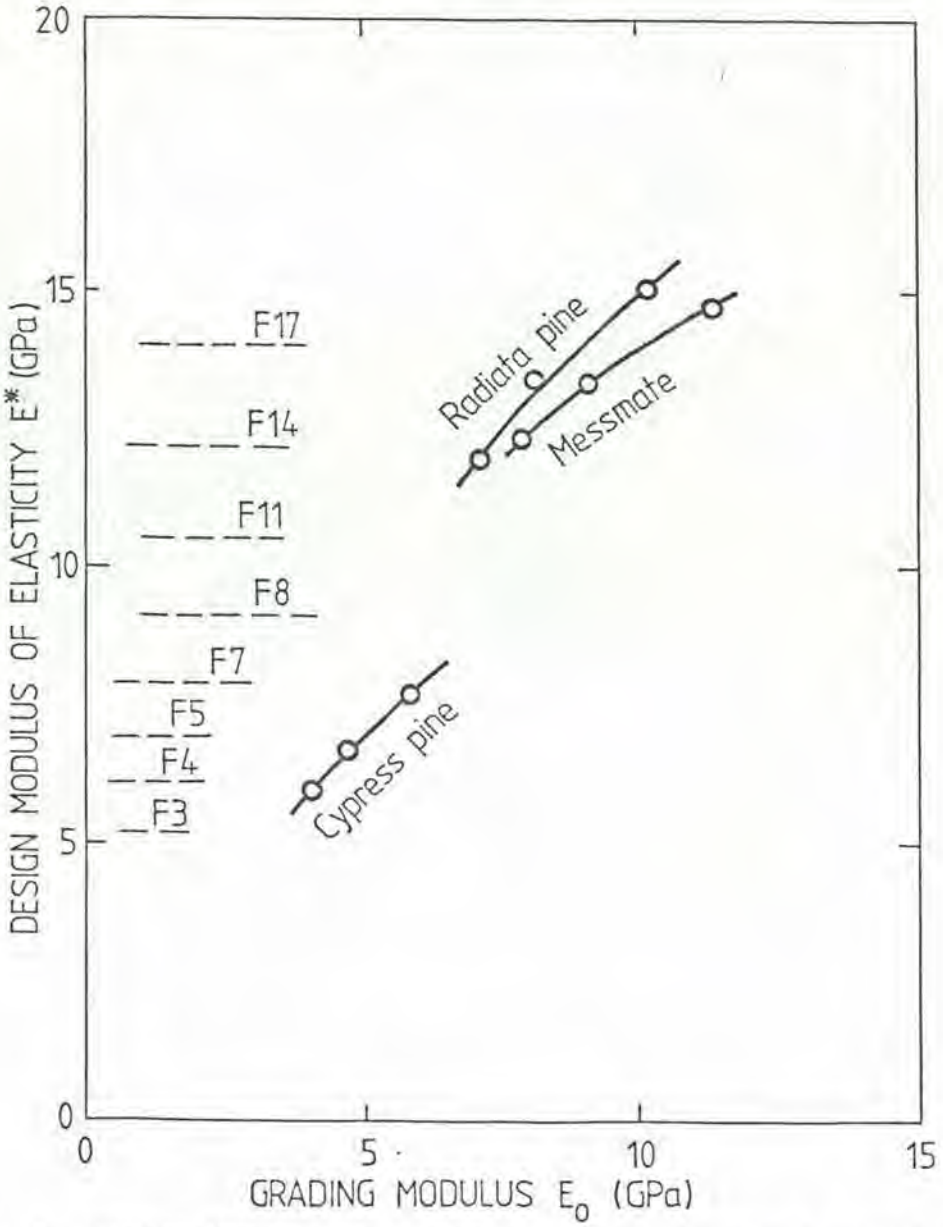

FIG. 3 DESIGN MODULUS OF ELASTICITY OF MECHANICALLY STRESS GRADED TIMBER

BRACING A TIMBER FRAME WITH WALL CLADDING

L. D. Armstrong and K. B. Schuster

ABSTRACT

The structural behaviour of sheet wall cladding of plywood, hardboard, particleboard, asbestos cement, plasterboard and steel, fastened to timber with nails was investigated under repetitive loading similar to that exerted on buildings by wind. Although the strength and stiffness of the assemblies varied considerably, their general mechanical behaviour was similar. The six types of common wall cladding would be suitable for use in diaphragms for bracing low-rise buildings.

1. INTRODUCTION

The traditional method of stiffening the wall frames of houses, and other low-rise buildings, in the longitudinal plane is by means of diagonal bracing of wood or metal sections. Armstrong and Schuster (1) have shown that such strip bracing is inadequate in resisting the wind forces experienced even in sheltered localities in Australia. The fact that so many buildings manage to survive windstorms may be attributed to the unintentional support provided by the cladding attached to the wall frames.

For many years, several overseas countries have been utilizing some types of wall cladding to provide in-plane bracing to walls of houses to resist wind or earthquake, and also the forces exerted on factory produced building elements during transport. Following the extensive damage caused to houses in Darwin in 1974 during cyclone "Tracy", structural shear panels constructed from plywood and hardboard are being applied in domestic construction in cyclone prone localities. The panels provide resistance not only to racking forces but also to the uplift forces which act on the wall frames due to the effects of wind on the roof structure.

The design recommendation (2) throughout Australia is that framed wall elements in racking should not deflect more than height/300 or 10 mm, whichever is the least, at design wind velocity. For a typical house embedded in a built-up area the recommended design wind velocity for deflection calculations is 33 metres per second and for houses on exposed sites the velocity is 47 m/s. Other criteria apply in design for strength. The magnitudes of the racking forces on a wall of a house of single storey may be up to 5000 newtons at a

wind velocity of 33 m/s and up to 10,000 N at 47 m/s. Where two-storey construction is used these figures would be increased.

There is an urgent need for improved bracing techniques in low-rise buildings, not only in new construction but also in improving existing buildings that exhibit racking distortions or that are being extended to two-storey construction. The improved bracing characteristics may be achieved through adequately fastening sheet materials to wall frames to form structural diaphragms. Several types of sheet products are used to clad framed buildings for protective and aesthetic needs and an important structural purpose would be served in utilizing such claddings to stiffen the buildings. The research work described here forms part of an extensive project concerned with a fundamental study of framed diaphragms and provides an assessment of the suitability of common cladding materials for use in diaphragms.

2. ASSESSING THE STRUCTURAL POTENTIAL OF CLADDING

The structural properties of sheathed diaphragms are determined from limited static tests on full-size panels and little is known of the basic behaviour and properties of the diaphragms and components, especially under repetitive conditions of loading similar to those exerted on buildings by wind. Full scale tests are time consuming and expensive and although essential in the long run to check predictions based on analytical methods, alternative testing techniques that may be simple and cheap should be sought. A simplified testing technique was developed in this work to assess the structural potential of cladding materials and the basic properties of the components in nailed diaphragms.

3. EXPERIMENTAL

A test specimen was designed in the form of a simple nailed joint, incorporating the cladding material, which was easy and cheap to fabricate and which could be tested under static or repetitive loading, in typical laboratory machines. Butt-jointed specimens, illustrated in figure 1, were fabricated from seasoned Pinus radiata D. Don, 70 x 45 mm in cross-section, joined with two cover plates, 240 x 70 mm in dimension, of 7 mm Pinus structural plywood, 6 mm hardboard, 8 mm water resistant particleboard, 10 mm plasterboard, 7 mm asbestos cement sheet and 0.8 mm flat steel sheet. Two clout nails, 30 x 3.15 mm dia., were used to attach each plate to the timber in the test section of each joint, except for plasterboard joints in which 30 x 2.8 mm dia. plasterboard nails were used. Tests were made on four replications of each type of joint.

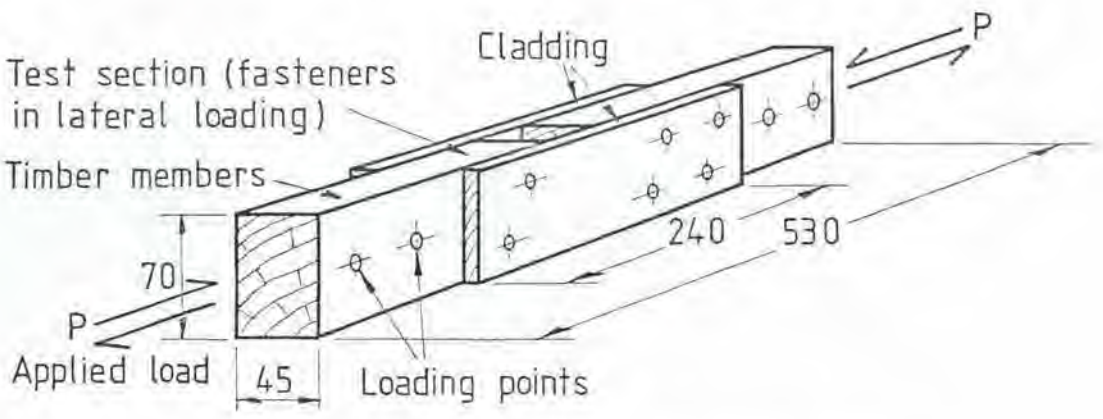

Fig.1 Specimen for tests on nailed joints

The load required to cause a joint slip of 0.4 mm was determined for each type of joint from static tests on two matched controls and was taken to be the design load for each joint. Over a period of 5 hours, the test specimens were subjected to four complete sequences of the following pattern of unidirectional repetitive loading, considered to be representative of racking loads imposed on walls by extreme winds.

889 applications of 0.48 design load.
100 applications of 0.65 design load
10 applications of 0.83 design load
1 application of design load

Detailed load-slip characteristics were measured. Following the repetitive loading sequences, each specimen was then tested to failure under static loading.

4. RESULTS

The load and slip measurements for the various joints are given in Table 1.

TABLE 1 - LOAD SLIP DATA

Type of Cladding	Static Properties of Controls		Joint slip during repetitive loading (mm)								Static Properties of joints after cycling	
			Sequence 1		Sequence 2		Sequence 3		Sequence 4			
	Load at 0.4mm slip Newtons	Maximum Load N	Max slip mm	Residual mm	Max	Resid	Max	Resid	Max	Resid	Load at 0.4mm Slip N	Max Load N
Pinus Plywood 7 mm.	1980	4860	.32	.09	.32	.10	.32	.10	.32	.10	2210	5040
Hardboard 6 mm.	2410	4160	.36	.12	.38	.13	.38	.14	.38	.15	2440	4150
Particleboard 8 mm.	1800	4720	.36	.10	.36	.11	.37	.12	.37	.12	1900	4425
Asbestos Cement 7 mm.	2690	4650	.41	.15	.44	.16	.46	.17	.47	.18	2690	4370
Plasterboard 10 mm.	729	1990	.36	.11	.38	.14	.40	.15	.41	.17	660	2080
Steel Sheet 0.8 mm.	3280	6540	.32	.10	.32	.11	.32	.12	.32	.12	4020	6660

5. DISCUSSION

The results of the tests given in Table 1 indicate that the static loads required to cause a joint slip of 0.4 mm were approximately 1800 to 2400 newtons for joints fabricated from particleboard, plywood and hardboard, 2700 N for asbestos cement, 3300 N for steel sheet and 700 N for plasterboard. The maximum loads were between approximately 2000 and 6500 N.

During repetitive loading most of the joint slip occurred in the first loading sequence of 1000 cycles and increased in the following three sequences of loading by up to 6 per cent in the wood products and steel sheet and by about 13 per cent in the asbestos cement and plasterboard. These increases were largely due to the development of inelastic deformations. The final slip values after 4000 repetitions of load ranged from 0.32 to 0.47 mm and between 32 and 42 per cent of these values were residual deformations.

When the joints which had been subjected to repetitive loading were tested to failure under static loading, the mechanical properties were found to remain practically unaltered from those evident in the matched control specimens.

Similar behaviour to that reported here for simple joints was observed by Armstrong and Schuster (3) in tests on full-size wall panels sheathed with structural plywood.

The evidence presented indicates the suitability of the cladding materials described here for use in sheathed diaphragms fabricated with nails. However, some confirmatory tests on full scale wall panels would need to be made to take into account buckling effects that may occur in thin cladding.

6. CONCLUSIONS

A laboratory test on a simple nailed joint under static and repetitive conditions of loading appears satisfactory for assessing the structural properties of sheet cladding. Both the elastic and inelastic responses may be determined.

When joints fabricated from timber members and small samples of plywood, hardboard, particleboard, asbestos cement, plasterboard and steel sheet, attached with nails, are subjected to repetitive loading, most of the deformation in each joint occurs early in the loading program and further slight increases occur with continued repetitive loading. These additional deformations are largely inelastic in nature. Repetitive loading, at least to design load, does not affect the subsequent behaviour of cladding joints under static loading.

Tests on simple joints have shown that sheet cladding commonly used in house construction is satisfactory for application in structural diaphragms to resist in-plane forces similar to those exerted on low-rise buildings by wind. Some confirmatory evidence needs to be sought on full scale wall panels to take into account buckling effects that may arise with thin cladding.

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PERFORMANCE OF SHEET FLOORING UNDER LONG TERM LOAD

P. R. Chapman

As part of the continuing programme of research into the utilization and properties of forest products, a study is being undertaken of the performance of some representative types of sheet flooring materials when subjected to a concentrated load of long duration.

One of the main aims of this study is to determine the magnitude of the long-term creep which occurs in various sheet flooring materials under sustained concentrated load and if possible how this responds to ambient moisture content changes as monitored by subfloor equilibrium moisture content samples.

METHOD

The materials being used in this study consist of four types each of Australian produced particleboard and plywood. These materials were laid as sheet flooring over a conventional timber sub-floor with joists at 450 mm spacing. The sheets were laid either in accordance with the individual manufacturers recommendations for the installation of flooring material or if these were not specified, then in accordance with the practice given in the relevant Australian standards or codes. The particleboard types consist of one bonded with urea formaldehyde resin, one bonded with a basically tannin formaldehyde resin and two bonded with phenol formaldehyde resin; all were produced by different manufacturers. The plywoods used were manufactured from karri, yellow carabeen, tulip oak and radiata pine veneers respectively and all were bonded with phenol formaldehyde resin. For comparison with the sheet flooring materials a conventional radiata pine strip flooring was laid over the same sub-floor construction and subjected to identical loading conditions.

The load that was applied to the flooring was 91 kgF. This load has been recommended by Boyd (1) in his study on the strength and stiffness requirements of domestic flooring, but the method of application differed. Boyd (*op. cit*) recommended that the load be applied through a 20 mm diameter tool In this study, the load was applied through a 50 mm diameter tool with a 100 mm radius of curvature at the point of application. This tool configuration is that recommended in BS.1811 (2) and was used in this instance as a somewhat similar previous study (3) had indicated that the smaller 20 mm diameter tool tended to create high local deformation and under certain conditions would even puncture the panel. As the main purpose of this study is to elicit deflection performance

it was decided that local deformation should, as far as possible, be kept to a minimum. Other workers (4) have also considered the 50 mm diameter tool appropriate for testing of this nature.

The load was applied to the flooring materials midway between sheet edges and midway between joists. The deflection occurring under the loading point and the sub-floor moisture content of the flooring materials as affected by ambient changes were monitored weekly.

RESULTS AND DISCUSSION

Examination of the results over a period of approximately 18 months indicates that all particleboards behaved in a qualitatively similar manner and that the deflection changes appear to bear some form of direct relation to the small period moisture content changes - an increase in moisture content being accompanied, in general, by an increase in deflection and vice versa.

The deflection response of plywood sheet flooring to moisture content change is rather obscure and no pattern of either direct or inverse response is at present apparent. The karri and yellow carabeen plywoods appear to show a slight tendency toward an inverse relation; the pinus plywood the converse and the tulip oak plywood no preponderancy toward either relation.

The deflection of the pinus strip flooring was very responsive to moisture content changes which occurred during the weekly measurement period - the relationship being distinctly inverse.

All the sheet flooring types still appear to be undergoing creep deflection as evinced by the time-deflection-plots although the creep rate shows some indications of degression.

Thickness variations occurring in the sheets over the period almost exactly duplicate those occurring in the moisture content samples. The thickness-time-plots also duplicate the undulations in moisture content-time-plots. This behaviour implies that the small sample moisture content changes give a good indication of the moisture content changes occurring in the sheets themselves.

The thickness and moisture content variations occurring in the radiata pine strip flooring are images of those occurring in the sheet flooring materials, at least in form, although the magnitudes show some slight variation depending upon the particular material.

The time-deflection plots of the sheet materials can therefore be compared with the time-moisture content plot of the strip flooring just as effectively as they can with their individual time-moisture content plots.

Figure I which shows typical time-deflection plots also shows the thickness and moisture content variations occurring in the radiata pine strip flooring.

The moisture content changes follow a definite seasonal cyclic trend but no reflection of this appears in the deflection results for the various sheet flooring types. The association between moisture content change and deflection of the radiata pine strip flooring is, however, very marked and becomes quite apparent if a mirror image of the moisture content plot is superimposed on the deflection plot. Although the strip flooring deflection does not follow every nuance of moisture content change, the overall pattern indicates an increase in deflection on desorption and a decrease in deflection on absorption.

Under conditions of controlled moisture content cycling, similar results have been obtained for timber by other investigators (5). To the writer's knowledge, a satisfactory explanation for the mechano-sorptive deflection behaviour of timber is yet to be forthcoming.

Determination of the moisture content response of plywood and particleboard when used as flooring is as yet far from clear and it appears that much work remains to be done if this effect is ever to be ascertained.

Table I presents some of the more important observations recorded over a period of 1½ years.

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TABLE I

Observations over a Period of 1½ Years (570 days)

Flooring Type	Maximum creep recorded + (mm)	Maximum relative creep ++	Time to maximum creep (days)	Range of thickness change (mm)	Range of moisture content change (%)
Particleboard * Phenolic Type 1	2.49	1.65	289	19.34 - 19.84	11.6 - 18.4
Particleboard Urea	1.91	1.18	507	20.77 - 21.28	11.4 - 17.2
Particlebaord Phenolic Type 2	2.70	1.96	507	20.12 - 20.66	10.9 - 18.5
Particleboard Tannin	1.71	1.13	507	19.31 - 19.74	12.3 - 18.0
Karri Plywood	1.66	1.03	534	12.65 - 12.87	11.0 - 17.4
Yellow Carabeen Plywood	1.74	0.93	282	14.76 - 14.94	10.9 - 18.2
Radiata pine Plywood	1.97	1.38	513	16.46 - 16.78	11.9 - 20.7
Tulip oak Plywood	1.92	1.34	534	14.70 - 14.97	11.5 - 22.6
Radiata pine strip flooring	1.09	0.77	282	21.09 - 21.45	12.6 - 21.2

* Results for this material relate to an observation period of 330 days only.

\+ Creep after initial deflection.

++ Creep after initial deflection expressed as a fraction of initial deflection.

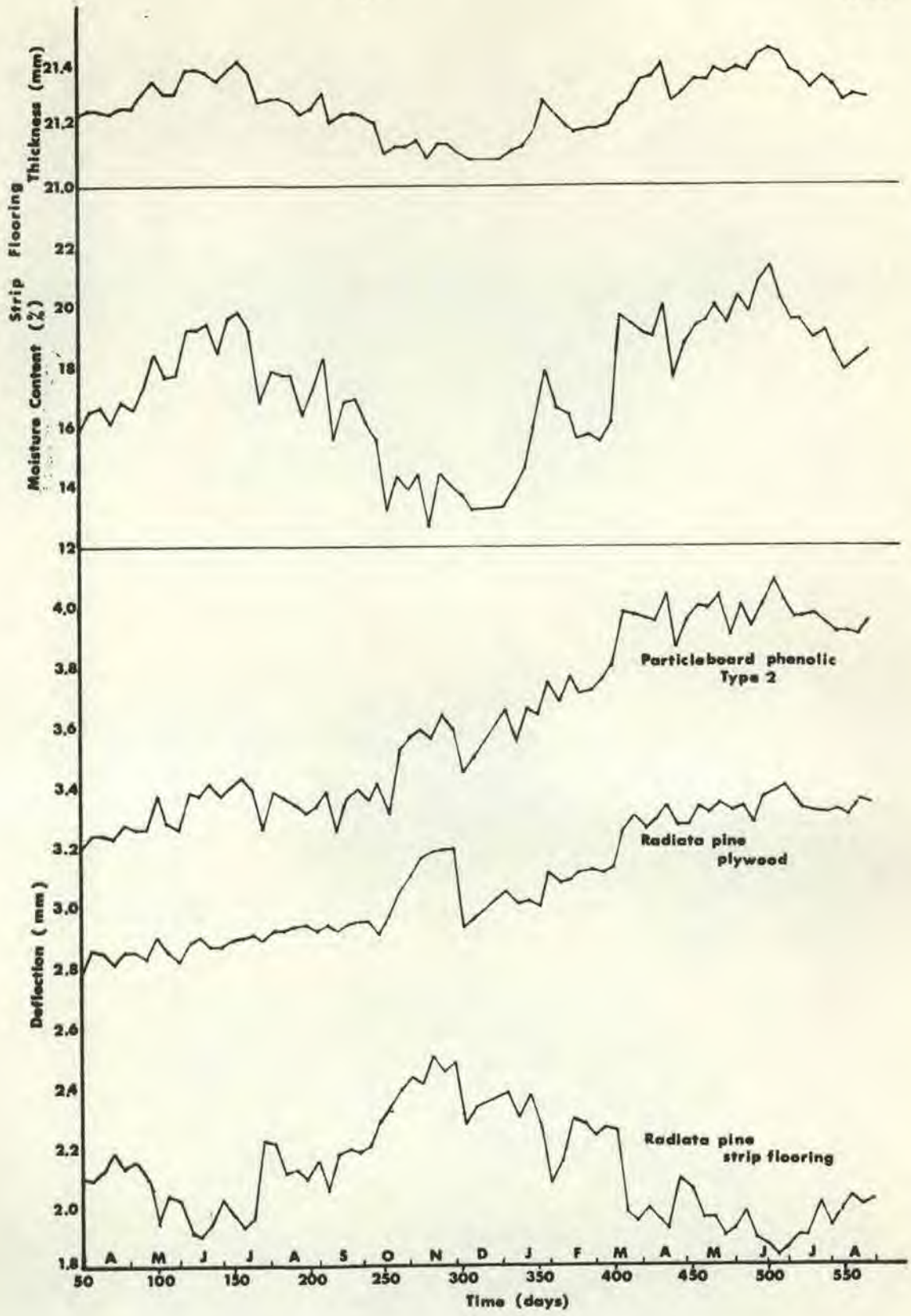

FIGURE 1. Typical plots of time against deflection, moisture content and thickness of representative flooring materials.

THE BEHAVIOUR OF NAILED WALL CLADDING UNDER REPETITIVE LOADING

L.D. Armstrong and K.B. Schuster

ABSTRACT

The mechanical behaviour of common wall cladding fixed to timber framing with nails has been investigated. Simple nailed joints fabricated with six cladding materials were subjected to five patterns of repetitive loading similar to those that may be exerted on low-rise buildings by wind.

The simplest loading pattern needed to assess the structural behaviour of wall cladding fixed to timber with nails appears to be a limited number of successive applications of design load in a single direction.

1. INTRODUCTION

It is common practice in several overseas countries to attach sheet cladding to framed walls in low-rise buildings to provide in-plane stiffness against the lateral forces due to wind, earthquake and various other causes. Until recently the data used in the design and fabrication of such diaphragms were determined from static tests on full-size wall panels based on the techniques recommended by the American Society For Testing and Materials (1).

Following Cyclone Tracy in Darwin in 1974, extensive research and product assessment was commenced in several laboratories in Australia on structural aspects of building elements and fasteners subjected to wind forces. As the loading that results from the action of wind on buildings is repetitive in nature, it became necessary to apply dynamic loading to building elements rather than static loading as previously employed. The application of a repeated loading technique in studying the behaviour of plywood sheathed diaphragms is described by Armstrong and Schuster (2).

Several repeated loading regimes have been devised by various workers to describe the action of wind on building elements and, taking these into account, a simplified pattern for use in Australia was recommended at a Workshop held

during July, 1977 at the Experimental Building Station, Department of Construction, and is fully described in Technical Record 440 (3). During discussions at the Workshop concern was expressed at the complexity and expense of testing large scale wall panels in basic studies and in product assessment. It was recommended that work already in progress at CSIRO on the behaviour of nailed timber joints under static and repetitive loading should be given priority to determine basic behaviour, to provide design data and to devise economic methods of assessing timber framed building elements.

2. EXPERIMENTAL

The test specimen illustrated in Figure 1 was used to investigate the effects of static, repetitive and reversed loading on joints fabricated from timber members and small samples of sheet cladding attached with nails.

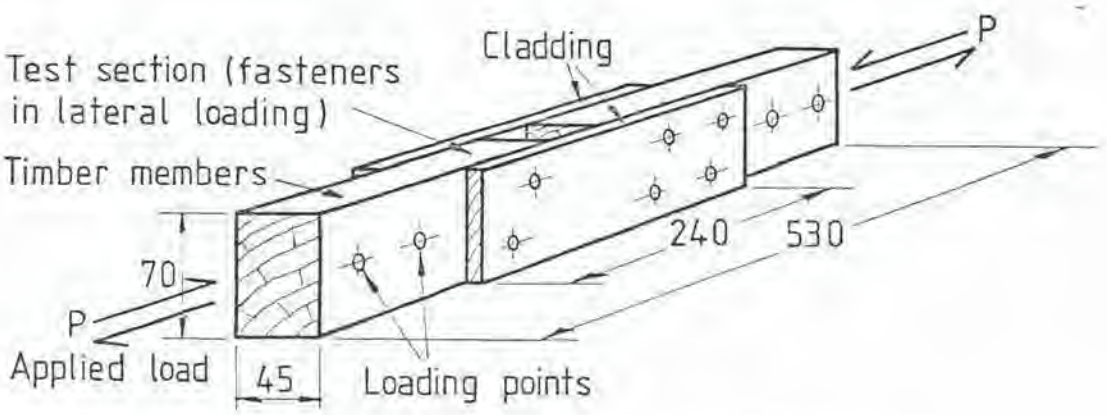

Fig.1 Specimen for tests on nailed joints

For each of six types of cladding, seven matched specimens were fabricated from each of four random sticks of seasoned *Pinus radiata* D. Don and sheets of cladding, giving four replications of each test under five patterns of repetitive loading and eight controls. A total of 168 specimens was involved. Cladding of 7 mm Pinus structural plywood, 6 mm hardboard, 4 mm "Fineline" particleboard, 7 mm asbestos cement and 0.8 mm flat galvanised steel sheet was attached

to the timber with 30 x 3.15 mm diameter clout nails, and 10 mm plasterboard was attached with 30 x 2.8 mm clouts.

Five patterns of repetitive loading, described diagrammatically in Figure 2, were applied to separate groups of specimens. As these experiments were planned and commenced prior to the Workshop responsible for Technical Record 440 (3), the repetitive loading pattern described in that document could not be included in the tests. Four replications of each type of test were made and test load values used in repetitive loading were those determined at 0.4 mm joint slip in static tests on the control specimens. Design loads for nailed joints are based on this value of slip. Following repetitive loading sequences all specimens were tested to failure under static loading and their load-slip characteristics were determined.

The joints fabricated from flat steel sheet were not tested under reversed loading because of the tendency of the material to buckle.

3. RESULTS

The properties of the various joints under static loading, before and after repetitive loading, are given in Table 1.

The load-slip characteristics of the joints under the various patterns of repetitive loading are illustrated in graphical form in Figures 3a to 3f. The joint slip measured during each loading sequence has been expressed as a multiple of that measured during the first sequence and is referred to as "relative slip". Where reversed loading was applied, slip in each direction was related to the initial slip measured in the appropriate direction.

4. DISCUSSION

The results of the tests given in Table 1 indicate that the static loads causing a joint slip of 0.4 mm were between 1980 and 2410 newtons for joints fabricated from plywood, particleboard and hardboard, 2690 N for asbestos cement, 3280 N for steel sheet and 730 N for plasterboard. The values of the maximum loads at failure ranged from 1990 to 6540 N.

When the joints which had been subjected to repetitive loading were tested under static loading, the load at 0.4 mm slip remained practically unchanged in joints that had been loaded in one direction only, but decreased substantially in joints that had been subjected to reversed loading. This reduction could be attributed to the nature of the deformation occurring in the material surrounding the nails. On the other hand, although the results are not given here, it

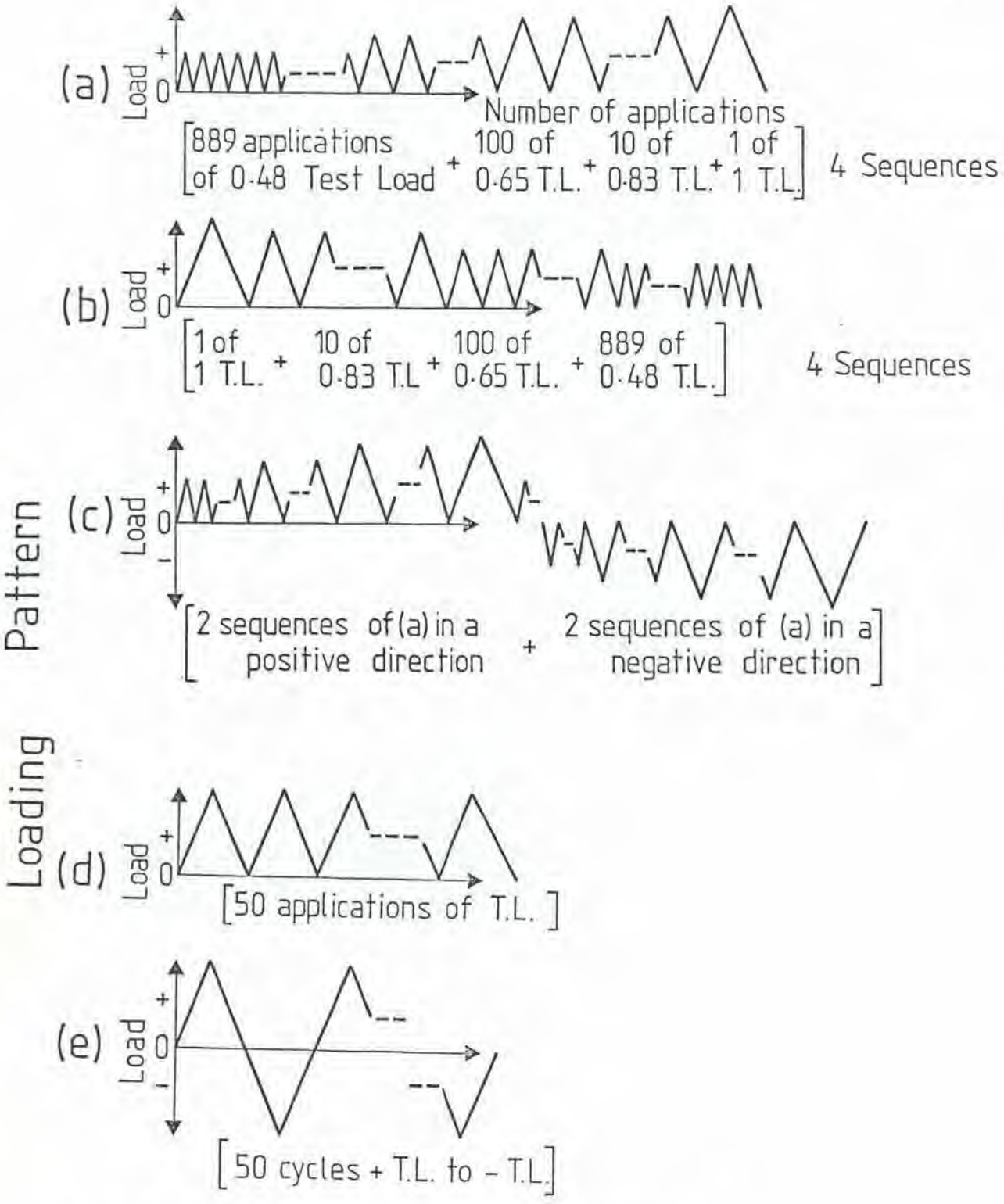

Fig.2 Repetitive loading Patterns

TABLE 1

PROPERTIES OF JOINTS UNDER STATIC LOADING

Type of Cladding	Static Properties of Controls		Static properties of joints after cycling				
			Loading Pattern a	b	c	d	e
Hardboard 6mm	Load at 0.4 mm slip (newtons)	2410	2440	2300	1840	2580	1130
	Maximum Load (newtons)	4160	4150	4260	4320	4490	4170
Particleboard 4mm	$P_{0.4}$	2090	2180	2100	1650	1940	1120
	P_{max}	3900	3900	4320	4180	3870	4310
Plywood 7mm	$P_{0.4}$	1980	2210	2130	1820	1940	1400
	P_{max}	4860	5040	4750	4680	4660	4830
Plasterboard 10mm	$P_{0.4}$	730	660	580	430	750	350
	P_{max}	1990	2080	1930	2080	2080	2070
Asbestos Cement 7mm	$P_{0.4}$	2690	2690	2860	2140	2750	380(1 spec. failed in rep. loading)
	P_{max}	4650	4370	4540	4440	4400	4790
Steel Sheet 0.8mm	$P_{0.4}$	3280	4020	2960	not tested	3520	not tested
	P_{max}	6540	6660	6580		6400	

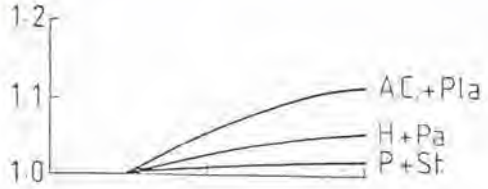

Fig.3a Relative slip V Loading sequence in Pattern (a)

Material	Abbreviation
Asbestos cement	A.C.
Hardboard	H
Particle board	Pa
Plasterboard	Pla.
Plywood	P
Steel sheet	St.

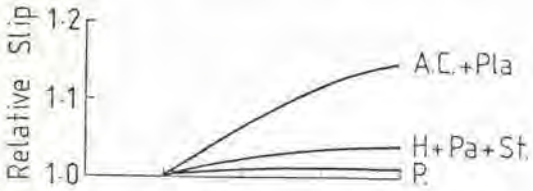

Fig. 3b Relative slip V Loading sequence in Pattern (b)

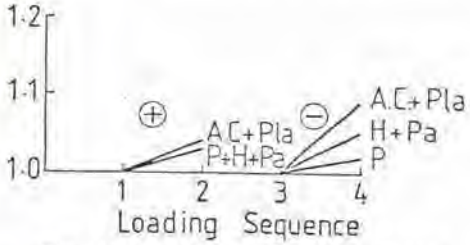

Fig. 3c Relative slip V Loading sequence in Pattern (c)
[+ Initial direction of loading]
[- Reverse direction]

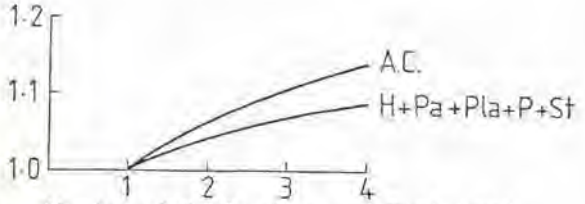

Fig.3d Relative slip V Loading (4 applications) in Pattern (d)

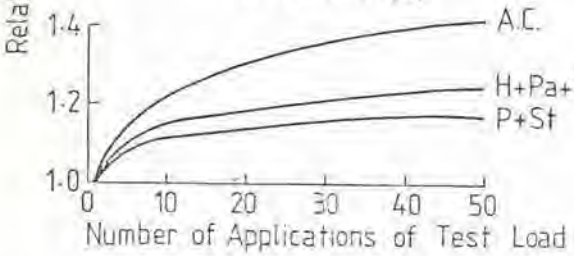

Fig. 3e Relative slip V Loading in Pattern (d)

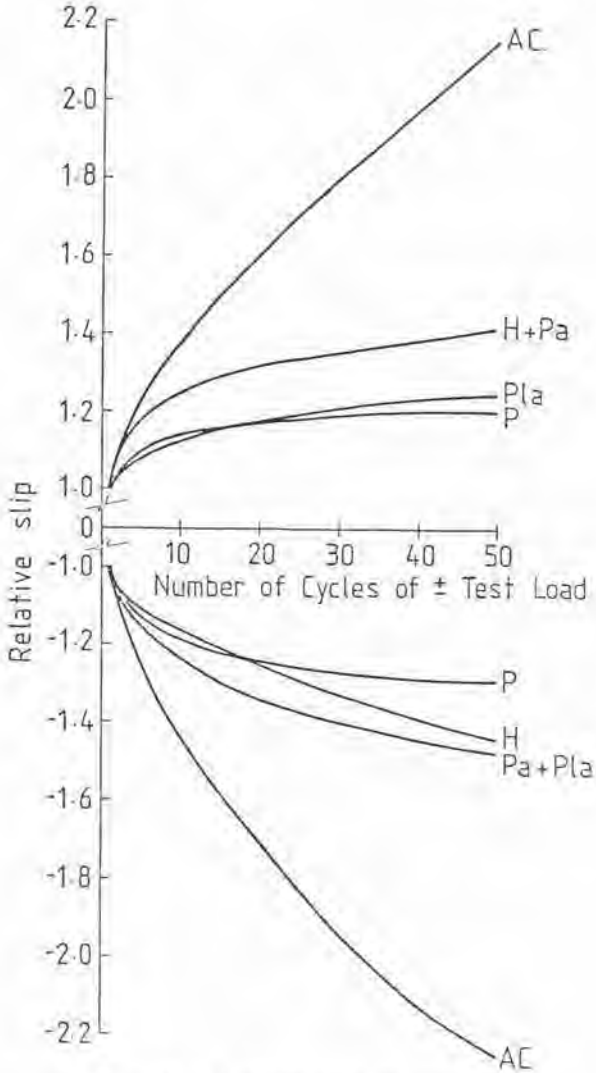

Fig. 3f Relative slip V Loading in Pattern (e)

Fig.3 SLIP OF NAILED CLADDING / TIMBER JOINTS UNDER VARIOUS PATTERNS OF LOADING

was found that specimens previously subjected to reversed loading exhibited no changes in static properties at values of slip above 0.4 mm. The maximum loads causing failure were similar in value in control specimens and in specimens previously subjected to repetitive loading.

The graphs in Figures 3a to 3d show that the slip in the joints continued to increase slightly during the successive sequences of repetitive loading adopted in these experiments. For joints fabricated from hardboard, particleboard, plywood and steel sheet the increases in slip were less than 10 per cent. For joints clad with asbestos cement and plasterboard, the increases in slip were between 10 and 15 per cent. During repetitive loading the order of the loading pattern, whether of increasing or decreasing configuration, did not affect the behaviour of the nailed joints nor did reversal of loading have any effect, at least after a limited number of applications. As shown in Fig. 3d, a slightly larger amount of joint slip was evident after four successive applications of test load (Pattern d, Fig. 2) than that arising during four complete sequences of complex repetitive loading patterns involving a similar number of applications of test load (Pattern (a) and (b) of Fig. 2). The differences in behaviour are probably due to stress relaxation phenomena in joints loaded over long periods. When joints were subjected to 50 applications of test load in a single direction (Pattern (d) of Fig. 2) the deformations continued to increase at gradually diminishing rates, but about 95 per cent of the total increases occurred in the first 20 applications of load.

It may be seen in Figure 3f that the slip in the joints subjected to 50 cycles of loading between ± test load (Pattern (e) of Fig. 2), with the exception of those clad with asbestos cement, continued to increase at a gradually diminishing rate to between 1.2 and 1.5 times the values measured under static loading. More than 90 per cent of the increase in slip occurred during the initial 20 cycles. The amplitude of the total joint slip reached during cycling between ± test load gradually approached a constant value. Although this loading pattern cannot be considered to be representative of the effect of wind loading on wall cladding, it was included in these experiments because of its importance in basic studies of joint behaviour and because of its possible application in other forms of practical loading.

The slip in joints fabricated from asbestos cement continued to rise sharply during cyclic loading with no indication of a reduction in the rate of increase after 20 cycles of loading. The load values at 0.4 mm slip, determined in static loading tests, were high and further cyclic tests at lower load values should be made to determine the practical usefulness of this material under cyclic loading.

5. CONCLUSIONS

Cladding of plywood, particleboard, hardboard, asbestos cement, plasterboard and steel sheet, nailed to timber framing in a specified manner, is satisfactory in resisting repetitive loading similar to that exerted on low-rise buildings by wind.

The order of the repetitive loading pattern, whether of increasing or decreasing magnitude, does not affect the load-slip characteristics of nailed joints. Similarly reversal of loading, at least in a limited number of applications, has no important effects on these characteristics.

The behaviour of nailed joints under repetitive loading appears to be determined by the highest load applied in the pattern and the number of applications of that load. Application of a similar number of loads at the highest value in a simple short term sequence produces a slightly enhanced effect on load-slip characteristics and would be the most convenient method for assessing the structural properties of building elements fabricated with nails.

6. REFERENCES

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STRAIN RECOVERY AFTER DRYING UNDER STRESS

P.U.A. Grossman

INTRODUCTION

Wood drying under stress develops a set. In other words, a residual deformation remains when the stress is lifted at the end of drying. Part of such a residual deformation can be removed by wetting and redrying; indeed, under some circumstances there remains virtually no residual deformation - the material has fully recovered its shape. Knowledge of the conditions that control the magnitude of recovery are of interest not only for understanding the mechanism of the interaction of stress and moisture changes but also in practice for ensuring a stable shape of distortion-prone wood after drying in weighted stacks.

A project which aimed at determining the influence of various treatments on the amount of possible recovery was undertaken by Dr. T. Arima, a guest worker from the Building Research Institute in Japan, who worked at the CSIRO Division of Building Research for one year in 1976-77. Full details of the study have been published elsewhere (1)(2) and this paper will only sum up the main aspects.

MATERIAL AND TEST PROCEDURE

The study was undertaken on two species, *Pinus radiata* D. Don and *Eucalyptus regnans* F. Muell. (mountain ash). The test specimens were beams 680 mm long and 15 x 15 mm in cross-section. Care was taken to obtain good matching of specimens whose response to different treatments was to be compared. Eight replications were carried out on each comparison.

While green, the beams were subjected to central bending and were kept in the bent state, each being clamped to another across a spacer. The reference ("standard") drying conditions were a temperature of 25°C and a relative humidity of 70 per cent for eleven days and of 50 per cent for five subsequent days. Other drying conditions as outlined below were imposed in various tests to compare their influence with that of the "standard". At the end of the drying period the beams were freed from all restraints and loads and their residual deflections were measured. The residual deflection was remeasured regularly

over a period of three months during which time the humidity was varied and before the end of which some of the beams were immersed in water.

INFLUENCE OF VARIOUS FACTORS ON RECOVERY

BEHAVIOUR OF THE MATERIAL AFTER "STANDARD" TREATMENT. At the end of the drying period at 25°C and 70 and 50 per cent relative humidity, removal of the clamps resulted in an immediate reduction in curvature, leaving an initial residual deflection of the beams of a little over half the deflection maintained during drying. How this residual deflection is gradually reduced under various successive humidity regimes is shown as a solid line in Fig. 1 which illustrates the response of radiata pine. It is seen that a little over 20 per cent of the initial residual deflection disappeared spontaneously over 14 days without any change in humidity, indicating a visco-elastic strain recovery. A rise in humidity to 80 per cent and the consequent moisture content increase caused substantial further recovery. After a rise to 90% r.h. there was only about ten per cent of the original residual deflection left and this was further reduced during another moisture cycle. Immersion in water then caused the beams virtually to straighten.

EFFECT OF SPECIES. Beams of *E. regnans* retained a somewhat higher residual deflection than those of *P. radiata*. Not only was the initial residual deflection a higher proportion of the deflection during clamping, but it reduced less throughout the whole period of recovery, leaving about 10 per cent of the initial residual deflection after immersion in water.

STRESS LEVEL. The highest stresses in the early stages of drying were about 40 per cent of the estimated modulus of rupture, i.e. they were of the order of design stresses. A comparison of the behaviour of beams stressed to that level with beams stressed to only about 27 per cent of the modulus of rupture indicated that the residual deflection immediately after stress removal and during all stages of recovery was proportional to the prior stress. This was corroborated by measuring the deflection at several points along the length of the beams and confirming that there was no disproportionately high curvature in the central most highly stressed section. It may be concluded that there is no threshold of stress that must be exceeded to produce a set. In view of the linear dependence it is justifiable to plot the recovery relative to the initial residual deflection as it is plotted on Fig. 1.

DELAYS IN MOISTURE INCREASE. Strain recovery depends on a "memory" of the original shape and it is conceivable that such a memory within the system might fade with time. The usual sequence of climatic changes imposed on the freed beams in these experiments allowed an initial two weeks of unchanged humidity. This initial period was omitted in some series of tests in which the humidity was raised to 80% immediately after unloading, thus allowing less time for the memory to fade. This had no influence on the total recoveries at respectively 80 and 90 per cent r.h. and after water immersion. While there was no observable loss of "memory" within two weeks, a waiting time of much larger order, say a year, may lead to noticeable effects. This has yet to be investigated.

TEMPERATURE. For one day during the drying the temperature was raised to 40°C for one set of beams, and to 50°C, 65°C and 80°C respectively for others. Such temperature increases were coupled with various controlled humidity changes and were introduced either at the beginning of drying or later during the drying process.

Some of the results are illustrated in Fig. 1. Higher drying temperatures resulted in less recovery after unloading, but such a blocking effect did not increase uniformly with the rise in temperature. While there was little influence of temperature up to 40°C and little difference between the effects of 65°C and 80°C during drying, the intermediate temperature range, 40 to 65°C, was shown to be critical. The influence of higher drying temperature was also shown to be more pronounced when the temperature rise occurred early in the drying process, as seen in Fig. 1.

CONCLUSIONS

The most important factor influencing the potential recovery of shape of wood that has been dried under stress is the temperature during drying. When this temperature exceeds 65°C early in the drying process, more than half the set is retained. Any proposed theory of mechano-sorptive deformation must take into account the role of the critical temperature around 50°C and the predominant importance of events in the early drying stages.

The results of this study should dispel apprehensions that exposure to moisture might cause distortion in wood that had been dried straight in a restrained condition. Since seasoning of wood in weighted stacks is normally done at raised temperature, the wood will essentially retain the straight shape in which it was held by the load during drying.

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PERFORMANCE CHARACTERISTICS OF SOME COMMERCIAL TRUSSES

R. H. Leicester and G. F. Reardon

ABSTRACT

This paper is a report of the measured performance characteristics of 18 commercial roof trusses, fabricated with toothed-plate connectors and subjected to sustained loads. Both stiffness and strength aspects were studied.

INTRODUCTION

Although satisfactory designs of timber trusses may be undertaken through the application of simple design procedures, it is not possible to make an assessment of their performance characteristics except in very rough terms, particularly with respect to their performance under sustained loads. This is because the performances of trusses are affected in a complex fashion by numerous parameters for which the available data is quite rough. Examples of these are parameters related to the slip characteristics of metal plate connectors subjected to biaxial loading and the creep buckling of structural timber. For this reason it was decided to measure directly the characteristics of commercial roof trusses of the types commonly used in domestic construction in Australia.

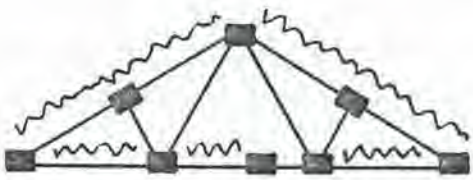
EXPERIMENTAL ASPECTS

A brief summary of some of the features of the trusses tested is given in Table 1. The designs of these trusses were based on the recommendations of the Timber Engineering Design Handbook (Pearson et al., 1962). All truss members were fabricated with initially green messmate (*Eucalyptus obliqua*) and joined by 14 and/or 18 gaugue toothed-plate connectors. The average moisture contents of the truss members at the start of the tests were in the range 20-50 per cent.

TABLE 1

DETAILS OF THE TEST TRUSSES

Truss Type	No. of Replic. ations	Pitch, degrees	Span, m	Design Details		
				roof type	dead load, kN	live load, kN
1	2	7	7.3	sheet	4.9	4.6
2	2	10	8.5	sheet	4.5	3.5
3	4	15	7.6	tile	7.8	2.3
4	4	18	7.3	tile	7.5	2.3
5	2	20	9.1	tile	9.4	2.4
6	4	26	9.1	sheet	6.1	4.7



■ toothed-plate connectors

range of member = 50 x 35 mm to 170 x 35 mm

Truss types 1, 4 and 6 by manufacturer 'A', truss types 2, 3 and 5 by manufacturer 'B'.

All trusses were placed under cover in a shed having two sides open to the weather, and a sustained load was then applied to each truss. The trusses were located in pairs for convenience of arranging a mutual restraint against buckling of the top chords.

For two trusses of each type the initial applied sustained load was equal to 1.75 the design dead load. This was reduced to the design dead load after 406 days. For all the remaining trusses the sustained load was kept constant at the design dead load.

The sustained loads were applied for roughly 5 years. The trusses were then unloaded, allowed to recover for 6 years, and finally loaded to failure in a laboratory.

TEST RESULTS

An example of the deflection characteristics of a truss under sustained load are shown in Fig. 1. This is stated in terms of the relative deflection Δ/Δ_o, where Δ and Δ_o denote the actual and initial deflections respectively. For all trusses, regardless of the time of the year at which the load was first applied, it was found that most of the creep took place within the first 400 days. Thereafter an annual cyclic movement was observed, but no measureable creep. Fig. 2 shows the deflection of a truss that deflected upwards, presumably due to large shrinkage effects of severe local cross grain in the top-chord.

Figs. 3-6 show the relationship between truss pitch and various deformation and strength characteristics of the commercially designed trusses. In addition it was also found that the stiffnesses on reloading were roughly 15 per cent less than the original values.

ASSESSMENT OF THE OBSERVED PERFORMANCE CHARACTERISTICS

A detailed assessment is outside the scope of this paper. In general terms it is seen that the characteristics of the shallower trusses are significantly poorer than those of the steeper trusses, both with respect to stiffness and strength.

The total deformations in all cases were quite small. Furthermore, the measured creep deformations are roughly the expected values if it is assumed that joint slip contributes roughly 25 per cent of the initial total vertical deflections (Reardon 1971). The measured strengths are in general adequate except that for the shallowest trusses the measured mean load factor on the design load is slightly less than the value of 3.3 that is desirable.

ACKNOWLEDGEMENTS

The truss program was initiated by R. G. Pearson, currently Associate Professor at the University of North Carolina, U.S.A.

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Reardon, G.F. (1971) - A Structural Analysis of Frames with Semi-Rigid Joints. Division of Forest Products Technological Paper No. 59, CSIRO, Australia.

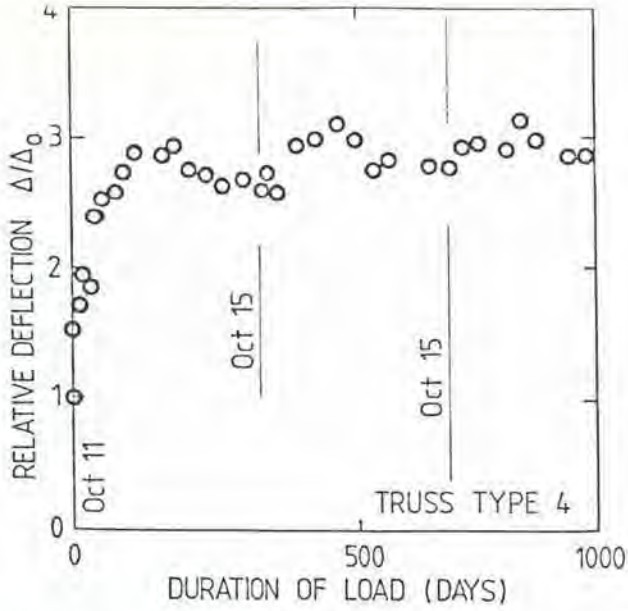

FIG. 1 EXAMPLE OF TRUSS DEFLECTION UNDER A CONSTANT SUSTAINED LOAD

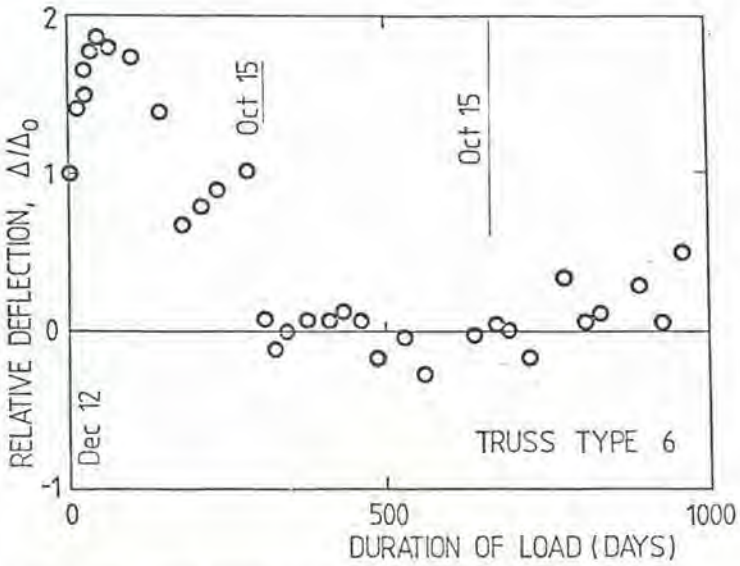

FIG. 2 UPWARD DEFLECTION OF AN ATYPICAL TRUSS UNDER A CONSTANT SUSTAINED LOAD

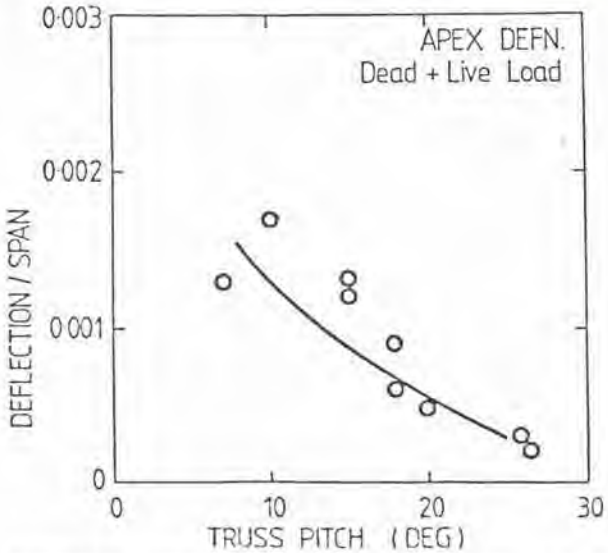

FIG. 3 INITIAL DEFLECTION OF TRUSS APEX AT THE TOTAL DESIGN LOAD

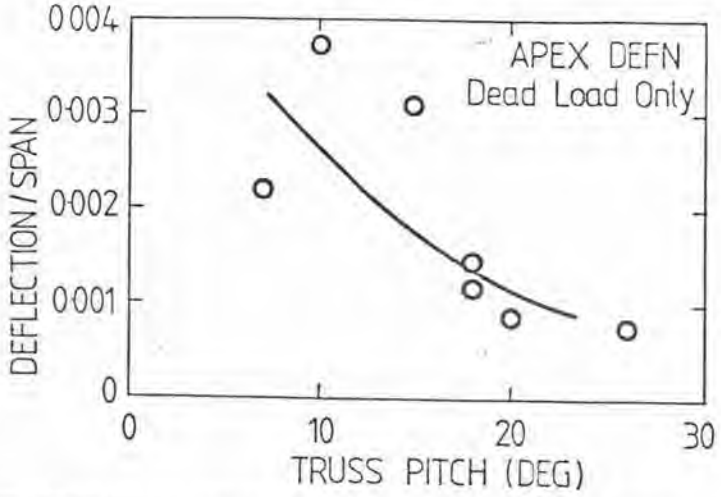

FIG. 4 DEFLECTION OF TRUSS APEX AFTER 400 DAYS UNDER DEAD LOAD ONLY

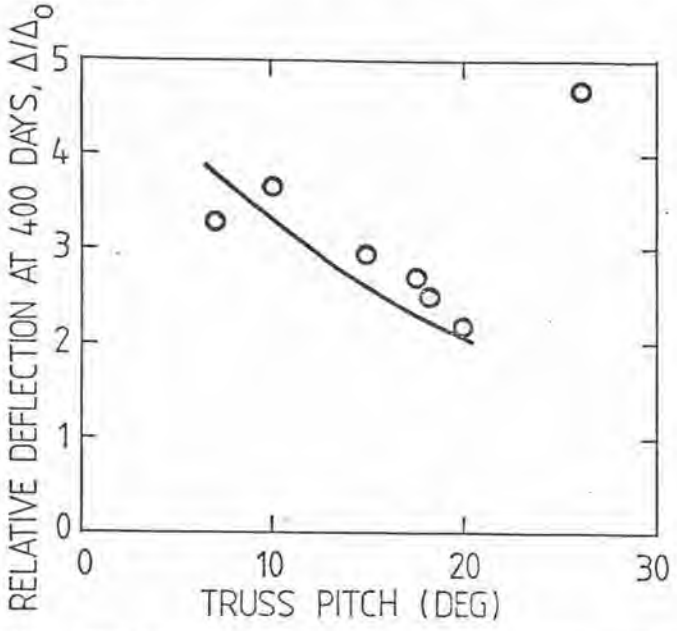

FIG. 5 RELATIVE DEFLECTION AT TRUSS CENTRE AFTER 400 DAYS UNDER SUSTAINED LOAD

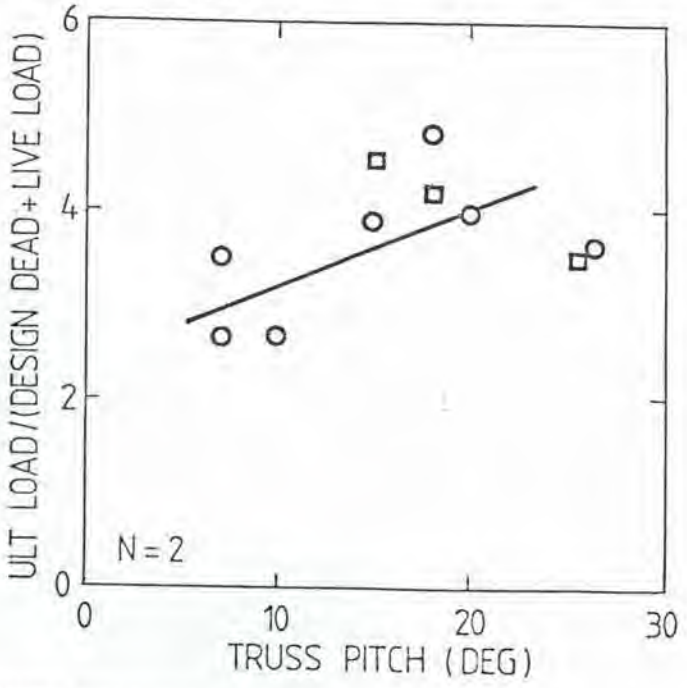

FIG. 6 ULTIMATE STRENGTH OF THE TRUSSES

EFFECT OF C.C.A. - PRESERVATIVE TREATMENT ON BENDING STRENGTH OF SMALL CLEAR SPECIMENS OF HIGH-TEMPERATURE-DRIED AND AIR-DRIED CARIBBEAN PINE

G.R. Siemon

ABSTRACT

Static bending tests (modulus of rupture and modulus of elasticity) of small clear specimens of copper-chrome-arsenic-treated and untreated Caribbean pine (Pinus caribaea Mor. var. hondurensis (Sénéclauze) B. et G.), both high-temperature-dried and air-dried, indicated that C.C.A. treatment resulted in a small though significant loss in strength and stiffness. As a secondary objective of the study, a comparison between the high-temperature-dried and air-dried material showed that high-temperature-drying resulted in a significant reduction in MOR in C.C.A.-treated, and a smaller, non-significant reduction in untreated specimens. The MOE was slightly higher for air-dried wood in both C.C.A.-treated and untreated specimens.

INTRODUCTION

Treatment of both sawn and round timber using copper-chrome-arsenic (C.C.A.) salts is a common commercial practice to increase service life by preventing or hindering attack by fungi or insects.

The effect of C.C.A. or other waterborne preservative treatments on strength properties can vary. Burmester and Becker (1963) concluded, after tests of 10 waterborne preservatives, that changes in bending and compression strength of red Baltic or Scots pine (Pinus sylvestris L.), Norway spruce (Picea abies (L.) Karst.) and beech (Fagus sylvatica L.), due to treatment were insignificant. Hesp and Watson (1964) reported a 4% reduction in bending strength after C.C.A.-treatment of red Baltic, which they considered unimportant in commercial practice. In contrast Holmgren (1958) found a 20% reduction in bending strength when red Baltic poles impregnated with BIS-salts were compared with untreated controls.

However, Burmester (1970) found treatment with copper-fluoro-arsenic (C.F.A.) salts resulted in a small percentage increase in compression strength. Because compression strength was increased, bending strength should also increase because it is a combination of compression and tension effects. Similar increases were reported by Shibamoto and Inove (1962) in a study of the effects of fluor-chrome-arsenate-phenol treatment on strength properties of suji (Cryptomeria japonica (L.f.) D. Don.).

The present study compared bending strength properties of small clear specimens of C.C.A.-treated and untreated Caribbean pine (P. caribaea Mor. var. hondurensis (Sénéclauze) B. et G.) grown in south-east Queensland. Separate samples were taker from both high-temperature-dried and air-dried material, and the effects of drying methods on bending strength were compared as a secondary objective of the study.

MATERIAL AND METHODS

The Caribbean pine came from a 21-year-old stand in Beerburrum State Forest, in south-east Queensland. The logs were sawn into 81 x 51 mm scantling at the Department of Forestry's experimental sawmill at Salisbury, Brisbane. The scantling was either high-temperature-dried using the conventional high temperature schedules of 120°C dry bulb temperature and 30°C wet bulb depression, or air-dried under shelter.

The specimens for this study were randomly selected, but selection was also based on ring orientation at both ends of a 750 mm defect-free length. Twenty-five high-temperature-dried and 25 air-dried pieces were cut along their length to give two side-matched samples of equal size.

One specimen from each matched pair was C.C.A.-treated commercially with a sawn timber charge to a nominal retention of 16 kg/m^3. All specimens were then strip-stacked in the laboratory for eight weeks. Immediately before testing, the specimens were dressed to 42 x 32 mm.

The static bending tests to determine modulus of rupture (MOR) and modulus of elasticity (MOE) were made on an "Amsler" Universal Testing Machine, using centre-point loading and a 14:1 span-depth ratio, with the rate of loading 2.0 mm/min.

After testing, a section was removed from each sample for moisture content (M.C.) determination using the oven-dried method. The strength values were adjusted to the standard 12% M.C. using 4% for each 1% difference in M.C., increasing the value if M.C. of the specimen was above 12%, and decreasing it if M.C. was below 12% (Mack 1979). The adjustment for MOE was 1½% for each 1% difference from 12% in M.C.%.

All relevant combinations between treatments were compared by using the relative paired or unpaired 't'-tests.

RESULTS

The mean values and coefficients of variation (C.V.%) for MOR and MOE are given below (Table 1).

TABLE 1

Mean Values and C.V.% for MOR and MOE (MPa)

		MOR		MOE	
Treatment*	No. Samples	Mean	C.V.%	Mean	C.V.%
C.C.A./HTD	25	71.9	18.4	8962	24.3
U/HTD	25	78.3	32.7	9515	28.4
C.C.A./AD	25	79.9	21.0	8853	29.0
U/AD	25	85.8	18.1	9275	26.2

* C.C.A. = preservative treated
U = untreated
HTD = high-temperature-dried
AD = air-dried

The difference between treatments, expressed as percentage of the means, and the results of the t-tests are shown in Table 2.

TABLE 2

Variations in MOR and MOE due to Treatment

Treatment Comparisons	Differences expressed as per cent of second term	
	MOR	MOE
C.C.A. vs U (HTD)	- 8.2 *	- 5.8 *
C.C.A. vs U (AD)	- 6.9 **	- 4.5 *
HTD vs AD (C.C.A.)	-10.0 *	+ 1.2 NS
HTD vs AD (U)	- 8.7 NS	+ 2.6 NS

where NS = non significant at the 5% probability level
* = significant at 5% level
** = significant at 1% level

DISCUSSION

The comparisons between C.C.A.-treated and untreated samples were based on side-matched pairs of specimens. These may provide more accurate results than comparisons using random samples, which was the situation with high-temperature-dried vs air-dried material.

The results indicated that C.C.A.-treatment resulted in a small but significant loss in MOR and MOE in both high-temperature-dried and air-dried material. Although the large coefficients of variation showed considerable differences between specimens of the sample tested (Table 1), the t-tests indicated a significant difference at the 5% probability level, and in fact MOR of air-dried material had a significant difference at the 1% level (Table 2).

Some variation in strength properties could be accounted for by the method used in this study, where high-temperature-dried specimens were C.C.A.-treated, then air-dried. In commercial practice any high-temperature drying would generally be after preservative treatment. Mechanical stress grading of matched C.C.A.-treated and untreated structural-sized pieces of slash pine, which were then high-temperature-dried before testing, has indicated a 14% reduction in strength (R.L. Hyne, unpublished report). This percentage reduction was based on the comparative distributions of stress grades in the C.C.A.-treated group and the untreated group.

The data from the present study showed 7% reduction in MOR of air-dried pine which was C.C.A.-treated, more than the 4% reported by Hesp and Watson (1964), but less than the 20% reported by Holmgren (1958). The BIS-salt-impregnated red Baltic poles in Holmgren's study were above fibre saturation point when tested, but no moisture content figures were given for the untreated controls. If these untreated poles were below fibre saturation point when tested, they would have an advantage in strength as seasoned timber is stronger than unseasoned.

Hesp and Watson (1964) concluded that the small reduction in bending strength they found resulted from the pressure treatment procedure with the aqueous solution, rather than from any inherent chemical or physical property of the preservative salts themselves. Burmester and Becker (1963) had previously suggested this theory.

The differences between high-temperature-dried and air-dried samples (Table 2) were partially due to the random selection methods used. The decreases in MOR of 10% for C.C.A.-treated and 8.7% for untreated reported here were larger than the 3% reduction found for high-temperature-dried slash pine (P. elliottii Engelm. var. elliottii) by Christensen and Gough (1975). The decrease in the untreated material was not significant. The small MOE increases in this study (1.2% for C.C.A.-treated, and 2.6% for untreated material) were similar to their results. Neither figure has statistical significance.

In summary, results of the present study on Caribbean pine indicated that C.C.A. preservative treatment reduces bending strength properties, the actual amount depending on the method of drying. Some allowance could perhaps be made for this reduction in bending strength when engineering design methods are used.

ACKNOWLEDGEMENTS

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BANDAGES AS GROUND-LINE MAINTENANCE TREATMENTS FOR POLES

H. Greaves

ABSTRACT

The problem of soft rot attack in the treated sapwood of hardwood poles is causing concern to the preservation industry in many countries around the world. There is a real demand for an effective *in situ* ground line maintenance treatment for poles in service in Australia, S.E. Asia, S. America, S. Africa and some other African countries. In Australia present practices include surface application of preservative (SAP), dressing the pole plus SAP (DSAP), sterilisation *in situ* (SIS), butt encapsulation techniques (BET), and preservative containing bandages (PCBs). By far the best of these systems for preventing further progress of soft rot in standing poles is the application of PCBs. This technique combines the aims and principles of all the other methods, but unlike them it is effective. CSIRO's bandages are discussed and the advantages of the present Mark IV version presented.

INTRODUCTION

It is probable that the preservation industry is currently facing one of its' biggest problems. In many countries preservative-treated hardwoods are being attacked in ground contact by soft rotting microfungi; in severe cases service lives have been reduced by as much as 75%. The worst examples have usually been observed in salt-treated poles, eg copper-chrome-arsenic (CCA) treated spotted gum in Queensland. However service records as well as field test data suggest that oil-borne treatments, such as creosote and pentachlorophenol, are also susceptible to soft rot.

In Australia, the problem appears to be greatest in tropical areas, i.e. Queensland. On the other hand, soft rot has been recorded in New South Wales, parts of Victoria, and in Hydro Electric Commission poles in Tasmania. We have also received reports of attack in treated poles in South America (Columbia, Ecuador, Brazil and Argentina), South Africa, Ghana, Nigeria, Bangladesh, Phillipines, Indonesia and Papua New Guinea. Even softwood poles in

northern Europe are not immune; about 4 million Zn-Cr-As treated Scots pine poles in the Swedish electricity transmission and telecommunications grid have been found to be affected (1). In contrast to the Australian problem however, the Swedish poles had an average service life of about 30 years - the more severe cases in Queensland have failed in less than 10 years.

There have been a number of reasons put forward for the inadequacy of the preservative treatment. Basically however there are two main schools of thought: the first suggests that preservatives are not penetrating into the critical layer of wood cell walls (microdistribution theory - 2, 3, 4, 5); while the second considers that salt treatments are not being used at high enough concentrations due to inherent susceptibility differences in different hardwoods (6,7). At the Division of Building Research we are developing preservative formulations which will deliver adequate levels of fungitoxicants to strategic parts of the wood structure. It is hoped that this research will lead to preservative systems for initial treatments capable of providing protection for new hardwood (and softwood) poles. In the meantime an effective *in situ* ground-line maintenance treatment must be provided to combat further soft rot in the world's standing pole populations.

GROUND-LINE MAINTENANCE TREATMENTS

There is a wide range of treatments being employed on poles in service which are intended to reinforce the critical ground-line zone against deterioration. In Europe and North America a number of commercial operations, e.g. Osmose, offer pole users a proven protection against decay and insect attack, servicing the poles on a contracted basis. These overseas concerns all utilise preservative bandage systems of one type or another.

In Australia there are basically 5 types of ground line maintenance treatments being used:-

(i) Surface Application of Preservatives (SAP). These systems involve spraying, brushing or pouring a preservative usually creosote, over a zone of the pole extending from about 600 mm above the ground to about 600 mm below ground. In Queensland SAP has been refined to the extent that a black dye is added to the creosote and the zone of application extends to almost 1.5 m above the ground - the only reason for this is that an inspector can tell at a glance whether the poles in his area have been visited by his field crews. The soft rot fungi are less easy to impress! SAP systems offer only minor benefits, the main one being that a measure of water repellancy may be confered

on the treated zone for a short time. Some preservatives even diffuse slightly, but for the most part it is impossible to apply adequate levels of anti-soft rot preservative, which will reach toxic proportions necessary to kill the soft rot at depth in the infected sapwood.

(ii) Dressing + SAP (DSAP). The only difference between DSAP and SAP is that the visible soft rotted wood is removed from the pole before preservatives are applied. The invisible soft rot, i.e. the microscopic pockets of decay which typically occur in our eucalypt poles many mm in advance of the main macroscopic zone of attack, are not affected by DSAP techniques. Methods of removing the visible soft rot include dressing with axes, and oxycharing with various types of burners. DSAP systems usually include puddling preservative with the backfill, and for a while this can reduce the soft rotting microflora. However the fungi will return as the population adapts, and in any case they are already in the pole behind the dressed or charred zones.

(iii) Sterilisation *in situ* (SIS). These techniques are applied to excavated poles in service and are intended to sterilise the zone of soft rotted wood. SIS can be achieved by either chemical or physical means. Chemical methods include the application of fumigants to the pole, and have had some measure of success in softwood poles in USA (8). However, with eucalypt poles the characteristic internal and external checks will allow the chemical fumigants to dissipate too rapidly. Physical SIS has been attempted by either steaming or irradiating the poles. Apart from the obvious handling problems with both chemical and physical SIS techniques, their effects on poles are transient; fungi (and insects) will return to the sterilised wood from the soil, the air, or parts of the pole not reached with the techniques, and will again commence to attack the wood.

(iv) Butt Encapsulation Technique (BET). The aim of this method of ground-line maintenance is to present a physical barrier to soft rot and other fungi so that they are unable to colonise and attack the wood. The best BET is probably with a new pole rather than one already in the ground, since, in theory at least, there are no fungi already in the wood and those that are may have been killed by the initial vacuum-pressure impregnation of the pole. Unfortunately higher fungi (basidiomycete centre rots) can survive the initial treatment, and when the pole butt is encapsulated both fungus and pole moisture can be locked in together. Where BET is applied to standing poles already in service the encapsulating medium, e.g. polyethylene wrap,

polyurethane foam, bitumastic coating, etc., not only locks in fungus and existing water but can lead to even worse sapwood attack. This has been demonstrated in the Wedding Bells State Forest stub trial (9), and in our own Highett stub trial.

(v) Preservative-Containing Bandages (PCBs). These represent the most effective means of applying preservative to the surface of a pole *in situ*. They usually consist of an absorbent inner matrix containing a diffusion fungicide which is married to an outer weather-proof backing (see Figure 1).

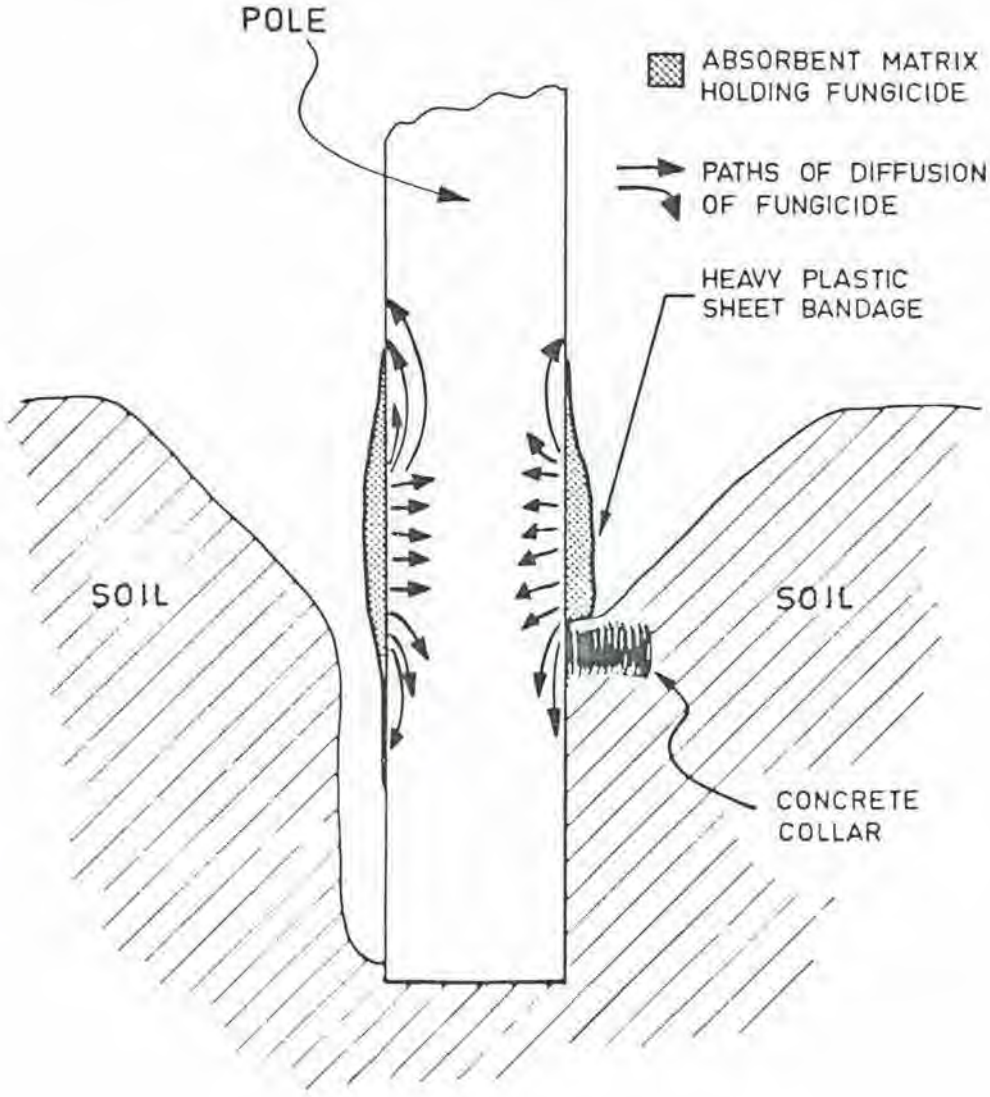

Fig. 1. Schematic representation of a typical PCB

The fungicide or preservative is sufficiently concentrated that it can diffuse from the inert carrying matrix through full sapwood depths and maintain toxic levels sufficient to sterilise the invading fungi. PCBs are applied to the critical zone of excavated poles (- they can also be applied to this zone on new poles before the pole is put into service -) which is approximately 100 mm above ground to 600 mm below ground. The important feature of applying PCBs is to ensure that the upper and lower edges are effectively sealed against rain and ground-water. Ideally the outer backing should provide the means of achieving this while confering robustness and durability to the bandage. PCBs combine the principles and aims of the other types of ground-line maintenance treatments, but unlike SAP, DSAP, SIS and BET they have the potential to prove effective. Table 1 lists a number of types of PCBs which are under study in this country.

THE CSIRO BANDAGE

This bandage has been developed as a result of an intensive laboratory screening programme in which a wide range of chemicals were tested for their efficacy in controlling soft rot, (10, 11, 12, 13), and a number of different bandage formats were assayed for suitable field performance. The bandage is now in trial under service conditions in Queensland, Tasmania, and Papua New Guinea. It consists of a compartmentalised polyurethane foam (14) which is impregnated with a multisalt copper fluoroborate solution, or Busan 30 (2-(thiocyanomethlthio benzothiazole)) or Permapruf T (a quaternary ammonium compound combined with tri-butyl tin oxide), or pentachlorophenol in hexylene glycol. These chemicals were the most effective of some 60 or more which were screened. In the current, Mark IV, CSIRO bandage the compartmentalised foam is backed by a bitumen lined heavy duty cross-linked polyethylene (XLPE)*. Earlier versions of our bandage were backed by 200 µm thick polyethylene sheeting which proved to be much less durable and rather prone to mechanical damage. The Mark III edition is currently under test on spotted gum pole stubs at Highett and relies on upper and lower edge seals of reinforced tape coated with bitumastic sealer (Figure 2).

* Manufactured by Raychem Pty. Ltd., N.S.W. Australia.

Fig. 2. CSIRO's Mark III PCB showing tape and bitumastic seal for upper and lower edges.

Mark IV bandages, in addition to the service tests already mentioned, are in stub trials at Wedding Bells State Forest, N.S.W., and Warrane field site, near Hobart Tasmania. These bandages are heat shrunk onto the pole *in situ* and a most effective weatherproof seal is thus formed; the heated bitumen lining the XLPE flows into checks and the shrinking polyethylene forces it to exude from the upper and lower edges. When cold the bitumen is still pliable enough to move with the pole's responses to the weather. The Mark IV bandage conforms well with uneven pole surfaces, is durable, can resist rough handling in the field, and does not look unsightly after it has been applied. Figure 3 shows the CSIRO bandage being applied and conveys some idea of the shrinkage and good fit achieved with this Mark IV version.

Fig. 3. CSIRO's Mark IV PCB showing heat shrinkage during application.

The early data from our various bandage trials suggests that fungitoxic chemicals are diffusing into soft rotted sapwood and that the Mark IV bandage should afford adequate protection against further progress of the soft rot. On present costs this bandage will vary between $15 - $20 depending on the chemical selected, and can be applied, after excavation of the pole, in about 20 minutes. The condition of sapwood beneath the bandage may be checked at intervals by removing small sections of the whole bandage with a wad-punch. Coring from beneath the 'inspection' hole' is optional. The section of bandage can then be replaced neatly in the hole and sealed in with tape and bitumen.

It is anticipated that the Mark IV bandage will last in excess of 5 years in service, and we are therefore developing techniques for replenishing the chemicals, should this be required, while leaving the bandage on the pole.

Bandages represent the best ground-line maintenance treatment currently offered. Unfortunately it has so far been difficult to convince the Australian pole-using utilities that this is so. However there are sufficient types and numbers under trial, both in service and on stubs, that within the next 3 to 5 years adequate data for the decision-making engineers should be available. On the other hand there will be at least a further quarter of a million treated eucalypt poles in service by then. Can we afford to wait this long and what will be used for ground-line maintenance in the meantime?

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Table 1 Commercial and experimental PCBs under trial in various parts of Australia

NAME	PRODUCER/DISTRIBUTOR	PRESERVATIVE INGREDIENTS	TYPE OF OUTER COVER
Cellavit	Cellavit Pty. Ltd.	1. PCP 2. Cu,F,B.	Laminated aluminised cotton skrim.
Creosote gel	Protectex Chemicals Pty. Ltd.	Creosote	Polyethylene, or XLPE
CSIRO	Raychem Pty. Ltd. - XLPE outer cover Joubert & Joubert - inner foam matrix	1. Cu,F,B. 2. Busan 30 3. Permapruf T 4. PCP	))) Heavy duty XLPE)
Govic Guy	Formerly agents, in Queensland, for Cellavit No. 1 bandage		
H-D Cream	Koppers Aust. Pty. Ltd.	PCP, Heptachlor	Polyethylene
Osmoplastic	Osmose Wood Preserving Co. of America, Inc.	F, PCP, Creosote, Cr. Dinitrophenol	"Osmoshield" - polyethylene backed by Kraft paper.
Patox	Cellavit Pty. Ltd.	1. Cu,F,B. 2. PCP, Creosote, F, Cr.	) Glass-fibre reinforced) polyvinyl chloride.
Pole-Nu	Chapman Chemical Co. (U.S.A.)	1. PCP, Creosote, chlorinated phenols 2. PCP, Creosote, F	)) Kraft paper)
Valchem Shield	Valchem (Aust.) Pty. Ltd.	Cu,F,B	Polyethylene
Wolmanit T.S.	Dr. Wolman GMBH (W. Germany) or BASF Aust. Ltd.	F, Dinitrophenol, Cr	Polyvinyl chloride.
Wolmanol B " CB " BF " CFB	Koppers Aust. Pty. Ltd. " " " " " "	F, Dinitrophenol, Cr Cu,B,Cr F,B, Dinitrophenol, Cr Cu,F,B	)) Early versions bitumenised) felt. Now heavy duty) polyvinyl chloride.

DISTRIBUTION OF SOFT ROT IN POLES IN N.S.W.

R. S. Johnstone, J. Hunter and P. Lind

ABSTRACT

An examination of the factors that promote soft rot attack and its distribution in timber poles is in progress in New South Wales. The work so far indicates that a number of parameters are associated with soft rot degrade including preservative type, soil type and moisture, terrain, geographical location, and the use of groundline treatments.

INTRODUCTION

A group to study the incidence and distribution of soft rot in preservative-treated hardwood poles in New South Wales was formed in October, 1975.

The principal objective of the group (N.S.W. Soft Rot Study Panel (1)) was to examine a representative selection of standing poles in this State and to relate the incidence of soft rot to as many factors as possible.

The method of operation was to utilise a full-time survey officer to systematically examine deterioration in treated poles due to these micro-organisms by a detailed inspection of randomly selected poles followed by chemical analysis of the preservative retention in the wood and microscopic examination for soft rot penetration and intensity.

It was anticipated that the study would take about three years and would include tests for association of as many parameters as possible that may influence soft rot and its spread of attack.

EXPERIMENTAL PROCEDURE

The sampling and testing procedures (Appendix) were designed to show the relationship of the following factors to the progress of soft rot attack:

(1) Type of preservative
(2) Preservative retention
(3) Timber species
(4) Soil type
(5) Soil condition
(6) Orientation
(7) Terrain

(8) Climatic conditions
(9) Type of remedial treatment
(10) Individual preservation plants
(11) Geographical location

RESULTS AND DISCUSSION

Up to June 1979 approximately 75% of the survey had been completed and a number of factors contributing to soft rot attack are apparent.

Many of these associations have been previously known or are predictable but there is little documented evidence of a systematic survey on this scale involving eucalypt poles.

Preservative and groundline treatments

Creosote proves significantly more satisfactory than copper chrome arsenic salt in resisting soft rot attack. There is no difference between high and low levels of creosote retention but high loadings of C.C.A. salt (16 kg per m^3 or greater) perform better than retentions of C.C.A. salt below this level.

This indicates that either the nominal commercial loading of creosote has a high safety margin or that the physical characteristics of creosote have a greater restraining influence on soft rot than C.C.A. salt.

Poles that had been maintained by existing groundline techniques (usually creosote) are significantly better than poles that had been given no remedial treatments.

Timber species

No clear-cut difference is evident between species in their sapwood resistance to soft rot although a trend may be apparent on completion of the survey.

Soil type and condition

Clay soils in the immediate area surrounding the pole are considerably worse than other soil types, with sand the least conducive to soft rot. No attempt has yet been made to physically or chemically analyse soil samples taken in the vicinity of each pole.

Soils classified as moist at the time of sampling are significantly worse from the viewpoint of soft rot than dry, wet, or waterlogged soils. Apparently an optimum blend of moisture and aeration are necessary to facilitate soft rot development.

Where poles are adjacent to cultivated areas the incidence of soft rot is significantly higher than in uncultivated situations and soft rot attack is

more pronounced in flat country than where the terrain is sloping.

Orientation

Timber samples are being taken at alternate cardinal compass points below groundline around the perimeter of the poles throughout the survey and results show no difference in soft rot attack between each of these four positions.

Climatic conditions

Temperature, humidity, rainfall and the number of raindays per year are not significantly related to soft rot attack.

Electricity distribution areas

A highly significant difference is evident between the electricity distribution areas. The worst areas for soft rot are the regions within 100 km of Sydney, possibly because of urban influences, and the far north coast of N.S.W.

Preservation plants

Of peripheral interest in regard to soft rot is that one particular treater in N.S.W. has produced a large proportion of poles below the required minimum preservative retention.

CONCLUSION

Soft rot presents a varying problem in treated transmission poles in N.S.W. with distinct differences between areas.

Factors contributing to soft rot attack that can be regulated are the type of preservative, adjustments to the level of C.C.A. salt in the pole, and the use of groundline maintenance treatments.

Secondary or uncontrollable parameters are terrain, soil type, and soil moisture content.

Species, orientation, and climatic conditions appear to have little or no effect on the incidence and intensity of soft rot attack in the areas surveyed in N.S.W.

(1) N.S.W. Soft Rot Panel members and their affiliations are:-

R. S. Johnstone - Forestry Commission of N.S.W.
R. Humphry - Energy Authority of N.S.W.
J. D. Price - Koppers Australia Pty. Ltd.
J. Massey - Allen Taylor & Co. Pty. Ltd.
W. Seaman - Telecom Australia (Headquarters)
M. Cray - Electricity Commission of N.S.W.
H. Atkinson - Prospect County Council.

APPENDIX

TEST PROCEDURE

SELECTION OF ELECTRICITY DISTRIBUTION AREAS These areas have been selected at random to include at least half of the Electricity Distribution areas in N.S.W.

SELECTION OF SAMPLING POSITIONS IN DISTRIBUTION AREA These positions have also been selected at random. If there are no pressure preservative-treated poles in that particular position, samples will be taken from pressure preservative-treated poles nearest to that position.

SELECTION OF POLES FROM SAMPLING POSITION Nine (9) pressure preservative-treated poles plus one (1) untreated natural durable pole selected from each sampling position. If possible the poles should be in sequence (i.e. along a road) with the starting point as close as possible to the sampling position selected. The poles selected are dug out to a depth of approximately 0.5 metre around the perimeter of the pole and back about the same distance to ensure a satisfactory inspection prior to sampling.

SAMPLING (SURVEY OFFICER)

(1) Pick test with knife to determine visual depth of degrade (if any).
(2) Drill and remove two plugs for analysis (chemical and microscopic) in sequential orientation and in close proximity to each other.
(3) Plug holes with treated dowel.
(4) Take soil sample.
(5) Disc details recorded.
(6) Soft Rot Survey label attached to pole.

CHEMICAL ANALYSIS One plug sample from each pole is analysed for preservative retention. For C.C.A. treated poles this is by A.A. Spectroscopy while in creosote treated poles a toluene extraction process is used.

MICROSCOPIC ANALYSIS One plug sample from each pole is examined for penetration and intensity of soft rot degrade. Microscopic slides are made beginning 2.5 mm from outside edge of plug sample and every 5 mm to a depth of 17.5 mm.

Four cross-sections are cut at each interval, and at least four fields of vision are observed from each cross-section.

If soft rot degrade is present in all four fields of vision in the four cross-sections examined at that interval, a "severe" condition is recorded. If soft rot degrade is present in only some of the fields of vision in any of the four cross-sections of the interval examined then a "light" condition is recorded.

EVALUATION OF GROUNDLINE MAINTENANCE ALTERNATIVES AGAINST FUNGAL DEGRADE - WEDDING BELLS POLE TEST SITE

R. S. Johnstone, W. D. Gardner, and W. Pitt

ABSTRACT

The pole test at Wedding Bells State Forest, near Coffs Harbour was installed in August, 1976, as a long-term project designed to assess the effectiveness of different preservatives and groundline treatments against soft rot and termite attack. The first inspection in December, 1978, indicated that some measure of protection was being given by existing groundline treatments, that bandage and encapsulating treatments may have some shortcomings, and that concrete surrounding a pole can facilitate decay.

INTRODUCTION

Techniques to control soft rot in preservative-treated hardwood poles were proposed at the 1977 Forest Products Research Conference (1) and the installation of a pole test at Wedding Bells State Forest near Coffs Harbour was described (2).

An elapsed time of two years since the installation of the Wedding Bells pole test could be insufficient for soft rot to be visually evident although soft rot may be present in association with wood decay.

It would be expected that wood decay fungi (basidiomycetes) would destroy the sapwood of poles if there were no impregnation by wood preservatives. Generally timber adequately treated with either copper chrome arsenic salt, creosote, or pentachlorophenol in oil would resist degrade by these fungi.

The comparison between groundline treatments and their relationship to sapwood degrade in this report is based on visible evidence of wood decay (predominantly white rots). Soft rot in timber has a different operational mechanism than decay but for the purposes of comparison of groundline treatments a barrier that would prevent the initiation of wood decay would tend to inhibit the development of soft rot.

It should be valid to look at these groundline treatments as indicators of their effectiveness against soft rot in pressure impregnated poles with a cautionary note that there may well be some change in the order of preference when the second inspection takes place in two years' time.

The system of installation and the types of pole and groundline treatments are shown in the Appendix.

INSPECTION PROCEDURE

A visual inspection was carried out to a depth of 0.5 metre of a quadrant of each spotted gum pole with untreated sapwood (see Appendix - Code number 2) at the site. In addition each pole of all treatment types in one compartment (Compartment 3) was inspected to the same depth around the full perimeter of the pole.

A quantitative assessment was made of the depth of penetration of decay into the sapwood of the timber and the groundline treatments graded on these estimates. Any degrade in untreated desapped durables (Code number 6) in Compartment 3 was noted.

RESULTS

The only poles in Compartment 3 to show sapwood degrade were poles with untreated spotted gum sapwood. The untreated desapped durable with a concrete collar (Code number 6A) in Compartment 3 showed significant heartwood degrade. All other poles in this Compartment gave no visual indication of fungal attack.

Effectiveness of groundline treatments based on this inspection are as follows:-

most effective:	Blue 7(B), C.C.A. gel (D), H.T. creosote (F), 5% P.C.P. in oil (J), Pole-nu (K), H.D. cream (L).
	H.T. creosote + aldrin (G)
	Tar enamel (C)
	Polyurethane (E), Polythene encapsulation (M), Basilit BFB (N), Polyurethane + additives (P)
least effective:	Concrete collar (A), Control (H), Ammonium sulphate (Q)

Note: Treatments on the same line are equally effective at this stage with a gradient from the most to the least effective.

DISCUSSION

The results give important predictions as to the likely performance of groundline treatments.

Spotted gum sapwood (untreated)

The worst degrade was apparent in the case of the control, the concrete collar, and the ammonium sulphate application.

No difference was evident between these poles and in all three cases the

sapwood was almost entirely degraded at the sampling point. A longer period of exposure will be necessary to differentiate between each of these treatments.

Encapsulation with either polythene sheeting or polyurethane (with or without the addition of toxicants) was almost as unsatisfactory. One of the bandage treatments was equally unsatisfactory. The poor performance of this bandage system was apparently due to incomplete physical contact of the toxicant with the timber under the impermeable barrier.

Slightly more effective was the tar enamel. Any value that the tar enamel may have had as a fungicide could have been reduced by the material acting as a moisture trap.

Six treatments gave the spotted gum sapwood complete protection from observable degrade over this limited period of two years.

These were H.T. creosote, "Blue 7", C.C.A. gel, 5% P.C.P. in oil, "Pole-nu", and H.D. cream.

Apparently by flooding the base of the pole and the surrounding soil with a liquid such as H.T. creosote or 5% P.C.P. in oil a measure of protection can be obtained provided that the integrity of the protective envelope is undisturbed.

Under similar conditions, a heavy brush coating on the timber of either a C.C.A. gel or H.D. cream can give protection for a two-year period.

Two bandages - one a heavy paste of organic toxicants and the other a mixture of diffusable inorganic salts - produced equally satisfactory results indicating that the combination of a suitable toxicant in association with a bandage application can be successful.

Desapped durable species

The desapped durable with the concrete surround in Compartment 3 showed severe fungal degrade in the heartwood. The control sample with just a soil back-fill was not significantly decayed. The difference between these poles may be further accentuated after a longer period of time.

CONCLUSIONS

(1) Some protection of poles is given by an envelope of a fungicide such as creosote or 5% P.C.P. in oil.

(2) A pole encapsulated in an impermeable material without a fungicide gives negligible protection against decay.

(3) Where a bandage treatment is used in order to protect a pole, the fungicide must not only be effective, but must completely cover the zone underneath the bandage.

(4) Concrete around the base of a desapped durable pole will probably increase the decay risk in the heartwood.

ACKNOWLEDGEMENTS

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APPENDIX

Poles nominally 3 metres in length were installed to a depth of 1 metre in 8 compartments of 100 poles per compartment, 2 metres apart with 3 metres between each row.

A total of 80 poles of each species/impregnation type were used to give 8 replicates of each groundline treatment and controls.

Groundline treatments were applied after installation, and inspections and further treatments will be undertaken at 2 yearly intervals.

The zone at which remedial treatments were applied was approximately 0.4 m below the groundline to 0.1 m above.

	CODE	DESIGNATION	DESCRIPTION
POLES	1	Pentachlorophenol	*E. maculata* - pentachlorophenol treated sapwood.
	2	Untreated	*E. maculata*.
	3	CCA (Tan C)	*Pinus radiata* - copper chrome arsenic salt treated sapwood.
	4	CCA (Tan C)	*E. maculata* - copper chrome arsenic salt treated sapwood.
	5	Creosote	*E. maculata* - creosote treated sapwood.
	6	Untreated	De-sapped highly durable species.
TREATMENTS			
	A	Concrete collar	Concrete poured in situ around the pole to a depth of 0.5 m.
	B	Blue 7	A concentrate of fluorine, boron & copper salts encased in a bandage.

CODE	DESIGNATION	DESCRIPTION
C	Tar enamel	A coal tar derivative produced by Koppers Australia Ltd.
D	CCA gel	A gelatinous copper chrome arsenic paste covered with polythene sheeting.
E	Polyurethane foam	Polyurethane encasing the pole at the groundline for 0.5 m.
F	H.T. Creosote	High temperature creosote conforming to AS 1143-1973.
G	H.T. Creosote + 0.5% aldrin	As above plus 0.5% aldrin.
H	Control	Untreated.
J	5% P.C.P. in oil	5% pentachlorophenol in oil & 0.5% aldrin.
K	Pole-nu	A gelatinous paste of creosote, pentachlorophenol & sodium fluoride in a bandage.
L	H. D. cream	A paste containing 5% pentachlorophenol & 1% heptachlor.
M	Polythene encapsulation	Polythene sheeting encasing the pole at the groundline for 0.5 m.
N	Basilit BFB	A concentrate of fluorine, boron & copper salts encased in a bandage.
P	Polyurethane foam + additives	Polyurethane plus 5% pentachlorophenol + 0.5% aldrin encasing the pole at the groundline for 0.5 m.
Q	Ammonium sulphate	0.5 kg per pole applied at ground level to induce soft rot.
ADDITIONAL POLES		
7	CCA (Celcure A)	*E. maculata* - copper chrome arsenic treated sapwood.
8	Creosote	*P. radiata* - creosote treated sapwood.
9	Pentachlorophenol	*P. radiata* - pentachlorophenol treated sapwood.
10	Creosote	De-sapped *E. maculata* - creosote boultonised heartwood.

EVALUATION OF THE PULSED-CURRENT RESISTANCE METER (SHIGOMETER®) FOR DETERMINATION OF THE INTERNAL CONDITION OF UTILITY POLES.

J.D. Thornton, W.G. Seaman and M. McKiterick

ABSTRACT

A number of Telecom poles, which had been removed from service to be replaced by a radio link, were inspected using an electrical resistance meter (Shigometer®). These poles were creosoted, non-durable Victorian species in service in New South Wales. Six of these poles, chosen to represent various internal conditions typical of the range of the population tested, are discussed here. Data, from traditional assessment methods on the standing poles, from visual inspection, drilling and resistance testing after cross-cutting, are presented together with photographs of a section of each pole. These data are presented to familiarise the reader with the obtaining and interpretation of electrical resistance values and to enable the reader to decide for himself whether this type of instrument may be a reliable and useful aid to the person determining the internal condition of service poles.

INTRODUCTION

An accurate, reproducible, non-destructive (or almost non-destructive) test method for determination of the internal condition of wooden service poles may be considered important for the following reasons:-

1. There would be a considerable financial saving obtained by removing only those poles containing insufficient sound wood.

2. There would be a reduction of the safety hazard resulting from the present inability to detect unsafe poles with certainty.

Major biological causes of internal deterioration of poles arise from consumption of wood by insects (chiefly termites) and wood-decay fungi. This deterioration is progressive. Physical defects comprise chiefly splits and checks. Any non-destructive investigation method must be able to readily distinguish non-progressive physical deterioration from biological deterioration.

The evaluation of any proposed instrument is an exacting and time consuming operation and the need for data on this subject has been recognised by the recent formation of a subgroup of Working Group II ("Fundamentals of Testing") of the International Research Group on Wood Preservation. This subgroup, entitled "non-destructive testing for the detection of defects in poles "is led by Dr. H. Greaves of CSIRO's Division of Building Research and includes workers from Canada, UK, USA, Sweden and Papua New Guinea.

It is desirable for evaluation purposes to be able to immediately destroy poles which can be simultaneously tested and destroyed has tended to make progress on these evaluations rather slow.

Preliminary evaluation of a pulsed-current resistance meter (Shigometer®) were performed in the laboratory, since the method is independant of the amount of timber present. This allowed small wood blocks to be fungally-decayed to definite extents in the laboratory where they could then be used to evaluate the decay detection device. These laboratory tests have been completed and have shown the meter capable of detecting decay at a very early stage and have suggested the method to be worthy of extensive field evaluation (Thornton, 1979 a,b).

The necessary removal of a line of Telecom poles from service in the Coonamble-Gulargambone area of New South Wales made available a sufficient number of creosoted non-durable poles to enable parallel investigations by non-destructive and destructive means.

This paper presents data on six of the 22 poles whose cross-cut sections were examined, at groundline and in many cases additionally 150 mm below groundline, using the Shigometer®. Data is also presented on the traditional assessments carried out by two of the authors (W.G. Seaman and M. McKiterick).

MATERIALS AND METHODS

The Coonamble-Gulargambone truck route comprised poles of chiefly messmate, spotted gum, blackbutt, candlebark and southern blue gum along with a few poles of other species. Seventy five percent of these poles were creosote treated in Victoria and 25 percent in New South Wales. The line was installed in 1963.

In October 1976 a sample number of these poles were inspected in service by the Telecom personnel authors of this paper, by traditional pole inspection methods. By this means poles may be drilled to assess the amount of sound timber remaining and the extent and type of biological degrade present. The poles are also struck with a heavy implement and the resulting sound used as an indicator of pole condition. For those poles which were suspect plugs were removed and the creosote content determined by laboratory extraction.

The poles were removed from service in October/November 1978 and transferred to the Telecom Divisional Headquarters in Dubbo, NSW. There they were crosscut into manageable sections and the section examined with the Shigometer® was that containing the groundline and below groundline portion of the original pole.

The pulsed electric current resistance meter, Shigometer® Model 7950 (Northeast Electronics Corporation, Concord, New Hampshire, USA) used in this test was developed by Dr. Alex Shigo of USDA Forest Service to monitor the quality of living forest trees. It is now widely used in the US for detection of defects in utility poles. The meter delivers a pulsed current between two points which are fixed approximately 5 mm apart near the tip of an otherwise insulated wound wire probe. Resistance to passage of the current can be read off a scale which is calibrated to give an interchangeable full-scale deflection of either 500 kΩ or 50 kΩ . The instrument uses six small batteries and is lightweight and portable.

Following the normal procedure (Shigo and Shigo, 1974) a hole 2.3 mm diam. was drilled horizontally to the centre of the pole along three radii, each 120° apart. The drill used had a 305 mm drill bit and was driven by a portable generator. Three radii were drilled at groundline and usually this was repeated, commencing at the same three points around the circumference but this time 150 mm below groundline. The drilling operation itself gives the operator some indication of the condition of the interior. The twisted-wire probe attached to the meter was then inserted slowly into the hole to

check that the hole is clear, and this exercise gives the operator further indications of the condition of the timber. The probe was then removed and this time inserted with an even motion whilst observing the needle on the resistance meter. Fluctuation of the needle indicated changes within the pole. The probe was then withdrawn and inserted again at 10 mm intervals, recording the resistance reading at each interval. The probe itself has no linear scale marked but the even pitch of the twisted wires enables the practiced operator to judge 10 mm intervals with reasonable accuracy. As well as recording the interval resistance values, for all readings above full scale deflection (500 kΩ), additional notes were made as follows:

No mechanical resistance to probe movement - indicated a hollow.
Little mechanical resistance to probe penetration - indicated dry termite gallery material within a hollow.
Considerable mechanical resistance to probe penetration - indicated sound timber.
Mechanical resistance of a "springy" nature giving an uneven and jerking probe entry - indicated brittle wood left behind after termite attack.

Photographs were taken of the crosscut face which was the face of the probe section under test which was closest to the groundline, normally this face was approximately 300 mm above groundline. These photographs, reproduced in this paper, were used to assess external and internal pole defects and also for the original inspector of the service poles to re-evaluate his 1976 conclusions.

RESULTS AND DISCUSSION

Some details of the six poles under examination here are given in Table 1. Five of the poles were *Eucalyptus obliqua* and the sixth *E. capitellata*. The sapwood thickness, where known, varied from 22 to 28 mm. The creosote retention, determined in three cases by plug extraction, was well below that which would have been originally expected to have been related to the charge retention sheet average value. The condition of each pole when in service in 1976, and the conclusions drawn by the inspectors, are presented in Table 2.

TABLE 1

Poles species and details[1] recorded as a result of 1976 inspection by traditional methods.

Pole No.	Species[2]	Sapwood thickness mm	Charge sheet retention kgm^{-3}	Plug retention kgm^{-3}
3	MS	22	246.7	60.9
6	MS	25	240.0	92.9
7	MS	-	-	-
10	MS	28	302.8	105.7
25	BS	-	-	-
40	MS	-	-	-

[1] - , data not recorded.

[2] MS, messmate stringybark (*Eucalyptus obliqua*, strength group C); BS, brown stringybark (*Eucalyptus capitellata*, strength group B).

TABLE 2

Traditional inspection (1976) results and conclusions

Pole No.	Condition	Conclusion
3	6 mm check length of pole 6 mm soft rot Drilled - 50 mm sound wood	Pole condemned - Decay
6	2-3 mm x 2 m checks No soft rot Drilled - 100 mm sound wood Termites entered through check	Pole condemned - Termite and decay.
7	Not examined	
10	No checks Surface rot Drilled - 50 mm sound wood	Pole condemned - Decay
25	No checks No soft rot Drilled twice - 125 mm sound wood Brown staining, internal collapse	Pole O.K.
40	No checks, internal collapse Surface rot Drilled - centre pipe 25 mm wide, 150 mm sound wood	Pole O.K.

Of the six poles included in this paper one was not tested, two were passed as sound, two were condemned due to decay and one was condemned due to termites and decay. Unfortunately it is not known how the condition of the standing poles changed between the October 1976 inspection and their removal in late 1978. Figure 1 shows cross cut faces of each pole, approximately 300 mm above groundline, after their removal in 1978. It is for example quite possible that the termite deterioration of Pole No. 3 commenced after the 1976 inspection. Table 3 presents data on defects apparent during the preparations for electrical resistance testing and a comparison can be made between these defects and those presented in the other two columns of the table.

TABLE 3

Pole defects indicated during preliminaries to electrical resistance testing (1978) and from photographs of crosscut poles.

Pole No.	Defects* indicated by		
	External circumference inspection	Mechanical resistance to drilling and to entry of Shigometer probe	Photographs taken of crosscut.
3	C3, T3	C, T^b, H	C3, T3, H2
6	C3, T3	C, T^a	C3, T3, H2
7	C2	T^a, H	C2, T1
10	Nil	S	D3
25	C3	C, T^a	C3, T1
40	C1	C, S, T^a	C2, D1, T1

*C, checking; T, termite deterioration; H, hollow; S, softened wood; D, decayed wood; 1, minor; 2, considerable; 3, severe and extensive; a, termite gallery material; b, springy and brittle wood left behind after termite attack.

External circumference defects (Table 3) were assessed from photographs of the relevant pole sections, and the internal defects from enlarged photographs of the crosscut area of the same pole section. Essentially external inspection could only be expected to indicate checking and its severity together with the abundance, if any, of termite gallery material within those checks. From the mechanical resistance encountered during drilling and the "feel" of the Shigometer® probe during the course of its insertion it is possible to determine the presence, but not normally the extent, of a number of defects (Table 3).

These include not only checks and hollows but also decay (indicated by softened wood), termite gallery material (shown by little resistance to probe penetration) and wood left behind after termites have moved on (indicated by dry, springy and brittle wood which makes probe penetration difficult and "jerky"). The presence of termite gallery material is usually further confirmed by the presence of powdery material, which may be wet or dry, seen lodged between the twisted wire probes on their removal from the hole and which material is obviously not of the same colour as either sound or fungal-decayed timber. These defects noted during Shigometer preliminaries gave a true qualitative indication of the identity of those defects which could be quantitatively assessed visually from the sectioned pole (Table 3 and Fig. 1). These preliminaries to Shigometry, involving removal of a minimal amount of wood, enable the operator to "feel" the interior of the pole and furthermore would enable a practiced operator to determine qualitatively those defects present.

Resistance values (k Ω) at 10 mm intervals along each of 3 radii, at both groundline and 150 mm below groundline, are given in Table 4. Data on 3 poles are presented to provide the reader with an impression of the range of actual values obtained. The approximate distance along each pole radius, as measured on the crosscut face of the pole, is included. Readings >500 k Ω are qualified by the mechanical resistance to probe movement at that point, as listed in the Materials and Methods section. Most readings in the outer 20 mm of each radius were >500 kΩ. However at other depths (Table 4, Pole No. 10, below groundline) readings reached as low as 3 kΩ .

The actual resistance values presented in Table 4, together with those values obtained for the remaining three poles, must of course be interpreted to show what is sound wood and what is deteriorated wood. Extensive tests in the US have shown (Shigo, Shortle and Ochrymowych, 1977) that when the highest readings obtained for sound wood within a pole were >500 kΩ , then readings below 250 k Ω were indicative of deteriorated timber. Employing this interpretation to resistance values obtained (Table 4) results in a separation of sound and deteriorated timber which is presented in Table 5. Interpretations for the data obtained on all six poles, at groundline and 150 mm below, are included. For each 10 mm interval reading the pole is concluded to be either sound, deteriorated, or hollow. Here a deteriorated notation can encompass fungal-decayed timber and moist termite gallery material, however the authors feel that the qualification deteriorated is a sufficient summary

TABLE 4

Resistance readings (KΩ) recorded along three radii of each pole*.

Pole No.	Radius	Height	cm along radius of pole 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	Pole radius
6	1	G	>500	>500	350	>500	>500	100	490	140	170	>500	>500	>500	120	>500					15.0
	2		>500	160	90	80	270	120	>500	>500	>500	>500	>500	>500	>500	>500	>500	>500	>500		17.5
	3		>500	>500	390	130	100	150	120	190	110	>500	>500	>500	>500	>500	>500	>500	>500		18.0
	1	BG	>500	>500	220	>500	>500	120	100	170	200	110	100	90	>500	>500					15.0
	2		>500	220	>500	180	90	120	210	>500	>500	>500	>500	>500	>500						17.5
	3		>500	>500	160	140	160	100	190	105	330	150	65	85	>500	150	>500	>500	>500		18.0
10	1	G	>500	>500	150	33	34	32	33	17	10	12	13	8	12	18	8	6			16.5
	2		>500	>500	140	25	33	41	180	400	16	21	130	9	8	13	6				18.0
	3		>500	>500	280	120	90	130	65	130	95	95	95	10	9	15	14	7	6		19.5
	1	BG	>500	>500	135	31	29	23	26	27	7	4	5	4	11	17	12	9			16.5
	2		>500	400	150	130	30	25	37	25	19	6	5	4	3	3	6	10			18.0
	3		>500	500	170	160	70	47	49	43	40	31	33	27	10	5	5	16	14		19.5
40	1	G	>500	>500	>500	>500	>500	190	150	400	>500	>500	>500	>500	>500						13.5
	2		>500	>500	>500	>500	>500	160	>500	>500	>500	>500	100	100							12.0
	3		>500	>500	>500	>500	>500	>500	>500	>500	>500	>500	>500	220	230	>500 >500					14.0
	1	BG	>500	>500	>500	>500	360	65	210	400	310	105	200	120	80						13.5
	2		>500	>500	>500	>500	>500	165	270	190	85	80	200								12.0
	3		>500	>500	>500	>500	>500	290	150	90	105	18	34								14.0

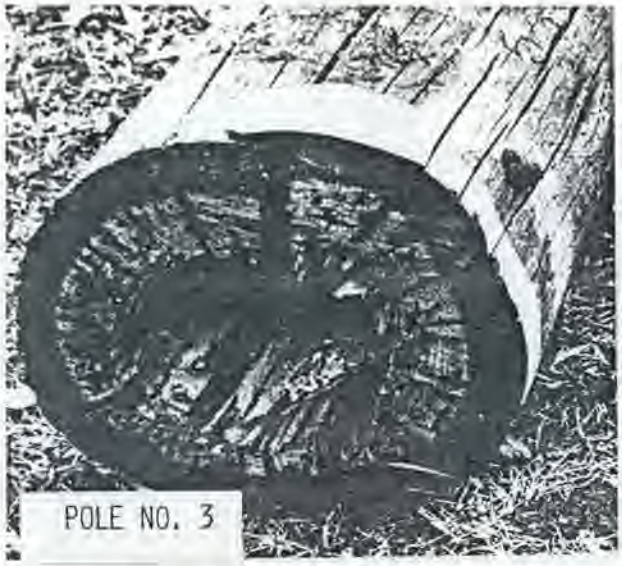
* G, groundline; BG, 150 mm below groundline; — hollow; ═ hollow with dry termite gallery material; ≡ hollow with springy and brittle wood left behind after termite attack.

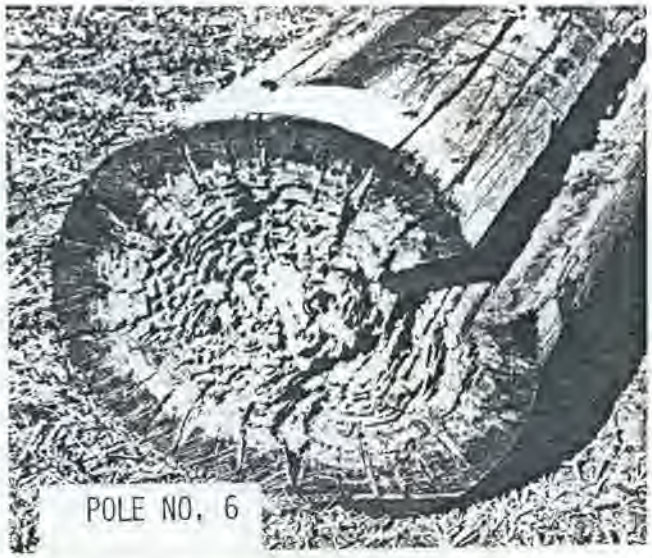
TABLE 5

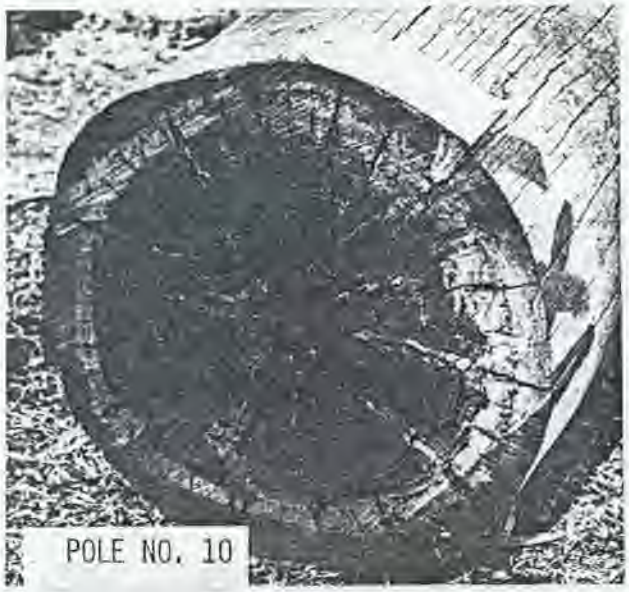
Condition of timber along three radii of each pole, as deduced from pulsed-current resistance values*.

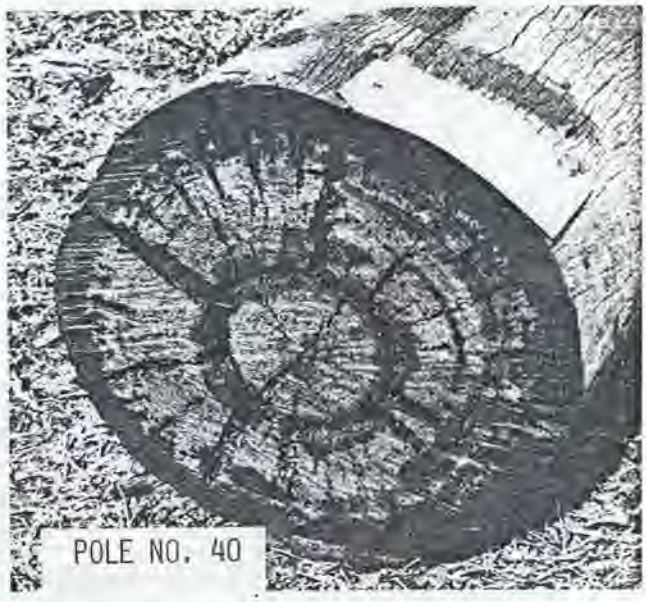
Pole No.	Radius	Height	cm along radius of pole 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	Pole radius cm.
3	1		S	S	S	D	D	D	D	D	D	D	D	D								12.5
	2	G	S	S	S	S	S	H	H	D	D	D	D	D	D	D	D					15.5
	3		S	S	S	H	H	H	H	D	D	D	D	D	D	D	H	H				13.5
	1		S	S	H	H	H	H	H	H	H	H	H	H	H							12.5
	2	BG	S	S	S	H	H	H	H	H	H	H	H	H	H	H	H					15.5
	3		S	S	S	H	H	H	H	H	H	H	H	H	H							13.5
6	1		S	S	S	S	H	D	S	D	D	H	H	H	D	H						15.0
	2	G	S	D	D	D	S	D	H	H	H	H	H	H	H	H	H	H	H			17.5
	3		S	S	S	D	D	D	D	D	D	H	H	H	H	H	H	H	H	H		18.0
	1		S	S	D	S	S	D	D	D	D	D	D	D	H	H						15.0
	2	BG	S	D	H	D	D	D	D	H	H	H	H	H	H							17.5
	3		S	S	D	D	D	D	D	D	S	D	D	D	S	D	H	H	H			18.0
7	1		S	S	S	S	S	S	S	S	S	S	D	D								15.0
	2	G	S	S	S	S	S	S	S	S	S	D	S/H	D								14.5
	3		S	S	S	S	S	S	S	D/H	S	S	S									17.0
	1		S	S	S	S	S	S	S	S	D	D	D	D	D	D						15.0
	2	BG	S	S	S	S	S	S	S	S	D	D	H	D	D							14.5
	3		S	S	S	S	S	S	S	D	D	D	D	D	D	D	D					17.0
10	1		S	S	D	D	D	D	D	D	D	D	D	D	D	D	D	D				16.5
	2	G	S	S	D	D	D	D	D	S	D	D	D	D	D	D	D					18.0
	3		S	S	S	D	D	D	D	D	D	D	D	D	D	D	D	D	D			19.5
	1		S	S	D	D	D	D	D	D	D	D	D	D	D	D	D	D				16.5
	2	BG	S	S	D	D	D	D	D	D	D	D	D	D	D	D	D	D				18.0
	3		S	S	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D			19.5
25	1		S	S	S	S	S	S	D	D	S	H	H	H	H	H						15.0
	2	G	S	S	S	S	S	S	S	S	D	S	H	H	S	S						15.0
	3		S	S	S	S	S	S	S	S	S	D										15.0
40	1		S	S	S	S	S	D	D	S	S	H	H	H	H							13.5
	2	G	S	S	S	S	S	D	S	S	S	S	D	D								12.0
	3		S	S	S	S	S	S	S	S	S	S	S	D	D	H/S						14.0
	1		S	S	S	S	S	D	D	S	S	D	D	D	D							13.5
	2	BG	S	S	S	S	S	D	S	D	D	D	D									12.0
	3		S	S	S	S	S	S	D	D	D	D	D									14.0

* G, groundline; BG, 150 mm below groundline; S, sound; D, deteriorated; H, hollow.









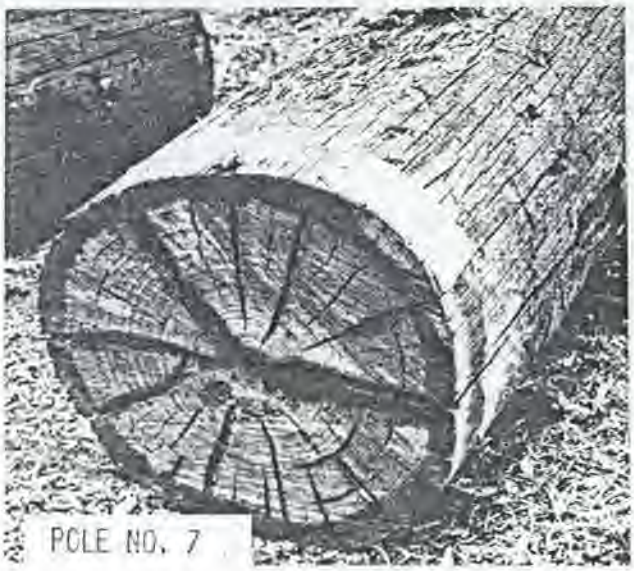


Fig. 1. Crosscut faces of poles.

of the poles condition. As pointed out earlier, preliminaries to Shigometer testing will usually enable a distinction between decay and termite gallery material should this be deemed necessary.

The data in Table 5 can be compared to the crosscut faces of the poles as shown in Figure 1. Table 5 clearly indicates the interior of Poles 3 and 6 to be hollow and deteriorated, that of Pole 7 to be sound with some central deterioration, that of Pole 10 to be extensively destroyed and that of Poles 25 and 40 to have some central defects. Although Table 5 includes the distribution of deteriorated and hollow timber, all that the inspector may require is to have knowledge of the thickness of the outer sound shell of timber. This data is given in Table 6 and includes the distance of continuous sound wood on the outside of each pole at each of the three radii

TABLE 6

Distance of continuous sound wood on outside of pole

Pole No.	Outer continuous sound wood at groundline. radius 1	2	3	Outer continuous sound wood at 150 mm* below groundline. radius 1	2	3
3	30	50	30	20	30	30
6	40	10	30	20	10	20
7	100	90	70	80	80	70
10	20	20	30	20	20	20
25	60	80	90		NT	
40	50	50	110	50	50	60

* NT, not tested.

It is apparent from this data as well as that presented earlier (Tables 4 and 5) that the condition of the pole 150 mm below groundline is inferior to that at groundline. This should not, of course, be taken as applicable to all poles around Australia since the position of the greatest deterioration would be normally expected to vary with such things as soil composition, soil drainage, vegetation cover, climatic conditions and possibly species of timber, timber density, timber treatment and deterioration hazard.

The assessment of the thickness of the sound timber shell of a pole, as determined here by the Shigometer, would be of undoubted advantage to any inspector deciding whether or not to condemn a service pole. Much of course will depend on the load the pole has to bear and its distribution. Therefore it is not considered desirable for the Shigometer technique to be used as the sole determination of the passing or failing of any pole in isolation from its intended purpose in the service line.

However, since the present study was intended as an exercise to evaluate the Shigometer, some attempt will be made to pass or fail each pole on Shigometer evidence alone. Here one must bear in mind two points. First, the sapwood of these poles, though not very thick (Table 1) nevertheless appears largely intact and was of course creosote treated. Second, one must bear in mind not only the pole's condition (as indicated in Table 6) but its likely condition up to the next inspection if that pole were to remain in service. Table 7 uses an arbitary value of a minimum of 40 mm continuous sound wood at all measurement points as being indicative of the passing of a pole.

TABLE 7

Comparison of Shigometer and traditional methods for pole evaluation

Pole No.	Shigometer[1]		Traditional[2]	
	Groundline	150 mm below groundline	Field	Crosscut plates
3	FAIL	FAIL	FAIL	FAIL
6	FAIL	FAIL	FAIL	FAIL
7	PASS	PASS	NT	PASS
10	FAIL	FAIL	FAIL	FAIL
25	PASS[3]	NT	PASS	FAIL[4]
40	PASS	PASS	PASS	PASS

[1] For the purposes of this exercise a pole is considered to fail if it has less than 40 mm of continuous sound wood on the outside of any of the three radial measurements.

[2] The field assessments and evaluation using the photographs were carried out by the same Telecom Inspector (M. McKiterick)

[3] Preliminaries to Shigometry testing (i.e. visual examination of pole) may well have resulted in the pole being failed due to severe splitting.

[4] Pole failed due to severe splitting.

Included in this table are the traditional inspection (1976) conclusions (as given previously in Table 2) and evaluations of the crosscut photographs by the same inspectors. In the case of the six poles, chosen for reporting here owing to their varied conditions, there seems to be good correlation between this arbitary interpretation of the Shigometer findings and the traditional assessment methods employed. A report of the Shigometer testing of all the 22 poles assessed will be published by the present authors elsewhere in the near future.

Acknowledgements

The authors wish to acknowledge the help of the staff of the Telecom Divisional Headquarters, Dubbo, N.S.W.

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THE ROLE OF THE ELECTRICITY SUPPLY ASSOCIATION OF AUSTRALIA IN THE BETTER CONTROL OF THE USE OF TIMBER POLES

Murray, J B

SECV

The Electricity Supply Association of Australia (ESAA) is a voluntary body comprising mainly of State and Commonwealth Authorities involved in the generation, transmission and distribution of electrical energy and other associated matters. The ESAA was founded in 1918 and now consists of 71 members and 5 affiliates.

Briefly, the main objects of the Association are:

(a) to facilitate interchange of information;

(b) to collaborate and advise bodies such as the Standards Association on relevant matters;

(c) to foster collaboration between Authorities;

(d) to co-ordinate the assembly of available information and statistics;

(e) to encourage and facilitate research;

(f) to facilitate consultation and co-ordination between members;

(g) to further the development, operation and management of the electricity industry.

Membership of the ESAA is open to any State Authority or to anybody whose principal function is regulating or controlling the generation, transmission, or distribution of electricity consumed primarily by the public. During 1976 the Constitution was amended to allow affiliate membership to corporate bodies engaged in Australia in the generation, transmission and/or distribution of electricity ancillary to an industrial or commercial operation, or to a publicly owned or controlled supplier of electricity to the public in a country which has a close relationship with Australia.

Each member nominates a representative to attend meetings, and these members elect an Executive Committee who manage the Association's affairs. At the present time the President is:

Mr J R Ashton, B.E., M.I.E. Aust
Commissioner
The Hydro-Electric Commission, Tasmania.

The ESAA has affiliations with the:

(a) International Union of Producers and Distributors of Electrical Engineering (Europe-UNIPEDE).

(b) International Conference on Large Electrical Systems (CIGRE).

(c) Electrical Research Board.

(d) Electric Power Research Institute (USA/EPRI).

(e) International Conference on Electricity Distribution (CIRED).

Information on topics from any of these bodies is available to ESAA members on application.

The ESAA is divided into five sections:

(1) Generation.

(2) Transmission and Distribution.

(3) Financial, Management, Accounting, Stores and Contracts.

(4) Marketing, Service and Load Development.

(5) Personnel.

To carry out the work of the Association, the above five sections have been set up and each section is divided into a number of committees for the purpose of carrying out investigational work of benefit to the members.

Any member having a particular problem can write to the Association seeking the experience of other members and this is usually handled through the relevant committee. Otherwise the request is circulated to other members by the Secretariat.

Committee 2.2, Overhead Transmission and Construction-Convener, Mr G Limbourn, Electricity Commission of NSW (EC of NSW) and Panel 2.2A, Internal Decay of Timber Poles-Convener, Mr J B Murray, State Electricity Commission of Victoria (SECV), have the most direct interest to electrical authorities concerned with the use of timber poles.

Committee 2.2 has representatives from the EC of NSW, the Electrical Authority of NSW (EANSW), SECV, the Sydney County Council (SCC), Shortland County Council, The Hydro-Electric Commission, Tasmania (HECT), The Electricity Trust of South Australia (ETSA), the North Queensland Electricity Board (NQEB), the South East Queensland Electricity Board (SEQEB), the State Energy Commission of Western Australia (SECWA), and the Queensland Electricity Generating Board (QEGB). Up to 10% of this Committee's time is concerned with the use of timber poles and generally from an engineering viewpoint.

Panel 2.2A has representatives from the SECV, the Prospect County Council, the State Electricity Commission of Queensland (SECQ), the EA of NSW, and the DBR/CSIRO. As well, the Forestry Commission of NSW has an observer. Its work directly concerns the presence of decay in timber poles and assisting authorities in its alleviation.

Panel 2.2A terms of reference are:

(1) to promote the collection and dissemination of any information regarding deterioration in wood poles and its control between ESAA members, research institutes and other appropriate interested parties;

(2) to discuss research relating to wood poles which has been planned, is required, or in progress in order to reduce duplication of effort, promote co-operative research and assist assessment of research priorities and activities;

(3) to make recommendations concerning improvements in technology, including economic aspects;

(4) to maintain a register of current investigations being carried out under the supervision of, or being sponsored by ESAA members.

The Panel meets once a year and discusses matters of interest within its terms of reference. A yearly summary of investigational work, being carried out by Authorities and Government bodies, is circulated to Panel 2.2A members. A Pole Bulletin is issued on subjects of interest in the pole decay and preservation area. Articles of interest are also provided for the ESAA quarterly bulletin.

Panel 2.2A suggested to Committee 2.2 that a pole symposium be held. The recommendation was accepted at a recent Section 2 Conference and at the present time arrangements are taking place for this function to take place at the Gold Coast during April 1980.

The ESAA on behalf of its members has ties with the SAA. In the timber field it had two representatives on Committee TM/15-Wood Poles which issued AS2209-Timber Poles for Overhead Lines, a standard of great importance to electrical authorities using timber poles. In the new timber Committees ESAA has one member on TM102 Timber Engineering and one on TM106 Timber Preservation. It was also represented on the CH12 Creosote Committee.

One of the most important aspects of the ESAA is the contact which takes place between its members at all levels and the consequent valuable exchange of information which occurs. In this way small authorities benefit from the work performed by larger ones that are in a better position financially, equipment and personnel-wise, to carry out work of an investigational nature. At the same time exchanges between larger authorities themselves are of great value.

THE IRG CO-OPERATIVE MARINE/FIELD TESTS

J.Beesley

The Division's involvement in the IRG marine and soft rot field tests continues a tradition which was started in 1955 when Hans Holmgren of the Swedish Forest Products Research Laboratory asked CSIRO to expose treated timber specimens for him, in Australia. A year later, Osmo Suolahti of Finland made a similar request. In 1963, the Swedes made a request for a second batch of preservative-treated timber specimens to be exposed on their behalf. These tests were inspected regularly and the sponsors advised of the details of each inspection. Thus, the IRG tests follow and established pattern with test timbers being supplied from overseas and inspection results being reported back to the sponsor - in this case, the IRG Secretariat.

Preliminary planning for the current series of tests of preservative-treated wood took place at the Vienna meeting of the International Research Group (IRG) on Wood Preservation in 1974. We were able to instal our first IRG specimens on 1st March, 1977, as part of an IRG test of preservative-tre treated hardwoods against soft rot. At about the same time, a duplicate set of specimens was sent to the Wood Technology and Forest Research Division of the N.S.W. Forestry Commission. By the time we had completed treatment and conditioning of the local timbers to be included, it was December of that year before the IRG test of treated timbers to be exposed to attack by marine organisms could be installed.

These IRG exposure tests are unique in a number of different ways:

* Both tests are being repeated in a number of different countries - the soft rot test is in 25 countries at a total of 36 sites, of which two are in Australia; the marine exposure test is at 12 sites in 10 different countries with only one Australian site.

* In both tests Alstonia scholaris, Fagus sylvatica and Pinus sylvestris have been used as 'reference' species both untreated, as controls, and impregnated with a copper-chrome-arsenic (CCA) preservative. In the soft rot test, the CCA-treating solution was used at concentrations of 0.66%, 1.53%, 3.01% and 5.60% (W/W), ostensibly to give a preservative retention of 4, 8, 12 and 32 kg/m^3 of CCA salt, respectively. In the marine test, the treating solution was used at concentrations of 3.0%, 6.0% and 10.0% (W/W), duplicating two of the concentrations used in the soft rot test.

* Both tests made provision for the inclusion of local timbers - in the soft rot test Betula pendula was supplied from U.K. and Eucalyptus regnans was added as the local species from Victoria. New South Wales chose to add E. maculata and Geissois benthami as the local contribution. For the marine exposure test we chose to add E. maculata and E. obliqua together with a non-eucalypt, Acacia melanoxylon. It should be noted that, for the soft rot test, the 'local' timbers were impregnated in the U.K. but, for the marine test, the 'local' timbers were impregnated locally to a schedule which detailed both treatment and post-treatment conditioning.

* With both tests inspections were specified for 6 months, 12 months and, thereafter, annually.

Noticeable differences between the two tests include the absence of Betula pendula from the marine exposure test and that in the latter both the reference species and the local species were impregnated with a second preservative - WOLMANIT CB, a copper-chrome-boron preservative. This impregnation of the reference species was performed in Germany but the Australian species were impregnated in our Laboratory with preservative supplied from overseas. In the marine test, provision was made for the return of one complete replicate of specimens to the U.K. at the end of 6 months (which has already been done) and for a second complete set to be returned at the end of 2 year's exposure. There has been no requirement for the return of any of the soft rot specimens but, as a matter of policy, as each treated specimen is condemned it is brought back to the Laboratory and retained for microscopic study.

The next inspection of the marine exposure test is planned for December of this year while the soft rot test is not due for inspection until March, 1980. Copies of the latest reports on these two tests are appended to this paper.

The stated objective of the soft rot test is to establish a world-wide field experiment to determine the performance of preservative-treated hardwoods with particular reference to soft rot (1). Incidental to this objective is the isolation and identification of the micro-organisms attacking (treated) timber in service, from existing field trials and from this particular test. Although no definite instructions have been given for the collection, isolation or identification of the micro-organisms to do so is included in the stated objectives.

The stated objectives of the marine exposure test are:

* To compare CCA and CCB preservatives in different timbers
* To record the severity of attack by marine organisms in different timbers, both treated and untreated

* To assess the attack on treated timber by marine bacteria and fungi
* To study the distribution of preservative components in those treated timber specimens which fail (2).

From past experience of 'failed' marine exposure test specimens, it is improbable that sufficient wood will remain for any unequivocal work on the distribution of chemical components to be done. However, as instructions have been given for the return of two complete replicates of the marine test, after 6 months and 2 years, respectively, this aim might still be achieved.

In spite of some short-comings, these two tests will be very useful as a basis for direct comparisons between the co-operating countries for both soft rot hazard and preservative performance in different hardwood timber species and, no doubt, will also be used to provide a yard-stick by which the relative natural durability of untreated timbers might be compared between different countries. It is interesting to speculate upon the differences which might become apparent on preservative performance between timbers on land and in the sea. It may well be expected that specimens and data from these two tests will prove to be source material for much future research.

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CSIRO

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PROJECT P. 8-23: PERFORMANCE OF PRESERVATIVE-TREATED HARDWOODS

with particular reference to soft rot

REPORT OF CONDITION OF SPECIMENS INSTALLED IN VICTORIA, Australia.

Part of IRG Working Group III - Preservatives and Methods of Treatment.

TEST INSTALLED - O'Shanassy Test Site, 1st March, 1977

First Inspection - 16th September, 1977
Second Inspection - 14th March, 1978
Third Inspection - 14th March, 1979

(Note: All specimens rated on the Division's standard scale for small specimens:

Rating 4 indicates sound specimen, no decay
Rating 3 indicates slight decay
Rating 2 indicates moderate decay
Rating 1 indicates severe decay

SR = Soft rot
WR = White rot

SUMMARY OF THIRD INSPECTION, March, 1979, after 106 weeks.

Species	Controls	0.66% sol.	1.53% sol.	3.01% sol.	5.60% sol.
Alstonia scholaris	4 failed '78 1 failed '79	1 @ 4 ('78)* 4 @ 4	5 @ 4	1 @ 4 ('78)* 3 @ 4 1 @ 3½	5 @ 4
Betula pendula	5 failed '78	1 @ 3½ ('78)* 1 @ 3 ('79)* 1 @ 3 SR 1 @ 3 SR+WR	1 @ 3½ 4 @ 3 SR	4 @ 4 1 @ 3½	5 @ 4
Fagus sylvatica	5 failed '78	3 @ 3½ 1 @ 3 1 Failed SR	2 @ 4 3 @ 3½	4 @ 4 1 @ 3½	5 @ 4
Pinus sylvestris	5 failed '78	4 @ 4 1 @ 3 ('79)*	5 @ 4	5 @ 4	1 @ 4 ('78)* 4 @ 4
Eucalyptus regnans	5 failed '78	1 @ 3½ 2 @ 3 SR 1 @ 2½ SR+WR 1 @ 2 WR	4 @ 3½ 1 @ 3 SR	1 @ 4 4 @ 3½	5 @ 4

Footnote: ('..)* indicates specimen broken and not replaced, with year.

At the conclusion of the inspection, all failed specimens containing preservative were returned to the Laboratory for further examination.

Undoubtedly, some breakage must be attributed to the mowing operations over the site but this is unlikely to be the only cause.

J.BEESLEY
11th July 1979

CSIRO

DIVISION OF BUILDING RESEARCH

FOREST PRODUCTS LABORATORY

P.O. BOX 56, HIGHETT, VIC. 3190. (GRAHAM ROAD) TELEPHONE 95 0334 TELEGRAMS BUILDRESEARCH MELBOURNE

PROJECT P. 5-14: IRG/COIPM INTERNATIONAL MARINE TEST

REPORT OF SECOND INSPECTION (12 months) IN AUSTRALIA

by

J. BEESLEY

CSIRO Division of Building Research

1. INTRODUCTION

Previous reports have presented full details of the treatment and installation of the test specimens in Sydney Harbour during December, 1977, and of the results of the first (6 months) inspection made during June, 1978.

At the June inspection it was apparent that the plastic tubing used to make up the frames from which to suspend the specimens was inadequate for the job and not strong enough to support the heavy fouling which had occurred. Consequently, frames were re-designed and rebuilt in a heavier grade of plastic tubing and, within a week or two of the actual inspection, the remaining test specimens were transferred to new frames. These have proved entirely adequate, as can be seen from the enclosed photographs.

In accordance with the Working Plan (see IRG/WP/414), the whole of the remaining part of the test was re-examined on 13th December, almost exactly 12 months from the day of installation. The inspection procedure previously adopted was again followed. Fouling was assessed for whole frames as there was no apparent difference between individual groups of specimens in the amount of fouling present; the specimens were then cleaned and again assessed for teredine and crustacean attack - which were recorded separately and independently.

Attached photographs give:

(a) General view of the operation, with IRG specimens on right;
(b) Two views of test frames, as recovered. The modified design is evident;
(c) General views of Frames C and D, after cleaning. On both frames the bottom ladder is of untreated specimens; the next ladder is of 3%-treated specimens, followed by 6% with those treates in 10% solution along the top-most ladder.

2. INSPECTION RESULTS

(a) Fouling: Characteristically, the heavy incrustacean of barnacles which can be expected on wood newly immersed at the test site does not recurr after the initial immersion and first cleaning. All subsequent fouling (following periodic scraping etc) includes a substantial proportion of Ascidians, Bryozoa, Hydroids and kelp - as well as barnacles.

No quantative assessments of fouling were made but no differences between treatments or specimens were apparent.

(b) Boring Organisms: Identification of marine wood-boring organisms to the specific level usually requires laboratory facilities so, as at the earlier inspection, the principle separation used was between MOLLUSCAN (Teredine) and CRUSTACEAN (Limnorid and Sphaeromid) types. No attempt was made to extract animals from specimens which had not reached the stage of being rated as 'destroyed'.

From the untreated specimens the only teredine observed was a species of BANKIA (probably B. australis). There was nothing to suggest that any other teredine was active.

Limnoria was the most abundant crustacean present although, in specimens from other tests at the same site, Sphaeromids were also present. Specific identification of the Limnorids recovered is being undertaken.

(c) Degree of Boring (in treated specimens): Obvious attack in the treated specimens was still very limited. No teredine attack was suspected in any of the treated specimens and only Limnorid attack was noted. This attack was restricted to the Fagus sylvatica specimens impregnated with a 3% solution of CCA - all 5 remaining specimens being equally affected and rated as "1" on the rating scale.

(d) Degree of Boring (in untreated specimens): For the untreated specimens, the results of the inspection may be summarised in tabular form -

DEGREE OF BORING, UNTREATED SPECIMENS ONLY

Gradings: 1 = slight attack
2 = moderate attack
3 = severe attack

Species & code	Instal. No.	Inspect. No.	Sound No.	Attacked by Teredines 1 2 3	Attacked by Crustacean 1 2 3	Failed at 6mts	Failed Tered.	Failed Crust.	Failed Unkn'
01.Alst. schol	12	10	1	2 1	3 5 1				
02 Fagus sylv.	12	10		4 3	1 6 3		3		
03 Pinus sylv.	12	1		1		11		1	
04 Acacia mel.	12	10					6	1	3*
05 Euc. macul'a	12	10		1	10				
06 Euc. obliqua	6	5	4		1				

* Specimen missing or too severely eroded for organism responsible to be determined with any reliability.

FIELD ASSESSMENT OF TERMITE FEEDING PREFERENCES USING TOILET-ROLL AND SMALL WOOD-BLOCK BAITS.

J.R.J. French, P.J. Robinson and N. Bartlett

ABSTRACT

A method for rapidly assessing the wood feeding preferences of subterranean termites in three different sites is described. The sites, dominated by *Callitris columellaris*, *Casuarina cristata* and *Eucalyptus oleosa* respectively, were pre-baited with toilet roll baits. Another type of bait, comprising small wood blocks of the three native timber species from each site, plus two commercial timber species, *Eucalyptus regnans* and *Pinus radiata* (both exotic to the area), were glued onto a glass plate, and each arrangement (5 per site) positioned alongside toilet roll baits infested with *Heterotermes ferox*.

A simplified, non-subjective rating system of termite attack indicated that termite feeding preferences could be readily assessed within 7 to 10 months. There was no interaction between the site and the timber species used. The Casuarina site featured less termite attack than the other two sites. *C. columellaris* was the least attacked of the timber species, with *C. cristata* rather more attacked. However there was little difference between the feeding preferences of *E. oleosa* (sapwood), *E. regnans* (sap-and heartwood) and *P. radiata* (sap-and heartwood).

INTRODUCTION

The presence of subterranean termites in desert grasslands and dry sclerophyll forests has been detected using toilet roll baits (5,6,7 8 and 4).

Williams (10) and Usher and Ocloo (9) developed micro-field tests to assess the susceptibility of small amounts of woody materials against subterranean termite attack. Small wood-blocks in a non-leaching situation, were sandwiched between glass plates and exposed to termite attack for up to

three months. Their results showed that quick and reasonably accurate information could be gathered from these micro-tests in contrast to any conventional large scale testing method. Also, Bultman and Southwell (3) and French and Robinson (4) found that foraging subterranean termites visited and more readily attacked small wood-stakes placed horizontally on the ground than those placed vertically, as is the practice in "grave-yard" test sites (1, 2).

We combined the advantages of toilet roll baiting following experiences of Haverty *et al* (5 and 6) and ourselves, using a glass plate technique, similar to those used by Williams (10) and Usher and Ocloo (9) in order to assess subterranean termite wood feeding preferences. In this paper we have chosen to use frequency of attack on wood species present in the baits, in an essentially free-choice situation, as the measure of termite wood preferences.

MATERIALS AND METHODS

Site description

All sites were located about 400 km northwest of Melbourne in the Victorian State Department of Agriculture Mallee Research Station near Walpeup. Three sites were selected in which to place the replicated baits. These sites were chosen as being representative of the three main vegetative types in the area. The dominant trees of each of the sites were *Callitris columellaris* (F. Muell), *Causuarina cristata* Miq., and *Eucalyptus oleosa* F. Muell and described in the test as the Callitris, Casuarina and Eucalyptus site respectively. Each site was flat, with sandy soils, and the dominant understorey vegetation was herbage of the saltbush type. Termite species collected at Walpeup in the vicinity of the three sites were *Amitermes xylophagus* Hill, *Coptotermes acinaciformis* (Froggatt), *C. frenchi* Hill, *Heterotermes ferox* (Froggatt), *Nasutitermes exitiosus* (Hill), *Schedorhinotermes reticulatus* (Froggatt) and *Microcerotermes* sp.

Installation of Baits

(a) Toilet roll baits:

Sixty-four rolls of toilet paper (Bowater-Scott®, 120 x 110 mm, 640 single-ply, bleached, unscented), wrapped with package tape to prevent unwinding, were placed on the surface of the ground at each selected ecotype. Eight rows were laid out running in a North-South direction, with rows and toilet rolls being 3 m apart. All toilet rolls were "anchored" in position using a short length of L-shaped steel wire inserted down the hollow centre of the roll.

Inspections of the toilet roll baits were made one month after installation, and then at 4, 8 11, and 13 months after exposure. All termite infestations and attacks were recorded but only the soldier castes collected whenever possible to simplify identification of termite species. After each inspection all the baits including wood blocks in the glass-plate arrangements were replaced in their original positions.

(b) Small wood block baits:

In the laboratory, blocks (120 x 20 x 20 mm) composed of sapwood and heartwood were cut from air-dried stems of the three dominant tree species found on the Walpeup sites, namely, *C. columellaris*, *C. cristata* and *E. oleosa*. Similar size blocks were cut from two economically important timber species *E. regnans* and *P. radiata*, though both species are exotic to the Walpeup area.

Two blocks of each timber species were randomly selected for each single glass-plate wood block arrangement. Then the ten blocks were randomly arranged on each glass-plate (300 x 300 mm) in two rows of five blocks, and held in position with a quick-drying glue on the 120 x 20 mm face. Five glass-plate arrangements were prepared for each of the three test sites.

One month after installation of the toilet roll baits, each glass-plate bait was installed in the field alongside a toilet roll bait infested with *H. ferox*. The wood blocks were positioned so that their top surface was level with the soil surface. Cement sheeting (300 x 300 x 5 mm) was then placed over each glass-plate in order to minimize breakage from roving wildlife, and falling tree material, apart from making their location easier when inspecting the site. Two L-shaped steel wires were placed into the ground at opposite sides of the cement sheeting holding the whole arrangement in position. Inspections of all wood blocks were made 3,7, 10 and 12 months after their installation in the field. Instead of a detailed rating system of termite damaged wood-blocks at each inspection (2)
a simpler non-subjective rating system was adopted. Any wood block that was attacked or infested by termites in any way was rated "2" points, and unattacked blocks given a "1" rating. The latter included blocks that were found to have been contacted or visited by foraging subterranean termites. Feeding frequencies were analyzed by Chi-square.

RESULTS

(a) Toilet roll baits:

The number of baits attacked and infested by various field populations of foraging subterranean termites during the test period extending from July 1977 to August 1978 are shown in Table 1. There was a gradual increase in the number of baits infested by termites on all sites, with a slight increase between the eleventh and thirteenth months. After 13 months, the pattern of attack on the baits was similar in all sites. *H. ferox*, not considered as a destroyer of natural wood, was the most commonly found subterranean termite infesting the baits on all sites. One bait was completely eaten out within four months by this termite species on the Casuarina site. Only after the eleventh month of the test were more than one species of termite found infesting the same bait (Table 1). *A. xylophagus* was associated with *H. ferox* in baits on each site, with the highest incidence (6) at the Casuarina site occurring after 13 months.

Microcerotermes sp. and *S. reticulatus* foragers were collected from a number of baits, but not found actively feeding alongside *H. ferox*. Only five baits on the Callitris site and single baits on the other two sites remained continuously infested with *H. ferox* during the test period. Most baits "visited" by termites at the earlier inspections were eventually found to be attacked and infested at later inspections.

(b) Small wood-block baits:

The total number of baits that were attacked per site between installation and the inspection concerned are shown in Table 2.

Termites visited and attacked wood-blocks irrespective of their position on the glass-plate. *H. ferox* was the most predominant termite species found attacking the small wood-block baits, with some attack by *A. xylophagus*, *Microcerotermes* sp. and *S. reticulatus*. One bait of *E. oleosa* at the Casuarina site was found to contain both *H. ferox* and *A. xylophagus* in the sapwood with only a thin septum of wood separating the two species in the bait.

There was no difference between plates on a site. One plate may have received more attacks than another in the same group, but the only significant evidence of this is at three months (P= .05). Also, there was no difference in the number of blocks attacked at 10 and 12 months after installation. The Casuarina site featured less termite attack than the other two sites. *C. columellaris* was the least attacked of the five timber species at each site, followed by *C. cristata*. There was little difference between the *E. oleosa* (sapwood), *E. regnans* (sap- and heartwood) and the *P. radiata* (sap- and heartwood) feeding preferences.

DISCUSSION

The field assessment technique to determine the wood feeding preferences by foraging subterranean termite species proved successful, with the data indicating that such feeding preferences could be detected seven to ten months after installation of the baits. The lack of a significant glass-plate effect (P=.05) meant that there was no interaction between the site and the timber species. This simplified the description of the data, and justified the adoption of a non-subjective rating system of termite attack and feeding preferences.

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Table 1. Total number of toilet roll baits showing termite feeding activity and number of baits ( ) attacked by positively identified termite species.

	Months after exposure			
Site	4 (Nov)	8 (Mar)	11 (June)	13 (August)
Callitris	20 (H=8)	28 (H=21)	49 (A=1) (H=39)	51 (A=3) (H=20)
Casuarina	18 (H=9)	30 (H=25)	50 (A=4) (H=38) (M=1)	51 (A=6) (H=20) (M=1) (S=1)
Eucalyptus	18 (H=3)	41 (H=19)	54 (A=2) (H=43)	49 (A=1) (H=17)

A = *Amitermes xylophagus* H = *Heterotermes ferox* M = *Microcerotermes* sp. S = *Schedorhinotermes* [illegible]*atus*.

Table 2 Number of wood-block baits attacked during the period of test by subterranean termites at Walpeup. (At each site there were 5 plates comprising 2 replicates of each of 5 timber species. All glass-plates were positioned alongside a toilet roll bait infested with *H. ferox*.).

		Months of Exposure				
Ecotype	Timber Species	3	7	10	12	Total
Callitris	A	4	5	8	8	25
	B	2	4	5	5	16
	C	1	2	2	2	7
	D	7	8	9	9	33
	E	5	8	9	9	31
	Sub total	19	27	33	33	112
Casuarina	A	4	5	5	5	19
	B	0	3	3	3	9
	C	0	2	2	2	6
	D	2	4	6	6	18
	E	3	3	5	5	16
	Sub total	9	17	21	21	68
Eucalytus	A	5	7	10	10	32
	B	1	3	5	5	14
	C	0	1	3	3	7
	D	7	10	10	10	37
	E	8	8	9	9	34
	Sub total	21	29	37	37	124

A = *Eucalyptus oleosa*
B = *Casuarina cristata*
C = *Callitris columellaris*
D = *Eucalyptus regnans*
E = *Pinus radiata*

TERMITE-FUNGI INTERACTIONS - RESPONSE OF *COPTOTERMES ACINACIFORMIS* TO FUNGAL DECAYED SOFTWOOD BLOCKS.

J.R.J. French, P.J. Robinson, and J.D. Thornton

ABSTRACT

Blocks of *Pinus radiata* sapwood were individually decayed by one of several wood decay fungi for periods of 4, 8 and 12 weeks. The fungi in half the number of blocks were killed by γ- radiation after the various decay periods, then all blocks, were offered to workers of *Coptotermes acinaciformis* in laboratory, free-choice bioassays. Termite feeding preferences for the 'dead' fungal decayed blocks were quantitively assessed whereas the method of assessment for the 'live' blocks was qualitative. Regardless of decay periods and condition of the fungi in the blocks, the termites consistently preferred to consume blocks decayed with the brown-rots, *Coniophora olivacea*, *Polyporus palustris*, and the white-rot, *Poria rata*. The brown-rot, *Gloeophyllum trabeum*, was one of the least attractive decay fungi to *C. acinaciformis*

INTRODUCTION

The attractiveness of fungus-infected woods to termites has been used in termite pest management strategies (4). Wooden bait blocks decayed by *Gloeophyllum trabeum* Pers. (ex. Fr.) Murr. with the insecticide mirex added, have proven successful in suppressing the activity of *Reticulitermes* spp. in North America (3;4). In Australia a bait, with mirex, but without a wood decay fungus, suppressed field populations of *Mastotermes darwiniensis* Froggatt (7; Spragg and Paton, unpubl. data).

This paper describes further laboraotry screening of several brown and white rot fungi known to be attractive and eaten by the subterranean termite *Coptotermes acinaciformis* (Froggatt) (5). The long term intention is to combine the more attractive fungi within insecticidal - wood baits for use as additional control measures against this subterranean termite.

MATERIALS AND METHODS

TERMITE SPEICES

C. acinaciformis were collected from a mound colony near Townsville, Queensland, six months prior to testing. The termites were maintained in a matrix of their own mound material and fed on *Eucalyptus regnans* F. Muell. heartwood under laboratory conditions of 26°C and 75% R.H. prior to the present bioassays. The term "termite feeding preferences" refers to the amount of wood consumed or damaged by the termites in an essentially free-choice situation.

FUNGI ASSAYED

In preliminary laboratory biaossays (5) several brown-rot and two white-rot fungi were shown to be preferentially attractive to termite workers of *C. acinaciformis, Mastotermes darwiniensis* Froggatt and *Nasutitermes exitiosus* (Hill). The same fungi were selected for this biaossay against *C. acinaciformis* (mainly workers) (see Table 1). The brown-rot *G. trabeum* was included in this investigation for comparative purposes, as this fungus has been used in other termite-fungal attractancy studies (2;1;6).

DECAYED WOOD BLOCKS

Sapwood blocks (30 x 15 x 5 mm, with 5 mm the direction of grain) were cut from a single treee of *Pinus radiata* D. Don. Decay periods of 4, 8 and 12 weeks were selected. Eighteen blocks per fungus (nine) tested were selected at random and decayed following the procedures of Thornton (8) but on a smaller scale using test tubes and plastic trays. Another 18 blocks were prepared as sterile untreated controls. AFter each decay period 50 percent of the blocks were weighed, conditioned at 12% moisture content (m.c.), reweighed in order to determine individual mass loss by decay, and then sterilized by γ- radiation* Half the number of untreated control blocks were similarly sterilized. Following sterilization, the blocks with 'dead' fungi were ready for test in the termite bioassay. A similar set of blocks was prepared for the 'live' fungal wood blocks.

* γ - radiation was carried out by ICI Australia Pty. Ltd. The temperature of this treatment is about 70°C.

BIOASSAY TECHNIQUE

The response of the *C. acinaciformis* workers to the various fungi grown in wood blocks was tested using a random multiple-choice method. This consisted of round white plastic containers (230 mm diam., 110 mm deep) into which 100 ml of bacteriological agar (Davis) 1% m/v) was poured. On setting, washed, unsterilized river sand, to a depth of 30 mm, was evenly spread over the agar. Each container held a complete set (see Table 1) of the nine test fungi plus a single untreated (=undecayed) block. All were placed individually on a half microscope slide, at random, on the sand surface around the perimeter of the container. Nine replicates for each set of 'live' and 'dead' wood blocks were grown for 4, 8 and 12 weeks respectively, giving a total of 54 containers. Four grams of *C. acinaciformis* (ca 800 individuals) were released onto the centre of each replicate container. All containers were covered with a glass sheet, and held at 26°C and 75% R.H. for the bioassay period of 28 days.

Termite feeding preferences were assessed for the γ- radiated wood-decayed blocks by measuring the amount of wood consumed by the termites as a percentage of the actual amount of decayed wood initially presented to the termites. It was not possible to directly calculate the amount of 'live' decay wood block being eaten as decay of the blocks continued throughout the bioassay period. Rather, a subjective rating of volume of wood consumed by the termites was adopted as follows, rating 1 for no attack; 2 for etching of the block or less than 20% eaten; 3 for 20 - 40% eaten; 4 for 40 - 80% eaten; and 5 for 80 - 100% eaten.

RESULTS AND DISCUSSION

BIOASSAY USING 'DEAD' FUNGUS-DECAYED WOOD BLOCKS

Table 1 shows the range of decay in the wood blocks tested, after rotting for 4, 8 and 12 weeks prior to their sterilization, and the amount of wood consumed by *C. acinaciformis* workers in the various replicates throughout the bioassay period of 28 days.

BIOASSAY USING 'LIVE' FUNGUS-DECAYED WOOD BLOCKS

Table 2 shows the mean damage ratings of termite feeding on the live fungus decayed wood blocks. The subjective rating indicated the mean volume of wood eaten by the termites.

Table 1 Decay range in the fungus-decayed blocks after rotting for 4, 8 and 12 weeks, and prior to sterilization and the mean amount of dead fungus-decayed wood consumed by *C. acinaciformis* workers during the bioassay period of 28 days.

Fungal species	Strain number of fungus	Decay range (% m/m)			Amount of wood consumed (% m/m)		
		4 weeks	8 weeks	12 weeks	4 weeks	8 weeks	12 weeks
*Pycnoporus coccineus**	1096	0-2.3	0-9.4	0-7.1	12.5	14.3	24.4
Trametes lilacino-gilva	1109	0-14.0	0-18.3	3.9-33.1	11.2	11.2	12.3
Coniophora olivacea	1779	0-22.9	0-43.9	0-51.3	16.6	20.2	24.6
Piptoporus australiensis	3081	2.4-16.3	0.8-29.6	34.6-50.0	16.7	14.7	24.2
*Poria rata**	5152	2.4-13.4	0-50.4	14.2-38.9	13.0	16.0	29.5
Polyporus palustris	7140	0-18.3	22.3-44.5	54.9-65.7	14.6	40.7	31.6
Poria cocos	7281	0-9.6	3.1-54.0	4.7-68.2	9.9	10.1	31.6
Gloeophyllum trabeum	7520	0-7.9	3.0-28.9	32.0-45.5	6.8	7.0	12.7
Poria monticloa	7522	0-24.4	29.9-51.2	47.7-60.2	9.3	14.9	14.1
Untreated control	UC	0	0	0	4.3	7.7	13.8

* white rots; all others = brown rots

GENERAL DISCUSSION

Direct comparisons of the amount of 'dead' and 'live' fungal-decayed wood blocks consumed by the termites was not possible as the amount of termite feeding on the 'dead' blocks was recorded quantitatively, whereas the feeding of the termites on the 'live' wood blocks was recorded qualitatively. However, we considered that to compare the major trends in termite feeding preferences between these two types of decay blocks may be instructive. So Table 3 was constructed, and depicts the ranking of the termite feeding preferences on the 'dead' and 'live' fungal decayed wood blocks.

Blocks containing 'dead' and 'live' decay fungi of *C. olivacea*, *P. palustris* and *P. rata* were consistently prefered by the termites than to the other fungi, particularly for blocks decayed for 8 weeks prior to termite feeding. These same fungi were ranked highly after decay periods of 4 and 12 weeks too, with some minor fluctuations in termite preferences. Our results show that *C. acinaciformis* workers, when given a free-choice situation, preferred to feed on several wood decay fungi, both 'dead' and 'live', other than *G. trabeum*, confirming earlier work by French (1978). This is apparently unlike the North American experience (see 2;1) which indicates that *Reticulitermes* spp. feeding was greatest on wood blocks decayed by *G. trabeum* for 6 to 8 weeks. However, the termite species and the wood substrates used in North America and Australia are different, and only the same strain of fungus was used in all bioassays. Ruyooka (6) also demonstrated that *G. trabeum* was not attractive to *N. exitiosus* within a eucalypt substrate, verifying the earlier study of French (5).

Field investigations to examine the attractivenesss and palatability of these same wood decay fungi to natural field populations of subterranean termites are in progress. Further details of the present laboratory and field studies will be published elsewhere.

Table 2 Mean damage ratings of termite feeding on wood blocks containing the live fungus after 28 days. Blocks were rotted for 4, 8 and 12 weeks prior to termite feeding.

Fungal species	Strain number of fungus	Mean damage ratings after various periods of fungal growth		
		After 4 weeks	8 weeks	12 weeks
*Pycnoporus coccineus**	1096	1.8	1.7	1.8
Trametes lilacino-gilva	1109	2.1	1.9	1.9
Coniophora olivacea	1779	3.0	2.7	2.6
Piptoporus australiensis	3081	1.1	1.0	1.0
*Poria rata**	5152	3.1	3.9	3.3
Polyporus palustris	7140	1.1	2.4	3.1
Poria cocos	7281	1.1	2.0	3.4
Gloeophyllum trabeum	7520	1.7	1.1	1.1
Poria monticloa	7522	2.0	1.8	2.8
Untreated control	UC	2.0	2.3	2.1

* = white rots all others = brown rots

Table 3 Ranking the 'dead' and 'live' fungal decayed wood blocks in order of termite damage after 28 days in a free-choice bioassay. The number indicate fungal strain numbers. Brackets link blocks of equal rating.

Fungal decay wood blocks					
4 weeks		8 weeks		12 weeks	
Dead	Live	Dead	Live	Dead	Live
3081	5152	7140	5152	[7140	7281
1779	1779	1779	1779	[7281	5152
7140	1109	5152	7140	5152	7140
5152	[7522	7522	UC	1779	7522
1096	[UC	3081	7281	1096	1779
1109	[1096	1096	1109	3081	UC
7281	7520	1109	7522	7522	1109
7522	[3081	7281	1096	UC	1096
7520	[7281	UC	7520	7520	[3081
UC	[7140	7520	3081	1109	[7520

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SYNTHETIC PYRETHROIDS AND WOOD PRESERVATION

C.D. HOWICK and J.W. CREFFIELD

ABSTRACT

The efficacy of some synthetic pyrethroids in the protection of wood against three species of Australian termites and the European House Borer has been assessed. The implication of these results is considered and the potential of stable and persistent synthetic pyrethroids as the insecticidal component of wood preservatives is discussed.

INTRODUCTION

In the 30 years since allethrin was first produced (1), the effectiveness of both natural and synthetic pyrethroids has become well established. Their high insecticidal but low mammalian toxicity, combined with high biodegradability and low persistence have made them ideal pesticides against a wide range of insects. In the field of wood preservation and remedial treatment however, there is a need for high persistence in the insecticidal component of formulated products. Insecticides such as arsenic and boric acid as well as persistent organochlorines such as dieldrin, chlordane and gamma-BHC have therefore been used.

The first synthetic pyrethroids in which characteristically high activity against insects and low mammalian toxicity were combined with greatly increased stability were described in 1973 (2,3). As well as being more photostable and persistent than their predecessors, several of the compounds were also more insecticidally active than many of the common organophosphates and carbamates. In fact, the more stable synthetic pyrethroids differ so markedly from the earlier natural and synthetic compounds as to constitute a new class of insecticides (4).

In 1975, the authors initiated a series of laboratory assessments to determine the termiticidal effectiveness of the more recent synthetic pyrethroids and their potential as the insecticidal component of future wood preservatives. The project fitted well into the overall program of the Conservation and Biodegradation Section at CSIRO's Division of Building Research, on the development and assessment of environmentally acceptable pesticides to combat wood-destroying insects.

LABORATORY ASSESSMENTS

Because the information given in this paper is intended to be of a general nature, details of the actual compounds used are not given here and specific results are not presented. It is anticipated that full details will be published elsewhere when current investigations are completed.

(a) TERMITICIDAL EFFICACY

Initial laboratory assessments with termites were carried out using a residual synthetic pyrethroid (SP-one) in comparison with aldrin - a compound of known termiticidal efficacy. Timber specimens were vacuum-pressure impregnated with both insecticides in a solvent of mineral turpentine plus 0.5% paraffin wax, and subsequently exposed in bioassays against three different species of Australian termites to obtain comparative 'toxic threshold' values.

The timber specimens were treated with the insecticides to the following loadings:- SP-one - 0.008, 0.04, 0.08 and 0.16 kg/m^3; Aldrin - 0.016, 0.08 and 0.8 kg/m^3. After treatment, half the specimens were subjected to a thorough leaching/volatilisation schedule. There were 10 replicates at each insecticidal loading, 5 leached and 5 unleached.

For each of the three termite species (*Mastotermes darwiniensis* Froggatt, *Coptotermes acinaciformis* (Froggatt) and *Nasutitermes exitiosus* (Hill)), each of 90 1 L jars contained one timber specimen in a suitable matrix and 10 g of termites. The layout and method of bioassay was in accordance with the technique devised by Howick and Creffield (5) except that with *C. acinaciformis* and *N. exitiosus*, details of matrix and ventilation were as described by GAY *et al.* (6). Termiticidal efficacy was determined from specimen mass losses and mortality of the test termites.

Results were most encouraging and indicated that the synthetic pyrethroid, when impregnated into wood, afforded similar protection to aldrin at one-tenth the loading.

(b) MICROBIAL SENSITIVITY

Subsequent laboratory assessments with termites were carried out using two residual compounds (SP-one and SP-two) and aldrin, comparing their effectiveness with and without an exposure period of soil burial. It was hoped by doing so, to determine the effect of soil micro-organisms on subsequent termiticidal efficacy of the pyrethroids and hence assess their persistence in wood.

Specimens (15 x 25 x 50 mm) of *Eucalyptus regnans* F. Muell. heartwood were vacuum-pressure treated with the insecticides in a solvent as before and as a result of the previous work, the one retention selected for the pyrethroids was 0.08 kg/m^3 and for aldrin 0.8 kg/m^3. After treatment and weathering, half the number of specimens used were subjected to a laboratory soil burial exposure for 6 weeks. The remainder were wrapped in foil and stored in a laboratory cold room. At the end of the 6-week period, all specimens were vacuum oven-dried and weighed, mass losses being calculated for those exposed to soil burial. These losses however, were less than 0.5% and therefore considered to be insignificant. Nevertheless, the series of laboratory bioassays was conducted against three termite species as before, to compare the performance of those blocks which had been given the 6-week exposure, with those which had not.

Although these bioassays did not produce data on the sensitivity of the compounds to microbial degradation, further valuable information was gained concerning their termiticidal effectiveness. If the 6-week soil burial is regarded as an extension of the rigourous leaching/volatilisation schedule applied after treatment of the wood specimens, the results are of considerable interest. They further demonstrated that when the first compound (SP-one) is impregnated into wood at a retention of 0.08 kg/m^3, it compares favourably in wood protection with aldrin at ten times that retention against all three species of termites used in the assessments. It was also demonstrated that at the same retention, the second compound (SP-two), although similar to the first, gave less satisfactory results against at least one termite species at the retention tested. This necessitated a further evaluation of insecticide retention relationships for the second compound before its potential for wood protection against all economically significant species of Australian termites could be determined.

(c) TOXICITY TO WOOD BORERS

A laboratory test of three residual compounds (SP-one, SP-two and SP-three) and aldrin against the European House Borer *Hylotrupes bajulus* (L) has also been carried out.

Five replicate blocks were treated with each of 10 concentrations of the insecticides in white spirit solvent and inoculated with six egg-larvae of *H. bajulus* according to European Standard EN 47. After X-ray examination at 1, 3 and 6 months, toxic values were determined for each compound.

Results showed SP-one and SP-two to give similar protection but with toxic values higher than aldrin, whereas those of SP-three were lower.

DISCUSSION

The future of wood preservation may be dependent on the use of environmentally safe and acceptable chemicals. The comparative safety of pyrethroids places considerable relevance on assessments of their efficacy in protecting wood against termites and wood borers.

Berry (7,8) has shown that one compound has a similar order of toxicity to that of gamma-BHC against the borers *H. bajulus*, *Anobium punctatum* (De Geer) and *Lyctus brunneus* (Stephens). However, it is noteworthy that it gave far better protection than gamma-BHC against *Reticulitermes santonensis* (Feytaud), the one species of termite tested. This result, together with the work of Indoue *et al* (9) and that of the authors reported herein, indicates that termites may be particularly susceptible to the stable pyrethroids.

These compounds would seem unlikely to be a satisfactory replacement for the persistent chlorinated hydrocarbons for soil treatment against termites, due to their extensive and rapid degradation by soil micro-organisms (10). However, more information needs to be obtained on their behaviour in wood and other materials in ground contact and on whether any chemical 'fixation' action occurs when they are impregnated into wood.

Some synthetic pyrethroid compounds have already been used experimentally during the manufacturing process to confer resistance against termite and borer attack to wood-based panel products such as particleboard, hardboard and plywood.

In the authors' opinion, the future of synthetic pyrethroids in wood preservation is of considerable importance to the future of the industry.

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DRYWOOD TERMITES IN AUSTRALIA

C.D. Howick and J.W. Creffield

ABSTRACT

This paper discusses the occurrence in Australia of indigenous and introduced (= tramp) drywood termites and summarises current research activities.

INTRODUCTION

The term "drywood termites" is generally applied to species within the genus *Cryptotermes* (Isoptera: Kalotermitidae). They tend to form numerous, small colonies within wood and need no contact with the ground, being able to derive sufficient moisture either from the atmosphere or from the wood they infest (1). Drywood termites therefore usually occur in areas where the relative humidity is high, temperatures are warm and Equilibrium Moisture Content (EMC) of timbers is favourable to their development.

The incidence and distribution of drywood termites in Australia has been discussed by several authors (2,3,4). There are four, named, indigenous species and in addition, four widespread tramp species are known to have become established on or near the Australian mainland (4,5,6). As these tramp species are easily transportable in timber and furniture, and as they are all capable of causing considerable damage to timber in buildings, their establishment has prompted an intensive research effort in Australia.

AUSTRALIAN DRYWOOD TERMITES

Detailed studies by workers of CSIRO Division of Entomology have resulted in a clarification of the taxonomic status of the various species. In addition to the four indigenous species (*C. primus* (Hill), *C. queenslandis* (Hill), *C. gearyi* (Hill) and *C. secundus* Hill)), a further eight new Australian species are in the process of being described (Gay and Watson unpubl. data).

All of these Australian drywood termites are found in standing trees, both living and dead and, with the exception of *C. primus*, do not appear to have become domesticated to the extent of infesting building timbers. *C. primus*, in tropical Australia, frequently infests house stumps and sub-floor timbers as well as dead trees in rural areas.

INTRODUCED DRYWOOD TERMITES

The four introduced species (*C. brevis* (Walker), *C. cynocephalus* Light, *C. domesticus* (Haviland) and *C. dudleyi* Banks) are all able to infest susceptible materials in buildings without having contact with the ground.

C. domesticus and *C. cynocephalus* have become established in Mossman, Queensland where *C. domesticus* is very destructive in flooring and internal partitioning of houses, sheds and garages and *C. cynocephalus* less so (4). *C. dudleyi* is well established on Thursday Island in Torres Strait (7), where recent inspections have revealed extensive damage to wooden fittings and furniture. *C. brevis* was discovered to be well established in Maryborough, Queensland in 1966 (3) and has since been located in buildings in one part of the city of Brisbane (4,6). Because of the destructive nature of *C. brevis*, considerable expense and effort have been directed towards control procedures to prevent or contain its spread. In Maryborough all houses in which infestations have been found, and in many cases those adjacent to them, have been fumigated with methyl bromide. In Brisbane the buildings and their contents, including Parliament House and other large structures have also been fumigated, in an operation costing around one and a half million dollars.

RESEARCH

In Australia, active research projects with drywood termites are in operation at three laboratories - CSIRO Division of Building Research and Entomology and Queensland Department of Forestry. Laboratory studies within the genus have been aimed at determining in more detail, those aspects of biology which have relevance to the ability of the introduced species to spread and become further established, as well as to methods of control and containment.

To this end, research has been aimed at the determination of ideal group size and composition for breeding, for materials susceptibility trials and for preservative and insecticide testing. Also the determination of optimum temperature/humidity regimes for the growth and development of the various species is required. Investigations have also been made into the production of alates and of supplementary reproductives and the establishement of incipient colonies. From this it is hoped that bioassays will be developed to examine the susceptibility of various materials to drywood termite attack. Techniques have now been established (8) using X-rays to study colony development and its progress in wood.

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SUBSTANCES FROM *GANOPHYLLUM FALCATUM* WOOD WITH TERMITICIDAL PROPERTIES

Y. Yazaki and W.E. Hillis

Ganophyllum falcatum (Scaly ash) is found in Queensland as a fairly scattered tree with the reputation for strong termite resistance. Although the timber is not available in quantity, its reputation for termite resistance warranted critical examination to determine whether *Ganophyllum falcatum* contains components toxic to termites and if so, to identify them and to develop their activity.

The wood and bark were tested by bioassay and termite toxicity was found only in the wood. The toxic components were removed from the wood by methanol extraction. The extract so obtained equalled about 10% of air-dried weight of the wood. The extract was separated into diethyl ether-, ethyl acetate- and water-soluble fractions and the termite toxicity was found to be concentrated in the water-soluble fraction. Three compounds A, B and C were isolated from the water-soluble fraction by Sephadex G-50 using water and Sephadex LH-20 using methanol. Only one, compound A, was found to be toxic to termites.

Compound A gave one spot with thin layer chromatography using silica gel in AcOEt/pyridine/water (12:5:4, v/v) and data from solubility, elementrary analyses and spectroscopic analyses (UV and IR) excluded the possibilities that compound A would be an alkaloid, a phenol, a long chain fatty acid or any terpenoid-type compound. It was not certain whether the compound was a polymer or a mixture of very similar compounds.

GLC analysis of methylated or acetylated compound A was not successful. The GLC analysis of silylated compound A revealed two major peaks and 4 minor peaks. GC-MS analysis of the silylated compound A indicated the molecular weights of the silylated compounds to be more than 200. Compound A was examined also by field desorption MS and electron impact/desportion MS. Field desorption MS indicated the presence of three compounds of molecular weight 394, 408 and 410 with a compound molecular weight 394 predominating and this was confirmed by the electron impact/desorption mass spectra. Furthermore, the presence of an ester group was likely and the loss of 18 from the molecular ions 394-18 and 410-18 indicated the presence of hydroxyl groups.

Compound A requires further purification and structural elucidation which will be coupled with bioassays to ascertain the exact nature of its toxicity.

ACKNOWLEDGEMENTS

We thank Mr J. Beesley for supplying *Ganophyllum falcatum* wood and bark and for his valuable discussion; Ms G. Urbach and Mr W. Stark for GC-MS determination and Dr K.E. Murray for field desorption MS and electron impact/desorption MS examination and Mr J.W. Creffield, Mr P.J. Robinson and Dr J.R.J. French for termite bioassays. Elementary analyses were done by the Australian Microanalytical Service.

FURTHER DEVELOPMENTS ON BRUCISING
SEMI-COMMERCIAL SCALE EXPERIMENTS WITH IMPROVED EQUIPMENT

T. A. Hawkins and J. H. Foxton

INTRODUCTION

In the treatment of hardwood rail sleepers, preservative penetration, even at high pressures, is largely confined to the vessels. Case or envelope penetration can be improved by incising the sleeper surfaces to a uniform pattern, thereby severing vessels and increasing the number of pathways open to the ingress of preservative.

It has been suggested that optimum results are probable if the incising blades are at an angle to the grain such that the maximum number of vessels will be severed at each incision. However, the stresses involved in incising dense Australian hardwoods this way would be considerable and a machine, sufficiently robust to efficiently produce an acceptable result during continuous commercial operation, is not available. Conventional machines, incising parallel to the grain, tend to part rather than sever vessels, and, as such, are considerably less effective than would be a machine operating on the above principal.

Recognising the shortfalling of conventional incising practices DBR/CSIRO technical personnel evolved, on an experimental scale, an improved system for the pretreatment modification of large section hardwood timbers. Aptly named 'brucising' to convey an impression of what it entailed, i.e. a combination of bruising and incising of the sleeper surface, the desired rupturing of the vessels was effected by passing the sleepers, under heavy load, over a roller fabricated from a series of blunt toothed transmission chain sprockets (Dale 1975).

Initial trials with green karri and jarrah sleepers indicated merit in this approach to surface preparation when, following Boultonising in creosote, the sleepers reportedly evidenced promising results in terms of improved uniformity of preservative penetration, 84 such sleepers are currently undergoing track testing in Pilbara iron ore lines.

It was considered that the prototype brucising roller could be improved upon. Further work by the CSIRO resulted in a 33% increase in sprocket tooth radial depth and a 50% increase in pitch of the teeth, i.e. the distance along the grain between incisions.

To facilitate testing of the improved machine, the equipment was transferred to a commercial sleeper treating complex where, in a co-operation project involving the CSIRO (supply of machinery), NSW Railways (supply of sleepers) and an industry member (supply of labour and supervision), 369 sleepers of three species were brucised.

MATERIALS AND METHOD

The Wood — Railway sleepers to the requirements of a New South Wales Transport Commission specification. Dimension 2440 x 230 x 130 mm.

Species

Spotted gum	(*Eucalyptus maculata*)
Blackbutt	(*Eucalyptus pilularis*)
Brush box	(*Tristania conferta*)

Condition Green

Treatment Schedule Variants

(1) 17 hour Boulton treatment of green material followed by 60 minutes at 1380 kPa hydraulic pressure. 40 minutes final vacuum.

(2) Air seasoning (after brucising) to a moisture content of not more than 25% at 15 mm below surface. Vacuum pressure schedule involving 1380 kPa hydraulic pressure to 'refusal' + 30 minutes'. 40 minutes initial and final vacuum.

Brucising Roll

22 x 245 mm diameter sprockets clamped together on a 150 mm diameter central shaft. Each sprocket with 20 teeth of 35 mm pitch. Radial depth of teeth 18 mm. Alternative sprockets staggered x ½ tooth pitch. 13 mm lateral clearance between rows of teeth.

Working Pressures

23150 kPa - 46300 kPa.

RESULTS AND DISCUSSION

From the onset of the work, a high frequency of stripping, i.e. tearing of the wood from the sleeper surface necessitated many changes from the format of the original experimental design.

Such stripping occurred only on the heartwood face of a sleeper and invariably originated from the source of an existing defect such as a minor gum vein or old termite gallery.

The problem stemmed (1) from the very high pressure - in excess of 460000 kPa - required to gain full 18 mm depth of tooth impression, and (2) the close proximity laterally of the rows of teeth. A flaw in the sleeper surface would result in loose wood being tightly compressed into the narrow channels between the individual rows of teeth (sprockets); this initial lifting of wood would then manifest itself in a snowballing effect in which large areas of the sleeper surface were quite literally rolled up, or off, to the full depth of tooth impression.

Attempts to obviate the problem by continuous spray application of soluble oil to the roller surface were unseccessful and it was eventually necessary to resort to extensive modification, i.e. the removal of alternate rows of teeth, in order to complete the trial.

Prior to the modification, 90 sleepers (62 spotted gum and 28 blackbutt) were brucised with the full complement of roller teeth. It must be emphasised that the overall pattern of tightly spaced tooth indentations, particularly on the sapwood and radial faces which were not prone to damage of the type outlined above, was completely effective in achieving the projected result - that is, the massive rupturing of vessels at regular intervals along the sleeper surface to a depth of 10 mm.

In assessing the surface damage it should be understood that the prototype brucising machine is a fairly rudimentary piece of equipment fabricated from a hydraulic workshop press. It possesses only a single brucising roll and, necessarily, each sleeper must be passed four times (each time under considerable load) through the machine in order to process all faces. It is probable that this repetitive subjection to high pressure contributed to some extent to surface damage of the type described. A commercially viable machine would be required to process all four faces in a single pass and it is probable that this attribute, coupled with improved mechanical design, could be used to advantage in largely overcoming the problems encountered in these early trials.

The roller modification referred to earlier entailed the removal of alternate sprockets, thereby effectively doubling the lateral clearance between rows of teeth. Though this modified tooth configuration departed to a large extent from the original concept of brucising, the tightly pitched, evenly spaced rows of blunt teeth still produced a surface identation pattern of considerably greater intensity than that achieved by conventional incising equipment.

The pressure (23000 kPa) required to maintain full 18 mm depth of tooth penetration was considerably less and there was no recurrence of the surface damage encountered earlier. A further 279 sleepers (100 spotted gum, 150 blackbutt and 29 brush box) was processed using the modified brucising roller.

Double brucising, i.e. processing each sleeper face twice in an effort to simulate the intense tooth pattern produced by the original roller, was largely unsuccessful due to the ungovernable tendency of the sprocket teeth to relocate in the original tooth indentations. However, the scope available for a brucising unit utilising rollers in tandem, or a similar mutliple roller design, is readily apparent and it is probable that future development will be influenced in this direction.

All Boultonised sleepers were treated with a 70:30 creosote/petroleum oil blend. The treatment results have not yet been fully evaluated but visual assessment, based on sections cross-cut from randomly selected sleepers, indicates that sleepers brucised with either tooth pattern show deep preservative penetration and uniformly good distribution.

Analysis of cores extracted from the centre of the upper surface of the same sleepers indicates a very high level of preservative uptake. It is probably that the final report on the project will demonstrate that the standard of treatment attained in both groups of test sleepers is superior to that achieved by ordinary incising methods.

Brucised sleepers set aside for air-seasoning are now approaching the required moisture level for conventional vacuum-pressure treatment.

A number of sleepers have been submitted to the Public Transport Commission of N.S.W. Mechanical Branch Laboratory, for extensive physical evaluation. It is anticipated that the tests will place particular emphasis on the resistance of the brucised zone to shear under lateral load. Railway engineers have speculated on the possibility of failure in track situations due to the severe mechanical disruption of the sleeper surface during the brucising process.

Completion of the strength tests will facilitate final testing of the remainder of the sleepers, when, with the co-operation of the N.S.W. Railways, it is planned to install groups of brucised sleepers in main line tracks at two climatically different locations in New South Wales.

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COMMERCIAL PLANT SCALE EXPERIMENTAL TREATMENTS
BRUSH BOX SLEEPERS

T. A. Hawkins and J. H. Foxton

INTRODUCTION

Brush Box (*Tristania conferta*) forms a substantial part of the Forestry Commission N.S.W. management plans. It must necessarily be removed from forests and therefore carries low royalty. The high availability of the species, surplus to foreseeable market requirements, suggested that if satisfactorily treated it could provide a massive sleeper resource for export and extend the species range for N.S.W. and Queensland Railways.

In 1961, a small number of brush box sleepers were Boultonised, followed by pressure impregnation at 1000 psi and installed at two sites in Queensland. One site was at Deeral in the wet tropical north with an annual rainfall of 400 mm. The other was at Melton, a Brisbane suburb. After 17 years in the track at Deeral, Boultonised brush box has shown excellent results, far superior to untreated iron bark (*Eucalyptus crebra*) or spotted gum (*Eucalyptus maculata*) used by Queensland Railways and has also withstood a derailment. At Melton, although not performing as well as the northern site, the performance can be regarded as better than untreated spotted gum and not to be ignored as an alternative to current species. In studying any results of this experiment it must be remembered that the treatment was carried out using 1000 psi. It was also found that the only satisfactory method of incising was to operate on green timber (Barnacle 1979).

Interest evinced by N.S.W. North Coast Sawmillers resulted in the initiation of a small scale trial aimed at producing reliable data on the performance of brush box sleepers processed during Boulton type treatment schedules of varying intensity.

The following presentation does not purport to be in any way definitive, but it is felt the importance of the subject is such that a progress report to date should be set out and this aim is the purpose of the paper.

MATERIALS AND METHODS

78 sleepers were mill cut from 12 logs harvested in the Grafton area 1-5 months earlier (representing the normal period of yard stockholding). Sleepers converted from each log were systematically identified but attempts to identify the position of individual sleepers within the log were largely negated due to the nature and speed of the sawing operation.

Each sleeper was incised on all faces (12 mm depth) to a standard commercial incising pattern. Sleeper plate holes were drilled prior to treatment and template patterns recorded on select sleepers as an aid to determining the extent of hole movement/distortion resulting from prolonged exposure to high temperatures during the Boulton process. A 175 mm x 75 mm gang-nail plate was applied to one end only of each sleeper.

Average sleeper moisture content, determined immediately before treatment was 64% at 15 mm below the upper tangential surface (range 57% - 77%).

The wood was divided into three groups (each of 28 sleepers) for treatment;

each group was subjected to a Boulton type pre-conditioning period of different intensity (with regard to time) i.e. mild - 10 hours, moderate - 14 hours and severe - 17 hours. Preservative temperatures were maintained in the range of 100-115°C for the duration of each Boulton period. Standard pressure impregnation cycles - 60 minutes at 1380 kPa hydraulic pressure followed by 30 minutes of vacuum at -85 kPa, completed each schedule variant.

All sleepers were treated with a 70:30 creosote/petroleum oil blend conforming to the N.S.W. Railway specification for impregnation of blackbutt (*Eucalyptus pilularis*) and spotted gum (*Eucalyptus maculata*) rail sleepers.

Note: Each of the three schedules outlined above is commonly utilised at a commercial level for the treatment of eucalypt sleepers; each group of test sleepers was therefore included with a larger group (charge) of other species being routinely processed for stock requirements.

RESULTS AND DISCUSSION

Following treatment the sleepers were stripped out and examined for evidence of process degrade, i.e. splitting and warping. All the wood was noted to be sound with no discernible difference in surface condition being evident between any of the three (Boulton intensity) groups. Such checking as had occurred was minor and comparable in degree to that generally encountered in other sleeper species processed by this method.

End splitting was not in evidence. It is probable that any benefits of the end-restraint (gang nail) system will become more apparent during track testing. Spike hole movement or distortion was negligible and rail plates were fitted without difficulty to sleepers during subsequent physical testing.

Five sleepers from each schedule type were delivered to the Public Transport Commission of N.S.W. mechanical testing laboratory for modulus of rupture and spike withdrawal testing. Similar numbers of spotted gum and blackbutt sleepers, in both the treated and untreated state, were included for comparative testing.

600 mm deep wedges were cut from the ends of randomly selected sleepers to permit an initial assessment of preservative penetration and distribution. A 19 mm diameter core removed from the upper central section of the same sleepers failed to provide adequate material for meaningful analysis for retention.

At the time of writing, cross-sectional biscuits recovered from sleepers destroyed during strength tests, are undergoing detailed laboratory assessment. Retention analysis will be in accordance with AS 1605, Method 401.

Not unexpectedly (the species is rated very refractory) preservative penetration evidenced by sleepers processed in the mild (10 hour) Boulton schedule was unsatisfactory, i.e. it did not consistently meet the minimum requirement specified by N.S.W. Railways for the preservative treatment of other sleeper species.

Preservative penetration and distribution achieved in both the intermediate (14 hour) and severe (17 hour) schedules did appear to be acceptable, however, and it is anticipated that laboratory examination of the aforementioned sleeper sections will support this visual assessment.

As yet the results of the tests have not been fully evaluated but available evidence suggests that the performance of the brush box sleepers will compare favourably with that of the control species. In co-operation with the N.S.W.

Railways, installation under test conditions in high axle load track of a number of sleepers, will complete the initial stage of this small scale test programme. It is further anticipated that information forthcoming from this early test will facilitate the planning of a more comprehensive project leading to the eventual acceptance and utilisation of brush box for sleeper production.

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THE DEVELOPMENT OF A PRE-APPLIED BARRIER FOR TREATED HARDWOOD POLES (THE GRAFTON POLE STUB TRIAL)

By T.A. Hawkins and J.D. Price

1. INTRODUCTION

This small scale trial was designed as an aid to the development of a simple cost effective 'barrier' for application to preservative treated hardwood poles prior to installation. The intended purpose of such a barrier would be to delay colonisation by decay organisms particularly of the Soft Rot type.

The systems evaluated were basically 'physical' barriers fitted closely to the pole surface for the half metre of its length from the groundline down. Several variants on this principle were involved, some purely mechanical, others incorporating recognised non-diffusible wood preservatives.

After an exposure period of 26 months sample plugs were withdrawn from beneath the barrier on one stub representative of each of the barriers tested. These were subjected to a quantitative cellulose enzyme activity test (1) for the purpose of comparing their effectiveness with each other and controls. On the basis of this test all of the systems trialed appeared to provide some degree of protection against colonisation by fungi with wood decay potential.

2. EXPERIMENTAL DETAIL

2.0 Site

On land in the Grafton (NSW) area occupied by a Wood Preservation plant the site is on sloping ground adjacent to a small creek and located to be completely removed from the operations area and free of any risk of becoming contaminated by chemical contamination.

The soil is clay covered by a 150-250mm layer of sandy loam, cattle are pastured on the site and all grass is short cropped.

2.1 Timber

Spotted Gum (E.maculata) treated with the Copper Chromium Arsenic preservative 'Tanalith' CA (see AS1604 - 1974, Appendix A, Table A2) except for a small number of untreated stubs of high natural durability.

Dimensions were 2.5 metres long with small end diameters in the range 200-300 mm.

2.2 Barrier Types and Materials

N.B. The numbers in brackets in the Summary below indicate the number of stubs used for each type.

2.2.0 X Linked Polyethylenes (ex Raychem)

1.0	Untreated	(6)	Whole Sleeve	(3)
			Tape	(3)
1.1	Treated	(6)	Whole Sleeve	(3)
			Tape	(3)

2.2.1 Other Mechanical Only Barriers

3M Tapes

Tape X	(6)		
Single	(3)	- With primer	(2)
		- Without primer	(1)
Double	(3)	- With primer	(1)
		- Without primer	(2)
Tape Y	(6)		
Single	(3)	- With primer	(2)
		- Without primer	(1)
Double	(3)	- With primer	(1)
		- Without primer	(2)

Other Tapes

Beiersdorf self Vulcanising	(1)
Beiersdorf Foil-backed	(1)

2.2.1 Cont'd.

Tar Enamels and Brush On Sealants

Koppers CA 50/CO Tar Enamel (3)
Koppers CA 50/HO Tar Enamel (3)
3M Flexible Waterproof Brush On Sealant (3)

2.2.2 Chemical/Mechanical Barriers

The 'chemical' portion of the barrier was created with the aid of Wettex (a proprietary cellulosic absorbent in sheet form). The preservative formulation used was applied either to the Wettex or the pole surface before its application. The materials used were:

High Temperature Creosote AS1143-1973 type (3)
Koppers Timber Protective 'HD' (2) Cream (3)
A 5% Process Oil Solution of Pentachlorophenol (3)

2.2.3 Oxy-Char Variants

Oxy Char (2)
Oxy Char + HT Creosote (2)
Oxy Char + 5% PCP/Oil (2)

2.2.4 Controls

Stubs comparable in terms of timber species preservative type and treatment history to those used for testing systems.

3. APPLICATION

All treatments were applied to the pole surface prior to installation. The following notes detail observations made during application of these treatments.

3.0 XL Polyethylene Sleeves

Some difficulty was encountered in maintaining a uniform pattern of heat application under outdoor conditions with resultant uneven initial shrinkage and a substantially higher time/gas consumption than was originally anticipated. However, minor improvements to equipment, together with additional experience in application techniques would probably greatly improve the above performance.

3.0 Cont'd.

XL Polyethylene Tapes

As above with the observation that the shrinkage ratio is lesser than in the XL sleeves and visual assessment of the point at which all 'cold pockets' of unreacted bituminous adhesive have been eliminated is difficult.

N.B. (A measurable degree of longitudinal shrinkage was observed during application of the XL sleeves. This was not apparent in the XL tape).

3.1 Other Mechnical Only Barriers

3M Tape X (Yellow Plasticised PVC)

A flexible tape easily applied over uneven contours. Adhesion was poor when the tape was applied directly to the pole surface. An excellent bond was obtained on surfaces pre-coated with 3M primer.

3M Tape Y (Grey Polyester)

A rigid inflexible tape which proved difficult to apply with any degree of neatness to uneven surfaces. Adhesive qualities were similar to Tape X.

Beiersdorf Self Vulcanising Tape

A pliable tape forming readily to uneven contours of the pole surface. Adhesion between timber and tape was good. The excellent self adhesive properties of the tape ensured a close-fitting impervious bandage.

Beiersdorf Foil Backed Tape

Easily applied though not as flexible as the above product. Adhesion to the timber surface was good and there was firm contact between adhesive facing and foil backing when bandaged around the pole. Slight damage incurred during installation in the post hole was readily repaired by finger pressure re-moulding of the punctured area.

3.1 Cont'd.

Tar Enamels CA 50/CO and CA 50/HO

Although of different formulation the physical appearance, adhesive qualities and application techniques were identical and both barrier treatments are therefore described under this one heading.

The medium viscosity enamels were applied cold by flood brushing along the area to be treated. This coated area was then overwrapped with a single layer of fibreglass bandage. The above application was repeated with a second coating of tar enamel/fibre-glass bandage (see footnote) and finalised with a third coating of tar enamel. Following installation in the post hole the treated section of the pole was left uncovered for 48 hours prior to backfilling in order to facilitate drying.

3M Flexible Sealant

An extremely viscid product. The supplier had recommended that it be applied with a roller but this was found to be impractical on a checked and uneven pole surface. The sealer was smeared on with a stiff brush and the resultant thick coarse coat was touch dry in 24 hrs. (Manufacturer recommends 24-72 hrs. drying period).

3.2 Chemical/Mechanical Barriers

Wettex,Pre-soaked in Creosote and Oil/PCP

Readily absorbed these preservatives yet remained reasonably clean to handle. Preservative uptake into the Wettex was not calculated but was such that 'bleed' stains beyond the perimeters of the bandage were visible soon after application of the Wettex to the pole. 'HD' cream was applied liberally to the timber surface prior to wrapping with Wettex and again buttered thickly on to the outer surface of the Wettex bandage (refer photographic record for detail).

3.2 Cont'd.

The Wettex bandage was overwrapped with 3M Tape Y (see Footnote 1). The tape would not adhere to the saturated Wettex but by heavily overlapping a double layer of tape a reasonably serviceable envelope was obtained. Following installation of the post the bandage was trimmed to approximately 50mm above ground level and resealed with an overlap of 3M Tape X and a single coat of 3M Primer.

3.3 Oxy-Char Variants

The pole surface in the critical half metre zone from groundline down was charred to a depth of approximately 6mm.

Oil/PCP and Creosote were applied to the requisite number of poles by flooding liberally over the charred area. This operation was carried out away from the post hole with care being taken to ensure that preservative, other than that adhering to the test piece, did not enter the post hole or contaminate the earth used in back-filling.

The system did not include the use of any form of overwrap to form a barrier between soil and stub.

4. INSTALLATION

4.0 Forty two (42) of the eventual total of 55 stubs were installed September 17, 1976, the balance as below were installed two months later on November 12.

Controls	(5)
Beiersdorf Tapes	(2)
Tar Enamels	(6)

See attached Appendix A for the Schematic Site Layout Diagram.

4.1 All post holes were excavated to a depth of 900mm.

4.2 All posts were set at 2,700 mm spacing between posts and between rows.

4.3 Pole caps were not fitted to test posts.

4.4 The limited number of test poles did not allow for satisfactory positioning by random selection. Instead, the test pieces were selectively installed in such a manner as to give the various barrier treatments equal exposure to soil conditions at varying positions within the relatively small test area.

4.5 During restoration of the test area earth was banked above the groundline perimeter of each pole to allow for possible settling of the soft ground. Following a period of initial settlement, a final site inspection was made and ground levels adjusted to eliminate any exceptional factors likely to reduce the likelihood of obtaining comparative results.

4.6 Identification was by means of numbered aluminium discs affixed approximately 450mm below the pole top.

5. EVALUATION OF RESULTS

At the commencement of the project the matter of how its progress should be monitored and the efficacy of the variation systems compared had not been resolved. This was mainly because at that time there were no reliable methods available for the purpose. It was thought that it might be possible to detect early breakdown by relative degree of softening and microscopic methods and that in due course gross visual differences would become apparent.

Fortunately at an early stage in the life of the project, workers doing research on Soft Rot at the University of Tasmania (1) offered to subject representative samples to their recently developed Cellulose Enzyme Assay. Accordingly samples were taken from one stub from each system group and submitted to the Cellulose Enzyme Assay. The attached Appendix B is an almost exact replica of the University's report on the results.

6. CONCLUSIONS

Two years is a comparatively short period of exposure in a trial of this nature therefore the results at this stage cannot be regarded as conclusive. They do however contain some interesting indications.

For example the presence of tough close fitting cross-link Polyethene sheaths on two untreated naturally durable stubs did not prevent extensive colonisation.

The Copper Chromium Arsenic treated controls also showed evidence of penetration but most barrier types appear to have inhibited it to some extent when applied to this substrate even the XLPE shrinkwrap.

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THE DEVELOPMENT OF A PRE-APPLIED BARRIER FOR TREATED HARDWOOD POLES

THE GRAFTON POLE STUB TRIAL

APPENDIX A

SCHEMATIC SITE LAYOUT DIAGRAM

Railway Line

43 X Control	44 X Control		
42 3M Flexible X Sealer	22 Treated Whole X Sleeve	21 3M Flexible X Sealer	1 Untreated X Whole Sleeve
41 Creosote X Wettex	23 Treated Tape X Sleeve	20 PCP X Wettex	2 Untreated X Tape Sleeve
40 PCP X Wettex	24 Tape X Single X Wrap + Primer	19 HD X Wettex	3 Treated Whole X Sleeve
39 HD X Wettex	25 Tape Y Single X Wrap + Primer	18 Creosote X Wettex	4 Treated Tape X Sleeve
38 Treated Tape X Sleeve	26 3M Flexible X Sealer	17 Tape Y Double X Wrap - Primer	5 Tape X Single X Wrap + Primer
37 Treated Whole X Sleeve	27 PCP X Wettex	16 Tape X Double X Wrap - Primer	6 Tape Y Single X Wrap + Primer
36 Untreated Tape X Sleeve	28 HD X Wettex	15 Tape Y Double X Wrap + Primer	7 Tape X Single X Wrap - Primer
35 Untreated Whole X Sleeve	29 Creosote X Wettex	14 Untreated * X Tape Sleeve	8 Tape Y Single X Wrap - Primer
34 Tape Y Double X Wrap - Primer	30 Tape Y * Double X Wrap - Primer	13 Untreated X Tape Sleeve	9 Tape X Double X Wrap + Primer
33 Oxy-Char X	31 Oxy-Char X + Creosote	12 Oxy-Char X + PCP	10 Oxy-Char X
32 Oxy-Char X + PCP	45 Enamel HO X	46 Beiersdorf X Foil Tape	11 Oxy-Char X + Creosote
47 Control X	48 Beiersdorf X S.V. Tape	49 Enamel CO	50 Control X
51 Enamel CO X	52 Control X	53 Enamel HO X	
54 Enamel HO X	55 Enamel CO X		

Creek

THE DEVELOPMENT OF A PRE-APPLIED BARRIER FOR TREATED HARDWOOD POLES

CELLULASE ENZYME ASSAY ON SAMPLES FROM THE GRAFTON POLE STUB TRIAL

APPENDIX B

Treatment	Stub No.	Percent Degradation of CMC[1]		Percent wood moisture (0-2cm)	Fungi Present[2]
Untreated with shrinkwrap sleeve	1	27.8	26.4	32	Paecilomyces sp.(P)
Untreated with shrinkwrap tape	2	25.0		52	P + Penicillium sp. (Pen.) + Phialophora mutabilis (P.m.) + Trichoderma sp. (T)
CCA controls	43	4.3	6.2	26	P + Pen.
	44	8.9		30	P + Pen. + P.m.
	47	4.8		28	P + Pen. + T + Altern.
	50	10.9		37	P + Pen. + P.m.
	52	2.2		42	P + P.m. + T
CCA + shrinkwrap sleeve	3	1.5	1.8	18	P
CCA + shrinkwrap tape	4	2.2		32	P + T
CCA + tape X no primer, 1 wrap	7	1.0	2.3	30	P + Pen. + Sporothrix
2 wraps no primer	16	5.8		36	P + Pen. + T
2 wraps + primer	9	<1.0		23	P + Pen.
1 wrap + primer	5	1.5		20	Pen. + P
CCA + tape Y no primer, 1 wrap	8	1.5	1.2	24	P
2 wraps no primer	17	<1.0		27	P + Pen.
2 wraps + primer	15	1.5		19	P + Pen.
1 wrap + primer	6	<1.0		22	P + Pen.
CCA + oxy-char	10	2.2		31	P + T
CCA + Char + PCP	(?11)12	<1.0		41	P
CCA Wettex Creosote	18	0.0		45	P + Pen.
CCA Timber Protective 'HD'	19	0.0		40	P + Cladosporium + Epicoccum
CCA + 5% PCP/Oil	20	0.5		38	P + Pen.
CCA + 3M Flexible Sealer	21	<1.0		25	P + Pen.
CCA + Beiersdorf Tape	46	0.0		22	P + Pen.
CCA + Beiersdorf Vulcanizing Tape	48	2.6		28	P + Pen.
CCA + KAP Enamel CO	49	<1.0		27	P
CCA + KAP Enamel HO	54	1.6		27	P + Pen.

[1] Carboxyl methyl cellulose (0.4%) in 0.1M sodium acetate buffer was incubated a 45°C for 1 hour with 0.3g (wet weight) sawdusted wood (0-2cm depth), in duplica for each core sample. Percentages given indicate the average cellulase activity for the two core samples/pole. No account has been taken of moisture content i the percentages listed.

[2] Listed in order of predominance.

CURRENT ACTIVITIES AND FUTURE NEEDS IN SAWING RESEARCH

E.P. Lhuede

1. INTRODUCTION

It is five years since McKenzie (1) at the 17th Forest Products Research Conference (FPRC) discussed aspects of research related to sawing technology. In the intervening period no specific investigations in the CSIRO Division of Building Research (DBR) have been conducted and/or reported relating to sawing research; however, as a consequence of extensive industry contact resulting from studies of noise in sawmilling, a background of data and observations has been acquired relating generally to aspects of saw performance and saw doctoring. It should be recognized that sawing research has proceeded at the N.S.W. Forestry Department, Division of Wood Technology (2) on aspects of blade life, also at the University of Adelaide on saw noise (3) and in numerous institutes.

The purpose of this paper is to survey progress in the area and to define those topics where further work could be undertaken without duplication of effort, and which may provide some measure of economic or social pay back to the timber industry and workers in that industry.

2. DISCUSSION

Of a number of aspects of both circular and band saw performance in soft and hardwoods three stand out as being amenable to and warranting some levels of scientific investigation. First, there is the continuing problem of the loss of product due to the width of the saw cut (kerf loss); secondly, there are difficulties associated with maintaining the stability of saw blades during cutting, and finally, the noise generated by saw blades both while cutting and not-cutting constitutes another important current problem in the sawmilling industry.

2.1 Circular saws

The kerf loss associated with circular saws is clearly related to stability considerations. Long experience, particularly in the hardwood industry, has shown that with the methods normally used by the industry a minimum thickness of blade and a specified side clearance will be necessary to achieve accurate and straight cutting. For instance, the saw used on a No. 1 resaw bench, which is probably the most widely used saw in the hardwood industry is approximately 1 m dia. and is normally 3.76 or 3.40 mm (i.e. 9 or 10G)

minimum thickness with 0.5 - 0.6 mm set. The methods of achieving stability on such saws are well understood, but some of the best technology available to the industry is not used to any marked extent in achieving this stability. Roll tensioning, which might be expected to produce precise deformations in a saw blade surface, with a predictable degree of tension in the periphery of the saw, is not widely used in the Australian hardwood industry. The tried and trusted method of hand hammering is still the most commonly practiced tensioning procedure and relies largely on the experience of saw doctors for its success. It is not considered likely that any major reduction in saw kerf will be achieved through advances in hammering technology. Research related to roll tensioning has been fully reported and work continues in some laboratories and, while it is possible that reductions in saw kerf might derive from its wider use, some hand hammering will always be required. The work of McKenzie and Heath (4) which was discontinued in the early 1970's was a useful local contribution to this topic.

Further investigation of roll tensioning and the transfer of this technology to the industry could provide two useful results:

(a) As the technology becomes better understood by the industry, saw doctors may be able to effect some reduction in kerf without sacrificing accuracy, and

(b) Reduction in hand hammering of blades would reduce the noise levels to which saw doctors are exposed. Such levels have been measured at 93-97 dBA.

Another aspect of achieving greater stability of circular saws relates to the use of improved guiding systems in conjunction with a floating mounting on the shaft. Saw collars which could move axially along the saw shaft (floating collars) were adopted by some hardwood sawmillers three to four years ago but appear to have been discarded by the industry generally, with one or two exceptions. More recently the introduction of advanced designs of multi-saw edgers to the Australian softwood industry using collarless saws on a fluted shaft, with wide area water lubricated guides has further demonstrated some advantages with such systems. These saws are 660 mm dia., of 2.2 mm (0.087") thickness, swage set to 3.18 mm (0.125") total width. Such saws might reasonably be regarded as being competitive with band saws for cant resawing.

Other overseas manufacturers are currently advertizing developments of collarless saws used in conjunction with water-cooled pressure guide pads (5). The possibility of using wide area guides with water cooling or with air as a lubricant (air bearings) to improve stability is not a new concept but the technique does not appear to have been widely used or investigated locally to

date. Further application of the basic concept to the hardwood saw bench warrants consideration.

The range of studies carried out over the last 20 years on saw blade stability are voluminous; the reviews by Mote and Szymani (6 & 7) list over 150 references to work carried out over this period of time and further work is still in progress on such aspects as feed back control of saw vibration (8). With this extensive background of work it is perhaps surprising that circular saw kerfs in hardwood conversion in Australia, have not, over the same period of time been reduced by more than one gauge thickness. Circular saw stability studies are in general amenable to mathematical treatments and much of the work has been of an academic nature. However, further developments might be more reasonably devoted to an experimental evaluation of a range of practical suggestions (4).

2.2 Bandsaws

A bandsaw has one major advantage in comparison to the circular saw, namely that it generally has a lesser kerf and both hardwood and softwood millers recognize this fact. The high strain bandsaws were introduced to obtain a further reduction in saw kerf and the saw frames produced to carry the higher levels of strain load are considered to have been better constructed than the older saw designs. There has been some doubt, however, whether the achievement of perhaps a one and possibly two gauge reduction in kerf has been worthwhile (9).

Bandsaw technology, as with circular saws, is extensively documented and Thunell's 1966 Review (10) lists over 480 separate references on band saw preparation and operation. A significant observation is that in the local industry band saws appear to be operated in a variety of situations with no apparent difficulty. If any problem exists it may be with the doctoring or preparation of the saw blade; while specific problems are difficult to identify, situations are encountered where apparently excessive cracking has been observed, and the damaged or discarded saw can be seen in most mill yards. In general, however, the saw doctor for any particular mill quickly develops tensioning practices which will ensure satisfactory performance - sometimes without knowing why his practice is successful. There are a number of comments that can be made; satisfactory tracking of a double-cut band is difficult to explain where flat ground wheels are used and one of the few in use in Australia has flat ground wheels. Advice in literature is often in conflict with practice; a recent publication (11) endorses the advice that has generally been given of grinding wheels at operating speeds with a slight crown while the majority of Australian band saw operators grind to a flat profile. The standard directions for

tensioning are to fit tension gauges of approx. 10-12 m dia. and to achieve back curvature of the blade of 0.25 mm in 1.2 m length; it is interesting to note that some of the most recently installed twins operating in softwoods use straight backed blades, although the tension crown is of the order suggested. This practice appears to have arisen due to the use of overhung wheels but the proposition is not clearly established or appreciated by many saw doctors.

If research work is to be undertaken on band saws, one area could well be in the development of a better understanding of tensioning techniques and principles and a transfer of this technology to saw doctors in the industry. It is very doubtful whether such information would, however, make marked improvements to the cutting rates or accuracy currently obtained. It may, assist with the training and education of saw doctors to some advantage, and, in the long term, improve blade life.

Apart from tensioning considerations (12), it has been suggested that blade instabilities which occur with the band sawing of hardwoods could be remotely sensed and corrected, possibly by reduction in feed speed. This is normally achieved by the sawyer and is one of the reasons for employing experienced and reliable operators on band breaking-down saws. The development of a sensor to obviate the task could be regarded as worthwhile.

2.3 Saw blades and noise

In the last 12-18 months, the major part of the Australian sawmilling and other industry as represented in New South Wales and Victoria has demonstrated increased concern with the protection of workers from noise and/or the reduction of the noise levels produced by machinery.

There are some aspects of saw noise that are directly related to vibration and stability considerations, and have therefore been widely researched. Some of the earliest work referring directly to saw noise was by Cudworth who in 1960 outlined the basic problems for saws of around 450 mm diameter mainly at non-cutting conditions (13). The existence of circular and diametral modes of vibration and the generation of vorticies by the saw teeth was recognised. Stiffening collars, composite blades, dampening material adhered to the blade, radial slots, modifications to the air flow around the saw teeth, and a variety of saw guiding systems were all suggested as means of reducing saw noise. This work is directly applicable to docking and panel saws where diameters are generally less than 500 mm, but to the present time much of this technology has not penetrated the Australian timber or woodworking industry.

Very few investigations have been directed specifically to the cutting noise generated by the 1 m and similar diameter circular saws that are widely used throughout the Australian hardwood industry and which are possibly the major

cause of noise problems in that industry. These saws generate levels of noise about 80-85 dB(A) while not cutting, but up to 110 dB(A) in a 75-100 mm cut in either hardwood or softwood. It is not clear what part of the noise is due to impact of teeth on the wood and what represents saw blade and timber vibrations.

The natural frequency of a disc for a given pattern of vibration can be expressed proportionally as

$$\text{frequency} \propto \frac{\text{thickness of blade}}{(\text{diameter})^2}$$

It is apparent that as a saw of a given thickness increases in diameter the natural frequency is reduced. For the typical circular saws used on resaw benches the general range of critical frequencies can be expected to be well below the operating speeds and this explains the reason for the absence of noise at idling with the larger diameter saws. Mote (6) has elaborated the theory to describe the effect of clamping collars on the range of critical frequencies and indicates that clamping increases the critical frequency above the unclamped condition.

Lhuede and Davern in the 1977 Conference discussed the noise levels produced by band and circular saws and the marked difference in levels of noise for the cutting conditions for these two saw types still needs further clarification. It was indicated also that the major input of noise with the larger diameter circular saws is at frequencies between 800 and 5000 Hz and the assumption is made that such frequencies are in excess of those associated with saw instabilities. Such instability and cutting noise are possibly not related except that if stable cutting can be obtained with thinner saws, noise in cutting may be reduced as a consequence of the narrower kerf.

Noise due to band saws has been suggested as being due to the contact between the wheel and the band and if this is the major cause its reduction poses substantial problems.

3. CONCLUSIONS

A number of areas of research have been indicated where there is a lack of knowledge and/or understanding of saw operation and performance. In some cases there is a need, of varying significance, both in the academic and economic sense, for investigations to be conducted in these areas and this need has existed for a period of years. Some degree of feedback of industry opinion would be desirable in establishing the need and priorities for further work.

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CENTRALISED LOG MERCHANDISING AND ITS EFFECT ON LOG VOLUMES AND VALUES IN THE A.C.T.

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ABSTRACT

This paper describes part of an investigation into the effect a centralised log making facility (merchandiser) may have on the volume and value of log products received from plantation thinning operations.

A substantial increase in the volumes of log products recovered was obtained with the yield of veneer saw, case, and fencelog all being increased. The value of log products recovered from the operations studied was increased by 24%.

A classification into log quality classes indicated that improvements could be made to the quality of the different log products recovered.

These gains are possible because of better information provided by the electronic log scanning, the decision making capacity of the merchandiser and the capacity to handle a greater number of log products.

The results obtained are valid only for the operations studied. Different stands and different logging crews could give different results.

Countering these gains could be increased costs arising from :

- additional transport, depending on the location of the facility in relation to the mill(s).
- the possibility of hauling and processing 'waste' material that may be sold at less than production cost.
- the capital investment associated with the merchandiser.

These aspects will be explored in future studies.

1. INTRODUCTION

This paper describes an investigation into one aspect of the technical and economic implications of changing from the existing logging system used in the A.C.T., to one in which long length material from thinning operations is brought to a central site for conversion into a range of products. Other aspects being explored jointly by Forests Branch and CSIRO's Harvesting Research Group are future round wood markets in the A.C.T., extraction and road haulage implications of the central log site and the design of a small log making installation employing electronic log scanning and decision making components.

The A.C.T. resource consists of approximately 13,000 hectares of P. radiata growing on a wide range of topography. About 20% of the resource is on slopes over 20°. Average haulage distance is about 50 km.

The present logging method involves haulage from roadside to mill in product lengths with a variety of methods of conversion and extraction. In the more accessible compartments trees are felled, limbed and converted into a limited number of log products at the stump and extracted to roadside by forwarder. From the steep sites and some smaller operations on easy terrain, tree lengths and long lengths are extracted by skidder or cable system to roadside where they are converted into a restricted number of log products.

About 85,000 m^3 of logs from thinning operations are supplied to eight different mills in the region of Canberra.

There is currently no market for pulpwood but this situation is expected to change when the Albury pulpmill commences in 1981.

Paradoxically there is a surplus of small log resource and an unsatisfied demand for small logs. The inability to meet demand largely arises from the limited number of assortments that can be recovered and poor log quality control associated with the existing logging systems.

The development of electronic log scanning and decision making systems to accurately measure diameter, length, taper and sweep, and to permit the input of log value and demand considerations, makes it possible to cut a stem into a number of log products with a high degree of quality control. More efficient and profitable use of the forest resource should follow.

This paper describes the work done to establish how both log volume and value would be influenced by such a system.

2. METHOD

Two hundred trees from thinning operations were measured to establish tree and log volumes produced by the faller. These are referred to as 'actual' production volumes. Then the same treeswere theoretically cross cut to give maximum product recovery and to improve the quality of logs produced. This is referred to as 'potential' production volume. Priority was given to the production of veneer log, then saw log, caselog and fencelog, in that order. The log specifications laid down by A.C.T. Forests were strictly adhered to in measuring 'potentially' recoverable volumes.(1)

It is assumed that the 'potential' production would closely approximate the production from a centralised log yard or merchandiser and that a market existed for all products in the proportions produced.

For further details on measurement methods refer to the detailed report presented to A.C.T. Forests Branch. (2) 1979.

3. RESULTS AND CONCLUSIONS

3.1 OVERALL RECOVERY

As would be expected mean CLY Volume*, increased exponentially with Diameter Breast Height over bark (DBHoB) (See fig.1). Likewise the 'potentially' recoverable volume, and the 'actually' recovered volume also rose exponentially with DBH.

However, a very low standard of utilization was 'actually' obtained by fallers in the lower diameter classes. From trees with diameters between 7.5 and 19.9 cm, on average only 44% of the CLY volume was actually utilized under existing cross cutting and logging techniques. 'Actual' recovery did, however improve with increasing diameter, and from trees measured with diameters over 40 cm, 88% of the CLY volume was utilized. (See Table 1.)

*CLY Volume is that portion of the tree which would be carried to a centralised log yard for primary conversion into logs. In practice it is merchantable volume i.e. volume to a 7.5 cm top, reduced by the volume of severe defect, e.g. sweep, breakage, etc.

TABLE 1.
Comparison of Mean Actual and Potential Recoveries, and Recovery Values

IOB ss i)	No. of trees in sample	CLY Volume (M^3)	ACTUAL RECOVERY (M^3) per tree						POTENTIAL RECOVERY (M^3) per tree					
			Veneer	Sawlog	Case	Fence	Total Recovered	Waste	Veneer	Sawlog	Caselog	Fencelog	Total Recovered	Waste
-19.9	63	.101	-	.008 7.9%	-	.037 36.6%	.045 44.5%	.56 55.5%	-	.010 9.9%	.021 20.8%	.54 53.4%	.85 84.2%	.016 15.8%
0-29.9	99	.338	-	.207 61.2%	.005 1.5%	.041 12.1%	.253 74.8%	.085 25.1%	-	.214 63.3%	.056 16.6%	.033 9.8%	.303 89.6%	.035 10.4%
0-39.9	37	.643	-	.511 79.5%	.006 0.9%	.015 2.3%	.532 82.7%	.111 17.3%	.105 16.3%	.422 65.6%	.046 7.2%	.018 2.8%	.591 91.9%	.052 8.1%
0+	13	1.379	-	1.167 84.6%	.048 3.5%	-	1.215 88.1%	.164 11.9%	.500 36.3%	.670 48.6%	.092 6.7%	.001 .1%	1.263 91.6%	.116 8.3%

IOB ss i)	ACTUAL RECOVERY ($) per tree					POTENTIAL RECOVERY ($) per tree				
	Veneer	Sawlog	Case	Fence	Total Recovered	Veneer	Sawlog	Caselog	Fencelog	Total Recovered	Waste
-19.9	-	.120	-	.777	.897	.150	.273	1.157	1.580	+76%
0-29.9		3.431	.070	.878	4.379	3.531	.744	.711	4.986	+14%
0-39.9		10.114	.083	.311	10.508	10.346	.609	.372	11.327	+ 8%
0+		26.396	.635	-	27.031	26.577	1.215	.029	27.821	+ 3%

Corresponding data for the 'potential' recovery were 84% and 92%.

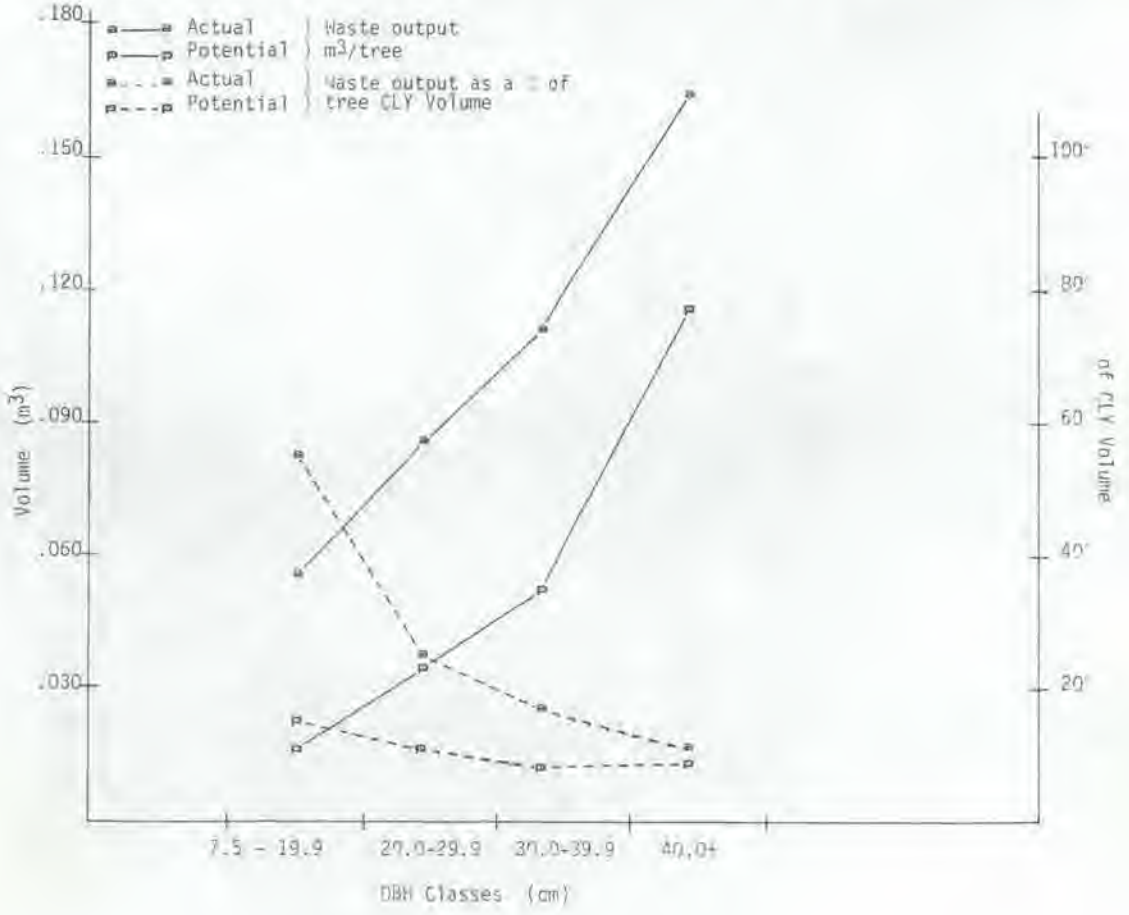
From both the 'actual' and 'potential' log production strategies a portion of the CLY Volume was unutilized, and was classified as 'waste'. (See Fig.2). 'Actual' waste consists of some recoverable log product plus pulpwood. 'Potential' waste consists of pulpwood only. A high proportion of the pulpwood would be in short lengths.

This waste could present a possible disposal problem in a merchandiser or could readily constitute a source of pulpchips or fuel. In the DBH class 7.5-19.9 cm 'actual' waste production was 56% of CLY Volume while 'potential' production was 16% of CLY Volume. However with increasing DBH, waste from 'actual' and 'potential' recovery approached similar proportions, and in the 40cm+ DBH class, the mean 'actual' waste production amounted to 12% of mean CLY Volume, while the 'potential' waste production made up 8% of CLY Volume.

2.2 RECOVERY OF INDIVIDUAL PRODUCTS

Log products considered were restricted to those currently cut from A.C.T. forests. These are veneer log, sawlog, caselog, and fencelog, as defined by A.C.T. Forests Branch.

Fig.2 Waste Output



2.2.1 VENEER LOG RECOVERY

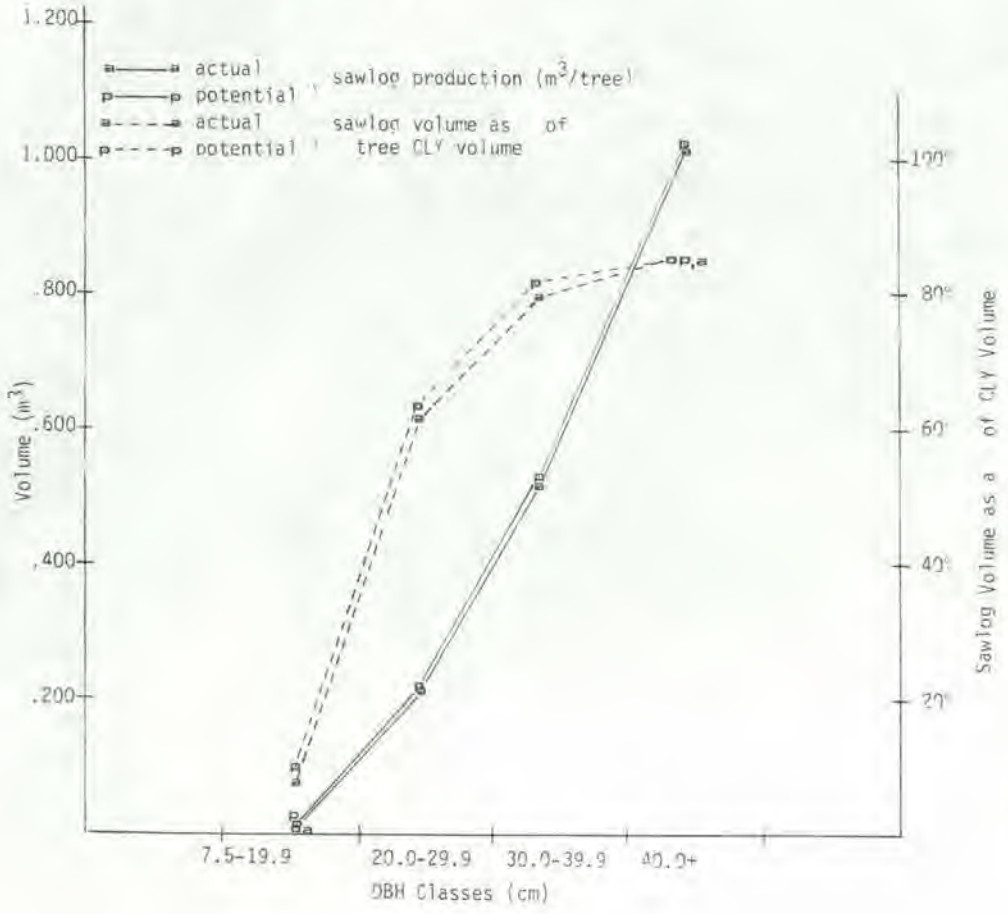
No veneer log was recovered in 'actual' operations. However, as fig.1 indicates, a considerable proportion of the CLY volume from trees over 30 cm DBH was in fact potentially recoverable as veneer log. Overall 16% of the CLY Volume of trees with DBH between 30 and 40 cm was potential veneer log, and this proportion rose to 36% of the total CLY Volume of trees over 40 cm.

At present veneer quality logs from thinnings in A.C.T. forests are sold as sawlog.

2.2.2 SAWLOG RECOVERY

As fig.3 shows clearly, the volume of recoverable sawlog increases rapidly with increasing DBH, both in terms of nett volume, and in terms of the proportion of the tree which is potentially sawlog material.

Fig.3 Sawlog Recovery



The 'actual' production of sawlog by the faller follows very closely the 'potentially' recoverable volume, and statistically the difference was often insignificant. However, in virtually every operation and in every diameter class, the 'potential' recovery was greater. In the larger scale operations, the increase was considerable (up to 12%).

TABLE 2

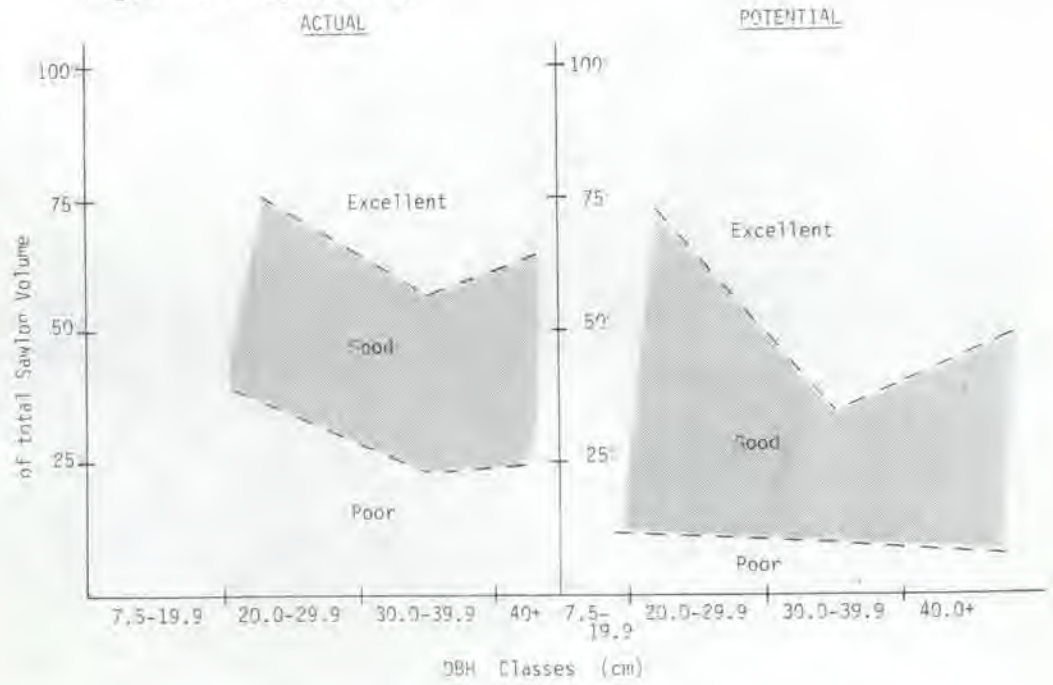
Log Lengths Produced

Length	2.4	2.7	3.0	3.3	3.6	3.9	4.2	4.5	4.8	5.2	5.4	5.7	6.0	Total
No of logs Actual	6	2		5	320									333
(%)	1.8	0.6		1.5	96.1									
No of logs Potential	36	7	19	16	92	4	9	7	62	22	3	1	45	323
(%)	11.1	2.2	5.9	5.0	28.5	1.2	2.8	2.2	19.2	6.8	0.9	0.3	13.9	

Table 2 shows how the range of lengths increased under the 'potential' crosscutting strategy, as compared with the 'actual' operational production. In the former, a wide range of lengths were cut to maximise recovery.

An improvement in sawlog quality is also possible under merchandiser conditions. (See fig.4)

Fig.4 Sawlog Quality

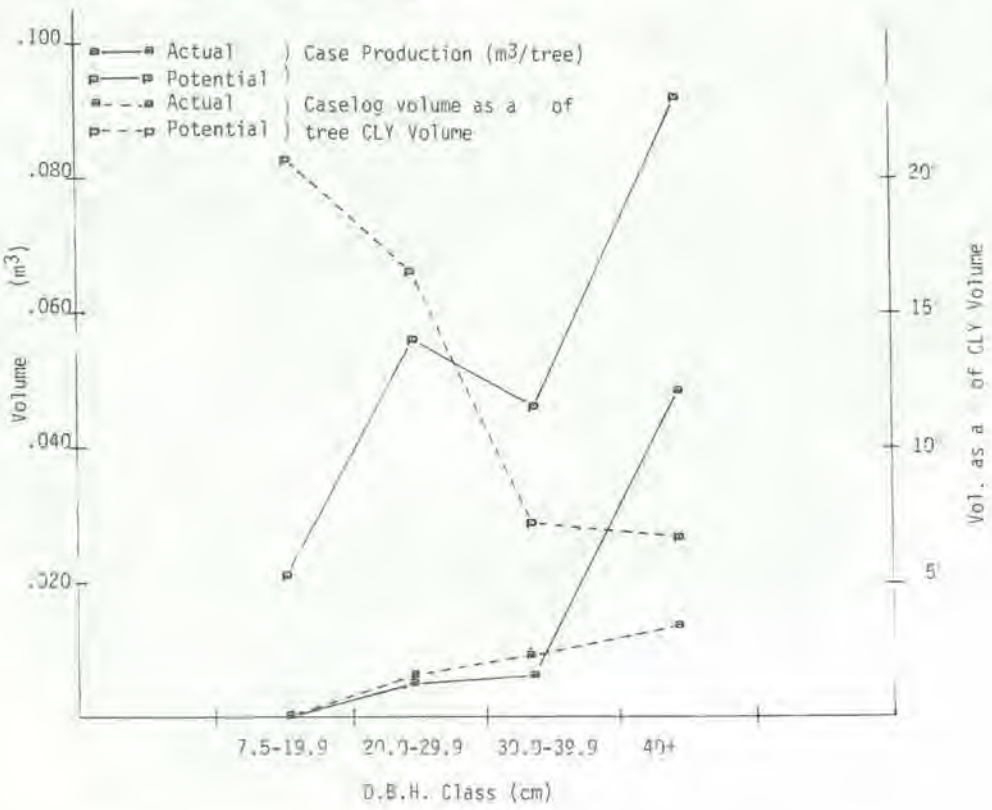


Logs were classified subjectively as 'Excellent', 'Good', or 'Poor'. A reduction in the proportion of 'Poor' sawlog, and an increase in the proportion of 'Excellent' quality sawlog is potentially achievable although to some extent there is a trade-off between quality and recovery. For example, if a lower quality log is produced then greater recovery is obtainable, and vice versa. The actual balance must be a management decision.

2.2.3 CASELOG RECOVERY

An upward trend is evident for 'potential' caselog volume per tree with increasing DBH, despite some irregularities relationship between volume recovered and DBH. The source of these irregularities was not a subject of this study, but from an inspection of the data, it is suspected that this is due to the recruitment of sawlog product from the case material.

Fig.5 Caselog Recovery



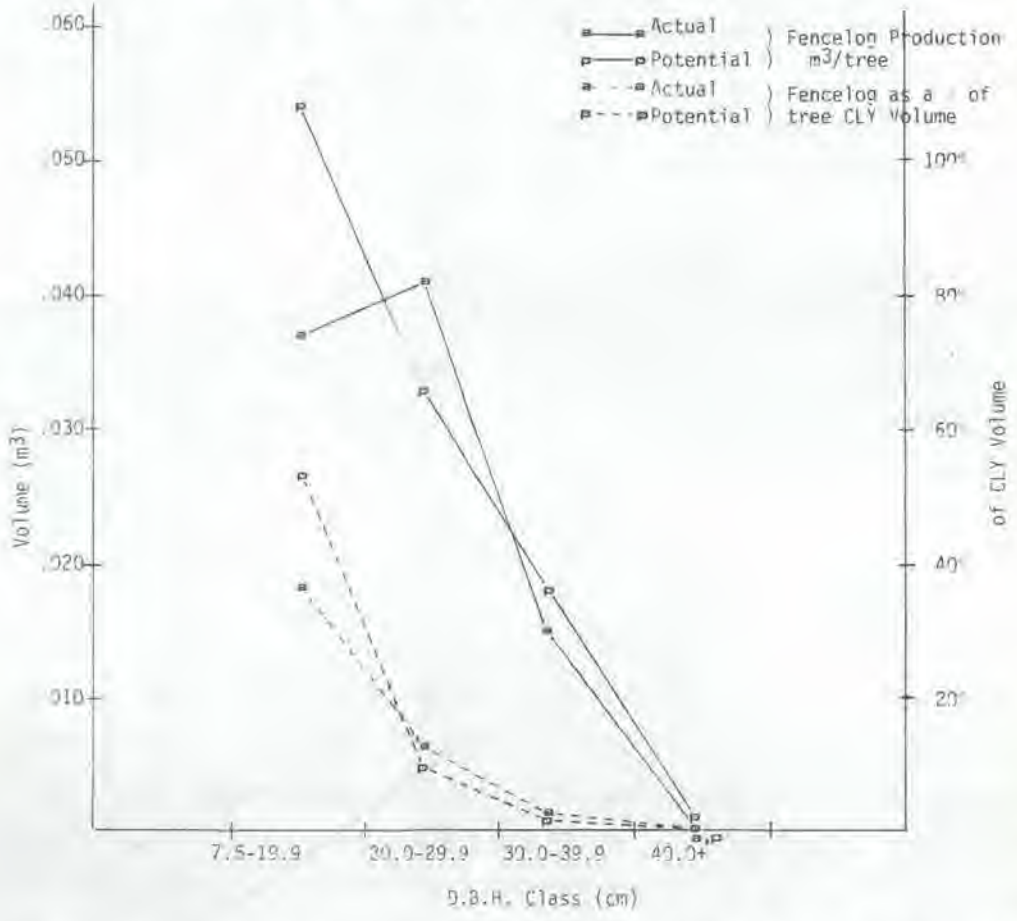
As a proportion of CLY Volume, the volume of caselog is of declining significance with increasing DBH. While 21% of CLY Volume is 'potential' caselog in the DBH class 7.5-19.9 cm, this declined to 7% of CLY Volume from trees with DBH's 40 cm and over.

The caselog portion of the tree is at present generally wasted, particularly in the small diameter classes, as indicated by Fig.5, because 'actual' caselog production was very low in relation to the potential recovery. No caselog was recovered by the fallers from trees in the DBH class 7.5-19.9 cm, but recovery increased with DBH, and 52% of total recoverable caselog was utilized from the DBH Class 40.0 cm and over.

2.2.4 FENCELOG RECOVERY

The volume and proportion of CLY Volume suitable for fencelog declined very rapidly with increasing DBH. (See Fig 6).

Fig.6 Fencelog Recovery



In the DBH class 7.5-19.9 cm, the volume of potential fencelog made up 53% of the CLY Volume, but only 0.1% of CLY Volume in trees over 40.0 cm DBH. In contrast to this result, the 'actual' recovery obtained by fallers was more irregular. 'Actual' recovery was below the 'potential' in three diameter classes,

i.e. 7.5-19.9 cm, 30.0-39.9 cm, and 40.0 cm+. In the DBH class 20.0-29.9 cm actual production per tree exceeded the 'potential' production. This result occurred because a significant part of the fencelog production is from timber which is sawlog by specification. The production of fencelog is mainly obtained by one contractor who concentrates on this product. Hence the tendency to utilize smaller sawlog as fencelogs.

2.3 THE VALUE OF IMPROVED RECOVERY

The value of the additional log volume produced and changes in the proportions of the different log products, was calculated using current A.C.T. log prices. Table 1 shows the average value of each product within trees of various diameters, and also the total average value of each tree.

The greatest increase in recovery value occurs in the 7.5-19.9 cm DBH class (76%) and declines to 3% in the 40.0+ cm DBH class. The bulk of this potentially increased value is due to increased output of caselog and fencelog, with the increase in the value of sawlog being relatively small. It should be noted that both 'actual' and 'potential' sawlog values include the values of veneer output because veneer and sawlog are not differentiated by price.

To convert the average values per tree of table 1, to values for a stand or forest presents difficulties. Depending on stand age and diameter distribution, thinning prescription, stand quality, contractors quotas, faller performance, and market demands for different products, the benefits obtained from maximising utilization will vary.

However if the following assumptions are made, an indication of possible gains can be obtained. These assumptions are (1) the annual cut of sawlog will be 70,000 m^3, and fencelog 15,000 m^3. (2) All annual quotas remain the same relative to each other for one year, and are adjusted to enable the production of sufficient sawlog and fencelog. (3) The trees sampled accurately represent the forest quality and diameter range for all thinning operations. (4) The faller maintains a standard similar to that measured and stays in similar forest and that the operations sampled are representative of all operations. If the above assumptions are made, then the mill door values of actual and potential recovery are as shown on Table 3.

TABLE 3.

Estimate of Volume and Value of Recovery over a 1-yr. Period, Actual and Potential

PRODUCT	ACTUAL		POTENTIAL	
	Volume m^3	Value $	Volume m^3	Value $
Veneer log	-		7384	170,000
Sawlog	69932	1,278,271	70349	1,233,000
Caselog	986	13,064	17613	233,372
Fencelog	14966	319,415	17078	363,761
Waste	39598		13086	
	125512	1,610,750	125510	2,000,133

By far the greatest gain in value is from the increased value of caselog production, however, significant gains also were attained in sawlog and fence-post production. Total increase in mill door value is almost $390,000 per year. It must be stressed however, that this result could vary greatly when any of the above assumptions did not hold.

DISCUSSION

The results of this study clearly demonstrate that in terms of both volume recovery and log quality, the central log yard could substantially improve the utilization of the resource. This effect is particularly marked within smaller diameter classes. Lower output means that returns to the forest owner are not as high as they could be, and Humphreys (1970), and Brown and Miller (1975) have clearly shown how defect (sweep and knots) will reduce the value of logs to the sawmiller.

Assuming a merchandiser can match the 'potential' recovery obtained in this study, and there is evidence to suggest that it can at least do that, the processing of long length logs through a merchandiser would substantially (a) increase volume recovered, and (b) improve log quality.

Some improvement in actual utilization could doubtless be obtained by merely increasing supervision and quality control in the forest and/or by cutting a range of sawlog lengths. To what extent recovery would be improved by these means, is, however, unclear. It is unlikely that the total advantages of a merchandiser could be matched, at least in the smaller diameter classes, but significant improvements are possible.

The advantage of a log merchandiser in increasing volume recovery would appear to decline rapidly with diameters exceeding 40 cm. However it should be noted that in terms of monetary value, the increased recovery from the larger trees is far more valuable per unit of volume than the increased recovery from smaller trees.

Other advantages to be gained through this form of processing are (1) greater control of log standards and quality, (2) increased flexibility of supply e.g. cross cutting procedure could be altered at short notice in response to short term market fluctuations, (3) a lower labour input at a time of rapidly rising labour costs and (4) future markets are likely to be developed for what are currently waste portions of the tree, and a long length logging system could be adjusted readily to accommodate these changes.

Problems however will be encountered. The initial monetary outlay required to establish a merchandiser is substantial and a high volume throughput is required to justify this expenditure.

An assessment of future log product demands is essential prior to investment in a merchandiser. A market for the increased volumes of case, fencelog and waste would be desirable. Pricing policy may need to be changed to encourage the sale of non-preferred lengths of sawlog and fencelog which would be inevitably produced.

Logging and transport costs will change, and as yet insufficient study has been carried out to determine the extent and direction of change.

This paper represents the first look at the feasibility of a centralised log making facility in the A.C.T. It suggests that some advantages would be forthcoming. However, further investigation is clearly required both to increase knowledge of aspects already examined, and to supply information on fields which have not been studied.

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STORAGE OF PINE LOGS UNDER WATER SPRAYS

J.C. Meachem

SUMMARY

Experience in New Zealand (1) is that pine logs can be economically stored under water sprays for upwards of three years without apparent degrade. Limited trials in Western Australia confirm this experience under more rigorous summer conditions and suggest that wet storage of pine logs, in addition to enabling log salvage after fire or windthrow, can become a useful commercial tool for improved flexibility in log procurement, e.g. to cover difficult conditions of winter log supply.

* * *

Prior to 1978 plantation windthrow in Western Australia was negligible. Plantation fire losses were small. No occasion had called for substantial salvage of pine logs and pine log stockpiles required rapid turnover to avoid losses due to fungal blue staining.

In April, 1978 Cyclone 'Alby' caused serious damage in Pinus radiata plantations. Soils were relatively dry towards the close of summer and few trees blew down, but large numbers snapped off at varying heights above the ground. This was in contrast to the more usual experience elsewhere in which most windthrown trees retain sufficient root function to keep them alive for salvage when convenient. Conditions were conducive to 'blue stain', and log salvage quantity, well in excess of the capacity of local softwood sawmills, called for a convenient and economical means of log storage. Moves were made to store logs in dams, but those of any size were remote and presented problems of later log recovery from deep water.

Spray storage was seen as the only prospect for effective salvage. Based on limited C.S.I.R.O. trials in 1964 (2) and on recent successful trials in New Zealand (1), arrangements were made to put salvage logs under water sprays at Greenbushes on the only site which offered electric power and an adequate water source. From the first telecommunication with New Zealand Forest Service (Clifton, Christchurch) a site was selected and cleared and the spray system developed and operational in 6 days. A two stage programme, each to accommodate 7 000m^3 was planned. In the event the first stage proved sufficient for the logs which came forward (5 500m^3). The system, using 'Klip Lok' aluminium pipes, broadly followed New Zealand practice, differing mainly in that -

Topic 4A/4 (ii)

1. Logs were butt ended to produce a consolidated stack, i.e. without access between stack rows. This reduced the cost of spray lines and handling in and out of stack presented no problems.

2. Optimum stack height of 5 metres could not be attained using a fork loader. Approach to stack ends was constrained by the angle of repose of logs. A truck mounted crane would be slower but should achieve full stack height.

3. Spraying was continuous during summer. If the full programme of 14 000m^3 had been attained there could have been advantage in spraying two halves of the log dump on a 20 minute on/off cycle. The rate of delivery was approximately 110 000 litres/hour - from a 30kW electric motor(with diesel backup) and direct coupled 100 mm pump - through 125 mm main - 50 mm spray lines - rotating jet sprays. For a continuing stockpile, i.e. depreciating capital over 10 years, the annual capital cost should not exceed $0.20 per cubic metre (1979), with operating costs at a similar level. (Assumes substantial recycling of water.)

Logs were removed from spray storage to mills over a period of 12 months. At the end of this time no checking, fungal or other degrade was apparent. Bark remained intact but was easy to remove. Sawn recovery was normal and sawing was easier - due to high moisture content and an apparent change in resin properties.

A sample of logs removed from stockpile was checked for moisture loss, onset of 'blue stain' and physical degrade. Mean moisture content of stored logs, at 120%, exceeded the mean of green logs from the same source. Rate of moisture loss in the first 7 days was 30% and thereafter at a mean rate of 3.5% per week to the 6th week. Drying conditions then became less favourable (April/May) and moisture content stabilised.

During the post storage period conditions were favourable to the development of 'blue stain'. Attack by Ips grandicollis became evident after 10 days, with severity in green logs much greater than in wet stored logs. Slight blue stain became apparent in green logs at the 21st day and all such logs were heavily affected at 5 weeks. At this stage only slight blue stain was evident in wet stored logs.

At the end of the trial some barrel checking was evident in stored logs where bark had been dislodged. The trials were limited and further work

will be carried out.

Commercial spray storage trials are now under way by the largest softwood log user in the State.

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THE EFFECT OF LOG SIZE ON THE ECONOMICS OF SAWING REGROWTH EUCALYPTS

G. Waugh

INTRODUCTION

The rapidly diminishing availability of high quality, large diameter logs from mature forests has meant that the hardwood sawmiller is having to become more reliant on small diameter logs from regrowth forests. The smaller diameters, combined with stem irregularities and wood quality problems such as large overgrown knots and growth stresses require a higher degree of grade sawing and have an adverse effect on sawmill production rates and the recovery and value of sawn products. These problems have lead many sawmillers to believe that much of the regrowth eucalypt resource is a doubtful economic proposition (1).

This paper outlines the effect of log dimensions on the profitability of operating sawmilling systems capable of handling small diameter eucalypt logs. The systems which were studied comprised of either a twin circular headsaw and light pony carriage or log edger, both with resaws on which final green dimensioned products were cut. The information presented is based on data collected and analysed from recent productivity (2) and economic studies (3) carried out on three such sawmills. The economic analysis was based on production rates for each mill and the estimated cost of establishing and operating an equivalent sawmill based on costs and green sawn product prices to at May 1975.

RESULTS

Figures 1a and 1b show the relationship between log diameter and production economics for the two types of sawmills.

Total costs have been segretated into three major components:

(a) Materials costs, comprising the mill door cost of sawlogs, transportation, cost of selling sawn timber and also fuel and energy costs,

(b) Labour costs, covering wages and associated insurance, taxes and social costs,

(c) Fixed costs, encompassing a 20 per cent rate of return on capital and the repayment of borrowed capital, plus routine maintenence, insurance and equipment replacement. A 20 per cent rate of return, while sounding high has often been quoted as a satisfactory before tax objective on capital invested in industries with similar risks and uncertainties to those found in the sawmilling industry.

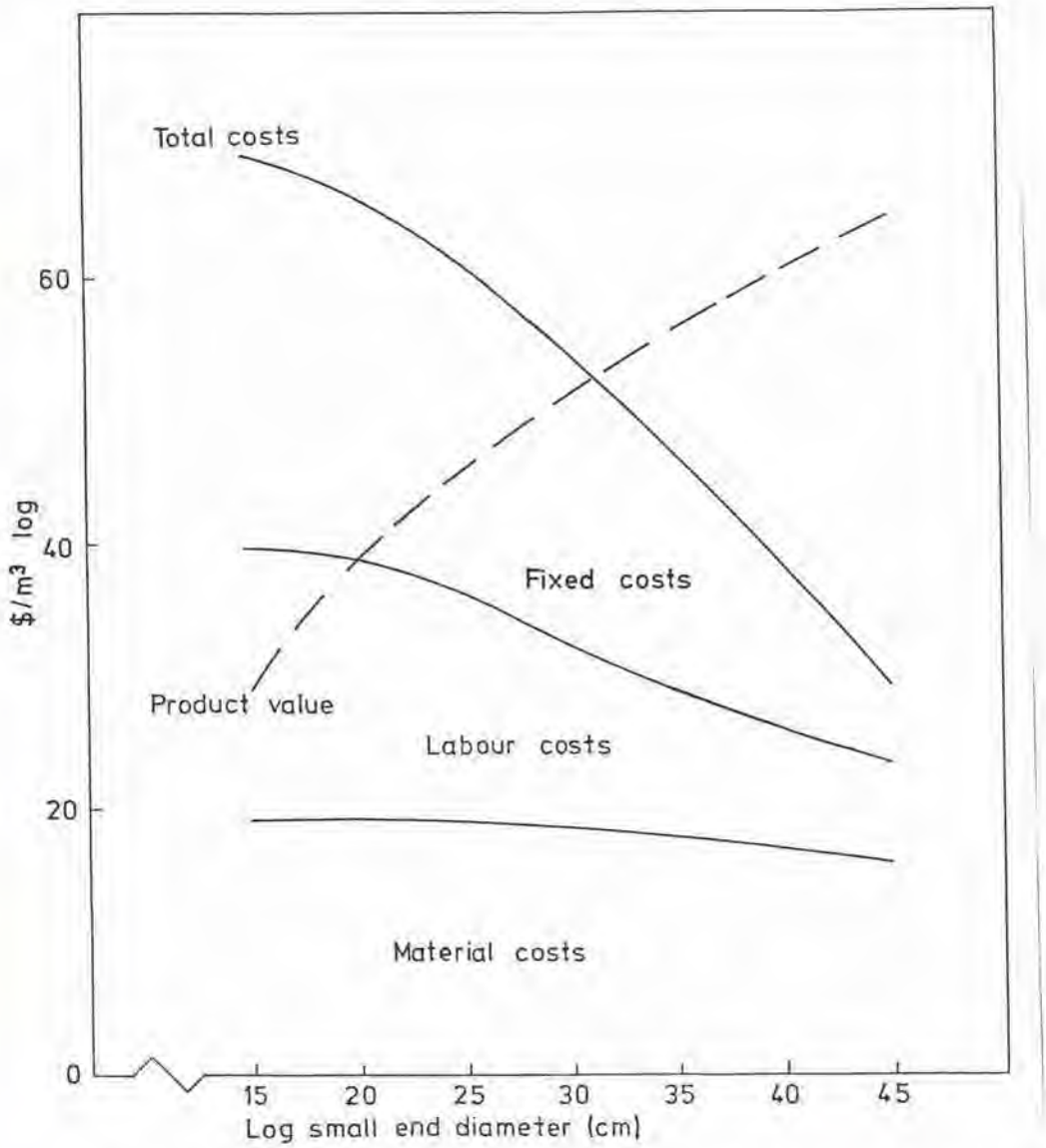

Fig. 1a. Costs and Returns associated with the Sawing of Small Diameter Hardwood Logs using a Log Edger and Two Resaws in series.

Materials costs were directly related to log volume input, whilst labour and fixed costs were initially related to operational time and as a result of productivity studies related to log volume input. Product values were related also to log volume input based on associated recovery studies.

DISCUSSION

Log length did not appear to have any significant effect on either product values or production costs in the sawmill using the twin edger (Fig. 1a). However, in the mill using the log edger, both product values and production costs were highly dependent on log diamter (Fig. 1a), but did not appear to have any significant relationship with log length. The low product value per cubic metre for smaller diameter sawlogs was mainly brought about by the lower

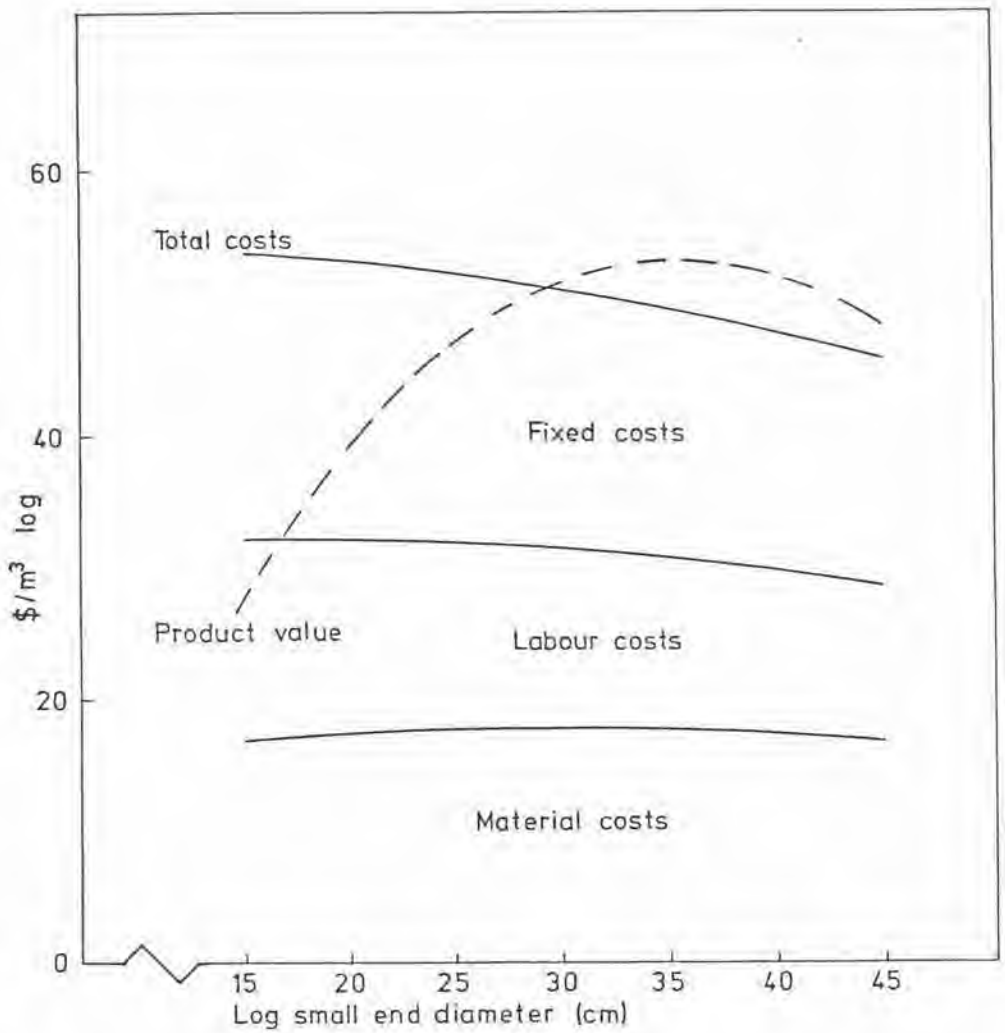

Fig. 1b. Costs and Returns associated with the Sawing of small Diameter Hardwood Logs of 4.2 metre length using a Pony Carriage, Twin Circular Headsaw and Two Resaws in series.

product recovery and reduced price for smaller dimensioned products, while the higher costs of converting these logs were due to lower production rates. This was in contrast to production costs in both sawmills using a lightweight "pony carriage" and headsaw to breakdown logs. The results shown in Figure 1b are for one mill only, but are reprsentative of both, which showed relatively little change in costs over the range of log diameters studied. This was achieved by the sawyer being able to adopt different sawing patterns for different sized logs. Product values showed a similar trend as for the mill using the log edger. However, log length did have a significant effect on the economics of converting small diameter sawlogs in both sawmills using a pony carriage (Fig. 2).

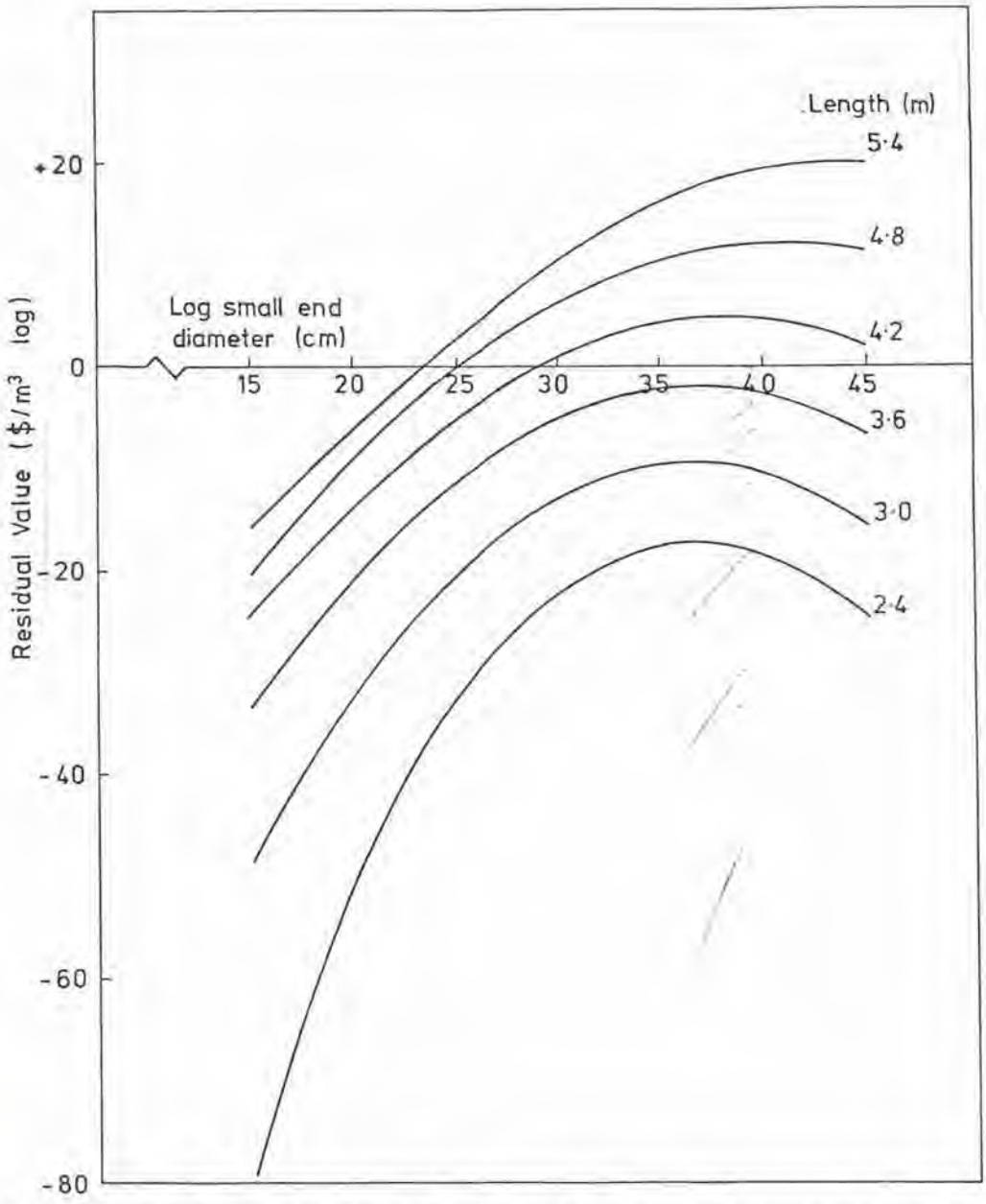

Fig. 2. Effect of Log Length and Diameter on the Residual Value (returns-costs) associated with the Sawing of Small Diameter Hardwood Logs using a Pony Carriage, Twin Circular Headsaw and Two Resaws in series.

The fact that numerous poor quality logs need to be cross-cut to short lengths results in lower residual values being obtained for short length larger diameter logs as well as for small diameter logs. As log diameter decreases, other problems such as sweep and growth stresses also become more critical (4), which means that it is only a very few logs of very good form under 30 cm small end diameter which could be cut in lengths of 4.8 m or longer.

The results of these studies indicate that to establish a sawmill to convert logs below 30 cm in diameter would not be a viable long-term proposition using the systems investigated in this study. However, in the short-term at least, a

sawmiller would be better off handling these logs rather than closing down, because the returns from logs in the 20 to 30 cm diameter range do exceed materials and labour costs and do partially meet fixed costs, a cost which he will incur whether he operates the mill or not.

Two other alternative lines of action are open, one is to obtain a suitable mix of log sizes incorporating a range of small and large diameter sawlogs which would still enable the sawmiller to achieve the desired rate of return. The other alternative is to delay harvesting (if possible) until a suitable size range of logs is obtainable, even a relatively few years can make a considerable difference to potential returns. For example, by relating the results from the sawmill studies to the distribution of log sizes available from the original stand of 36-year-old *Eucalyptus regnans* and applying growth rate prediction data the likely distribution of log sizes five years ahead were obtained, giving the production results in Table 1. Higher levels of productivity through reduced fixed and labour costs per unit input and higher sawn product values all contribute to the higher returns achievable by utilizing the older and larger sawlog resource.

TABLE 1

Expected Production Levels from Different Sawmilling Systems Converting Logs from a Good Quality *Eucalyptus regnans* Stand at Age 36 and 41 years

Production Factor	Age (years)	Mill Type		
		Log edger and two resaws in series	Pony carriage and two resaws in series	Pony carriage and two resaws in series
Number of sawlogs (x 1000)	36	26.8	37.7	56.5
	41	24.1	33.5	49.1
Volume throughput (m^3/year x 1000)	36	10.9	15.3	23.0
	41	11.8	16.4	24.1
Residual value ($/$m^3$ log)	36	7.20	3.29	5.05
	41	13.37	4.99	6.20

CONCLUSION

The results obtained from these studies indicate that the sawn conversion of young regrowth eucalypts can be profitable. However, a thorough investigation into prevailing and anticipated market conditions, capital costs, harvesting costs and precise data regarding the size and availability of the

resource would be vital before investing capital in sawmilling regrowth eucalypts.

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DEGRESSIVE BLADE PERFORMANCE QUANTIFIED BY ALTERATION IN SAW-CHIP CHARACTERISTICS

A. Krilov

SUMMARY

Practical trials have confirmed the validity of a new concept established on the dimensional variability of saw-chip configuration. This provides a non-destructive assessment of the sawblade behaviour in service and a practical means of forecasting its potential.

INTRODUCTION

Extensive studies in the field of timber processing have clearly indicated that the progressive wear of the sawtooth cutting edge affects adversely the formation of the *optimum chip* (1), which is directly responsible for fluctuations in sawblade potential.

These dimensional alterations in the saw-chip configuration representing the realistic picture of the degressive blade performance have never been, to our best knowledge, properly investigated.

The object of this paper is, therefore, to relate the process of chip formation to sawblade performance, and try to establish a non-destructive evaluation of the sawblade efficiency, based on alteration in saw-chip dimensional characteristics.

This leads to the author's contention that under ideal conditions, when the normal force is concentrated along the sharp frontal edge of the cutting tool, the percentage of the optimum chip should be the highest. It should regress with wear of the saw and be replaced gradually by an increasing percentage of compressed small-sized chips.

Dimensional variability of chip sizes can thus be related to operating condition of the cutting tool and therefore replace with advantage outdated assessment techniques, which necessitate destructive testing of the saw.

EXPERIMENTAL DATA

The experimental work was carried out on a vertical 2.45 m dia. IF log bandmill using a standard 350/2.41 mm UDDEHOLM sawblade, chosen at random from the existing production stock and suitably prepared for hardwood cutting according to the usual swaging, sharpening and hardening techniques.

To limit variables the experiment was applied to one timber species only, namely brush box *(Tristania conferta)*, possessing a fine texture, green density of 1155 kg/m^3, interlocked grain and high silica content (0.97 g/100 q of o.d. material). This particular species was chosen because of the severe dulling effect of the silica inclusions on sawteeth reducing dramatically the working life of the blade. It was expected therefore that any alteration in the saw-chip configuration would appear more distinct and occur facter, simplifying the sampling procedure.

The practical work was programmed to fit into a routine mill operation and the saw-chip sampling was carried out at pre-determined intervals (Fig. 2) during the working cycle of two hours. During this time observations of the blade performance were carried out at half-hour intervals, when log input was also recorded.

Chip samples were dried in a forced draft oven at 70°C for 24 hours. When dry, 30 g samples were sifted in a mechanical shaker through a series of B.S. sieves from >2.4 mm down to <0.2 mm.

Results obtained from the sifting are represented in Table 1, expressed as the oven-dry weight percentage of material for each saw-chip size class.

TABLE 1

Quantitative distribution of saw-chips into size classes during one 2 hour working cycle

Sample No.	Sampled at (min)	Chip size class (mm) - percent o.d. weight					Percentage of chips >0.6 mm size
		>2.4	2.4-1.2	1.2-0.6	0.6-0.2	<0.2	
1	1	2.53	8.78	67.10	17.93	3.66	78.41
2	7.5	6.93	20.67	55.70	13.70	3.00	83.30
3	15	1.47	23.53	55.87	15.90	3.23	80.87
4	30	5.27	20.33	56.63	14.50	3.27	82.23
5	45	1.80	22.40	46.13	25.00	4.67	70.33
6	60	1.20	11.67	49.13	32.40	5.60	62.00
7	75	2.66	7.80	48.17	37.37	4.00	58.63
8	90	0.73	1.47	30.70	58.30	8.80	32.90
9	105	0.33	1.90	43.50	46.20	8.07	45.73
10	120	1.23	2.20	39.60	48.10	8.87	43.03

Graphical presentation of the above data shows that the optimum saw-chip size range is situated between 0.6-1.2 mm (Fig. 1), which is further confirmed by the application of Antoine's formula (2).

DISCUSSION

If, for practical purposes, all chips over 0.6 mm size are assumed to be "large", whereas those under 0.6 mm are classified as "small", we can present graphically the percentages of both (Fig. 2) and relate them to log input. Though the latter should be considered as illustrative only, because the raw log input volumes took no cognizance of variations of size and defect, a definite deterioration trend in the sawblade performance is apparent. Indeed, Fig. 2 demonstrates clearly the sawblade behaviour at any particular point of its working cycle, showing that the maximum efficiency was achieved during the first 30 min of cut, when the blade was in optimum working condition and the highest feed speeds were recorded. From that point, the dulling effect on the sawteeth cutting edge became increasingly evident. After 87 min of cutting the sawteeth were so blunt that production of large and small size chips was roughly equal. Thereafter the percentage of smaller chips increased steeply, indicating clearly that the sawblade efficiency is nearing its end. This situation continued roughly for the next half an hour, when the general conditions of the saw became such that the experiment had to be halted.

The experimental data represented on Fig. 2 clearly indicate that the working cycle on any blade can be broken, for practical purposes, into three distinct phases, each covering the period of time when, respectively:

i) The work is carried out at the maximum efficiency (Phase I).

ii) The blade is still cutting reasonably well, although there is a rapid decline in its performance (Phase II).

iii) The tool is still able to cut (Phase III) but with such losses in efficiency, that it should have been replaced (preferably at the 87th minute in our specific case).

The quantitative data provided by this experiment has been substantiated also by numerous microscopic observations of the saw-chip samples, collected during the 120 min of the blade working cycle. From these observations it can be deduced that large chips (>0.6 mm) have generally a clear-cut geometrical shape and are fairly regular, suggesting that the sawblade is still performing with some efficiency.

The structure of the small chips (<0.6 mm), however, appears to be highly irregular, presenting a rather torn-out, pulverised aspect. Dimensional configuration of these samples indicates the low level of sawblade efficiency, which deteriorates steadily with saw-chip production suggestive of abrasive action rather than cutting.

This is clearly shown in Pl. 1 and Pl. 2, where respectively a large chip

(representative of Phase I) and small chip (representative of Phase II) were examined by means of a Philips Scanning Electron Microscope (PSEM) 500, operated at 12 Kv. leaving no doubt about the validity of the hypothesis presented in the introductory part of this paper.

CONCLUSIONS

Although the conventional methods of sawblade assessment are basically sound, they are inappropriate in the production situation where the continuous testing and non-interference with the operational cycle are required.

The practical results of above investigation have revealed the possibility to develop an original and non-destructive method for continuous sawblade behaviour assessment, based upon the dimensional variability of the saw-chip configuration.

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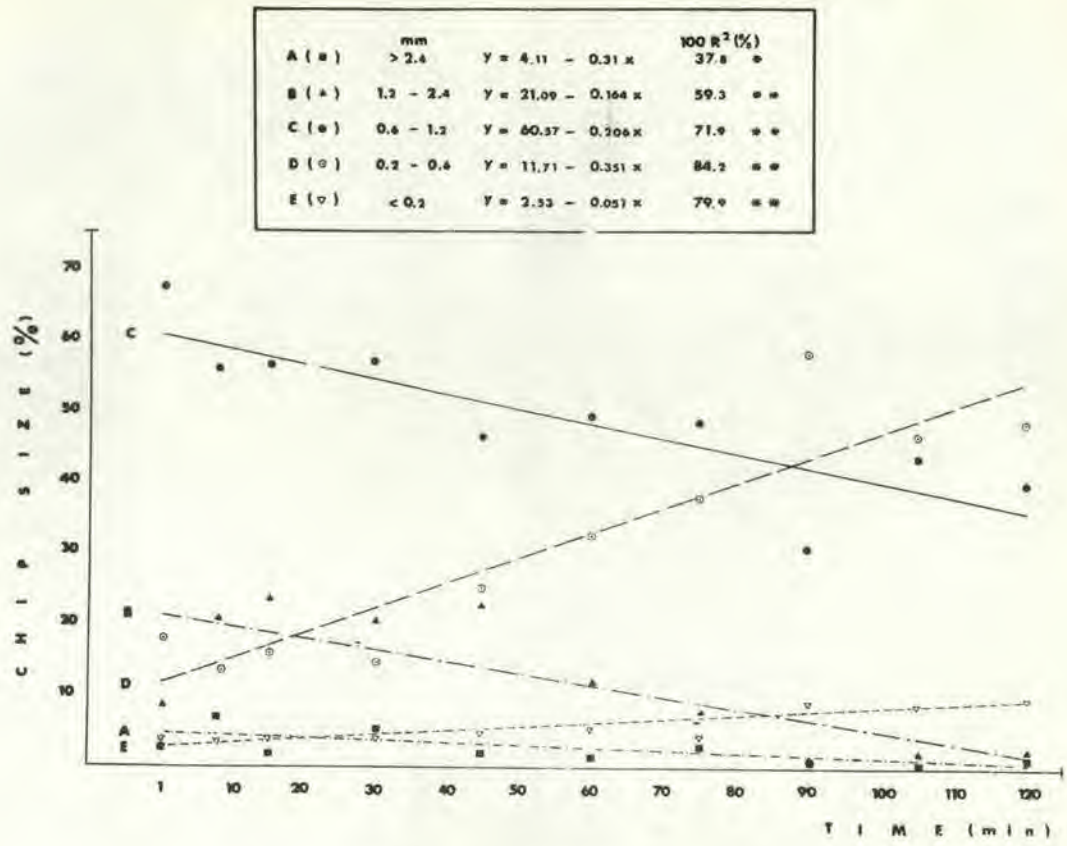


FIG. 1. Dimensional saw-chip distribution showing the optimum chip range.

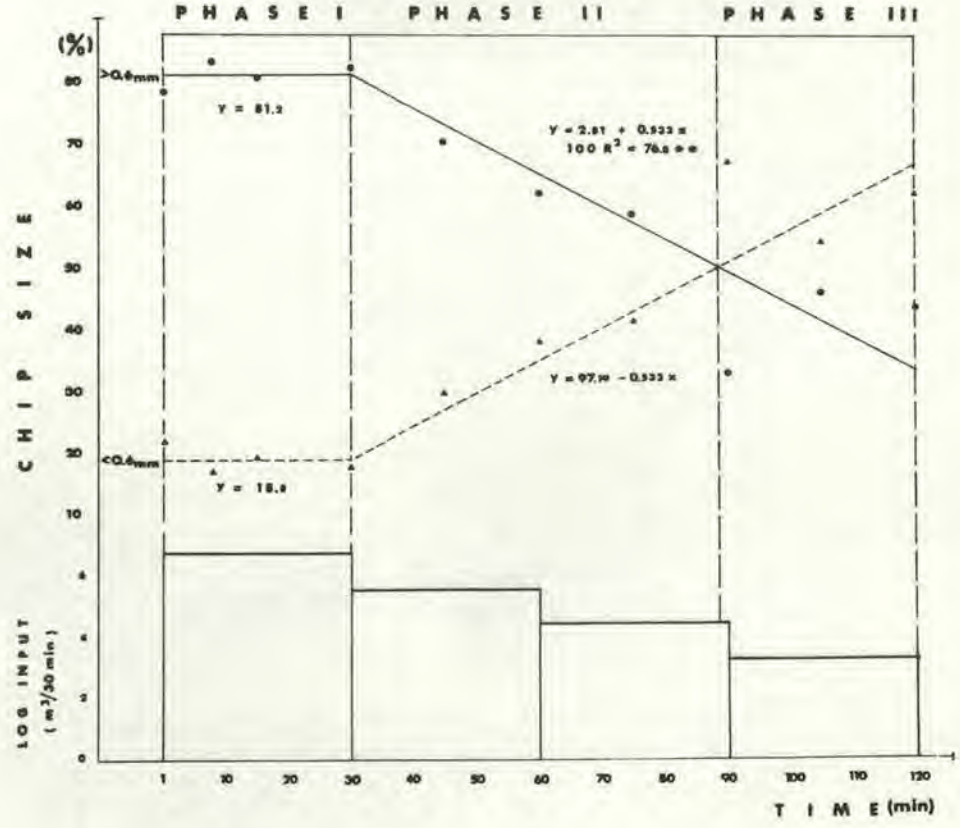
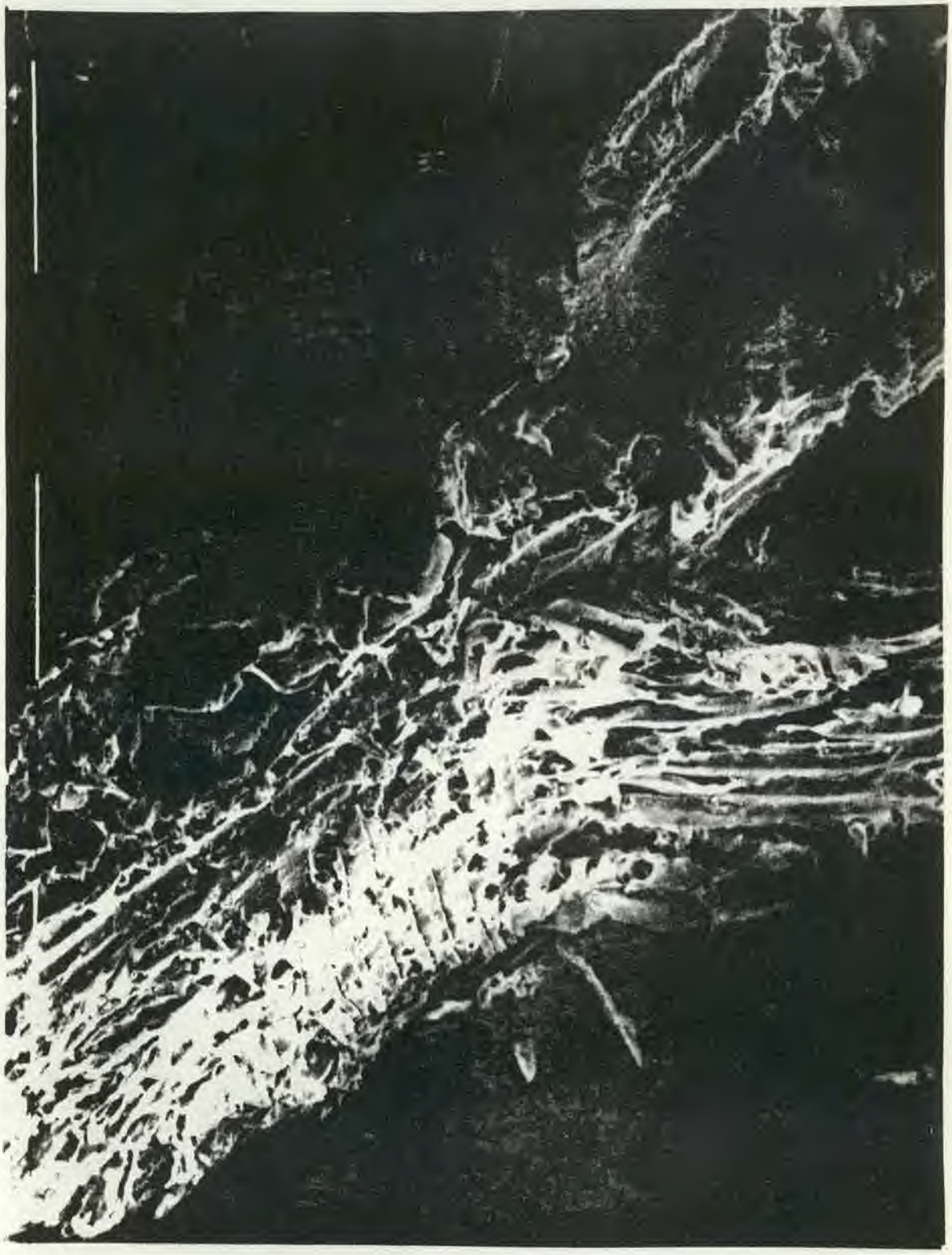


FIG. 2. Relationship between saw-chip size and sawblade efficiency.

PL. 1. General view of a "large" chip representative of Phase I (each dash represents 100 µm).



PL. 2. General view of a "small" chip representative of Phase III (each dash represents 100 μm).

ENERGY AND SAWMILLING

E.P. Lhuede

INTRODUCTION

A need for better information on the energy requirements for the production of sawn timber has developed due to a number of factors. Both in the construction of a new mill and in providing a power source, where the mill is not connected to an electricity grid, a knowledge of the maximum and average power and current demands is required for the optimal sizing of power supply components. Such information has commonly been based on past experience or wiring regulations (1) and suitable margins of safety have been used to ensure adequate cable and generation capacity. The documentation of data specific to saw mills is not extensive.

More recently, interest has focused on energy usage for the production of building components (as well as other commodities) and calculations of process and gross energy inputs to timber production systems have been made (2),(3). Aspects of these data warrant consideration.

Some of the data related to these various aspects of energy requirements and use are introduced and discussed in this paper.

POWER REQUIREMENTS FOR SAWMILLING

Power is consumed in a sawmill by a few relatively large motors on air compressors, hydraulic pumps, sawbenches, fans and chippers and by a greater number of smaller powered drives on conveyors; the smaller motors may, in a modern hardwood mill, account for 50 per cent of the total installed power and will be operated intermittently. The loads imposed on circular saw benches have been shown to fluctuate over wide ranges (4) and it may be expected that maximum power inputs will not occur at the same instant on each bench motor. As a consequence of the variable load, and also due to the high number of low powered motors, the overall electrical power factor for a sawmill can be expected to have a low value. For two hardwood mills producing green sawn timber at ouputs of 40-50 m^3/day, values of the power factor of 0.45 and 0.5 have been measured for average operating conditions and similar figures have been determined for softwood milling. From the measurement of maximum and average current flows for the mills at the power factors stated, the ratio of the maximum power usage to total installed power is of the order of 0.45 and the ratio of average power used to installed is 0.35.

The data is limited and indicates the need to obtain further measurements for mills of different size and type.

The major use of this information is for:

(a) the sizing of supply mains to a mill, and

(b) estimating the operating costs of various power sources for a mill.

(a) SIZING SUPPLY CABLES

On the assumption that the maximum power is 0.4 of the installed motor capacity and the power factor is taken at 0.5, the basic relationships:

"Electrical Power supplied, watts = $\sqrt{3}$ x phase to phase voltage x line current x power factor".

This can be used to show that:

maximum line current = 1.1 x installed motor power (kW).

This relationship can be compared with formula used in the timber industry which states that:

maximum line current = 1.3 x installed power x diversity factor.

The diversity factor is based on general experience and is commonly taken as 0.6 for green hardwood milling, and takes into account both the percentage loading on the motors and power factors. The numerical factor of 1.3 is directly derived from the relationship between electrical power, phase to phase voltage and line current.

Thus, maximum current = 0.78 x installed power (kW).

The maximum line currents determined on either basis differs by 40 per cent. Use of the data provided in wiring regulations lead to an even greater difference and indicates a need for further measurements.

(b) SELECTION OF A POWER SOURCE

Where a mill is at the design stage, a comparison of the costs of using different energy sources may be necessary. Average power consumption will determine energy costs, while the maximum demand is required to determine the power of a prime mover where grid power is not used. Typical prime movers that may be considered are diesel or gas engines, steam or gas turbines or steam engines and the capacity of the source can be obtained directly after allowing for the efficiency of the electrical generator and supply system.

Of more interest however, is the estimation of operating costs of a prime mover and the comparison of these with grid power. Currently, using the SECV low voltage industrial power supply Tariff D (July 1979) the cost of providing electrical power to a mill with 890 kW of installed motor power with a power

consumption of 0.35 of the installed value is $2450 for 160 hours per month (@ 4.9¢/kWh). Where the electrical mains are close to the mill both connection and maintenance charges will be minimal. An alternative to using grid power is to instal a diesel-generator set, and to the present time some mills are powered in this way where monetary penalties are attached to providing grid power. For a diesel-generator to produce the necessary 310 kW, the capital cost for a new installation may be of the order of $65,000 with an associated capital charge of $930 per month (calculated as an equivalent annual value). Fuel costs for a diesel to deliver the necessary power at the terminals, with diesel fuel at an undiscounted cost of $190 per tonne is $2260. Generally such sets can be operated without certificated full-time operators but a part-time operator cost is included in the data of Table 1. Maintenance charges may be significant.

A second alternative to grid power is to use a steam boiler and turbine or steam engine. Capital costs can be expected to be higher than with the diesel generator system as a second hand boiler of the size required may cost $100,000, and there will be specific operating charges with such a plant ($1000/month) as well as maintenance costs. Where natural gas and a prime mover capable of using this as a fuel are available, similar capital and operating costs may be assumed as have been suggested for the diesel-generator set. The price of natural gas on a "cents per megajoule" basis is 40% of that of industrial diesel fuel and operating fuel costs have been assumed to be less by this proportion.

The possibility of using producer gas derived from charcoal can also be considered. The capital cost of the prime mover and its operating efficiency is assumed to be 60 per cent of the diesel or gas fueled engines, but a gas producer unit is required. The capital cost is suggested as $10,000. From published data (5) the fuel requirement has been estimated as 26 tonne of charcoal per month at $60/tonne. Operating and maintenance charges are listed in Table 1.

The data of Table 1 is intended to show an order of magnitude of operating costs rather than definitive values and high cost factors can be assessed from this listing.

ENERGY REQUIREMENTS FOR PRODUCING TIMBER

A range of values of the energy inputs required to produce a kilogram of sawn wood has been reported by Hill (3). Two bases of reckoning, namely process energy requirements (PER) and gross energy requirements (GER) are quoted and comparisons between the GERs for various materials is made.

The clear meaning of GER should be recognised; where a material can be considered to have an alternative use as a fuel then the heat of combustion is included in the envelope of energy inputs required to produce the material.

TABLE 1

Assessment of Costs of Providing 310 kW of Electrical Power to a Sawmill for 160 hours per month Using Different Energy Supply Systems

Basis of cost	Cost per month	
Electrical grid power, mains adjacent to mill no maintenance charge	$2450.00	
Diesel-generator set		
Fuel at $190/tonne (non-discounted)	2260.00	
Cost $65,000 installed	950.00	
Maintenance and part-time operator assumed	400.00	
		$3610.00
Steam engine (or turbine) and boiler		
Assumed capital cost $140,000	2000.00	
Fuel green logged at $3/tonne	300.00	
Full-time operator	1000.00	
Maintenance	200.00	
		$3500.00
Gas engine (probably dual fuel), fired on natural gas where available		
Capital cost $70,000	1000.00	
Fuel at 0.17¢/MJ	880.00	
Maintenance and part-time operator	400.00	
		$2280.00
Gas engine fired on producer gas		
Capital cost $70,000	1000.00	
Fuel at $60/tonne, 26 tonne/month	1550.00	
Gas producer (assumed $10,000)	150.00	
Maintenance and part-time operator	1000.00	
		$3700.00

For wood, values for PER have been reported at between 1 and 7 kJ/kg [Hill (3)]. However, for the mills considered in this paper, the PERs are possibly less than 0.5 kJ/kg allowing that liquid fuels as required for log transport and handling around the mill are of similar energy value to electrical energy. This value (0.5) is less than has been established from considerations of Australian national statistics or from data obtained from other sawmills where actual costs of electrical power and of liquid fuel have been the basis of costing. A point of note is that a doubling of transport costs will cause a 50% rise in PER, although a considerably lesser change to GER will result.

The preference for using either GER or PER in an energy analysis can affect the position of timber in a table of energy requirement values and places it at a distinct disadvantage to other material where GER is used. The justification

for the use of GER is that wood has an alternative use as a fuel. Currently, timber commands about $60 per tonne as a green building material if considered on a saw log basis, while as a fuel the highest value that could be expected currently is considered to be $25-$35 per tonne. An objection to the use of GER as a basis for determining energy requirements of a material is that the community places a value on sawn timber that is generally greater than the value as a fuel. The situation may develop, however, where fuel availability in certain areas comes to be of such importance that combustible materials such as wood cease to have a greater commercial value as a building material than as a fuel. Its replacement in building by metals could, under some conditions, come to be economically justified.

CONCLUSIONS

Where electrical grid power is readily available to a sawmiller this is the cheapest method of powering a mill. Engines using natural gas are economically attractive but this fuel may escalate in price at a greater rate than electricity and will not be available in many areas where sawmills are located. There is a need to obtain better data on the energy usage in a range of size and type of sawmill, and the industry should be aware of the different bases of assessing energy requirements for the production of timber.

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STATUS OF THE CONTINUOUS FEED HIGH TEMPERATURE KILN PROJECT

F.J. Christensen and R.L. Northway

INTRODUCTION

The concept of drying timber by a continuous process was evolved within the Division of Building Research, CSIRO, several years ago. Patents for a horizontal continuous feed kiln, covering both method and apparatus, have now been granted in Australia (1) and several other countries.

A prototype was built to test the concept using the very high tempratures and air velocities which had been experimentally derived for use with plantation-grown softwoods by Christensen and Barker (2). In this machine, the timber to be dried was conveyed horizontally from inlet to outlet during which it was dried, conditioned and cooled. Extensive testing demonstrated the feasibility of a continuous feed drying process for sawn timber, particularly in terms of uniformity of drying and fast processing times. However, the steel fingers used to support and carry the timber through the kiln were unable to adequately restrain pith-included boards thicker than 25 mm against their tendency to warp.

To overcome this restriction on the commercial application of the concept, Barker and Northway (3) designed a continuous feed kiln through which the timber was moved vertically. This design should realize the advantages demonstrated for the horizontal prototype over conventional batch-type kilns and, because of its more effective restraint, would increase the recovery of thicker timber meeting acceptable standards of warp. Christensen and Northway (4) have described the vertical continuous feed kiln and its commercial status, and outlined its potential capabilities and value to the timber industry.

Although a prototype of this kiln has not yet been built, it was considered that a test facility consisting of a reversible air flow tunnel kiln equipped with a variable stack loading system and direct natural gas heating would be capable of adequately simulating its principal operational features. The experimental kiln built for this purpose and tests simulating the continuous kiln cycle are briefly described later.

CONCEPT OF THE CONTINUOUS KILN

Figures 1 and 2 show the general layout of the vertical version of the continuous feed kiln.

Green timber of one thickness at a time is fed by conveyor A (Fig. 1) to the infeed deck B where a layer of boards is accumulated. At the appropriate time, this is transported over the stack C and deposited on stickers placed across the top of the stack. A layer of boards is then removed from the bottom of the stack by the following series of operations: the stack support platform D moves downwards until the sticker gap between the two lowermost layers of boards is level with the series of stack supporting tines E; these are moved through the gap until their tips engage supports provided on the far side of the stack; D drops below the level of the outfeed conveyor F which transfers the bottom layer of boards and stickers from the kiln; D then rises to support the stack and the tines are retracted. This cycle is repeated at a rate set by the drying characteristics of the timber and the kiln conditions.

Air circulation from centrifugal fans G is directed by the duct system H to make four passes through the portion of the stack in the drying zone. Control of humidity is by venting moist air after the second pass, i.e. at position 6 in Fig. 2. Preheated make-up air is added after the fourth pass, having first been drawn through the portion of the stack in the subsequent cooling zone. The cooled timber then absorbs moisture condensed on its surface as it passes through the saturated steam atmosphere of the conditioning zone. In the final cooling zone, sufficient stack height is provided to ensure that the timber is cooled close to ambient temperatures before being removed from the kiln.

For heating the kiln the following options are most likely to be used in a commercial unit:

1. Hot oil coils in the air circuit, probably arranged to reheat between passes, so that a constant though not necessarily the same temperature is maintained for air entering each of the four passes in the drying zone.

2. Direct heating with suitably scrubbed flue gases supplied from a wood-waste burner or gas burner, ducted into the air circuit at two or more passes in the drying zone.

3. Indirect heating by flue gases with air-to-air heat exchangers forming part of the air circuit in two or more passes of the drying zone.

A prototype unit could be equipped with oil or gas burners to be virtually identical in operation to option 2.

SIMULATION OF THE CONTINUOUS FEED KILN CYCLE

The Division's experimental tunnel kiln enables the following features of the continuous kiln cycle to be simulated:

1. The separate processing phases and a progressively increasing load experienced by a layer of timber as it passes from the top of the stack through the stack pre-loading, drying, initial cooling, conditioning and final cooling zones until ejected from the bottom.

2. The periodically reversing direction of air circulation through the stack as it successively travels through the four passes in the drying zone.

3. The effect of having only one source of heat input in the air circuit, or the provision of reheat facilities at one or more subsequent passes in the drying zone.

4. The influence of co-current or counter-current flow operation in the drying zone, i.e. the green or dry timber respectively is subjected to the highest inlet air temperature.

DESCRIPTION OF THE EXPERIMENTAL SIMULATION KILN

The kiln, as shown in Fig. 3, is symmetrical in section. Two reversible tubeaxial fans are joined by circular to rectangular transition pieces to ducts 3.2 m wide and 0.4 m high. Two natural gas burners are situated in the upper bends so that, according to fan direction, one at a time can be fired to heat the kiln to dry bulb temperatures in excess of 200°C. The lower mitre bends mate to the removable working section.

A torsionally rigid frame forms the base of the working section, and carries a stack comprised of boards 3.10 m long transverse to the air flow and 0.4 m high. The length of the air path through the stack, i.e. across the width of the boards, can be up to 2.4 m. The roof of the working section, also a torsionally rigid frame sits on top of the stack. One side of the working section is fixed, while the other is removable for loading and unloading.

Two hydraulic cylinders mounted on the upper frame at the centre of each side are connected by rods through the stack to the lower frame. Oil pressure to the cylinders exerts a compressive loading on the stack and can either be set to a constant value or arranged to increase over the period of the complete drying cycle. Since the lower frame is mounted on air slides, the stack can be removed from the kiln for cooling with the loading system still operating.

Four panels, two of which carry steam inlets, can be positioned to enclose the sides of the stack, thereby enabling it to be conditioned while still under restraint. The panels are removed during the final cooling period.

Furthermore, provision has been made to determine the effect on drying of varying: (1) stack width from 1.2 to 2.4 m; (2) sticker thickness from 20 to

40 mm; (3) timber thickness from 25 to 50 mm; (4) wet bulb temperatures from 50 to 90°C; and (5) air circulation rates through the stack from 6 to 12 m/s.

THE SIMULATION TESTS

Details of six tests with variations in material and drying conditions are given in Table 1. Each test stack comprising six layers of eighteen boards approximately 3.1 m long, 105 mm wide and 42 mm thick was built on the lower frame of the kiln using 25 mm thick stickers at 500 mm spacing. The upper frame was then placed on the stack and the hydraulic loading system connected. This was set to provide a linearly increasing top load for the estimated duration of the complete seasoning cycle. The load was increased from an initial value of 460 kg/m^2 (simulating the pre-loading on the timber before it enters the drying zone in the vertical continuous feed kiln) to a final value at the end of the seasoning process of 4300 kg/m^2 (i.e. the equivalent of a block of concrete 1.8 m thick covering the entire top of the stack). After moving the working section into the kiln and closing the open side, the drying cycle for each test was conducted according to Table 1. Air velocity was 10 m/s between boards for each test. At the completion of the drying phase the stack was cooled with a forced draught, removed from the kiln and steamed for one hour. The stack was finally allowed to cool for one hour before the top loading system was disconnected, the top frame removed and the stack dismantled for evaluation.

Measurements of mass, thickness, twist, spring and bow were made on all boards before and after drying. One sample was taken from each board for oven-dry determination of final moisture content.

RESULTS OF SIMULATION TESTS

Very low levels of final distortion were obtained for all test runs, as shown in Table 1. Although the very high loading left sticker indentations on most boards the worst of them resulted from differences in initial thickness of up to 7 mm between individual boards. No indentations were discernible after machining and there was no suggestion of any weakness as indicated by a continuous ink spray applied during subsequent stress grading.

Despite the different drying times for material at different initial moisture contents, which suggest advantages in segregating heartwood from sapwood, this does not appear to be mandatory for drying at the high temperature/low humidity conditions used, i.e. run of the mill material consisting of varying proportions of heartwood and sapwood can be satisfactorily dried. Very small differences in final moisture content were found between individual boards when the average moisture content was below 12%.

TABLE 1

Results of the Simulation Tests

Run	Species & type	Initial moisture content (%)	Inlet dry bulb temperature+ (°C) 1st hour	2nd hour	3rd hour	4th hour	5th hour	6th hour	7th hour	Total drying time (h)	Final Distortion (% meeting half of AS1400 limits for structural grades) Twist	Spring	Bow	Final moisture content (%)
5	P. radiata - run of the mill	77	to 195	170	(150 (120	120	-	-	-	4	100	100	100	15
9	P. radiata - heartwood	44	205	165	150	140	-	-	-	4	100	91	98	10
10	P. radiata - heartwood	44	140	150	165	205	-	-	-	4	100	85	96	6
13	P. radiata - sapwood	118	205	165	150	140	135	130	130*	7½	100	100	99	10
14	P. radiata - sapwood	120	220	180	165	140	140*	140*	-	5½	100	100	99	9
15	P. radiata - sapwood	120	140	165	180	205	205*	-	-	5	100	99	98	11

+ Direction of circulation reversed hourly

* Direction of circulation not changed

The temperature drop across the stack, particularly during the first half of drying was large, even for the relatively dry heartwood as in Run 9 where the outlet temperature at one pass was used as the input temperature for the next one. Thus, some degree of reheating between passes is considered to be necessary in a vertical continuous feed kiln.

Since both co-current and counter-current drying gave satisfactory drying, the slightly shorter drying time achieved with the latter is not considered to be sufficient justification for exposing almost dry timber to very high temperatures, i.e. of the order of 200°C.

The latter parts of the seasoning cycles used i.e. initial cooling, steaming and final cooling each of approximately one hour's duration, produced stress-free material with satisfactorily low moisture gradients.

CONCLUSIONS

These simulation tests indicate that a vertical continuous feed kiln as described would be capable of drying plantation softwoods with minimal distortion and suggest that:

- Some reheating will be required between passes particularly between the first and second passes in the drying zone.
- The first pass through green timber should preferably be at the highest drying temperature, i.e. the use of co-current flow conditions.

. Conditioning with steam for one hour followed by cooling under load for at least one hour can provide adequate stability of the dried timber.

Sufficient information is available to enable a commercial prototype to be built so that optimum process conditions and operating costs can be accurately determined.

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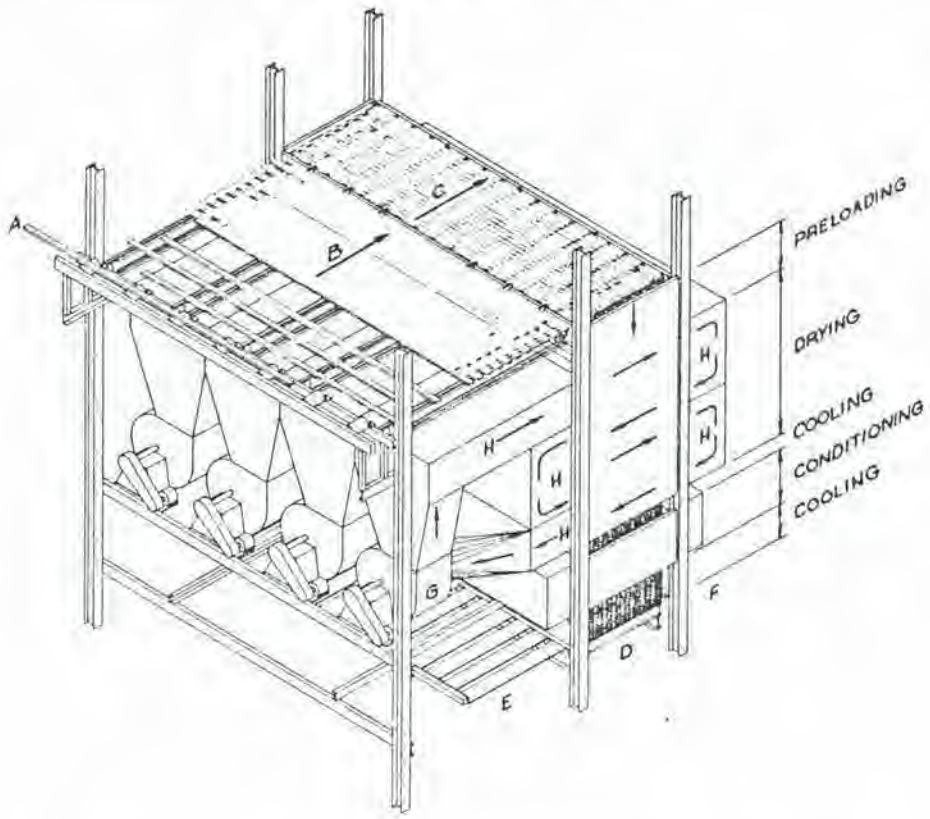

FIG. 1. The Vertical Continuous Feed Timber Kiln

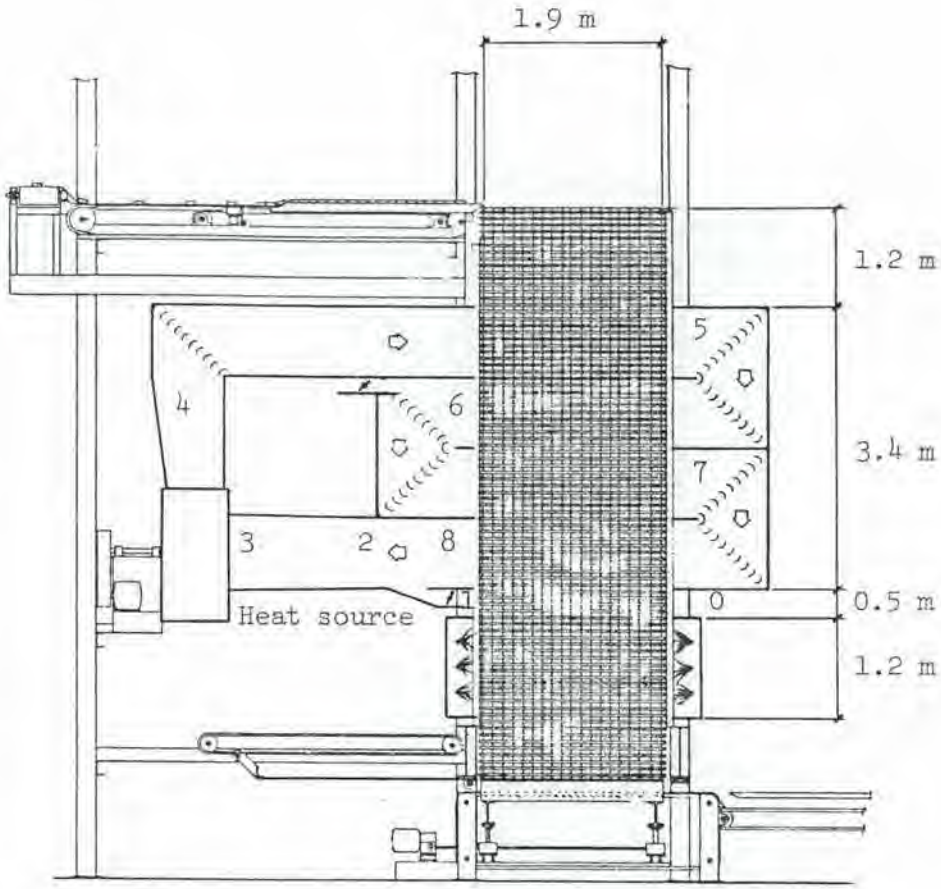

FIG. 2. Section Through the Vertical Continuous Feed Kiln

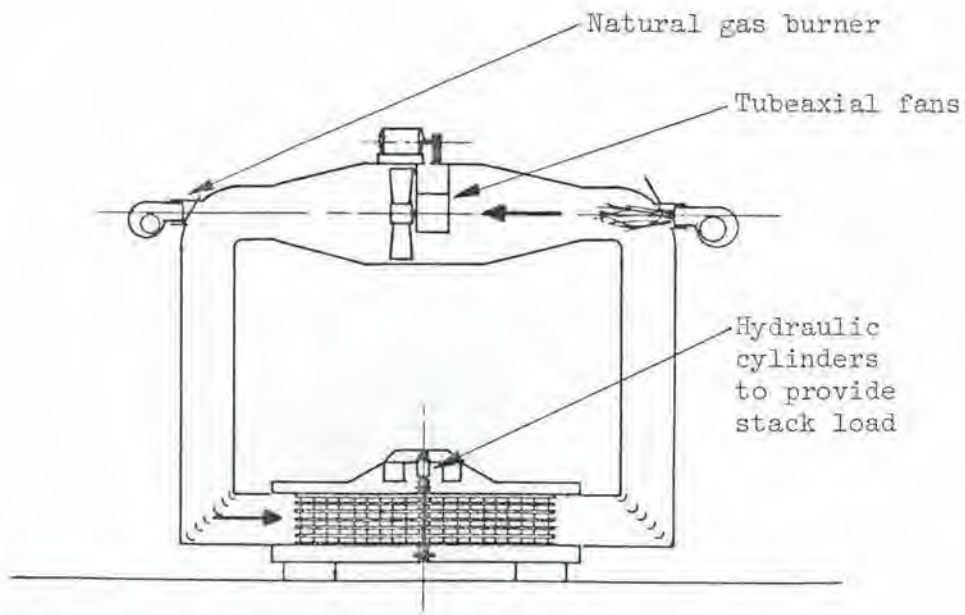

FIG. 3. The Reversible Tunnel Kiln used to Simulate the Continuous Kiln Cycle

INFLUENCE OF DYNAMIC TRANSVERSE COMPRESSION AND REDRYING CONDITIONS ON INTERNAL CHECKING IN 45 mm THICK CCA TREATED RADIATA PINE

C.A. Berni and F.J. Christensen

INTRODUCTION

Since the introduction of high temperature drying of softwoods in Australia in the early seventies, it has been recognized that this method is not entirely suitable for the redrying of sawn pine timber treated with copper-chrome-arsenic (CCA) preservatives, particularly for 45 mm and thicker timber which can develop unacceptably high levels of surface and internal checking.

Compared with untreated timber, the risk of checking in CCA treated timber during redrying is increased by the occurrence of steeper moisture gradients and the resulting higher drying stresses derived from the combination of two effects: (a) a reduction in wood permeability due to an increased level of pit aspiration during initial drying and treatment and (b) a moisture content after full-cell treatment which is higher than the green value.

It has been found that by reducing the dry bulb temperature from 120°C to 80-90°C during redrying, practically all checking can be eliminated in 45 mm thick CCA treated radiata pine but at the expense of about a four-fold increase in drying time which adds significantly to the cost of drying. On the other hand, the subjection of green or partially dried wood to dynamic transverse compression is a simple and low cost method which is claimed to increase the wood's permeability (1), and is another approach to a possible solution to the problem of internal checking in the thicker sizes of treated pine during redrying.

Dynamic transverse compression consists of passing sawn timber through a pair of rollers preset to apply a predetermined level of compression prior to or at some stage during drying, and the system should be suitable for in-line processing. Optimum compression levels were found to be 7.0-8.5% for green yellow birch (2) and 12.5% for eastern white spruce at 20% moisture content prior to impregnation with a waterborne preservative (3). The purpose of transverse compression in this latter case was to improve preservative penetration and no reference was made to any effect on internal checking.

EXPERIMENTAL PROCEDURE

The timber consisted of predominately backsawn sapwood boards from the Mt Gambier area of South Australia. One 100 mm by 100 mm by 5 m long flitch

was taper-sawn from 10 logs from different trees. Each flitch was ripped and cross-cut to yield 20 specimens each 100 by 50 by 450 mm. One specimen from each flitch was randomly allocated to one of the 20 selected treatment groups, giving a total of 10 specimens/group. The treatments consisting of:

3 compression levels - 10, 15 and 20% of actual green thickness

3 stages of application - before initial drying, after initial drying but before preservative treatment, and after preservative treatment

2 redrying schedules - conventional (85°C) and high temperature (120°C).

These 18 groups of specimens together with two groups of controls dried at either 85°C or 120°C account for the 20 treatments. Specimens were dynamically compressed at a speed of 140 mm/s.

To minimize any checking during the preliminary drying to about 25% moisture content before preservative treatment, all of the timber was dried (at the one time) under virtually predrying conditions. Both ends of each specimen were end-sealed with aluminium foil before drying was commenced and were retained in that condition during the subsequent processing stages.

After preliminary drying, all specimens were treated simultaneously by the full-cell process to a CCA salt retention of 12 kg/m^3, after which they were stored in plastic until required for further processing.

Observations on internal checking were made on two randomly selected specimens after preliminary drying and on the remaining eight specimens from each treatment group after redrying. All specimens were cross-cut at two fixed positions along their length. The width and thickness of each check were measured with calipers and the approximate area of checking calculated from these dimensions to give a quantitative assessment of its extent.

RESULTS AND DISCUSSION

Basic drying data for the 45 mm thick radiata pine specimens subjected to dynamic transverse compression, both before and after preservative treatment, are given in Table 1.

These results clearly show the vast difference in redrying time for conventionally and high temperature dried specimens. The substantial increase in moisture content during pressure treatment can be observed from the initial "preliminary" value and the initial "redrying" values.

Results for the quantitative assessment of degrade in CCA treated and redried specimens at 12% moisture content are given in Table 2.

TABLE 1

Type of drying	Drying conditions			Mean moisture content		Drying time h
	DBT* °C	WBT+ °C	Air speed m/s	Initial %	Final %	
Preliminary	50	43	1.5	102	25	158
Redrying	85	75	3.0	126	12	157
Redrying	120	70	5.0	119	12	29

* Dry bulb temperature

\+ Wet bulb temperature

TABLE 2

Dynamic transverse compression		Total area of checks for each treatment in mm^2	
Compression level - %	Stage of application	Conventionally dried	High temperature dried
0	-	57	320
10	A	19	364
	B	57	346
	C	3	1012
15	A	18	703
	B	25	485
	C	16	606
20	A	6	505
	B	88	535
	C	3	525
		Means: 29	540

A - Before preliminary drying

B - After preliminary drying but before preservative treatment

C - After preservative treatment

For the specimens redried at high temperature, these results indicate that neither the compression level nor the stage of application of the dynamic transverse compression treatment influenced the level of internal checking that occurred after redrying to 12% moisture content. However, for the conventionally dried specimens, all three levels of dynamic transverse compression significantly reduced the total area of checking when applied to either the green or

the freshly treated timber but not to the partially dried timber at 25% moisture content.

The results in Table 2 also show that the method of redrying after treatment had a massive effect on the severity of checking after final drying to 12% moisture content. On the average, the area of checks in specimens dried at high temperature was twenty times greater than with conventional drying. This result is based on the measurements made on 80 specimens from each of the conventional and high temperature dried groups. The remaining 40 specimens, examined at the end of the preliminary drying stage, showed no apparent internal checking.

Shown in Fig. 1 are the mean moisture gradient profiles at the end of drying for all specimens dried under the three different drying regimes. These curves were constructed from data obtained from oven dry determinations made on five distribution sections cut from each moisture content sample. Numbers 1 and 5 refer to the case sections, 2 and 4 to the intermediate sections and 3 to the core section.

The moisture gradient profiles indicate that the development of checking is related to the steepness of the moisture content gradients. After the initial drying and after the redrying with the conventional schedule the gradients were small compared with that obtained after redrying at high temperature. In redrying at conventional temperature, the slight development of internal checking suggests that the stress levels developed during this drying regime were not greatly different from those in the initial drying. This is in marked contrast to the high stress levels, as evidenced by the much more extensive checking, from redrying at high temperature.

CONCLUSIONS

1. The application of dynamic transverse compression at three separate stages in the processing of 45 mm thick CCA treated radiata pine did not reduce the extent of internal checking in specimens redried at high temperature. It did significantly reduce internal checking in treated and conventionally redried specimens subjected to 10, 15 and 20% compression levels in the green condition before initial drying and in the near-saturated condition after preservative treatment.

2. No apparent internal checking was produced during the preliminary drying of the green timber to 25% moisture content under predrying conditions. As measured by the cross-sectional areas of checks present in dried specimens at 12% moisture content, redrying of the treated timber at high temperature caused severe internal checking whereas redrying at conventional conditions resulted in practically no internal checking. It is considered that the development of

internal checking is principally related to the steepness of the moisture content gradients developed during drying, these being related to the severity of the drying conditions.

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EFFECT OF PRE-FREEZING ON THE SEASONING OF BACKSAWN BOARDS FROM TASMANIAN GROWN EUCALYPTS

F.J. Christensen and M. Neylon

INTRODUCTION

Commencing in January 1977, a joint CSIRO/Tasmanian Timber Industry research project was undertaken to try to find a seasoning technique that would produce an acceptably low level of drying degrade in all backsawn boards from Tasmanian grown eucalypts.

Traditionally, the bulk of board quality material produced in Tasmania has been quartersawn and, generally, could be dried satisfactorily with any surface checking being confined principally to the edges of boards. Decreased demand for strip flooring and other mouldings from substantially quartersawn timber led to a serious reassessment of sawing patterns by the Tasmanian timber industry, with the result that some sawmillers have already converted to backsawing practices and others are expected to follow suit.

In reaching this decision, a prime consideration was the good prospects for the sale of wide figured boards of select quality to international markets. Other factors were the expectation of increased recovery of sawn timber, faster conversion times and a slightly shorter seasoning period. However, for the generally refractory eucalypt species milled in Tasmania, there is a high risk of surface checking developing on the faces of an imprecisely known proportion of backsawn boards and an increased level of collapse, possibly of an irrecoverable nature. These can be considered as two separate problems to overcome since collapse can occur without the incidence of checking and vice versa, although collapse in itself can lead to checking. As the appropriate Australian Standards AS1702/1705 - 1974 (1-4) do not permit any face checking whatsoever, seasoning techniques developed must be effective therefore in reducing the combined problem of collapse and checking.

Collapse is believed to be caused by high surface tension forces developed in the wood cells during the drying process. Although some or even all of the collapsed wood can be recovered by reconditioning, the intensity of the collapse contributes to the overall stresses developed in the wood and the consequent formation of degrade during drying. In contrast to quarter sawn timber, where collapse is often evident as "washboarding" on the face of the board, the effect of collapse in backsawn timber is most likely to appear as an overall

distortion of the board.

Surface checks may occur during the initial drying stages on the tangential surfaces of sawn timber, frequently along the medullary rays - the weakest part of the timber. They develop when the strength of the timber in tension across the grain is exceeded by the drying stresses arising from the differential shrinkage of the timber as it dries from the surface inwards. The more impermeable the timber, the steeper the moisture gradient and the greater the magnitude of the drying stresses for a given set of drying conditions. The effect is heightened by the application of relatively high dry bulb temperatures and/or low relative humidities during the early stages of drying. Surface checks may close during the later stages of drying but can re-open during reconditioning and remain so thereafter. If surface checking cannot be prevented by control of the drying conditions at the surface of the timber, either psychrometrically or with chemical pretreatments, then another approach is to try to increase the timber's inherent permeability. The work reported here shows this can be achieved to some degree, though not to the extent required in all cases for the adequate suppression of drying degrade, by a prefreezing treatment.

PREFREEZING CONCEPTS

By prefreezing is meant the subjection of green timber to ambient temperatures of -10°C or lower (by one of a number of alternative methods) until the maximum internal wood temperature has fallen sufficiently to freeze the free water in the cell lumina, while all or much of the bound water in the cell walls remains in the liquid phase. However, as the freezing temperature decreases, the amount of non-freezing water in the frozen wood should also decrease (5).

The latter phenomena can be explained by Kubler's postulate (6) that water vapour migrates out of the cell wall and freezes on the ice formed in the cell lumen, the driving force being provided by the vapour pressure of the unfrozen cell water being higher than that of the ice.

Thus, particularly in saturated or near-saturated wood, the cell walls of frozen timber are being stressed in tension and may fracture as a result of the action of one or more of three phenomena:

(i) expansion of cell lumen ice due to its positive cubical co-efficient of expansion with decreasing temperature

(ii) increase in the volume of cell lumen ice due to cell water vapour freezing on it

(iii) shrinkage of the cell wall as it loses moisture.

If sufficient cell walls are fractured during prefreezing, then an increase in wood permeability could be expected.

PREVIOUS WORK

The first known trials with the prefreezing of Tasmanian eucalypt timbers were conducted in 1958 by W.G. Kauman and E.R. Pankevicius (unpublished data) using green 25 mm cubes cut from *Eucalyptus delegatensis* and *E. regnans* boards. Prefreezing at -5°C compared with unfrozen controls, both of which were dried under a kiln schedule deliberately chosen to encourage collapse, reduced apparent collapse present before reconditioning by some 40 per cent (11% c.f. 19%), although both showed a volumetric shrinkage of 12% after reconditioning at 12% moisture content (all shrinkages being expressed as a percentage of the original green volume). This considerable reduction in the intensity of collapse development during the early stages of drying could reduce the risk of related checking at that stage.

In 1967, a semi-commercial trial to determine the influence of prefreezing on the subsequent drying behaviour of 45 mm thick *E. obliqua* boards was conducted at Smithton, Tasmania, on a joint CSIRO/Timber Industry basis by F.J. Christensen and T.J. Connolly (unpublished results). In this experiment, some 1.7 m^3 of 3.8 m long backsawn boards (135 pieces) in stickered stacks were frozen to an average internal temperature of -18°C in 16 h in a freezing chamber running at -25°C but lacking effective forced-air circulation. Together with an equal volume and number of matching controls, they were briefly air dried, then predried at 38/32°C (DBT/WBT) and finally kiln dried at 52-66/46°C. All material was presteamed for a standard 4 h period before prefreezing and/or air drying but the controls only were reconditioned for 10 h between predrying and kiln drying. Total processing times were 118 days for the prefrozen material compared with 132 days for the controls. Furthermore, the results indicated that, while more collapse remained in the prefrozen material than in the reconditioned controls, the prefrozen material produced 6% more acceptable timber after drying than the controls, gave 36% more select grade quality timber, and showed a 19% increase in monetary value. However, these gains must be balanced against prefreezing treatment costs, which still remain to be determined.

CURRENT INVESTIGATIONS

EXPERIMENTAL PROCEDURE

(i) Trials at -10°C: A series of four batches of Tasmanian *E. delegatensis* timber, each of 20 green boards, were used in this experiment. Each batch, from one tree only, yielded 40 sample boards each 500 mm long x 100 mm wide x 35 mm thick, both ends of which were end-coated with several coats of lacquer. Half of these sample boards were frozen in a -10°C room where the circulating air velocity was 0.5 m/s while the remainder were retained as controls.

Prefrozen and control boards were matched on a one-for-one basis.

After freezing, half of the prefrozen boards together with half of the controls were air-dried while the rest were predried at 37/34°C, both to a moisture content of about 20%. At this stage, 20 sample boards from each batch (representing equal numbers from the air dried and predried groups of prefrozen and control boards) were reconditioned. All 40 sample boards from each batch were then kiln dried at 70/60°C to a final moisture content of close to 12% before final conditioning in a 12% equilibrium moisture content (e.m.c.) room.

(ii) Trials at -30°C: Four batches of 100 mm wide x 35 mm thick timber were again used but with the distinction that each batch consisted of 6 boards from each of 6 trees. These 36 boards yielded a total of 72 sample boards/batch in which prefrozen and control boards were again matched on a one-for-one basis. Half of the sample boards were frozen in a progressively decreasing ambient temperature, finally stabilized at -30°C, until the core temperature in most boards had fallen to -25°C. The reduction in temperature was achieved by pumping liquid nitrogen at a controlled rate into a reservoir on the floor of a laboratory kiln in which the vents and other openings were tightly sealed and the variable speed fan set to give a very low circulating speed. As the liquid nitrogen evaporated, it was circulated through the strip-stacked boards in the kiln across which a negligible drop in temperature was maintained by controlling the in-feed flow rate of liquid nitrogen.

After freezing, each batch of boards was randomly allocated to one of four groups comprising nine frozen samples and nine matching controls. Each tree was represented at least once within each of these groups, which were dried under a wide range of different conditions, although one group from each batch was seasoned according to current practice, i.e. predried, reconditioned and kiln dried. The other drying conditions tried, in decreasing order of severity, were:

1. Kiln drying from the green at 180/90-100°C to an average moisture content at 14%.
2. Kiln drying from the green at 120/50°C, interspersed with 30 min. steaming periods at 2 hrly intervals, to an average moisture content of 19%.
3. Predrying to about 40% moisture content followed by kiln drying at 120/50°C to an average moisture content of 21%.
4. Kiln drying from the green at 70/35°C to an average moisture content of 18%.

5. Drying from the green at 35/32°C and at a low circulation rate to an average moisture content of 28%.

6. Drying from the green at 16/14°C in a commercial progressive kiln to an average moisture content of 28%.

7. Air drying from the green to average moisture contents of 20% and 25% for each of two runs respectively.

In each run listed, half of the material was reconditioned after drying to the moisture contents shown and, apart from Item 1, all was finally kiln dried at 70/60°C to a moisture content of about 12% before final conditioning in the 12% room.

RESULTS AND DISCUSSION

(i) Trials at -10°C: Most of the material used was predominantly backsawn except for one complete batch of almost fully quartersawn boards (Batch 1).

It required approximately 17 h to obtain a core temperature of -8°C in the sample boards which lost only 2-3% in moisture content during that period for initial values ranging from 80-130%. No surface checking was apparent after prefreezing. A freezing room temperature of -10°C was selected on the basis of previous research (7) showing that shrinkage after drying in Californian redwood boards prefrozen at -7°C or below was reduced by half or more relative to matched controls.

After reconditioning and final drying, there was very little difference in the appearance of prefrozen and control boards, whether air dried or predried. Comparatively little degrade was evident, particularly in the one batch exhibiting extensive gum-ringing.

The mean cross-sectional shrinkage values given in Table 1 show a similar lack of effect of prefreezing on the behaviour of the wood.

In most cases, a one-way analysis of variance of the results showed that treatment differences are not significant. However, for batches 1, 3 and 4, shrinkage of the predried and not-reconditioned samples (both prefrozen and controls) was significantly greater than that of the predried and reconditioned controls (used for comparison). The large differences between certain of the batches for each of the treatments indicate the wide between-tree variation of the material. Batches 3 and 4 showed significantly lower shrinkage than batch 1 (at the 1% or 0.1% levels) and batch 2 (mostly at the 5% level or better).

The low level of drying degrade in the timber used in these runs highlights the practical difficulty of obtaining experimental material which is likely to be troublesome in drying, even when specifically selected on that basis at the

sawmill. Unfortunately, the drying behaviour of each batch could not be determined until after each run was completed.

TABLE 1

Mean cross-sectional shrinkage+ (%), after reconditioning and/or final drying, in 35 mm thick boards prefrozen (PF) at -10°C and matched controls (C)

Batch No.	Predried				Air dried			
	Reconditioned		Not-reconditioned		Reconditioned		Not-reconditioned	
	PF	C	PF	C	PF	C	PF	C
1	24.0	25.4	30.3	34.3	23.0	25.9	25.1	26.0
2	17.8	20.0	22.1	22.7	17.1	17.0	21.8	22.6
3	9.5	9.7	20.2	35.5	11.2	12.1	13.7	14.2
4	11.0	11.9	18.2	22.0	9.6	10.1	10.9	11.9
Mean of means	15.6	16.8	22.7	25.7	15.2	16.3	17.9	18.7

+ Expressed as a percentage of the green cross-sectional area.

(ii) Trials at -30°C: The bulk of the timber was predominantly backsawn except for batch 5, of which slightly more than half was quartersawn.

During the prefreezing of batches 5, 6 and 8, an ambient kiln temperature of -30°C was reached in about 1½ h and a core temperature of -25°C in most of the sample boards in 4½-5 h. This rate of cooling was almost eight times faster than for batches 1-4. Due to faulty liquid nitrogen pumping equipment during the course of freezing batch 7 material, it took 5½ h to reach an ambient kiln temperature of -30°C and 7 h for all boards to fall just below -15°C when cooling had to be terminated.

For all batches, prefrozen samples tended to dry faster than their matching controls, typically by about 20%, suggesting that prefreezing increased the wood's permeability.

After drying, there was no apparent difference in appearance between each prefrozen board and its matching control. However, very marked differences in the severity of drying degrade occurred both within and between batches. In general, the less severe drying conditions produced the least amount of degrade, although this trend was confounded in some cases by the wide differences in between-tree behaviour of particular boards. For material from batches 5 and 7, best results were obtained with air drying to about 20-25% before reconditioning

and kiln drying. Predried material developed comparatively little degrade with timber from batches 5 and 6 but severe degrade with that from batches 7 and 8. Reconditioning of predried material from batch 8 re-opened surface checks and produced little collapse recovery. Comparatively little surface or internal checking but substantial irrecoverable collapse occurred in material from batch 7 dried in the low temperature progressive kiln.

Cross-sectional shrinkages given in Table 2 cover the same treatment parameters as given in Table 1.

TABLE 2

Mean cross-sectional shrinkage (%), after reconditioning and/or final drying, in 35 mm thick boards prefrozen at -30°C and matched controls

Batch No.	Predried				Air dried			
	Reconditioned		Not-reconditioned		Reconditioned		Not-reconditioned	
	PF	C	PF	C	PF	C	PF	C
5	12.9	13.7	13.8	18.3	9.7	11.7	10.3	11.5
6	11.3	14.3	16.9	20.8	-	-	-	-
7	26.6	32.2	30.5	36.7	13.6	17.2	17.1	21.0
8	24.1	30.6	32.8	37.9	-	-	-	-
Mean of means	18.3	22.2	25.0	30.0	11.6	14.3	14.6	17.4

Again, most treatments did not significantly affect residual shrinkage after reconditioning and/or final drying. An exception was the reduced shrinkage obtained by air drying material from batch 7 instead of predrying it, in which case corresponding differences were significant at the 1% level at least. In contrast to batches 1-4, predried material from batches 5-8 did not show significant differences in shrinkage between the reconditioned controls and the not-reconditioned prefrozen samples. Furthermore, predried timber from batches 5 and 6 had lower average shrinkages, significant at either the 1% or 0.1% levels, than that from batches 7 and 8. For the air dried timber, differences in average shrinkage of material from batches 5 and 7 were significant at only the 5% level.

Despite the representation of 6 trees in each of batches 5-8, there were still very large between-batch differences in shrinkage, the actual extent of which is only partly shown by the mean values in Table 2. Actual differences can be illustrated by the results for the predried, reconditioned controls:

shrinkage ranges for batches 5 and 6 were 12.4-17.2% and 9.3-22.0% respectively compared with 23.5-40.3% and 19.2-40.0% for batches 7 and 8 respectively. This suggests that the two former batches were from a different population to the two latter ones. Furthermore, the timber from batches 7 and 8 was extremely refractory in drying, had significantly higher green moisture contents than batches 5 and 6, and was distinctly pinkish in colour in the green condition in contrast to the usual brownish-white of *E. delegatensis*. These differences indicate that the material from batches 7 and 8 was probably atypical of the species.

Obviously, high shrinkage alone is not the sole criterion for excessive drying degrade: batches 1 and 2, admittedly each from one tree only, had moderately high shrinkage but developed very little drying degrade.

OBSERVATIONS AND CONCLUSIONS

These are subject to the proviso that a great deal of variability in drying behaviour occurred both within and between the different batches of timber.

1. For all drying conditions used, prefrozen timber tended to dry at a faster rate than the matched controls thereby indicating an inherent increase in wood permeability induced by prefreezing.

2. Prefreezing did not noticeably alter the amount of drying degrade in prefrozen specimens and matched controls dried under the same conditions.

3. For the most refractory timber, the mildest drying conditions tended to give the least drying degrade.

4. Average cross-sectional shrinkage was invariably lower in the prefrozen timber than in the matched controls but differences were generally not statistically significant.

5. Drying conditions did not significantly affect residual shrinkage after reconditioning and/or final drying to 12% moisture content.

6. The atypicality of certain batches of timber was manifested by their substantial differences in shrinkage, colour, green moisture content and dried quality.

7. The slight and severe levels of drying degrade in different batches of timber with comparable shrinkage values indicated that high shrinkage is not the only factor responsible for severe degrade when the same drying conditions are used.

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DRYING OF 90 mm THICK RADIATA PINE FURNITURE TIMBER

F.J. Christensen

INTRODUCTION

A fairly common problem encountered during the high temperature drying of 90 mm thick radiata pine timber destined for furniture components is the development of some degree of surface and internal checking. Because the latter does not become evident until the interior of the timber is exposed by machining operations, it is important to ensure that the drying schedules used are unlikely to cause internal checking.

Whereas a high percentage of green-off-saw radiata pine timber up to 45 mm thick can generally be dried without internal checking at temperatures of up to 180°C dry bulb temperature, this is not the case with 90 mm squares which may develop serious internal checking with the standard 120°C schedule. This is related to the steeper surface to interior moisture gradients and the resulting higher drying stresses due to the longer moisture paths with the thicker timber.

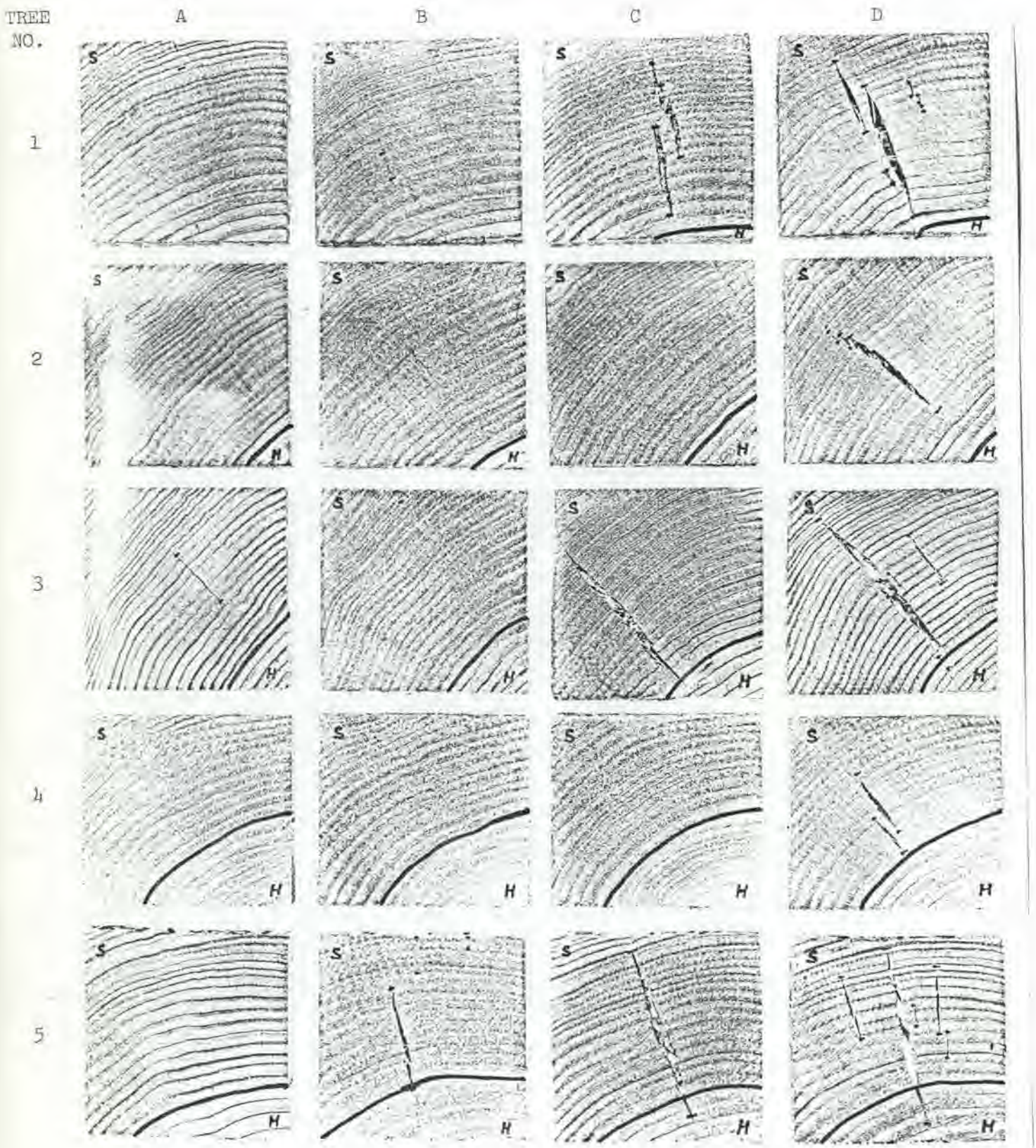
An answer to this checking problem lies with the use of milder drying conditions that will reduce the steepness of the moisture gradients. The work reported here is a preliminary determination of the efficacy of several drying schedules in respect of preventing internal checking in 90 mm thick radiata pine timber for use in the manufacture of furniture components.

EXPERIMENTAL PROCEDURE

A 3 m long by 105 mm (green) square was supplied from each of 10 different trees of age 50 years from the Mt Gambier district of South Australia. As shown in Fig. 1, this material covered the range of from 100% sapwood to about 80% heartwood. Between individual specimens, there was little difference in rate of growth of the sapwood whereas differences in rate of growth of the heartwood were somewhat more pronounced. The angle of sawing varied from about 45° to fully backsawn.

Four 600 mm long specimens were cut from each 3 m length of timber. Both ends of each specimen were sealed with aluminium foil attached by contact adhesive. One of the four specimens from each tree was randomly allocated to one of the four drying schedules given in Table 1. D is a constant rising temperature (CRT) schedule of the type where the difference in temperature between the surface and core of one of the "substantially sapwood specimens" was maintained at 10°C.

DRYING SCHEDULE



S SAPWOOD H HEARTWOOD

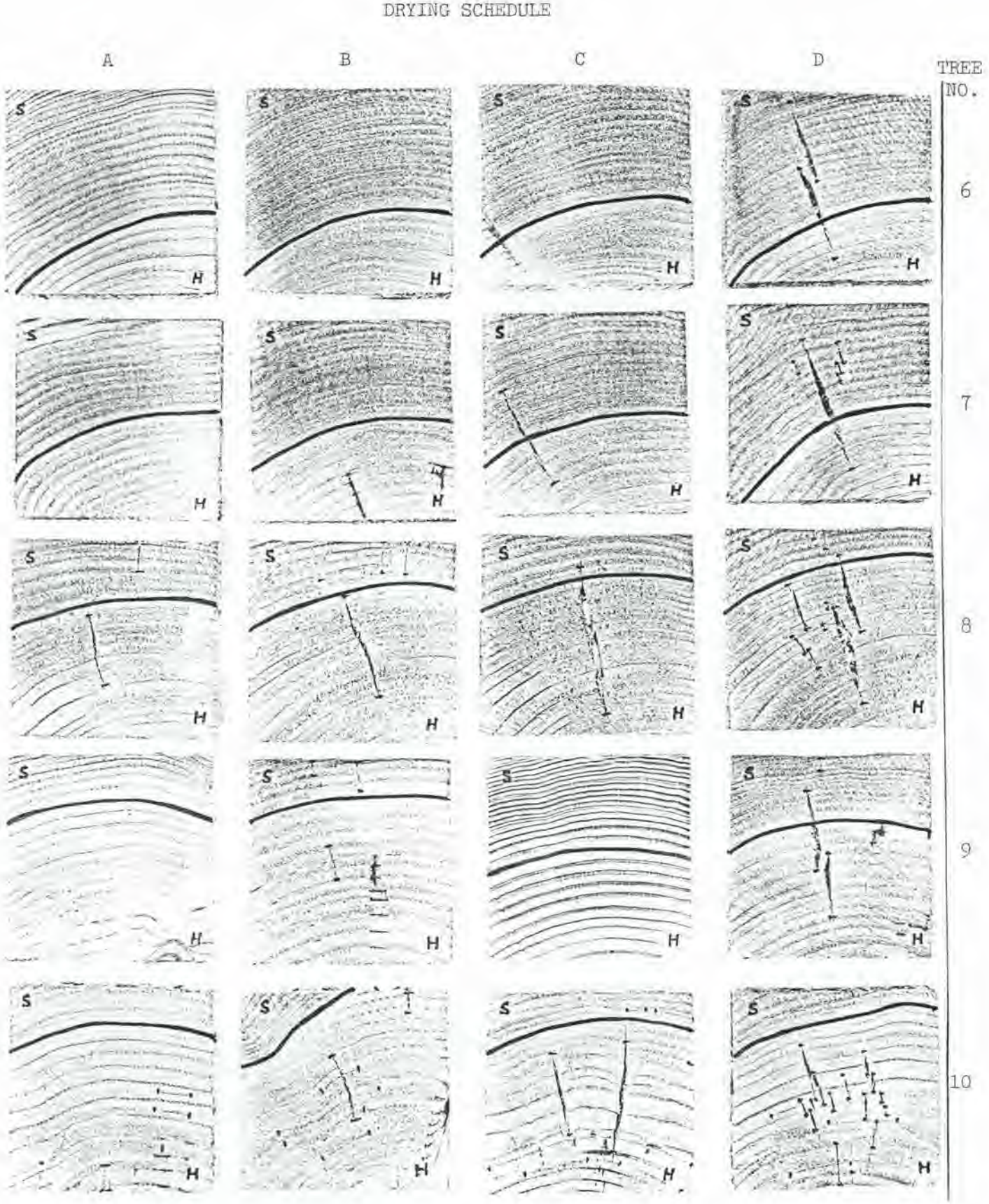


FIG. 1. Extent of internal checking after drying and conditioning at 12% EMC

Immediately after drying with schedules A, C and D, the timber was steamed at 100°C for 3 or 6 h. Subsequently, all timber was conditioned at an equilibrium moisture content (EMC) of 12% before sectioning and photographing.

RESULTS AND DISCUSSION

Drying times and moisture contents for the four schedules are given in Table 1. Initial moisture contents, which were similar for each of the four groups of specimens, averaged 92% and ranged from 44-121%.

TABLE 1

Drying schedules and results for 90 mm squares of radiata pine

Drying schedules				Drying time h	Steaming time h	Average moisture content - %	
Code	DBT* °C	WBT+ °C	Air speed m/s			After drying	After steaming
A	85	70	3	144	6	9	14
B	100	70	3	72	-	17	-
C	120	70	4	42	3	3	8
D Start Finish	40 105	30 40	3	96	3	14	17

* Dry bulb temperature + Wet bulb temperature

The wide variations in moisture content after drying and steaming arose from the practical problem of not knowing in advance the drying time that would be required for each schedule and the resultant overdrying and underdrying of the various batches. In view of the excessively high moisture pick-up during the 6 h steaming period for the Schedule A material, subsequent steaming periods were reduced to 3 h.

Figure 1 gives an indication of the extent of internal checking developed with each of the four drying schedules. It is apparent that there is a direct relationship between the severity of the drying schedule and the extent of internal checking. Even with the mildest schedule A, slight checking occurred in three of the ten specimens. This suggests that even milder conditions may be required to eliminate all internal checking in furniture grade timber from mature trees. There is no clear indication that the proportion of sapwood and heartwood present in a particular piece of timber affects the amount of internal checking that occurs during drying. Surface checking was very slight with schedules A and B and moderately severe with schedules C and D.

In fairness to the CRT schedule, which did produce the worst result, the controlled temperature difference of 10°C between the surface and core of the timber was selected on an arbitrary basis. It is possible that a better result might have been obtained with a smaller temperature difference although there is not much scope for reduction without extending the drying time considerably.

Further material has been obtained and prepared for another series of drying schedule tests. When completed, the best of all the schedules will be checked on a pilot scale for both internal checking and distortion, the latter not being clearly indicated by 600 mm long specimens.

CONCLUSION

Since, in 90 mm square sections of radiata pine timber for furniture applications the least amount of internal checking was developed with the mildest drying condition used, it is concluded that even milder conditions than 85/70°C will be needed to eliminate internal checking entirely.

AN APPROACH TO THE DRYING OF *EUCALYPTUS LAEVOPINEA* AND *E. AGGLOMERATA* USING CRT (CONSTANT RISING TEMPERATURE)

N. M. Nassif

INTRODUCTION

Eucalyptus laevopinea and *E. agglomerata* are two species used for reforestation in different areas of New South Wales, but the current knowledge of their wood properties is limited. An investigation was launched to provide authentic information about their mechanical and physical properties. One of the aspects studied was their drying characteristics. The approach adopted in the part of the investigation reported here was to use constant rising temperature which has been reported by Dendrick (1, 2, 3) and Quéméré (4) to accelerate kiln drying without increasing drying degrade. The main object of the project was to minimise drying time, volumetric shrinkage and wood degradation.

MATERIAL AND METHOD

Twenty *E. laevopinea* trees were sampled. Nine came from different locations in the Glen Innes District with altitudes ranging from 850 to 1200 m above sea level. The other eleven came from three locations in the Newcastle District with altitudes of 500 to 730 m. Two trees of *E. agglomerata* were sampled from one location in the Newcastle District, and a further ten trees from one location in the Bateman's Bay District. Both locations had similar altitudes of 300 to 400 m above sea level.

Central bark-to-bark flitches were sawn from head and butt logs, and resawn into 100 x 25 mm and 100 x 50 mm backsawn and quartersawn boards. Sections, for moisture content (m.c.%) and theoretical oven dry weight determination, were cut from each end to leave 0.6 m long samples, which were then end coated with a bituminous emulsion.

Four drying runs were carried out, using 48 samples in each run grouped in eight batches of six replicates, representing two species, two thicknesses and two directions of cut. Shrinkages were calculated at each stage of drying, as the percentage reduction in thickness and width related to the green measurement. After drying, all samples were reconditioned, planed all round, then graded according to AS 082-1965(5).

The laboratory kiln used to dry the samples was electrically heated and

steam humidified, with variable fan speed. Temperatures were regulated by automatic controllers. Vernier calipers and micrometers were used to measure the widths and thicknesses of the samples respectively. The temperature schedules used in the runs were similar to constant rising temperature (C.R.T.) except that the dry and wet bulb temperatures were raised manually in steps instead of continuously by pre-programmed controllers. The main differences between the four schedules were in the rate of raising the dry and wet bulb temperatures. The initial dry bulb temperature (D.B.T.) and the wet bulb temperatures (W.B.T.), as well as the rate of increasing the temperature per hour for each run are shown in Table 1. In the third run the samples were air dried from green to a mean m.c. of below 25%, then kiln dried. The fourth run was kiln dried using two C.R.T. schedules, the first from green to a mean m.c. of about 25%, and the second to complete drying. The scedules can be expressed by the following equations, bearing in mind that the temperatures were raised in steps and not continuously, as shown in graphs 1 to 4.

Run 1

D.B.T. (°C) = 30 + 0.25 t (t = time in hours)
W.B.T. (°C) = 28 + 0.15 t

Run 2

D.B.T. (°C) = 30 + 0.15 t
W.B.T. (°C) = 28 + 0.1 t

Run 3

air drying to a mean m.c. of below 25% then
D.B.T. (°C) = 30 + 0.25 t
W.B.T. (°C) = 28 + 0.1 t

Run 4

from green to a mean m.c. of about 25%
D.B.T. (°C) = 40 + 0.1 t
W.B.T. (°C) = 38 + 0.05 t

then
D.B.T. (°C) = (final D.B.T.) + 0.25 t
W.B.T. (°C) = (final W.B.T.) + 0.15 t

At the end of the first stage of run 4 the final D.B.T.'s were 58°C and 71.6°C, and the final W.B.T.'s 47°C and 53.8°C for 25 mm and 50 mm respectively.

All samples were reconditioned after the mean m.c. of each group of six replicates had fallen to below 20%. They were steamed at 100°C (saturated steam) for two hours for the 25 mm and four hours for the 50 mm samples, after one hour heating from ambient to 100°C.

RESULTS AND DISCUSSION

1. The volumetric shrinkage after reconditioning for each sample at 20% m.c. was calculated using the following equation

$$Sv = St + Sw - \frac{St\ Sw}{100}$$

where

Sv = volumetric shrinkage after reconditioning (%)
St = shrinkage in thickness after reconditioning (%)
Sw = shrinkage in width after reconditioning (%)

This assumes that longitudinal shrinkage is negligible.

The effects of the variables: species, thickness, direction of cut, kiln run schedule, and forestry district on volumetric shrinkage after reconditioning were analysed by analysis of variance. There were no significant differences between species, and the results for both species have been pooled. The effects of thickness and direction of cut will be reported elsewhere.

2. Table 2 shows the mean volumetric shrinkage after reconditioning for each run, and the significance of their differences. Shrinkage was significantly lower in Run 3 than in the other runs. This run had the mildest early drying conditions as it was air dried to a mean m.c. of below 25% before kiln drying. The lower shrinkage in Run 2 than in Run 1 (5% level) is probably attributable to the slower increase in severity of the drying conditions. The differences in shrinkage between the runs could be due to differences in degree of irrecoverable collapse, differences in the severity of the drying stresses developed, or a combination of both.

3. The mean volumetric shrinkage after reconditioning for the *E. laevopinea* samples from Newcastle District was 7.00%, whereas that from Glen Innes District was 10.45%. These are significantly different at the 1% level.

Eucalypt species, particularly *E. fastigata*, *E. viminalis* and *E. obliqua*, growing at higher altitudes in northern N.S.W. are regarded by sawmillers as poorer than the lower altitude species, due to their greater tendency to collapse, check and split during drying. Similar opinions have been expressed about *E. laevopinea* which is regarded more favourably as a species for sawn timber production in coastal than in tableland districts. This tends to be confirmed by the larger shrinkage in the samples from Glen Innes, which came from higher altitude sites than the samples from Newcastle.

Ghali (6), whose samples came from the same trees as the samples used in the drying investigations, also found higher shrinkage values for samples

from Glen Innes than for those from Newcastle. He also found that the Glen Innes samples were lower in density than those from Newcastle. As collapse normally increases as density decreases (Campbell and Hartley (7)), the differences could be due to collapse that was not recovered during reconditioning.

There was no significant difference between the mean volumetric shrinkages after reconditioning of the *E. agglomerata* samples from the two districts sampled.

4. Results of grading the samples to AS 082-1965(5) are shown in Table 3.

As the building grade is the lowest and cheapest grade, we can rank the runs, starting with the run with the least number of building grade samples and finishing with the highest, viz. 3, 4, 2, 1. Run 3 also provided the highest number of samples in select grade. This run also had the lowest volumetric shrinkage after reconditioning, and the grading confirms that the best quality dried product will be produced by using very mild early drying conditions.

Much of the degrade was due to wood defects - mainly borer holes and kino veins - and it will probably be necessary to select the green wood on the basis of its defects for the production of select grade dried material. For applications such as dried framing, most drying degrade is of little consequence and more severe conditions can be used.

Fairly severe internal checking occurred in some of the 50 mm samples in Run 1, particularly in the *E. laevopinea*. This indicates that the conditions were too severe for the production of select grade material, particularly in 50 mm thickness. Some less serious internal checking also occurred in a few 50 mm samples in Runs 2 and 4.

There was little overall difference in the amount of degrade between the two species. The influence of thickness and direction of cut will be reported in detail elsewhere, but the general observations can be made that there was less degrade in the 25 mm than in the 50 mm samples, and more face checking in the backsawn than in the quartersawn samples. This is typical of the eucalypts and confirms past experience that more severe schedules can be used for thinner material, and quartersawing should be considered for maximising the production of select grade dried material.

5. Table 4 shows the initial m.c.'s of the samples and their standard deviations (S) as well as the drying time to 20% m.c. for each batch in the four runs.

Run 1 was the fastest of the kiln drying runs from green. This was

expected, as it had the highest rate of temperature increase. It also gave the worst results in grading, and had the highest volumetric shrinkage after reconditioning.

Run 4 was the next fastest, and in grading was superior to both Runs 1 and 2. The two-stage schedule approach used in this run appears promising, and will be investigated further. It may be possible to reduce degrade by starting at lower temperatures, and to accelerate the drying later in the run by changing to the second stage at m.c.'s higher than 25% and using more severe conditions in this stage.

The 50 mm samples of *E. laevopinea* dried faster than *E. agglomerata*. This agrees with the general tendency of drying rate to decrease with increasing density, as *E. laevopinea* is lower in density than *E. agglomerata* (M. Ghali, pers. comm.). The effect of species on drying rate was less marked in the 25 mm samples.

As anticipated, backsawn samples dried faster than quartersawn in all runs.

CONCLUSION

The drying characteristics of *E. laevopinea* and *E. agglomerata* are typical of eucalypts with similar wood defects and densities that do not collapse severely. Constant rising temperature is a promising approach to kiln drying them from green, particularly using a two-stage schedule starting with mild conditions, and changing to more severe conditions when the m.c. has fallen to about the fibre saturation point. To minimise drying degrade it may be necessary to use a preliminary period of air drying before final kiln drying.

ACKNOWLEDGEMENT

The author would like to thank A. Lamond and R. Lee for technical assistance, and P. Lind for carrying out the statistical analyses.

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TABLE 1

Temperature schedules

Run No.	Initial temperature		Rate of increasing temperature per hour		Rate of increasing temperature per hour below 25% m.c.	
	D.B.T.	W.B.T.	D.B.T.	W.B.T.	D.B.T.	W.B.T.
1	30°C	28°C	0.25	0.15	0.25	0.15
2	30°C	28°C	0.15	0.10	0.15	0.10
3	30°C	28°C	-	-	0.25	0.10
4	40°C	38°C	0.10	0.05	0.25	0.15

TABLE 2

Mean volumetric shrinkage (%) after reconditioning in the four runs. Values shown are pooled means for *E. laevopinea* and *E. agglomerata*.

Run	R3	R2	R4	R1
Mean	6.59	8.17	8.35	9.20
5%		———	——	———
1%		———		———

Means underlined with the same line are not significantly different at the level shown.

TABLE 3

Results of grading to AS 082-1965

Run		R1			R2			R3			R4		
Species/ thickness	Cut	Sel.	St.	B.	Sel.	St.	B.	Sel.	St.	B.	Sel.	St.	B.
E. laevopinea 25 mm	Q.	3	3	0	1	3	2	2	4	0	2	4	0
	B.	0	4	2	0	3	3	0	4	2	1	4	1
E. agglomerata 25 mm	Q.	1	4	1	1	4	1	3	3	0	3	3	0
	B.	1	3	2	1	4	1	1	2	3	0	4	2
E. laevopinea 50 mm	Q.	0	1	5	2	2	2	2	3	1	0	2	4
	B.	0	1	5	0	4	2	0	5	1	0	4	2
E. agglomerata 50 mm	Q.	0	3	3	1	3	2	1	5	0	0	5	1
	B.	1	0	5	0	1	5	0	5	1	0	4	2
25 mm total		5	14	5	3	14	7	6	13	5	6	15	3
50 mm total		1	5	18	3	10	11	3	18	3	0	15	9
E. laevopinea total		3	9	12	3	12	9	4	16	4	3	14	7
E. agglomerata total		3	10	11	3	12	9	5	15	4	3	16	5
Run total		6	19	23	6	24	18	9	31	8	6	30	12

Sel. = select grade
St. = standard grade
B. = building grade

Q. = quartersawn
B. = backsawn

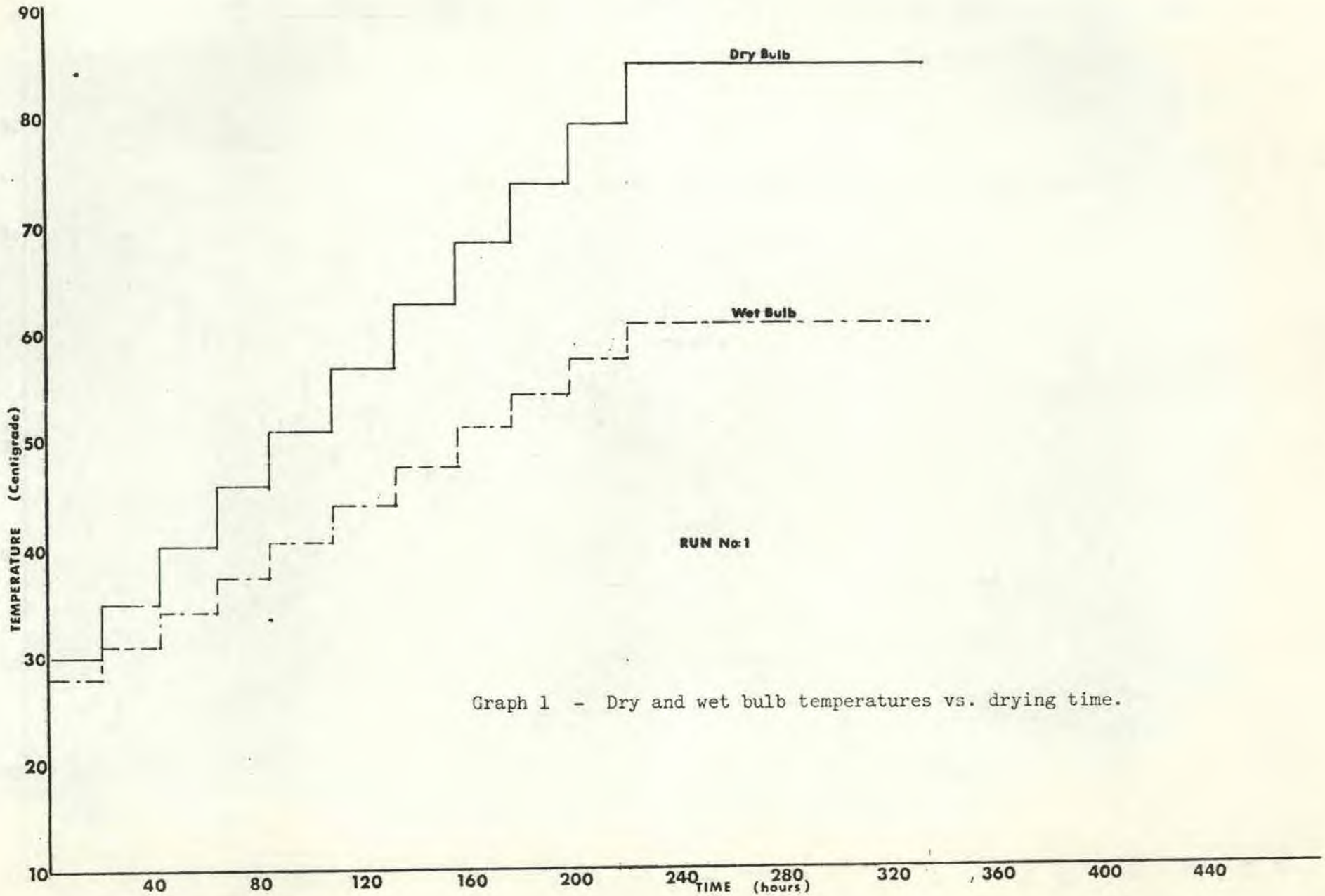
TABLE 4

Initial m.c.% and drying time to 20% m.c. for each batch for each run

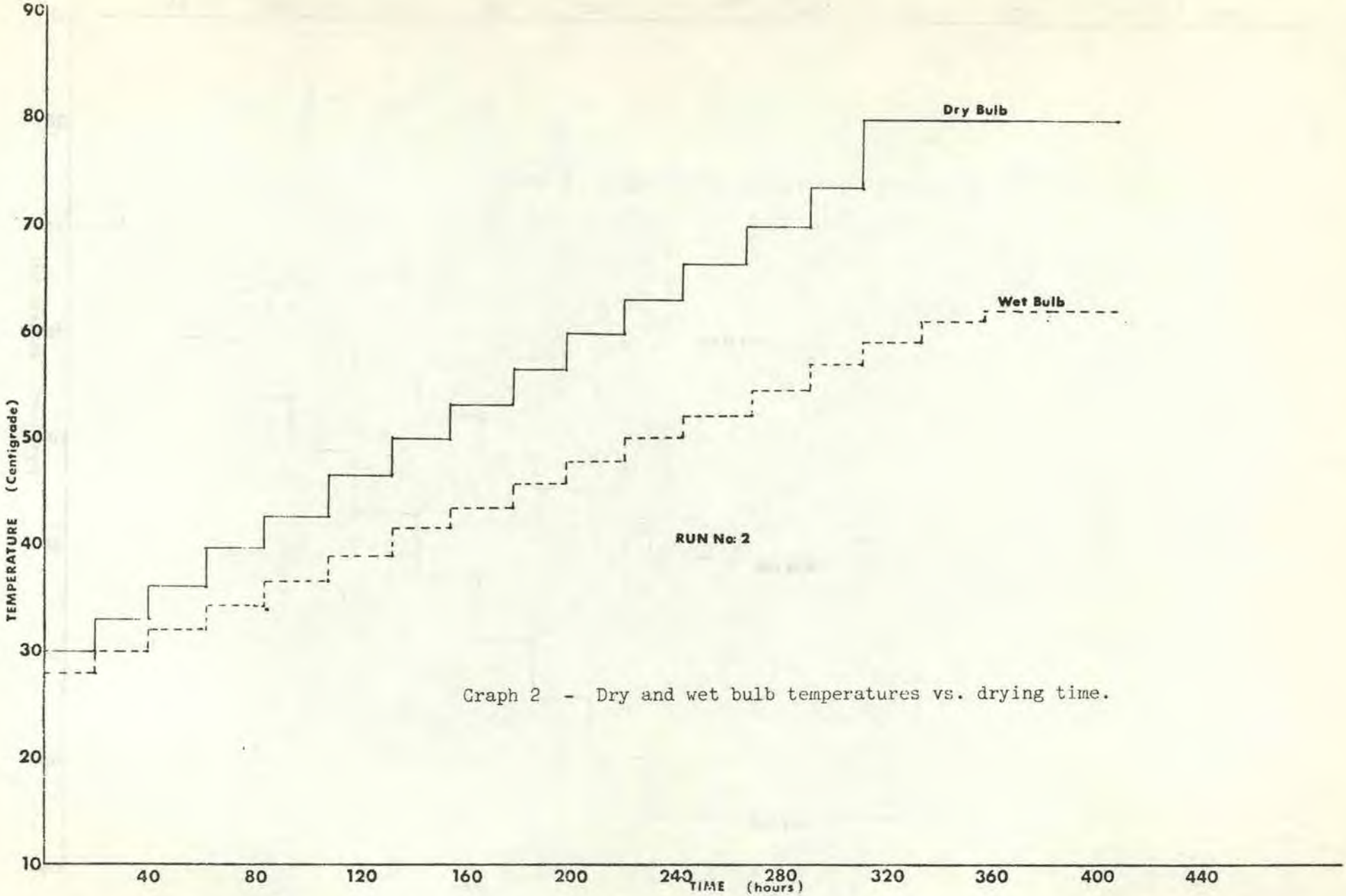
Batch		Run 1			Run 2			Run 3			Run 4		
		Mean initial m.c.	Standard deviation S	Time in hours	Mean initial m.c.	Standard deviation S	Time in hours	Mean initial m.c.	Standard deviation S	Time in hours	Mean initial m.c.	Standard deviation S	Time in hours
E. laevopinea													
25 mm	Q.	67.0	10.90	197	63.5	14.55	256	62.3	18.05	31	57.4	8.30	215
	B.	70.0	11.70	196	72.0	14.14	236	67.5	18.14	41	60.1	19.50	203
E. agglomerata													
25 mm	Q.	52.4	15.37	164	61.0	10.30	248	60.4	14.35	59	55.3	13.66	205
	B.	67.8	12.29	166	66.9	21.73	225	68.8	17.47	49	66.6	16.22	208
E. laevopinea													
50 mm	Q.	62.9	18.77	288	64.8	12.23	404	61.7	11.35	132	72.5	11.44	398
	B.	73.0	13.93	257	67.4	18.84	360	64.8	14.28	84	66.5	16.04	338
E. agglomerata													
50 mm	Q.	61.4	15.28	277	62.5	8.66	390	65.1	13.97	115	64.1	11.31	364
	B.	61.1	13.22	244	63.5	11.25	332	66.1	22.32	105	62.3	21.33	331
Mean of run		64.5		224	65.2		306	64.6		77	63.1		283

Note: Run 3 was air dried from green to below 25% m.c. for 1313 hours for the 25 mm and for 3160 hours for the 50 mm before kiln drying to 20% m.c.

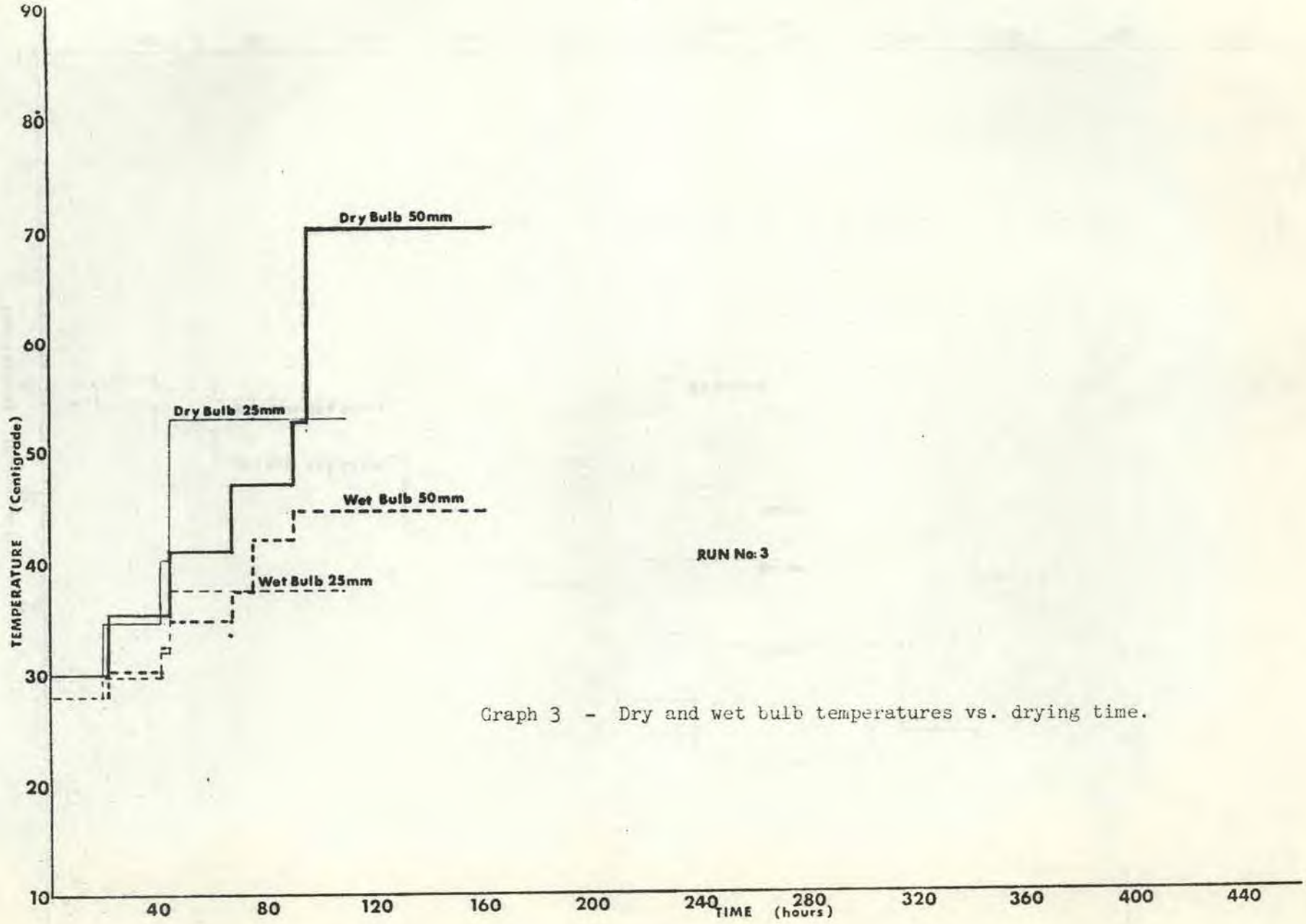
Q = quartersawn; B = backsawn.



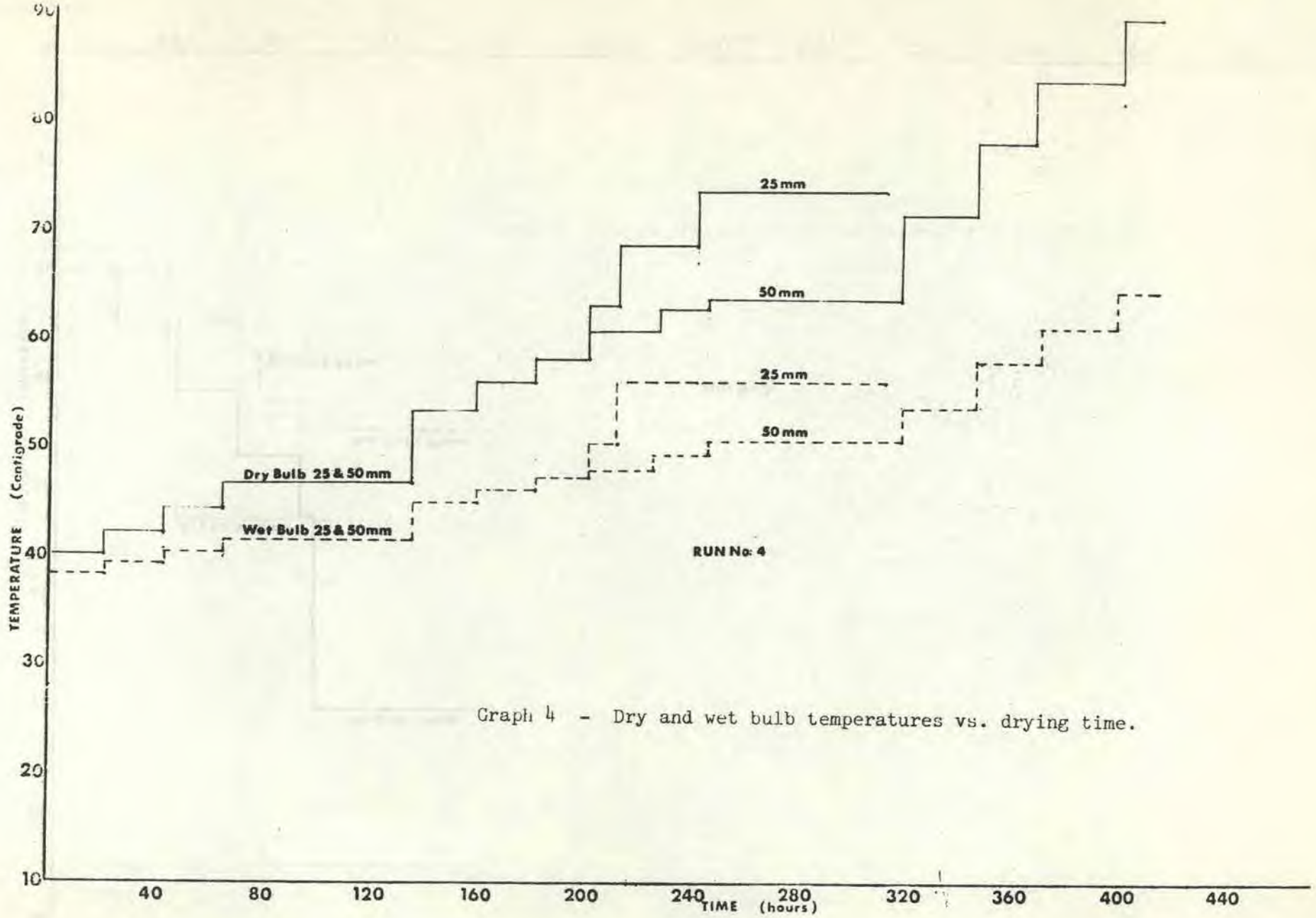
Graph 1 - Dry and wet bulb temperatures vs. drying time.



Graph 2 - Dry and wet bulb temperatures vs. drying time.



Graph 3 - Dry and wet bulb temperatures vs. drying time.



Graph 4 - Dry and wet bulb temperatures vs. drying time.

WOOD FOR ENERGY GENERATION

AN ESTIMATE OF AVAILABILITY FROM AUSTRALIAN FORESTS

by

E.D. Harries

ABSTRACT

Wood available for energy generation from Australian forests is considered as the difference between potential annual growth and the quantity required for other purposes. It is assumed this wood could be obtained from 50 per cent of the area of forest after excluding conservation reserves. Productive native forest lying within 200 km of major population centres is shown to have a potential of some 10 million tonnes oven-dry per annum of wood available for energy generation assuming these forests are intensively managed. A further 1.5 million tonnes oven-dry may be available from existing forest plantations.

Further research is needed into the potential supply capacity of the poorer quality forest areas, which are very extensive and currently produce very low volumes of timber products.

INTRODUCTION

Wood as a fuel has had such a long and close association with our culture that a return to its use is seen by many with a sense of nostalgia - and although the economic dominance of petroleum as a source of energy has lasted barely a generation, we tend to lose sight of the fact that the use of wood and its derivatives for energy generation already has an extensive technology.

The search for alternatives to petroleum is inevitably resulting in a re-evaluation of the potential for using wood. Monitoring the changes in the economics of the various options is an essential part of this search, and this requires a knowledge of the physical availability of the raw material.

In Australia several studies have looked at the potential of wood as a source of energy (1, 2, 3, 4); estimates have been made of land suitable and for growing forests as energy crops or for similar material (1, 4, 5); studies have been made of the potential productivity of such crops (6, 7); and estimates have been made of wood residues available for energy generation (8). However the potential availability in Australia of wood from the forest for such purposes has not been reported. This paper derives an estimate from presently available information and indicates deficiencies in the resource data.

ESTIMATING WOOD AVAILABLE IN THE FOREST

The task of conducting a forest inventory becomes more costly as one attempts to obtain more detailed information on standing volume, growth and yield. Declining use of wood for fuel over the past 50 years in Australia has resulted in data for this class of material being rarely collected. The forest services of the States and Territories have concentrated their attention on those components of forest produce in demand - sawlogs, pulpwood, posts and poles, etc., and more recently evaluation of intangible forest values associated with recreational pursuits and nature conservation.

In this paper the quantity of wood in the forest which may be considered available for energy generation is not based on an estimate of the standing volume of suitable material. It is an estimate of potential growth per annum less the volume of wood committed to other uses. In the absense of appropriate data, potential growth volume is taken down to current merchantable diameter limits for pulpwood, i.e. not total biomass. To illustrate the potential of this raw material supply and the deficiencies in our knowledge of it the following assumptions have been adopted:-

1. The forest resources considered are limited to geographical zones surrounding major population concentrations. A range of 200 km is the approximate limit from the population centre within each zone.

2. Areas of forest in conservation reserves proclaimed as at 30 June 1971 are excluded and 50 per cent of the balance of potentially productive native forest is considered to be unavailable for harvesting of wood for the reasons advanced by Florence and Shepherd (9).

3. Harvesting of rainforest will be excluded.

4. The areas of forest land are those reported by the FORWOOD Conference (10), current as at June 1971.

5. Cutting will be limited to the equivalent of the annual increment possible with intensive silvicultural practice (9) and the potential of special "energy plantations" is excluded.

Based on the limitation of the first assumption a total of 6 zones have been demarcated. Each zone is composed of one or more of the Forest Production Regions as defined for the FORWOOD Conference (10). The location of these zones is indicated in Figure 1.

Gross areas of productive forest and estimates of potential sustained wood volume produced from these areas are set out in Table 1. The figures for potential productivity are derived from the best available estimates reported for intensively managed forests in forest types appropriate to those in each zone (11, 12, 13). It is to be noted that the figures used for Class I forest fall within the range for intensively managed Eucalypt forest quoted by Florence and Shepherd (9), when clear-cutting systems of silviculture are adopted. Very little information on the productivity of Class II and III forests was available. Where published information on productivity was not available estimates were based on extrapolation of data published for similar forest types.

The volume of wood committed to other uses in each zone is derived from the estimated removals in 1980 prepared for the FORWOOD Conference (10) or subsequently revised estimates made available by the State Forest Services to the Forestry and Timber Bureau.

Potential production on an oven-dry weight basis was calculated using basic densities for the major species specified in the forest type descriptions (10).

Estimates of wood potentially available for energy generation are derived in Table 2. Because of deficiencies in information it was assumed that volumes removed from each type were in proportion to the areas of each type and basic density was weighted in proportion to the areas of each type in each zone.

DISCUSSION OF RESULTS

For the 6 zones considered in this paper the estimates of wood potentially available from native forest for energy generation amount to 9.9 million tonnes per annum on an oven-dry (O.D.) weight basis. A further 1.5 million tonnes O.D. is also indicated as being potentially available from plantations.

An examination of the data in Table 1 reveals the apparent importance of the higher quality forests (Class I). While these forests occupy relatively small areas their impact on total wood production is great because of the very much higher productivity rate. These areas have received most attention from forest services and it is likely that they will be largely retained for future sawlog production.

The low productivity figures for Class II and III forest are applicable to management regimes aimed at producing sawlogs. For maximum volume production independent of stem diameter much higher productivity rates may be possible. The combined area of these forest types is more than five times the area of the Class I forest and thus the potential for greater overall production of fuel wood may lie in these areas. In addition there are very extensive areas of low grade forests and woodlands which are not considered in the forest classification system used by FORWOOD (10), which may also be used to produce wood for energy generation.

CONCLUSIONS

Provided the existing native forests within 200 km of the major population centres (excluding Adelaide) are managed for intensive wood production, about 10 million tonnes (oven-dry) of material suitable for energy generation could be produced. An additional 1.5 million oven-dry tonnes may be available from existing forestry plantations.

Whether this material will be economically available for energy generation will depend on the energy cost of harvesting and transport to appropriate conversion plants, as well as the conversion process. This cost will tend to decrease with increasing concentrations of raw material on a given site. Hence the higher quality forests must initially be favoured for the production of wood for energy generation.

However, when other factors are considered, especially the need for these forests to provide other values, one becomes less confident of their practical ability to supply. The lower quality forests are much greater in extent, yet we know very little of their potential for small diameter wood production or the economics of such production.

In the context of the search for alternative sources of raw materials for energy generation, research aimed at improving the productivity and economics of growing wood in the lower quality forest areas of Australia may yield the best returns.

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TABLE I

Estimate of Potential Production From Selected Forest Areas

Zone	Location	'FORWOOD' Regions Included	Areas of Forest* ('000 ha.) I	II	III	IV	Potential Production Volume $m^3/ha/a$	'000m^3/a	Weight (oven-dry kg/m	'000t/a
1	S.E. Qld. and Nth Coast NSW.	8,11	309				14.0	4 326	703	3 041
				408			1.0	408	922	376
					856		0.5	428	902	386
						95.4	12.0	1 145	525	601
					TOTAL			6 307		4 404
2	Central Coast N.S.W.	15,16,27	479				14.0	6 706	690	4 627
				534			1.0	534	900	481
					932		0.5	466	900	419
						15.8	10.0	158	525	83
					TOTAL			7 864		5 610
3	South coast, central and northern table-lands N.S.W.	18,21,22	357				11.6	4 141	700	2 899
				634			3.3	2 092	769	1 609
					1321		0.7	925	800	740
						80.0	18.0	1 440	404	582
					TOTAL			8 598		5 830
4	Central Victoria**	27,28,29 30,31	518				12.6	6 527	505	3 296
				3011			2.5	7 528	704	5 299
					353		1.5	530	649	344
						136.6	18.0	2 459	404	993
					TOTAL			17 044		9 932
5	Tasmania	33,34,35 37	435				11.6	5 046	500	2 523
				1641			2.5	4 103	700	2 872
					-		-	-	-	-
						44.7	18.0	805	404	325
					TOTAL			9 954		5 720
6	Perth, W.A.	44	-				-	-	-	-
				1495			1.0	1 495	567	848
					21		0.5	10	600	6
						15.0	16.0	240	400	96
					TOTAL			1 745		950

* Forest Categories - I : Eucalyptus Productivity Class I (after FORWOOD (10))
II : " " " II
III : " " " III
IV : Plantations, all species.

** Data for this zone was compiled by a process of interpolation from FORWOOD data (10).

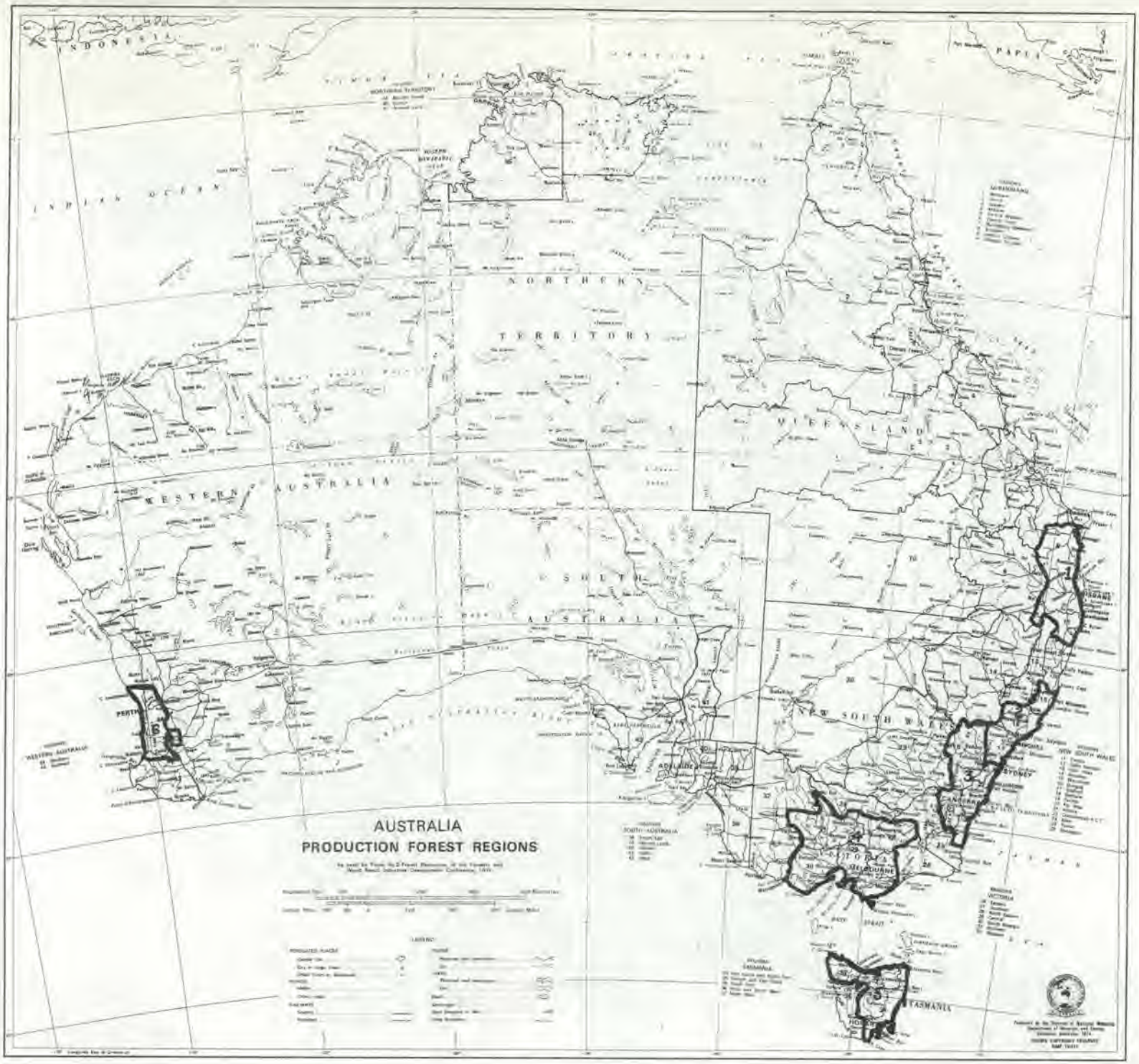
TABLE 2.

Estimate of Wood Potentially Available from
Selected Forest Areas in 1980 for Energy Generation

Zone	Forest Type	Potential Production ('000t/a O.D.) Gross Area	Net Area	Removals from Forest 1980* ('000 m^3)	('000t O.D.)	Wood Available From Forest for Energy Generation, 1980 ('000 t O.D.) Native **	Plantation
1	Native**	3 803	1 902	810	596	1 306	
	Plantation		601	610	320		281
2	Native**	5 527	2 764	1 301	934	1 830	
	Plantation		83	90	47		36
3	Native**	5 248	2 624	345	255	2 369	
	Plantation		582	513	207		375
4	Native**	8 939	4 470	1 612	983	3 487	
	Plantation		993	1 001	404		589
5	Native**	5 395	2 698	3 413	2 013	685	
	Plantation		325	410	166		159
6	Native**	854	427	355	201	226	
	Plantation		96	92	36		60
	TOTALS	29 766	17 565	10 552	6 162	9 903	1 500

* Forecast yields, FORWOOD 1974 and F. & T.B. 1978.
** Includes Eucalypt Productivity Classes I, II and III, after FORWOOD (10).

FIGURE 1


INDONESIA
PAPUA
INDIAN OCEAN
NORTHERN TERRITORY
QUEENSLAND
WESTERN AUSTRALIA
SOUTH AUSTRALIA
NEW SOUTH WALES
VICTORIA
TASMANIA
PERTH
ADELAIDE
SYDNEY
MELBOURNE
HOBART
AUSTRALIA
PRODUCTION FOREST REGIONS

PROPERTIES OF *PINUS RADIATA* BARK EXTRACTS IN RELATION TO THEIR USE FOR ADHESIVES

K. F. Plomley, P. J. Collins and R. E. Palmer

1. INTRODUCTION

Aqueous extracts of the bark and wood of certain trees contain high concentrations of polyhydroxy phenols (tannins), which react with formaldehyde to form resins. This reaction is the basis of their use as adhesives.

Extracts vary widely in their properties (4,5). Adhesion, rate of gelation with formaldehyde, and viscosity are especially important, since minimum requirements for these properties have been established for commercial synthetic resin adhesives. Tannin based adhesives must comply with these requirements if they are to gain ready acceptance by industry.

Strong wood to wood bonds have been obtained with *Pinus radiata* bark extracts (3), but problems have been encountered in formulating adhesives because of the high viscosity of some high yield extracts and also because of the relatively fast reaction of radiata polyphenols with formaldehyde over a wide range of pH at ambient temperatures.

This paper reports studies of properties of different extracts of the butt bark of *Pinus radiata* and of the effects of different treatments, which were examined with the aim of providing adhesive formulations suitable for industrial use.

2. EXPERIMENTAL

REACTION OF EXTRACTS WITH FORMALDEHYDE

The influences of pH between 4 and 7 and of temperature between 25°C and 90°C on the gelation of an aqueous solution of 60°C extract with paraformaldehyde are shown in Table 1. The extract concentration of the test solutions was constant at 35%.

At the same concentration and pH 5.5 the gelation times at 60°C of solutions in 10% and 20% methanol were increased by about 30% and 60% respectively.

The amounts of Stiasny precipitate formed by the aqueous extracts, methanol solubles, and fractions obtained by ultra-filtration (see below), are given in Table 2. The method of Wissing (6) was used with 0.5 g samples of extract.

TABLE 1

Gelation Time (min) of 60°C Extract with Paraformaldehyde

Temperature (°C)	pH 4.0	5.5	7.0
25			110
40	300	91	
60	21	9.9	
90	3.1	2.2	

TABLE 2

Amount of Stiasny Precipitate Formed by the Aqueous Extracts and Various Fractions

Extracts and Fractions	Stiasny Precipitate (% of extract solid)
20°C	69.9
60°C	80.1
100°C	82.0
100°C, 1% Na_2CO_3	82.8
100°C, methanol solubles	87.2
fraction > 10^6*	103.9
fraction < 10^6	71.9

* Fraction of 100°C extract containing compounds which have the molecular size of the corresponding number molecular weight Dextran.

VISCOSITY OF AQUEOUS SOLUTIONS OF EXTRACTS AND FRACTIONS

The viscosities at 25°C of aqueous solutions of 20°C, 60°C and 100°C aqueous extracts at a solid concentration of 45% and pH 4 were found to be 0.3, 2.8 and 18 Pa.s respectively.

The sample of the fraction of 100°C extract of less than 10^6 nominal molecular weight limit (NMWL) Dextran was too small for the determination of viscosity at 45% solid content. The viscosity of the fraction was compared with that of 20°C and 60°C extracts at 23% solid content. The viscosities for the fraction, 20°C and 60°C extracts were 0.011, 0.007 and 0.017 Pa.s respectively.

INFLUENCE OF pH ON VISCOSITY

The viscosity of aqueous solutions of 60°C extract was measured at pH 3.4 to 10.2 at 25°C. The pH was adjusted with sodium hydroxide and the final concentration of extract in water was 35%.

Between pH 3.4 and 4.2 the viscosity was low, about 0.4 Pa.s. Viscosity then increased with pH to a maximum of about 1.8 Pa.s at pH 6.5 and decreased to 0.2 Pa.s at pH 10.2. Viscosities were measured 1 h and 23 h after adding sodium hydroxide; there was an increase in viscosity after 23 h, which was least between pH 3.4 and 4.2.

EFFECT OF TREATMENT WITH SODIUM METABISULPHITE

A 40% aqueous solution of 100°C extract was heated at 80°C with 1.25%, 2.5%, 5.0% and 7.5% sodium metabisulphite for up to 6 h. Viscosity decreased with increase in sulphite concentration up to 5%; the difference between the effects of 5% and 7.5% was slight. With 5% sodium metabisulphite viscosity decreased from about 5 Pa.s to 0.54 Pa.s in 2 h and 0.27 Pa.s in 6 h.

EFFECT OF METHANOL AND PHENOL

The viscosity of an aqueous solution of 100°C extract at 43% solid content was 11.8 Pa.s. At the same concentration in 10% and 20% methanol the viscosities were 2.7 and 1.1 Pa.s respectively. By adding phenol equivalent to 5% of the solid content the viscosity of the 43% aqueous solution was reduced to 7.9 Pa.s.

EFFECT OF TEMPERATURE

The viscosity of an aqueous solution of 100°C extract at pH 4 decreased from 12.9 Pa.s at 25°C to 2.0 Pa.s at 40°C and 0.75 Pa.s at 50°C.

EFFECT OF FRACTIONATION BY ULTRAFILTRATION

A P.C.I. Tubular Type B1 ultrafiltration system was installed for the preparation of adequate quantities of fractions for studies of adhesive properties. The system comprises 18 tubes of 12 mm bore and 1200 mm long housed in the B1 module with series flow end caps.

In an initial test of the equipment a 5% aqueous solution of 100°C 1% Na_2CO_3 extract was filtered with a T7/B P.C.I. membrane of 0.1 micrometer particle size rejection. Average ultrafiltrate flow was 400 ml/min with a feed pressure of 586 kPa. The viscosity of the ultrafiltrate (55% of the original extract) was found to be extremely low, 0.09 Pa.s at a solid content of 45%. Better separation of the desired fraction was obtained by using

larger quantities of water; a second ultrafiltration with 10^3 NMWL Dextran membrane removed this water as well as low molecular weight materials.

A 0.5% solution of the methanol soluble fraction of 100°C extract was ultrafiltered with a T2/A P.C.I. membrane system at a feed pressure of 860 kPa. Water was removed at the rate of 1.4 litres/min. A final concentration of 21% was achieved when pumping was stopped due to depleted feed volume.

ADHESION

Adhesion tests were made with veneers at 12% moisture content using two-ply shear test specimens according to AS1321.3-1975.

Adhesives prepared from 60°C extract and with pH adjusted to 4.0, 5.0, 5.8 and 6.8 with sodium hydroxide gave uniformly high wood failures (88%-98%) with coachwood (*Ceratopetalum apetalum*) veneers at 12% moisture content when tested dry, after 24 h immersion in cold water and after 72 h in boiling water. Wood failure differences were not significant.

The adhesive properties of 20°C, 60°C and 100°C extract treated with sodium metabisulphite (5%, 80°C for 2 h) were compared using coachwood and tulip oak (*Argyrodendron actinophyllum*) veneers. The results, together with a limited test of the methanol soluble fraction of 100°C extract using tulip oak veneers, are given in Table 3.

In a test with tulip oak veneer, 60°C and untreated 100°C extracts showed no significant difference in bond quality.

TABLE 3

Bond Quality after 72 h in Boiling Water of Coachwood and Tulip Oak Veneers Bonded with *P. radiata* Extracts

Extract	Failing Load (MPa) and Wood Failure (%)	
	Coachwood	Tulip Oak
20°C	2.435-100	3.542-12
60°C	2.582-98	3.692-28
100°C, sulphite treated	2.863-90	3.874-30
100°C, methanol solubles		3.650-36

3. DISCUSSION

The working life and curing time of tannin-formaldehyde adhesives are controlled by pH and the use of paraformaldehyde as the crosslinking agent.

For wattle tannin adhesives an adequate working life is obtained at about pH 7. The results in Table 1 show that at pH 7 a radiata tannin solution of 35% solid content has a gelation time of only 110 min at 25°C.

Factory conditions make it more realistic to formulate industrial adhesives for use at 40°C than at 25°C. At this temperature the gelation results indicate that an adhesive pH less than 5.5 is desirable. The practicability of formulating radiata tannin adhesives at pH 4 in order to obtain a longer working life is supported by experimental results which showed that at pH 4 gelation time at 90°C was short, viscosity was relatively low, the rate of increase in viscosity (in the absence of formaldehyde) was at a minimum value, and there was no significant difference in bond quality between pH 4.0 and 6.8.

For sulphite treated extracts or solutions of extracts in dilute alcohol, the pH could probably be slightly higher without decreasing the working life, since both these treatments had a retarding effect on gelation.

Temperature and pH have a strong influence on viscosity as well as on extract yield. For example, the viscosities of aqueous solutions of 20°C, 60°C and 100°C extracts were 0.3, 2.8 and 18 Pa.s at 45% solid content. This increase in viscosity was accompanied by an increase in the proportion of a cold water insoluble fraction. The viscosity of the 100°C extract was too high for normal conditions of use as an adhesive.

Dalton (1) prepared alcohol soluble fractions of a number of tannins and observed that they had lower viscosities than the whole extracts, owing to the elimination of a fraction of the highly condensed tannin rather than of non-tannin material. The methanol solubles of the 100°C extract of the present studies amounted to 87% (Y. Yazaki and W. E. Hillis, unpublished data). The viscosity of the methanol soluble fraction was found to be 0.5 Pa.s at 47% solid content.

When the various extracts, 20°C, 60°C and 100°C were fractionated by ultrafiltration with membranes of nominal molecular weight limit (NMWL) Dextran of 10^3-10^6 in a Millipore 47 mm stirred cell, it was shown that the extracts contained approximately 7-22% of a fraction of molecular size larger than that of 10^6 NMWL Dextran (Y. Yazaki and W. E. Hillis, unpublished data).

After the removal of this fraction from 100°C aqueous extract, the residual extract had a much lower viscosity, being intermediate between the 20°C and 60°C extracts measured at 23% solid content.

Studies by two-dimensional paper chromatography indicated that fractions of molecular size larger than 10^3 NMWL Dextran contain predominantly polyphenolic compounds differing only in degree of polymerisation. It was found that the fractions of molecular size larger than 10^3 NMWL gave Stiasny precipitates of 83-92%, while the fraction less than 10^3 NMWL Dextran yielded a precipitate of 41%, indicating a larger proportion of non-reactive material (7).

Comparing the fractions greater than and less than 10^6 NMWL Stiasny precipitates of 104% and 72% were obtained, showing a larger proportion of reactive material in the higher fraction.

Since the amounts of various fractions that could be prepared with the Millipore cell were small, larger scale ultrafiltration techniques were examined. Because of the possibility that insoluble fractions in dilute solutions (especially hot water extracts) would precipitate and foul thin channel type membranes, a P.C.I. Tubular Type B1 system was installed. As well as providing sufficient quantities of extract fractions for the assessment of adhesive properties, the equipment makes possible studies of the efficiency of the process. Initial experiments with this sytem have been reported above.

Improvement in the separation of the desired fraction was obtained by using large quantities of water, which had to be removed at a later stage. This was effected by a second ultrafiltration with membranes of 10^3 NMWL Dextran. This process could prove to be of industrial value as an athermal dewatering method, thus avoiding thermal and oxidative degradation of the product.

Further work is under way to explore the possibility of using an "open" reverse osmosis membrane of approximately 5×10^2 NMWL Dextran to remove water and low molecular weight unreactive material, but to retain reactive polyphenols.

A number of other methods of reducing viscosity have been examined. The solubility of tannins may be increased by heating with sodium sulphite or metabisulphite and it was shown by Dalton (2) that by this treatment the viscosities of tannin solutions were reduced to a level suitable for the preparation of adhesives. Dalton found that the lowest viscosities of radiata tannin solutions were obtained by heating at 90°C with 5% sodium metabisulphite for 240 min. The experimental results reported here for 100°C extract show that viscosity was reduced sufficiently for adhesives use by milder treatments, such as 5% sodium metabisulphite at 80°C for 2 h.

The use of 10 or 20% of methanol in water as solvent for 100°C extract reduced the viscosity at 43% solid content to a level suitable for adhesives. Methanol also increased the gelation time by as much as 60%; this effect reported by Dalton (1) for wattle bark extract may be useful for prolonging the working life of radiata tannin adhesives. The addition of 5% of phenol to an aqueous solution at 43% solid content was less effective.

The viscosity of a solution of 100°C extract was reduced significantly by increase in temperature to 50°C. This method of viscosity control is practicable for particleboard manufacture with separate application of the cross linking agent.

Adhesion tests showed no significant difference in the bond quality of 60°C and sulphite heated 100°C extracts and the methanol soluble fraction of 100°C extract with tulip oak veneers. The bond quality of the 20°C extract was lower than for other extracts with tulip oak veneers. This may have been due to the combined effects of low viscosity extract and relatively high veneer moisture content. A lower concentration of reactive polyphenols may have contributed also.

In another test no significant difference was found between the bond qualities of 60°C and untreated 100°C extracts with tulip oak veneers.

4. CONCLUSIONS

The working life of radiata tannin adhesives can be controlled satisfactorily by pH and the use of paraformaldehyde as cross linking agent.

The methods available for reducing the viscosity of 100°C or similar extracts fall into two categories:

1. Removal of the highly polymerised fraction mainly responsible for the high viscosity, by separating the alcohol insolubles or by ultra-filtration.

Extraction of the bark under milder conditions which leaves less soluble highly polymerised material in the bark can be considered as belonging in this category.

2. Reduction of the viscosity of the whole extract by treatment with sodium sulphite, by the addition of alcohol or phenol, or by increasing the temperature of the solution before use.

5. ACKNOWLEDGEMENTS

We thank Dr Y. Yazaki for preparing samples of the methanol soluble fraction of 100°C extract, for samples of some fractions prepared by

ultrafiltration and for discussion.

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SIMULATED EXPOSURE TESTS ON PARTICLEBOARD FLOORING

By G. N. Christensen

INTRODUCTION

One of the potential advantages of particleboard for flooring is that it can be laid in uninterrupted runs over large areas of floor in so-called "platform construction". A disadvantage of platform construction is that the laid floor is exposed to the weather for a period until the building is enclosed. During this exposure damage can arise from the dimensional changes caused by alternate wetting and drying of the board.

When good building practice is not observed, pools of rain-water may form on floors which may then be heated by solar radiation to temperatures as high as 65°C. Swelling stresses can cause distortion of the floor and even displacement of walls if due care is not taken to leave expansion gaps when the floor is laid. On re-drying, further distortion occurs as the boards react to sets that developed whilst they were swelling under restraint. Gaps between boards usually finish wider, and cupping, bowing and edge-swelling can produce unacceptable departures from flatness of the floor surface.

Bootle and Chapman of the N.S.W. Division of Wood Technology recently observed the performance of three brands of Class 1 particleboard flooring and one brand of Class 2 board in platform construction during exposure to weather for 13 months(1).Their main conclusion from the test was that board stiffness was the mechanical property most likely to be affected by exposure.

In cooperation with the Technical Sub-committee of the Australian Particleboard Manufacturers Association, the Division of Building Research undertook tests to try to better understand the behaviour of particleboard flooring exposed during platform construction.

EXPERIMENTAL METHOD

In these tests, outdoor exposure was impractical. Accordingly, floors were tested in succession on an indoor frame whilst subjected to simulated outdoor exposure. Outdoor wetting was simulated by ponding water over the whole floor surface, and solar heating was simulated by 20 infra-red lamps placed to give a surface temperature of 65°C.

Each make of board supplied was subjected to a cycle involving wetting, heating, radiant heat drying and re-equilibration. Each cycle took from 4 to 6 weeks during which movement in the plane of the board, vertical distortion of both particleboard and joists, and stiffness of the floor were measured. Board properties were determined both before and after exposure.

The six commercial boards used in the investigation were all types sold as Class I flooring, three were based on phenol (A,B,C), two on tannin (D,E) and one on melamine (F).

It is stressed that the results from these tests, using very limited samples, may not have been typical of the brands at that time, and manufacturing changes have occurred since. The purpose of the experiment was not to compare brands but to observe the behaviour of as wide a range of Class I flooring as practicable.

Specimens were cut from each of the six samples of board received and subjected to tests based on AS 1859-1976 plus some additional measurements. Most of the stress generated in floors that are wetted after laying arises from the restraint to swelling in the sheet direction. It was therefore decided to compare the linear swelling pressures of the six makes of board. After some preliminary trials, an empirical procedure was adopted using methyl alcohol instead of water as the rate of water penetration was far too slow.

From each brand of particleboard, four test boards each 1.37 m x 0.73 m were laid on seven dressed hardwood joists spaced at 450 mm centres. The joists were bolted to two 100 x 100 mm bearers 1.45 m between centres, and each bearer was supported on three rigid piers.

When laying the floor, the four boards were pressed together by hand to close the joints but no other pressure or clamping was used. Before laying a test floor, the thickness of each of the four boards was measured at six positions. At the conclusion of the exposure test the four boards were removed and measured again to determine the residual change in edge thickness.

After laying the floor, an initial set of dimension measurements was made at all points shown in FIG. 1. The external dimensions of the floor were measured in directions both perpendicular and parallel to the joists by means of dial gauges, and the extent of opening or closing of the gaps between boards was also measured. The moisture content also was measured using a capacitance type meter calibrated for each brand of particleboard separately. Finally, the service deflection of each laid floor was determined as in AS 1859-1976.

The top surface of the floor was then ponded with water for a period of seven days. On either the fifth or sixth day the lamps were turned on for 8 hours during which time the water temperature rose to approximately 65°C.

The wetting of the top surface of the floor generates a bending force in the particleboard. In consequence, some vertical deflection of the joists occurs, and of the board between the joists. This was measured by dial gauges at seven points directly beneath the mid-line of one of the four boards (FIG. 1).

After a total of seven days ponding, the excess water was removed and the floor stiffness again measured whilst the floor was still wet. The maximum moisture content was not known.

Drying under the lamps consisted of up to 20 daily cycles of 8 hours on and 16 off to simulate outdoor drying conditions. Drying continued until the moisture meter reading had fallen to the initial value. For the first floor tested (Brand C), it was found subsequently that the moisture content of the board edges was still too high, as shown by further shrinkage in edge thickness of the boards after removal. For the following five floors, therefore, drying was continued until the mean moisture content in the centre of the panels was 1 or 2% below the initial value.

The floors finally were left for a minimum of three days without heating before the final measurements were made. It was impractical to leave floors in place until complete equilibrium was re-established as this would have required several more weeks per floor. However, after removal from the joists all boards were stored for a further period before the final thickness measurements were made. At this stage the edge moisture contents were all within 1% of the original value.

Finally test specimens were cut from the re-dried boards to determine whether there had been any change in properties.

DISCUSSION

In a short paper it clearly is not possible to discuss the results in detail. It will have to suffice to list some of the more important observations and conclusions.

Behaviour of the floors during exposure

(i) Movement in the plane of the board - Linear swelling of the boards by about 1.25 mm per metre during wetting (Table 5) was accommodated almost

entirely in external expansion, the tightness of the joints at laying mostly preventing movement at the joint edges. The total board expansions in the six floors were between 30% (board F) and 47% (boards C and E) of their unrestrained VPS swelling (Table 3). The reduction is attributed to both restraint by nailing and incompleteness of wetting, the under surface of all floors remaining at least partially dry.

On re-drying, all boards shortened to less than their original dimensions, Measured externally, the shortening of the floors was mostly in the range 0.5 to 0.8 mm per metre (Table 6), the under-dried floor C being omitted. At the joints, gap openings of about 1 mm occurred, equivalent to about 0.3 mm per metre of floor length perpendicular to the floor joists and 0.8 mm per metre parallel. This difference is thought to be due primarily to the different nail spacings, 150 mm and 450 mm along the butt and T and G joins respectively. Some of the external swelling perpendicular to the joists led to bending and tilting of the outermost joists. For this and other reasons, the swelling figures obtained in the present experiment cannot be applied directly to floors of other sizes.

(ii) Stiffness - Wetting of the floor led to a drop in stiffness (Table 5), the fall being much greater for board F than for the other five. On re-drying, the stiffness recovered partially to finish at approximately 80% of the dry value for the five, but at only 40% for board F. There was a greater reduction in stiffness near the joints than at the panel centres, probably because wetting of the boards through to the under surface usually occurred near the joints.

(iii) Vertical movement and thickness swelling - During the wetting phase, upward bowing by the joists of approximately 1 mm and by the board between joists of a further 2 mm was observed (Fig. 2). On re-drying, these upward deflections were lessened and in some cases reversed so that the boards tended to cup between joists. The final departure from flatness was aggravated in some boards by uneven thickness swelling (Fig. 3), the edges finishing thicker than the rest of the sheet. In combination these two effects produced departures from surface flatness of over 2 mm.

In the case of the two floors A and F that had a second cycle of wetting and drying, the effects observed at the end of the first cycle generally increased after the second (not tabulated). This was true for both linear shrinkage and cupping of the floors betwen the joists. In floor stiffness

however only board F showed a further reduction, finishing at 33% of the initial value.

Changes in board properties after exposure

Comparison of mechanical properties of the boards before and after the floor test (Table 7) shows that all three measured properties were affected, internal bond and MOE more than MOR. The effect on MOE, namely reduction to 76% of the original value, was fairly similar to that for stiffness (Table 6) that is, reduction to 80% at the panel centre and to 70% near the T and G. However, the big reduction in stiffness in board F was not reflected in its MOE values and the relation between MOE and stiffness is being looked at further.

Correlation between floor behaviour and board properties

Although wetting of the floor did not reach saturation level, the correlation between swelling of the floor (Table 5) and the VPS linear swelling (Table 3) was 0.75 and, of the floor swelling with density, (Table 1) 0.78 for all boards, and 0.98 if board F is omitted. The low swelling of board F in the floor test may be attributed to its high resistance to wetting and water penetration.

The assumption that the nett linear shrinkage of the board after one complete cycle was due to a compressive set induced during the wetting half of the cycle receives support from the high correlation (0.95) between this nett shrinkage and the compressive set in MeOH swelling under load (Table 4). The nett shrinkage is also correlated inversely (-0.88) with the swelling pressure generated during the MeOH swelling.

Comparison between board types

In view of the very limited samples used, the apparent differences observed between brands in this experiment may not be significant. In general the two tannin boards had properties and performance within the range of the three phenolic boards, although the tannin boards tended to swell a little more. As would be expected, the board containing melamine was clearly more susceptible to damage at 100°C. In the floor test (maximum temperature 65°C) floor stiffness was strongly affected, but the board's mechanical properties after test, though consistently low, were less affected than its stiffness.

REFERENCE

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TABLE 1

PROPERTIES OF BOARDS AS RECEIVED - MECHANICAL PROPERTIES

Brand	Density kg/m^3	Modulus of Rupture (MPa)			Modulus of Elasticity (MPa)			Internal Bond (KPa)		
		Dry	After vps	After boil	Dry	After vps	After boil	Dry	After vps	After boil
A	678	15.2	9.8	7.9	2320	1350	1010	584	309	147
B	650	18.6	10.7	8.9	2530	1360	1140	689	323	186
C	683	24.7	15.7	12.3	2960	1820	1370	744	386	197
D	692	19.9	13.6	9.2	2830	1720	1500	588	319	182
E	726	28.6	13.2	9.8	3570	1640	1200	797	319	125
F	694	19.4	12.8	4.0	3130	1900	580	848	400	40
Mean	687	21.1	12.6	8.7	2890	1630	1130	708	343	146
No. of specimens per brand	6	2	2	2	2	2	2	4	4	4
Max. coeff. of variability for any brand (%)	4.1F	15.6C	19.9F	12.3E	17.3E	21.6E	21.8E	29.5D	26.6D	19.2D

TABLE 2

PROPERTIES OF BOARDS AS RECEIVED - SWELLING AND ABSORPTION

Brand	SWELLING				ABSORPTION	
	Thickness (mm)		Linear (%)		Total (%)	
	After VPS	After boil	After VPS	After Boil	After VPS	After boil
A	8.9	11.5	0.37	0.32	82.7	87.0
B	10.7	13.0	0.26	0.24	96.6	98.5
C	5.9	9.7	0.28	0.29	79.8	86.7
D	7.6	12.2	0.39	0.43	81.7	83.9
E	11.4	17.8	0.39	0.43	81.1	89.7
F	8.0	20.6	0.30	0.48	74.3	103.6
Mean	8.8	14.1	0.33	0.37	82.7	91.6
No. of specimens tested per brand	4	2	4	2	4	2
Max. coeff. of variability for any brand (%)	17.7B	9.4E	17.5E	24.4C	11.7F	5.8E

TABLE 3

SWELLING PRESSURE IN METHANOL AND ASSOCIATED DIMENSION CHANGES
(FOUR SPECIMENS PER BRAND)

Brand	Density (kg/m^3)	Swelling force (N/mm)	Swelling pressure (MPa)	Time to maximum swelling (min)	Methanol uptake (%)	Increase in height (%)		Increase in width (%)		Increase in thickness (%)	
						wet out of press	re-dried	wet out of press	re-dried	wet out of press	re-dried
A	629	27.8	1.45	110	61.9	0.14	-0.14	0.70	0.09	9.9	0.99
B	650	29.2	1.45	270	57.1	0.16	-0.06	0.63	0.07	10.2	2.39
C	680	37.8	2.03	155	49.0	0.18	-0.02	0.58	0.09	8.2	1.05
D	645	31.3	1.72	85	50.5	0.23	0.03	0.71	0.19	10.8	1.43
E	666	28.1	1.57	150	55.9	0.19	-0.10	0.67	0.18	11.0	1.56
F	613	29.5	1.59	425+	61.2	0.12	-0.01	0.57	0.17	8.1	1.27
Mean	647	30.6	1.64	200	55.9	0.17	-0.05	0.64	0.13	9.7	1.45
Max. standard deviation for any brand	46B	4.8D	0.27D	110B	7.0B	0.04A	0.06A	0.12D	0.08D	0.7D	0.7B

TABLE 4

STIFFNESS OF FLOOR AS LAID

Brand	Mean Thickness mm	Mean Deflection (mm) per 1000N*	
		Panel Centre	Near T & G
A	19.7	2.86	4.18
B	20.4	1.49	1.95
C	19.4	1.41	1.71
D	19.2	1.60	2.56
E	18.5	1.37	2.05
F	19.3	1.19	1.45
Mean		1.65	2.32
Max. coeff. of variability for any brand (%)		10.8D	12.1D

* Each value is the mean of three measurements

TABLE 5

STIFFNESS OF FLOOR
WET AND RE-DRIED

Brand	WET*				RE-DRIED			
	Deflection (mm/1000N)		Stiffness (% of initial value)		Deflection (mm/1000N)		Stiffness (% of initial value)	
	Panel centre	T & G	Panel centre	T & G	Panel centre	T & G	Panel centre	T & G
A	4.6	6.8	62	61	3.46	5.48	83	76
B	2.3	3.0	65	65	1.75	2.53	85	77
C	1.8	2.5	78	68	1.48	2.19	95	78
D	2.3	4.1**	70	62**	1.77	3.18***	90	81***
E	2.3	3.7	60	55	1.68	2.91	82	70
F	3.6	4.8	35	30	2.90	4.12	44	35
Mean	2.8	4.2	62	57	2.17	3.40	80	70
Max. coeff. of variability for any brand (%)	17.7B	11.5F			10.1B	10.1A		

* Approx. value only as deflection not linear with load

** Some surface crushing apparent

*** Measured in new positions

TABLE 6

LINEAR MOVEMENT OF FLOOR DURING WETTING CYCLE
(PER CENT OF FLOOR DIMENSION)

Brand	Direction	INITIAL DRY TO WET			WET TO RE-DRY*			INITIAL DRY TO RE-DRY*		
		External expansion	Gap closure	Total board expansion	External expansion	Gap closure	Total board expansion	External expansion	Gap closure	Total board expansion
A	butt	.113	.005	.118	-.183	-.063	-.246	-.070	-.058	-.128
	t&g	.092	.021	.113	-.167	-.116	-.283	-.075	-.095	-.170
B	butt	.086	0	.086	-.155	-.033	-.188	-.069	-.033	-.102
	t&g	.088	0	.088	-.141	-.100	-.241	-.053	-.100	-.153
C	butt	.145	.006	.151	-.111	-.041	-.152	+.034	-.035	-.001
	t&g	.112	0	.112	-.122	-.017	-.139	-.010	-.017	-.027
D	butt	.149	.005	.154	-.201	-.036	-.237	-.052	-.031	-.083
	t&g	.128	.030	.158	-.178	-.097	-.275	-.050	-.067	-.117
E	butt	.160	.006	.166	-.237	-.035	-.272	-.077	-.029	-.106
	t&g	.152	.052	.204	-.195	-.148	-.343	-.043	-.096	-.139
F	butt	.081	.003	.084	-.156	-.017	-.173	-.075	-.014	-.089
	t&g	.087	.007	.094	-.154	-.065	-.219	-.067	-.058	-.125
Mean	butt	.122	.004	.126	-.186	-.037	-.223	-.069	-.033	-.102
	t&g	.110	.018	.128	-.167	-.105	-.272	-.058	-.083	-.141
Mean expressed in mm.	butt	3.36	0.11	3.47	-5.11	-1.02	-6.13	-1.90	-0.91	-2.81
	t&g	1.59	0.26	1.85	-2.42	-1.52	-3.94	-0.84	-1.20	-2.04

* Mean values exclude Brand C results

TABLE 7

COMPARISON OF MECHANICAL PROPERTIES OF BOARDS BEFORE AND AFTER FLOOR TEST

Brand	MOR			MOE			IB		
	Before	After	%	Before	After	%	Before	After	%
A	15.2	14.6	96	2320	1860	80	584	638	109
B	18.6	16.1	87	2530	1890	75	689	608	88
C	24.7	24.0	97	2960	2570	87	744	664	89
D	19.9	18.2	91	2830	2300	81	588	369	63
E	28.6	22.2	78	3570	2380	67	797	600	75
F	19.4	15.5	80	3130	2140	68	848	545	64
Mean	21.1	18.4	88	2890	2190	76	708	571	81

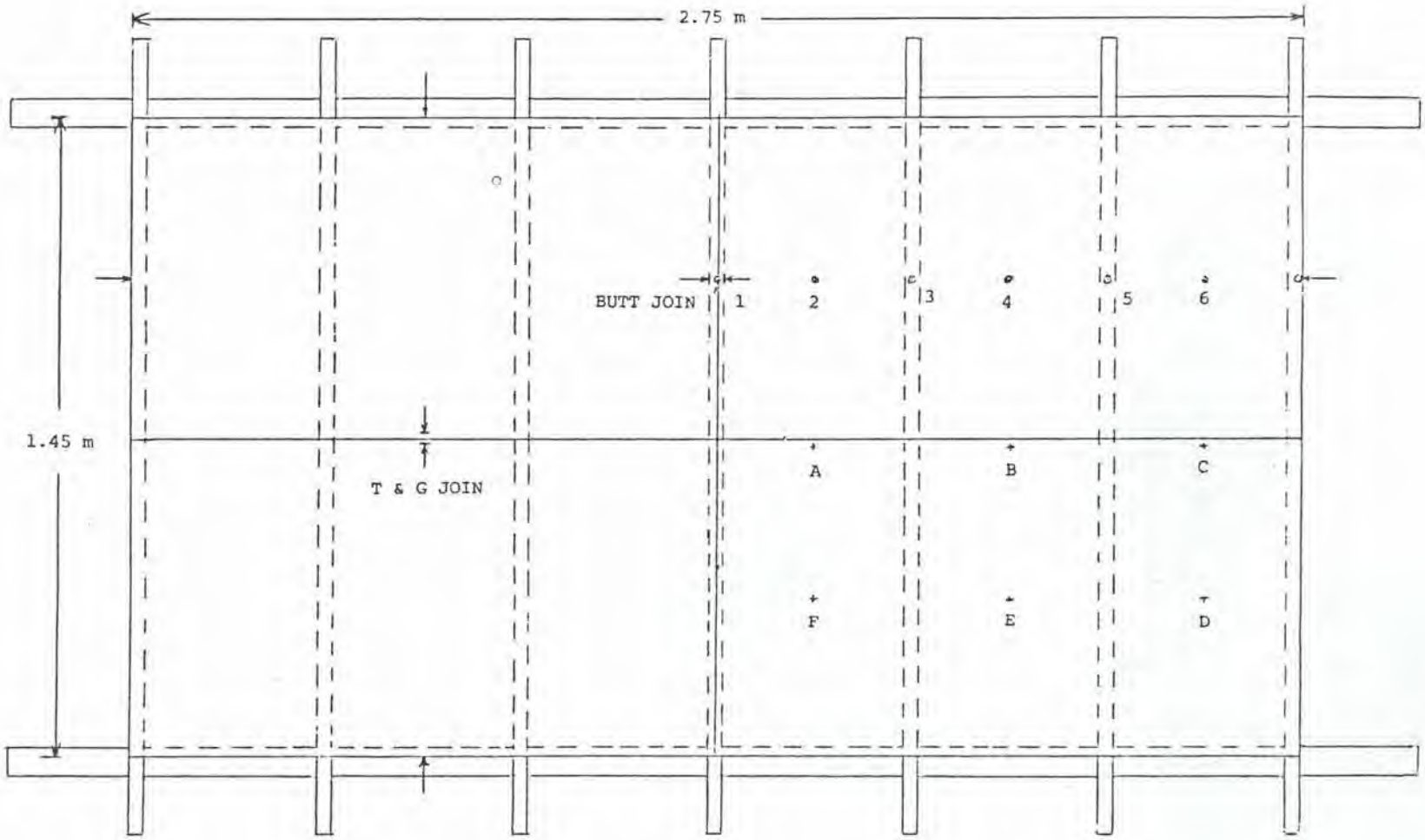


FIG. 1

Plan of the test floor, Arrows indicate measuring points for linear movement. A, B, C, D, E, F are loading points for stiffness measurement. 1, 2, 3, 4, 5, 6, 7 are locations of measurement of vertical deflection.

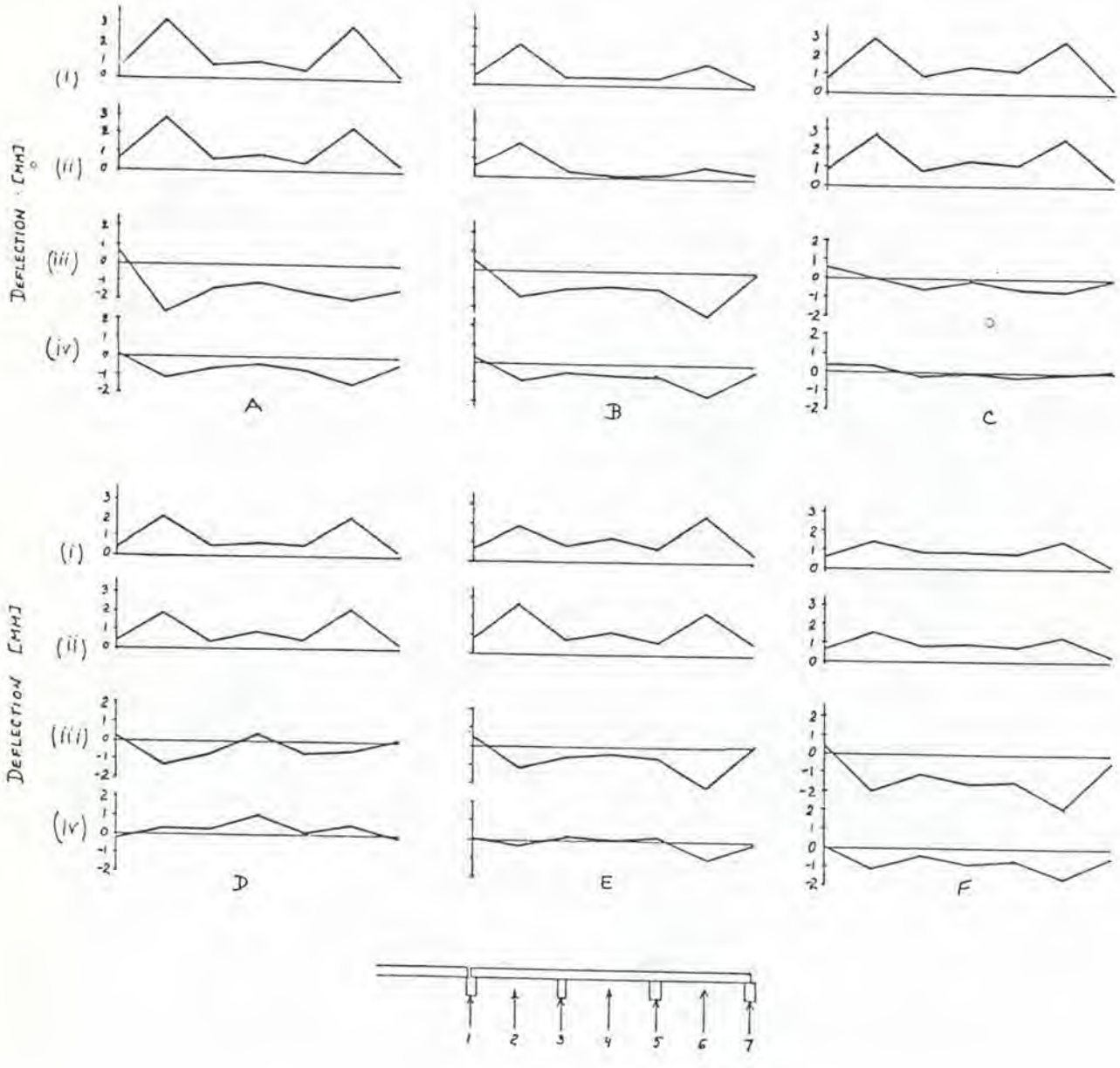


FIG. 2

Vertical deflection of the floor at each of seven positions at four stages in the wetting-redrying cycle.

(i) the end of the first heating with the floor covered with water;
(ii) immediately before the start of drying;
(iii) at the time of maximum downward deflection during drying;
(iv) at the end of the cycle after a period at ambient conditions.

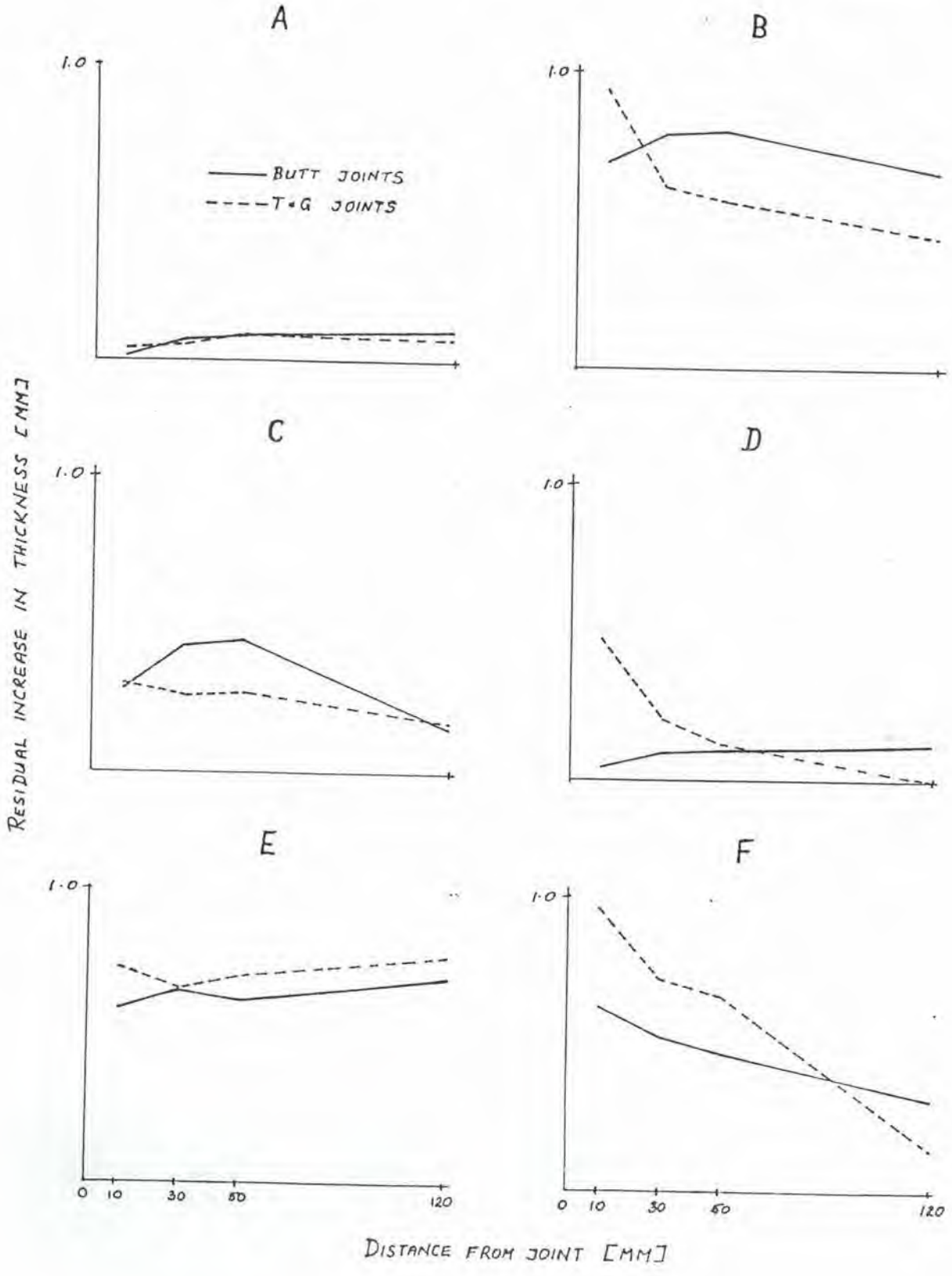


FIG. 3

Final increase in board thickness at points up to 120 mm from butt and T & G joints.

ENERGY FROM WOOD

C.C. Curtain and G. Gartside.

The formation of the OPEC cartel in 1973 conjured up the spectre of ultimate limits to the availability of oil. Coming shortly after the appearance of the much-discussed and debated First Report to the Club of Rome which was published in a summarized form as "The Limits to Growth" (1), the short term politically-induced oil crisis and the longer term economic squeeze put on the West by OPEC became transformed into an "energy crisis". This in turn led to extensive discussions of energy policy and to the development and application of relatively rigorous methods of energy analysis. In this climate it is understandable that close attention should be paid to renewable sources of energy - after all didn't we have to manage with only these until a relatively short time ago? Amongst the renewable sources is wood, man's oldest fuel. Today firewood is still the dominant source of energy for the world's poor, giving more than one thousand million people their daily kitchen fire, much of their home heating and heat for backing bricks and curing of foodstuffs, tea, tobacco and rubber (2).

As the industrial revolution gained momentum wood gave way to coal which in turn gave way to oil and natural gas. The extent and rate of this change varied, but by the 1960's in North America, most of Europe, Japan and Australia wood had become merely a supplementary fuel.

Is it possible that wood will again become an important source of energy in industralized societies? To answer this we must ask in turn the same questions about wood as about any other energy resource. These are:

1. What is the size of the resource?
2. What is its geographical distribution?
3. What is the energy cost of winning it?
4. What are the economics and the social and environmental costs of exploiting it?
5. Having in mind the above what are the best end uses?

In this brief paper we only have time to examine these questions in the Australian context.

THE SIZE OF THE RESOURCE

It is well known that at present Australia is not self sufficient in timber and pulpwood and will not be so until 2010 when the *Pinus* planting program initiated under the various Forestry Agreements Acts in this decade matures (3). Even then there would be nothing left over for fuel wood, except thinnings for which other uses had not been found. To increase the size of the resource it would be necessary to plant substantially more trees, unless estimates for the future demand for timber and pulpwood have been too optimistic. Stewart et al (4) have made a detailed examination of forests as fuel resources. Although these authors felt that there was no firm basis for assessment they suggested that a fuel wood plantation program of 1.1 Mha would be feasible on marginal farm land using either *Pinus* or short rotation *Eucalyptus*. This would yield 220 PJ/a of primary energy, 9% of the national primary energy consumption of 2,500 PJ/a. Forestry, logging and sawmill residues were estimated to be 7 and 2 million tonnes D.W. respectively. It was assumed that half these residues would be available for fuel production. Fung, Liversedge and Lhuede (5) assessed the potential of timber residues as an energy source and found that some 3×10^6 tonnes would be available annually on oven dry basis, yielding 60 PJ.

THE GEOGRAPHICAL DISTRIBUTION OF WOOD AS AN ENERGY RESOURCE

The geographical distribution of wood is of importance compared with coal and oil because of the lower energy content per tonne. Some comparison are made in Table 1.

TABLE 1

Fuel	Energy Content GJ/te
Coal [av]	26
*Wood [av]	9.5
Oil	37.9

*Assuming 50% moisture content.

Land favourable for fuel wood production may be found in south-east Gippsland, along the north and south coasts of New South Wales and in parts of Northern Tasmania. None are particularly close to the major energy consuming urban and industrial centres.

THE ENERGY COSTS OF FORESTRY FOR FUEL

It is not only necessary to take into account the amount of energy required to win a resource but it is also very important to consider the quality of energy needed. Is the requirement mainly for low grade heat or for mechanical work or for the chemical energy necessary for fertilisers? How much of the energy comes from oil, or other scarce resources? Stewart et al (4) estimated that the direct energy needed to run a fuel plantation would be about 1 GJ/te and there would be an approximately equal amount of indirect energy required - both adding up to about 13% of the total energy in the wood. Two thirds of this energy would come from oil. The energy balance with forest industry residues varies according to whether they are treated as a waste or are debited with their share of the energy costs of the forestry operation which produces them.

THE ECONOMICS AND SOCIAL AND ENVIRONMENTAL COSTS OF WOOD AS AN ENERGY SOURCE

Various costs have been placed on wood. Stewart et al (4) placed the full production cost of fuelwood at a regional conversion plant at $30 - $60/tonne O.D. the lowest being an amended figure for short rotation eucalypt plantations (7), and for current eucalypt woodchip production, whilst the highest is an estimate for short rotation pine production. The probable wood prices are compared with coal and oil in terms of c/MJ in Table 2.

TABLE 2

Fuel	Cost
Coal ($10/te)	.0380 c/MJ
*Oil (12¢/ℓ)	.4 c/MJ
Wood ($30/te)	.19 c/MJ
($60/te)	.38 c/MJ

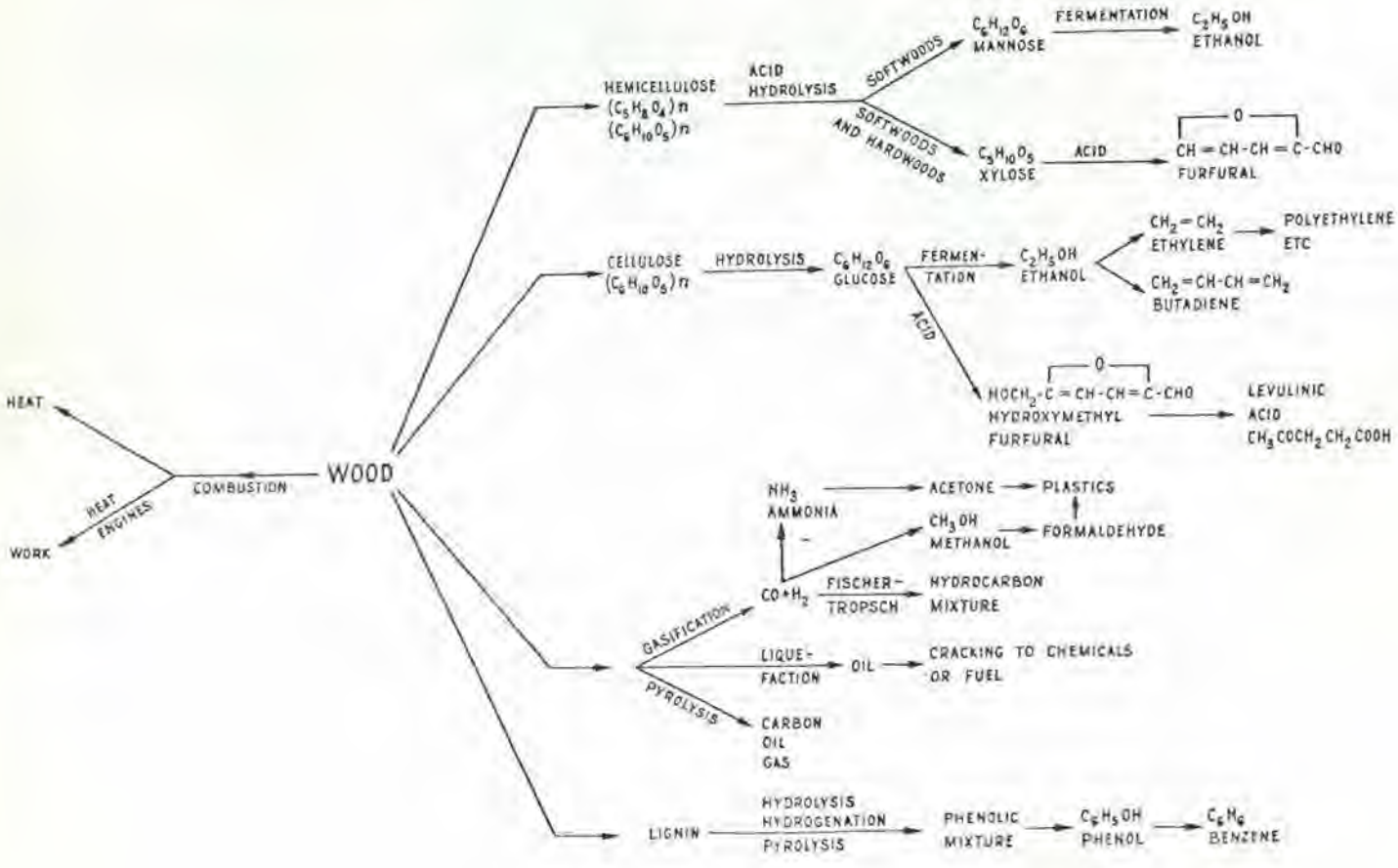
*Industrial diesel fuel at 30/6/79

Clearly wood at its most expensive is close to oil in cost. Wood wastes are cheaper than the range considered but only small quantities are available at any one location. However, since these locations are often remote wastes offer the best cost differential with current fuels. Even at $30/te wood is five times dearer than coal but has certain

short and long term environmental benefits. It is low in sulphur and ash and therefore does not require the costly environmental control measures associated with coal burning. Provided soil erosion is minimized and fertility maintained it is renewable resource. The major long term benefit may be that if the rising carbon dioxide content of the atmosphere is due to the combustion of fossil fuels and global deforestation, and if this is going to lead to undesirable climatic changes, then rapid moves to renewable fuels and reforestation will be necessary. This could be within the time span of present forestry programs. On the debit side extensive and intensive energy forestry could compete for other land uses, such as food production, water catchment, many forms of forest recreation and wilderness. It has in fact been eloquently argued that the replacement of native forests in all their diversity by plantations has already gone too far with the risk of drastic reduction in the gene pool sizes of many indigenous species of flora and fauna (9). If we ignore the long term environmental advantages of renewability it is clear that in the medium term even open cut mining of coal disturbs far less land for PJ of energy delivered than energy plantations. For the U.S.A. the ratio is approximately 1:2700 (10).

WHAT ARE THE BEST END USES FOR WOOD AS AN ENERGY SOURCE?

The different ways in which energy can be obtained from wood are summarized in Fig.1.



The reactions on the right hand side are of the greatest concern to those interested in direct replacement of the premium convenience fuels, oil and gas, with products derived from renewable resources. Unfortunately, a combination of low overall conversion efficiency and high raw material cost makes all of these processes expensive. For example, it has been estimated that methanol from wood at $45/tonne would cost approximately 30¢/litre, (4) compared with methanol from coal at 10¢/litre (11).

On the other hand the simple option on the left hand side of the equation is already economic in areas where wood can replace oil transported over long distances. Using the most efficient methods such as cogeneration (13) in integrated forest products industries it should be possible to provide for not only all the energy needs of the industry from residues alone, but it may even be possible to export energy in the form of electricity. It has been suggested by Johnson and Sarkanen (12) that near energy self-sufficiency is possible for the U.S. forest products industries in large part as a result of 220×10^6 magawatts delivered to the rest of the economy.

To take a local example, the pulp and paper industry in Tasmania accounts for 15% (9.5 PJ/a) of all that State's energy consumption. About half of this energy is from local supplies of coal, hydroelectricity and wood fuel - the other half is from oil (13). It has been estimated that the energy available from the forest harvesting residue and the unused woodwaste is about 13.5 PJ/a (14). This contrasts with the continuous output from a major hydroelectric scheme such as the Pieman of 6.3 PJ/a. In some contexts therefore utilization of wood wastes for energy will not only save oil, but might equally conserve capital and other scarce resources, such as wilderness threatened by further hydroelectric development.

In conclusion it may be said that wood, particularly waste wood, will come to play an increasing role as a conserver of other sources of energy particularly if it can be used where it is produced in cogeneration systems. On the other hand it is an expensive starting material for the production of the "biomass fuels", notwithstanding its year-round availability.

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Paper for 19th Forest Products Research Conference

EXPLOSION PULPING

H. Mamers, D. Menz, J. Yuritta.

ABSTRACT

Explosion pulping is a rapid and versatile method for producing paper-making fibres from a wide variety of plant materials. The technique appears to have particular advantage for the pulping of annual and fast growing plants, using less chemicals and giving pulps of improved drainage properties relative to conventional methods.

INTRODUCTION

The explosion pulping method is based upon cooking the furnish under elevated gas pressure in a specially designed digester and then defibrating the product by high velocity discharge at the end of the cooking period.

The layout of the experimental laboratory scale explosion digester system is shown in Figure 1. The 115 mm internal diameter stainless steel digester vessel had a maximum operating pressure rating of 13.8 MPa (2000 psig) and a working volume of 6 litres. The material to be pulped was charged into the digester, the digester sealed and the contents then heated by direct injection of 1.72 MPa (250 psig) steam via valve 2. Upon reaching the required cooking temperature, valve 2 was closed and valve 1 opened to admit high pressure nitrogen from the gas storage tank. At the end of the cooking period, valve 3 was opened. The high pressure nitrogen forced the cooked furnish through the defibrating nozzle and into the collecting tank. The 60 litre collecting tank retained liquor and solids but permitted the escape of gas and vapours to atmosphere.

The design of the defibrating nozzle had a major influence upon the extent of fibre release obtained during the digester discharge. The multiple bar nozzles developed during the course of the investigation operated by successively folding the discharging material over the bars of the nozzle where it was then pulled apart by the concurrently discharging liquor and gas. The construction of an eight bar nozzle is shown in Figure 2.

RESULTS AND DISCUSSION

A wide variety of softwoods, hardwoods, agricultural residues and fast growing plants have been successfully treated by the explosion pulping method. It was found that best results were obtained by pre-impregnating the plant materials with pulping chemicals prior to charging into the digester. Pulping chemicals successfully used during the course of the investigations have included caustic soda, sodium sulphite, sodium bisulphite, N.S.S.C mixtures, kraft mixtures, ammonium hydroxide and calcium bisulphite.

Table 1 summarizes the conditions used to pulp a number of different furnishes and Table 2 summarizes the properties of the pulps obtained.

The explosion pulping method was very fast, giving chemical or semichemical pulps in a few minutes at cooking temperature. The chemicals demand was generally less than for conventional cooking, with particular advantage being observed in the pulping of agricultural residues such as bagasse and wheat straw. The pulps from agricultural residues and fast growing plants also had better drainage characteristics than conventional pulps, due to fragmentation of parenchyma cells during the explosive discharge through the digester nozzle.

CONCLUSIONS

(1) Explosion pulping may be used to produce papermaking quality pulps from a wide range of furnishes including fast growing plants and agricultural residues.

(2) Explosion pulping is very fast, with chemical and semichemical pulps being obtained after only a few minutes at cooking temperatures.

(3) The chemical demand for explosion pulping is generally less than for conventional techniques.

(4) Explosive discharge of the cooked furnish through the digester nozzle readily fragments parenchyma cells to give relatively free draining pulps from fast growing plants and agricultural residues.

TABLE 1

Explosion pulping of pre-impregnated furnishes.

Heatup - 3 min to reach 200°C from ambient

Cook	Furnish	Chemicals on o.d. furnish (wt. %)	Cook temp. (°C)	Time at cook temp. (min)	Digester pressure (MPa)	Total yield (%)	Screened yield (%)	Kappa No. of screened pulp
EX-1	Mixed "ash" Eucalypts	10.1% Na_2SO_3 + 2.3% Na_2CO_3	200	3	13.8	76.6	-	-
PX-1	P. radiata	4.2% Na_2SO_3	190	3	13.8	87.4	-	-
WX-1	Wheat straw	2.4% NaOH	155	3	6.9	57.7	52.6	55.4
KBX-1	Kenaf bark	10.1% NaOH	200	10	13.8	47.8	46.3	23.7
BX-1	Bagasse	7.4% NaOH	200	3	13.8	51.8	51.4	15.7
KWX-1	Kenaf wood	13.8% NaOH	200	10	6.9	46.4	43.2	84.0

TABLE 2

Hand sheet properties of explosion cooked pulps

Cook	Furnish	Total yield (%)	Beating revs*	Freeness (Csf)	Drainage time (sec)	Bulk (cm^3/g)	Tear index (mNm^2/g)	Breaking length (km)	Burst index ($kPa\ M^2/g$)	Brightness (%)
EX-1	Mixed "ash" Eucalypts	76.6	12,000(P)	215	-	1.77	8.6	6.6	3.7	-
PX-1	P. radiata	87.4	8,000(P)	521	-	2.46	7.9	2.9	1.3	28.3
WX-1	Wheat straw	57.7	0 4,500(L)	365 170	10.2 22.1	1.66 1.47	7.2 6.1	7.0 9.5	4.9 6.9	21.8
KBX-1	Kenaf bark	47.8	0 9,000(L)	518 247	5.2 8.6	2.02 1.67	38.2 19.5	5.7 10.5	4.9 9.1	22.4
BX-1	Bagasse	51.8	0 4,000(P)	519 138	5.2 20.5	1.66 1.40	9.2 7.0	5.4 8.4	3.8 6.2	35.5
KWX-1	Kenaf wood	46.4	0 9,000(L)	437 192	6.9 14.8	1.60 1.34	7.0 5.0	4.5 7.4	2.5 4.5	22.5 19.1

*(L) = Lampen mill

(P) = PFI mill

WOOD FIBRE - CEMENT COMPOSITES

R.S.P. COUTTS

INTRODUCTION

Alternative fibre sources are being sought for a range of cement products, as a replacement for asbestos.

There has been considerable research into developing high performance reinforcing fibres such as Kevlar, carbon, boron etc. The cost of these fibres restricts their use to specialized applications and they are not feasible alternatives at the present time. Many academic studies are being conducted overseas in which these specialty fibres are being incorporated into a cement matrix.

The Division of Chemical Technology has been involved in an investigation of cellulose fibre reinforced composites for the last four years. At the 18th Forest Products Research Conference some preliminary work on the development of wood fibre-cement composites was described. (1)

Some compensation for relatively poor mechanical properties of wood fibres compared to synthetic fibres is provided by their low density, low cost and low energy demand during manufacture (2). Most of the asbestos cement sheet manufactured in Australia now contains wood pulp fibres in amounts up to 50 per cent of the total fibre furnish. It is hoped that our studies may show that it is possible to replace the asbestos fibres entirely with wood fibres and form a reinforced cement sheet product with mechanical and chemical properties acceptable to the industry.

The composite appears to have good durability with no decrease in strength after three years, but some reduction in fracture energy. This behaviour results mainly from the gradual formation of a very strong bond between the cement and the fibre. Recent work at the Division (3) has shown that the use of coupling agents can modify the interfacial region between the wood fibre and the cement matrix and change the mechanical performance of the composite.

THE INTERFACIAL PROBLEM

The interfacial bond strength in wood fibre reinforced cement composites should be dependent upon the fibre surface treatment. Lignified wood fibre contains at its surface hydroxyl groups (-OH), either phenolic (from the lignin component) or alcoholic (from the cellulose component). This purely organic surface is found to be incompatible with the inorganic polymers present in the cement matrix (silicates, aluminates and to a lesser extent ferrites of calcium). For this reason a coupling agent which promotes adhesion between the fibre surface and the matrix is desirable.

The most acceptable theory for the mode of action of coupling agents is that the coupling agent acts as a link between fibre and matrix by the formation of a chain of covalent chemical bonds. This necessitates the coupling agent possessing chemical functionality which can accommodate a chemical reaction with both fibre and the matrix. Likewise if the theory is applicable only a small amount of the coupling agent should be required (theoretically a monolayer).

We have tested a range of metal derivatives which contained either reactive chloro or alkoxy groups and in some cases stabilizing groups. These derivatives were used to modify the surface of the cellulosic fibres and then the treated fibres were incorporated into the fibre reinforced cement composites.

A possible explanation of the mechanism for this type of coupling can be given by considering the reaction between the coupling agent (with either a reactive chloride or alkoxide group present) and the fibre surface as shown in Figure 1.

After the treated fibre is immersed in the cement mix the high pH of the aqueous medium could strip off some or all of the remaining protective groups present on the metal atom of the coupling agent and so form metal hydroxide species which, in turn form a new surface on the fibre. This would be compatible with the inorganic cement system and so by normal curing and strengthening processes (invovling μ-oxo and μ-hydroxo bridges) the treated fibres could be incorporated into the cement mix and so complete coupling of the wood fibre reinforcement to the matrix via a chain of covalent chemical linkages.

Due to the proposed mechanism the groups that remain on the metal

atom in the final coupled composite may play a major role in modifying the interfacial region between fibre and matrix, but to attempt to explain such an effect in terms of the mechanical performance of the final product would be difficult. The effect of these groups still remains to be examined by synthesizing a range of coupling agents containing different chemical moieties at fixed positions in the molecule and testing them in the fibre reinforced composites.

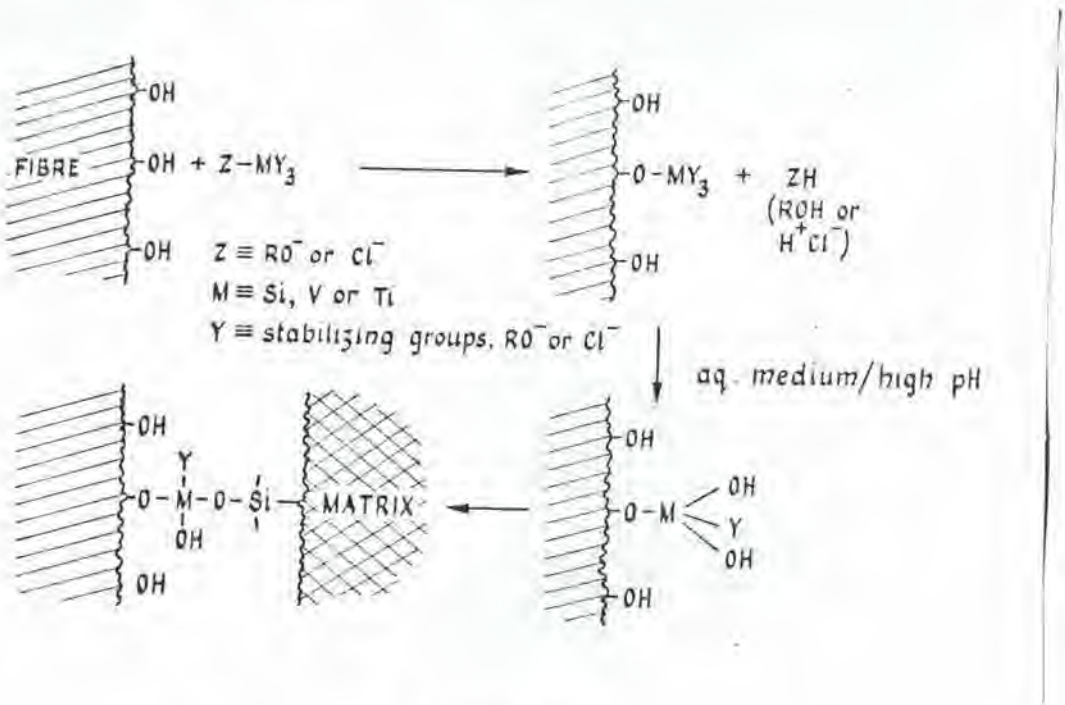

Figure 1.

COUPLED COMPOSITES

The incorporation of wood fibres into the matrix increased the modulus of rupture and fracture energy of the matrix (1). The higher impact resistance of the composite is derived from the stretching and pull-out of fibres which occur at comparatively large strains after the failure of the matrix. This fibre pull-out has been confirmed by the use of scanning electron microscopy.

The results of this investigation were obtained in an attempt to observe the properties of the composites formed from treated fibres. The effect of variation of surface treatment is demonstrated in Figure 2 where we see that over long periods of time the modulus of rupture can be made to increase or decrease by comparison with the control depending on the surface treating agent.

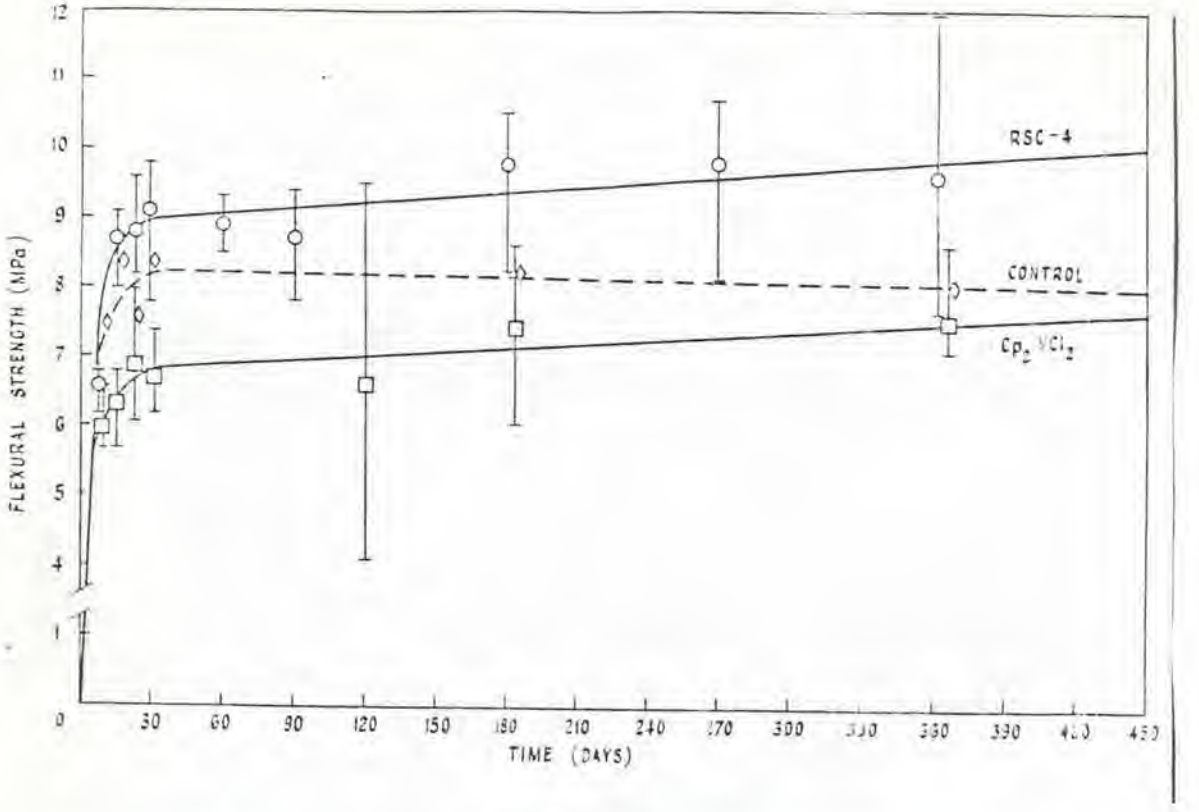

Figure 2.

The low concentration needed to bring about this change in behaviour (Figure 3) indicates the additive is having a surface effect at the interface of fibre and matrix. This study has shown that early strength can be achieved with some of the coupling agents, thus enabling the handling of products to be speeded up.

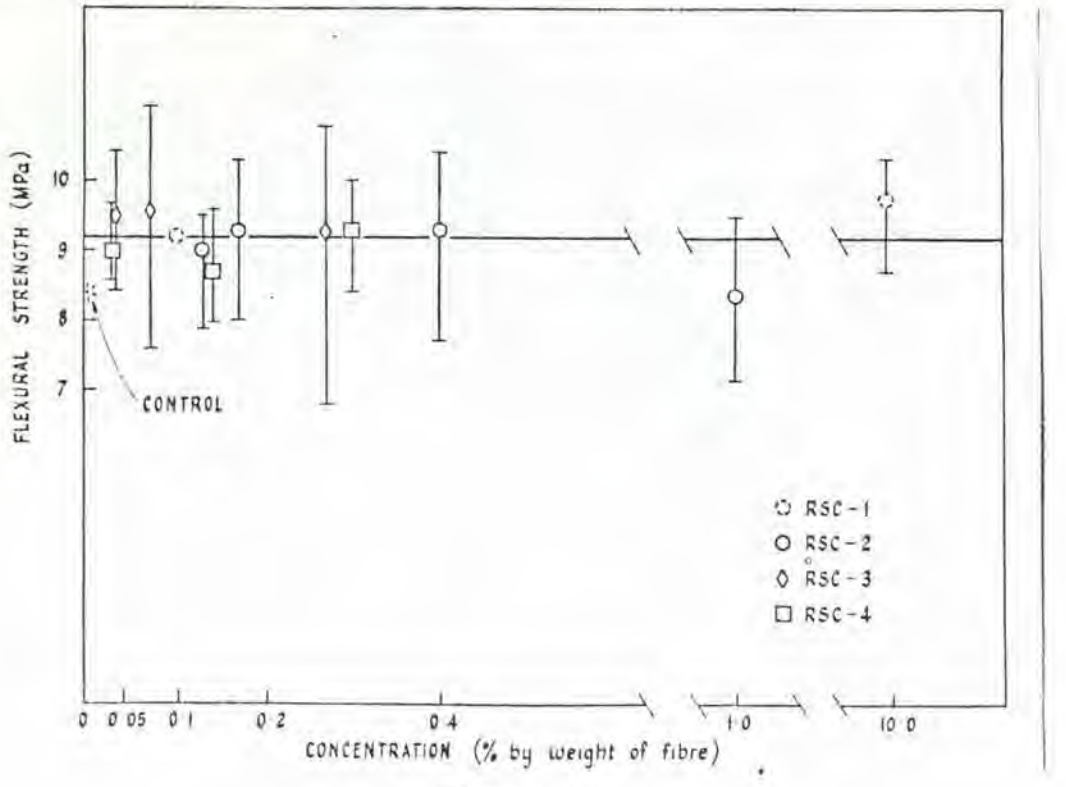

Figure 3.

CONCLUSION

The objective of this work was to study the effect of modifying the interfacial bond between the reinforcing fibre and the matrix by the use of coupling agents; in so doing we have demonstrated that the flexural strength and fracture energy of the composites formed can be varied to some degree.

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COMPOSITES OF COMMERCIAL WOOD PULP FIBRES AND CEMENT

A.J. Michell

INTRODUCTION

Cement and concrete products are notable for their weakness in tension unless they are reinforced by some means and for their lack of toughness which gives rise to frequent cracking under impact loads or thermal shock. The use of reinforcing fibres to overcome such deficiencies is well known with asbestos and glass fibre reinforced cements now being established materials. Wood pulp fibres in the form of softwood kraft fibres have been incorporated in varying amounts in some grades of asbestos cement sheets manufactured in Australia since the 1960's.

Campbell and Coutts (1, 2) have examined the variables in the wood fibre-cement system and determined the range of conditions under which composites having useful properties can be produced from wood fibres and cement. One potential problem is the poisoning of the cement curing action by substances extracted from the fibres by the alkaline environment (pH 12.5) of the cement. Sandermann and co-workers (3) developed a method for assessing the likelihood of this by comparing the rise in temperature of an ordinary Portland cement-water mix with that of the same mix containing the suspect substances. The method depends on the rise in temperature accompanying the cement-water reaction being reduced when the reaction is retarded. Weatherwax and Tarkow (4) have shown that the time taken by an experimental mix to reach maximum temperature relative to the time taken by a standard mix is a simpler index of the ability of that mix to form a composite having useful mechanical properties.

In this paper the modulus of rupture, impact toughness and time to reach maximum temperature of composites of ordinary Portland cement and wood pulp fibres made or available, commercially, in Australia are compared.

RESULTS AND DISCUSSION

The times for the various mixes to reach maximum temperature together with the modulus of rupture and toughness values obtained for the hardened samples are given in Table I.

Topic 4B/9

TABLE I

Properties of Wood Pulp Fibre-Cements

Added Pulp	Time to reach max. temp[a] h	Modulus of Rupture[b] MPa	Impact Toughness[b] J
None (Control)	11.3 (11.0 - 11.7)	5.8 (1.5)	1.3 (0.4)
Papermaking Fibres			
P. radiata Kraft	10.7 (9.3 - 12.2)	8.4 (0.9)	9.0 (0.7)
P. radiata TMP	10.2 (10.0 - 10.8)	6.9 (0.5)	5.1 (0.8)
P. radiata refiner groundwood	11.1 (10.8 - 11.3)	7.3 (0.6)	3.0 (0.6)
Eucalypt Kraft	10.2 (9.3 - 11.0)	7.5 (0.7)	6.4 (1.7)
Eucalypt NSSC "S" Grade	10.3 (9.8 - 10.9)	7.2 (0.8)	6.0 (0.9)
Eucalypt NSSC "C" Grade	9.9 (9.7 - 10.1)	6.8 (1.3)	3.6 (0.9)
Newsprint	10.7 (10.5 - 10.9)	6.4 (0.6)	3.5 (0.4)
Bagpaper	10.5 (10.4 - 10.7)	7.8 (0.7)	6.5 (0.6)
Fibreboard Fibres			
P. radiata Asplund	11.5 (11.0 - 12.0)	8.4 (1.0)	5.8 (1.4)
Eucalypt Asplund	17.7 (16.2 - 19.2)	6.6 (0.6)	2.4 (0.4)
Eucalypt Asplund ($CaCl_2$ treated)	9.3 (9.3 - 9.4)	6.3 (0.5)	2.8 (0.6)
Eucalypt Mason gun	22.0 (17.9 - 26.1)	4.4. (1.1)	2.4 (0.3)

[a] Range of times in parentheses

[b] Standard deviation in parentheses

The results have been obtained at a fixed fibre content and at a fixed water/cement ratio from samples produced by moulding and air curing. Campbell and Coutts (1) found that the modulus of rupture of pulp fibre-cement composites increased slowly with increasing content of non-papermaking fibres up to 7 per cent (weight basis) but in the case of kraft fibres diminished when the fibre content was greater than 3 per cent. In this work the fibre content has been held at 2.5 per cent. The mixes all had a water/cement ratio of 0.36 with account being taken of the amount of water absorbed by the fibres during mixing of the slurry (1). In general, the lower the water/cement ratio the better are the mechanical properties of hardened cement pastes but furnishes containing papermaking fibres and cement require higher water/cement ratios for adequate mixing than do furnishes having the same content of non-papermaking fibres.

The mixes with eucalypt Mason gun and eucalypt Asplund fibres took much longer to reach maximum temperature than did the control samples but the mixes with other fibres showed only small variations from the time taken by the control sample.

However, poisoning could still occur in some of the mixes, not showing evidence of poisoning in this study, if autoclave conditions are used to cure the mix. The substances retarding the set in the eucalypt Mason gun and eucalypt Asplund pulp-cement mixes have not been investigated in this work but it is known (5) that the woods from which the pulps are made are high in polyphenolic extractives which are not removed by Mason gun or Asplund processing and which are soluble in cold alkali. As fibres containing intermediate amounts of polyphenolic extractives were not studied here the results do not allow comment on Chittenden's contention (6) that measurements related to the heat of hydration are of practical use only for the extremes of the cement poisoning range. All the pulp fibre-cement composites studied here with the exception of the Mason gun fibre composite showed increased moduli of rupture relative to the control with the increase being greatest for fibres derived from *P. radiata*. As the times to attain maximum heat for the eucalypt fibre-cement mixes, other than for Mason gun and Asplund fibres, do not indicate interference with the set of the matrix the lower values of the modulus of rupture for these mixes are suggestive of some small dependence on fibre length. The results also show that the impact toughness of fibre-cements derived from *P. radiata* is generally superior to that of fibre-cements derived from eucalypts when the same kind of pulping process has been used to separate the fibres. The lower values of impact toughness shown by the cured *P. radiata* refiner groundwood-cement and newsprint-cement mixes can be attributed to the shorter fibres present

and the difference in magnitude suggests that the impact toughness of fibre-cements is much more dependent on fibre length than is the modulus of rupture. These results are in agreement with the predictions of Campbell and Coutts (1).

A known means of overcoming cement poisoning by woody substances is to treat the substance prior to incorporation in the cement with a cement accelerator such as calcium chloride (6). Treatment of the eucalypt Asplund fibre-cement mix with calcium chloride accelerated the rise to maximum temperature during curing but did not alter substantially the modulus of rupture or the impact toughness of the cured mix.

CONCLUSIONS

Of the commercial wood pulp-cement mixes studied at a fixed fibre content and an intermediate water/cement ratio the best properties were obtained with a *P. radiata* Kraft fibre-cement mix. However, more favourable composite properties might be obtained from papermaking pulp fibre-cements by better mixing at higher water/cement ratios and from non-papermaking pulp fibre-cements by the use of lower water/cement ratios (1). For optimum impact toughness in the composites it is important that the fibre length be maintained during separation of the fibres. Pulp fibres having high alkali extractive contents such as those made by the Mason gun and high temperature Asplund processes from certain mature eucalypts are quite unsuited for this application.

A fuller version of this paper has been submitted to the Appita Journal for publication.

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THE POTENTIAL OF YOUNG TROPICAL HARDWOODS FOR HIGH YIELD PULPING

A.F. Logan and N.W. Hansen

INTRODUCTION

At the 18th Forest Products Research Conference, work on the sulphate and NSSC pulping and papermaking characteristics of a number of fast-growing, hardwood plantation species from tropical areas was described (1). The results showed that most species possessed very good properties which would enable utilization in the manufacture of a wide range of pulp and paper products.

In connection with a CSIRO "Pulping Project On Papua New Guinea Hardwoods", undertaken on behalf of the Papua New Guinea Office of Forests, the pulping studies on potential reforestation species have been extended to investigate their suitability for the production of high yield pulps for inclusion in newsprint furnishes.

This paper presents an account of the results obtained on pulping *Acacia auriculiformis*, *Albizia falcataria*, *Eucalyptus deglupta*, *Eucalyptus tereticornis*, *Gmelina arborea*, and *Terminalia brassii* from Papua New Guinea by the G.I.B. (groundwood from impregnated billets), cold soda semichemical and refiner mechanical processes.

WOOD SAMPLES

Plantation-grown samples of *A. auriculiformis* (age 5 yr, basic density 570 kg/m^3), *E. deglupta* (age 14 yr, basic density 377 kg/m^3), *E. tereticornis* (age 5 yr, basic density 655 kg/m^3), *G. arborea* (age 10 yr, basic density 378 kg/m^3), *T. brassii* (age 12 yr, basic density 275 kg/m^3) and a natural regeneration sample of *A. falcataria* (age c. 10 yr, basic density 249 kg/m^3), all from Papua New Guinea, were examined.

The butt, middle and top section of the trunk respectively from three trees was used to provide three debarked billets from each species for G.I.B. tests as well as composite chip mixtures for each species for cold soda semichemical and refiner mechanical pulping tests.

To facilitate the assessment of the different pulps from the reforestation species, comparisons were made against pulps prepared from Tasmanian wood, commercially acceptable for pulping by these same high yield processes.

Topic 4B/10

G.I.B. PULPS

The G.I.B. process (2) was developed and is used commercially by Australian Newsprint Mills Ltd, Tasmania. The process produces better quality groundwood pulp from young regrowth *Eucalyptus spp.* (age 25-50 years) than is obtainable by the normal groundwood process.

Briefly, the process consists of forcing sodium hydroxide solution into debarked wood billets by high pressure from a pump before normal stone grinding of the billets, the long axis of the billets (and fibre alignment) being parallel to the axis of rotation of the stone to minimise shortening of the fibres.

A range of treatments was obtained for each species to enable interpolation of properties at an energy consumption of 1000 KWh/o.d. tonne of wood as a basis for comparison of the species.

A. auriculiformis and *E. tereticornis*, probably due to their wood structure and comparatively high basic density, adsorbed only a small quantity (1.4%) of sodium hydroxide during the billet impregnation stage of the process. Liquor did not penetrate to the centre of the billets, hence partial softening of the whole wood structure to facilitate whole fibre separation, essential to the G.I.B. process, was not achieved. A high percentage of fines was produced from the unsoftened wood. Pulp quality would be expected to be low since the pulps under such conditions are more akin to normal stone groundwood pulps. Unsuitable handsheet strength levels proved to be the case. Bonding strengths were negligible. Brightness, particularly for *A. auriculiformis*, was low. An increase in energy consumption would not improve the situation since drainage times were already too high and the fibre classification showed that grinding was degrading the unsoftened fibres. Only a change in impregnation conditions to give complete penetration by the sodium hydroxide, if practical, and grinding at an appropriate energy consumption might improve pulp quality. In general, these two species cannot be recommended as suitable for the production of G.I.B. pulp because of their resistance to penetration by sodium hydroxide solution.

G. arborea and *T. brassii* both produced good quality G.I.B. pulps except that their drainage times were high. A lower energy consumption (higher production rate) would reduce drainage times to an acceptable level and other properties should still be satisfactory. The billet samples of both species were practically completely penetrated by the sodium hydroxide liquor and adsorption was at a satisfactory level.

The *A. falcataria* billets were readily impregnated and the high (7.6%) sodium hydroxide absorption reacted to considerably soften the billets resulting in a high proportion of +48 mesh fibrous material and low fibre fines. This level of sodium hydroxide absorption produced very good strength properties, but low bulk and brightness. It is most probable that a lower concentration of sodium hydroxide in the impregnating liquor to reduce absorption to the more economical level of 3.5 - 4.5 per cent would produce, at an appropriate energy consumption, a satisfactory quality G.I.B. pulp at a "just acceptable" brightness.

The *E. deglupta* billets also impregnated readily, absorbing a somewhat high amount of sodium hydroxide (5.6%). Except for low pulp brightness, all other properties were at satisfactory levels and would probably remain so at a lower sodium hydroxide absorption. The necessity to bleach this pulp to a brightness level suitable for a newsprint furnish would need to be considered before accepting this species for production of G.I.B. pulp.

COLD SODA SEMICHEMICAL PULPS

The commercial process is usually on a continuous basis employing a Prex screw which compresses the chips, squeezing out some moisture and sap before allowing them to expand in sodium hydroxide solution. The chips move up a tower filled with the sodium hydroxide, are then drained and fed to the refiners. Complete penetration of the chemical is essential, as in other pulping processes, if maximum pulp quality is to be obtained.

In the laboratory, equipment for impregnation to provide a constant and complete uptake of sodium hydroxide for each species was not available. Air dried chips were soaked in sodium hydroxide solution until the chips had absorbed c. 7 per cent NaOH on o.d. wood. Defibering of the chips and refining of the pulp was done in a laboratory Bauer refiner fitted with 203 mm diameter plates.

No attempt was made to produce a 7 per cent NaOH pulp from *E. tereticornis* since even at 8.7 per cent NaOH absorption pulp quality was not acceptable. For the other species at c. 7 per cent absorption the pulp yields were between 84 and 87 per cent compared with the commercial wood furnish value of 83 per cent at the same alkali absorption. The effect of increased alkali absorption on handsheet properties varied with the species, strength changes were relatively minor but generally positive.

Topic 4B/10

Standard opacity values for the Papua New Guinea species were satisfactory but pulp brightness was 6 to 9 units lower than the pulp from commercial chips, except for *E. tereticornis* and *E. deglupta*; the latter being c. 15 units lower. This would involve higher bleaching costs to be usable in a newsprint furnish.

In all cases, continued refining to a lower freeness improved bonding strengths - breaking length, burst index and wet rupture energy. Tearing strength changes were minor, except for *T. brassii* pulp which had the highest tear index; this fell with continued refining but not below an acceptable level even at 60 freeness.

Except for *E. tereticornis*, all species at the same alkali absorption and at 100 freeness produced satisfactory cold soda pulps suitable for use in a newsprint furnish. *T. brassii* had outstanding pulp properties followed by *A. falcataria*, *G. arborea* and *A. auriculiformis* in that order with *E. deglupta* ranked as "just acceptable" compared with the results on the commercial wood furnish.

REFINER MECHANICAL PULPS

Short fibre woods do not generally respond well to stone grinding or refiner treatment unless combined with a thermal or chemical treatment to soften the wood and facilitate whole fibre separation, which increases costs. The action of a refiner with suitable plate pattern causes less fibre damage than stone grinding and is generally considered preferable for the mechanical defibering of short fibre woods in those cases where a particular species does respond.

It was considered necessary to check the response of the young Papua New Guinea woods to refiner mechanical pulping as this is one of the simplest ways of producing a very high yield pulp which may be useful in a newsprint furnish.

Air dried chips were saturated with water under vacuum to restore the chips to a moisture content approximating the freshly cut condition. Pulps at various freeness levels were prepared using a laboratory Bauer refiner.

Unfortunately the casing and plates of the Bauer refiner at the laboratory are not stainless steel. This combined with acidic extracts from the chips and the high temperature developed during defibering caused staining of the pulps such that the optical tests were of little significance, except to show

that the three *Eucalyptus spp.* and *A. auriculiformis* were the most affected, probably because of their tannin content.

In all cases, increased defibering treatment (associated with higher energy consumption) in the refiner improved pulp properties so that, by defibering to lower than 50 freeness, tearing and bonding strengths could be improved to some extent if this was necessary, provided energy costs and the ability to handle pulp with a higher drainage time permitted.

The results indicated that *A. falcataria*, *T. brassii* and probably *G. arborea* at pulp yields between 94 and 96 per cent would probably provide useful refiner mechanical pulps suitable as a component of a newsprint furnish with *A. falcataria* the most promising species. *A. auriculiformis*, *E. deglupta* and *E. tereticornis*, particularly the latter, showed little response to the process with poor pulp strength development. This result agrees with the decision to reject young *Eucalyptus spp.* from commercial mechanical pulping but shows that other young, short fibre species can be found which would be suitable for the refiner mechanical process. It is noted that the best refiner mechanical pulps were made from the two species (*A. falcataria* and *T. brassii*) with basic density under 300 kg/m^3.

These findings show the need for further refiner pulping studies on these species using the thermomechanical process, and in particular with chemical pretreatment to produce chemi-thermomechanical pulps. This work will be commenced shortly.

DISCUSSION

A. falcataria and *T. brassii* were clearly the most suitable species for the three high yield pulping processes examined. These species had the lowest basic density and were the lightest in colour. *G. arborea* was the next best species for these processes. *A. auriculiformis* and *E. deglupta* seem to have limited uses for mechanical pulp production and *E. tereticornis* is unacceptable for G.I.B., cold soda semichemical and refiner mechanical pulping.

It is interesting to compare the high yield pulping properties of these species with results of sulphate and NSSC pulping tests (1). *A. falcataria* and *T. brassii* were very suitable for sulphate and NSSC pulp production, but *E. tereticornis* could not be recommended for these processes. *A. auriculiformis* and *E. deglupta* produced good quality sulphate and NSSC pulps however, the properties of their high yield pulps were relatively poor. This emphasises the need to test potential reforestation species

for a range of pulping processes and also supports the suggestion that in any reforestation scheme a number of plantation species should be available for pulping (1).

The species tested show suitable growth characteristics in various areas in South-east Asia and the results of mechanical pulping tests, such as those presented, should serve as a guide for future reforestation programmes. This information should be of further interest to developing countries when it is considered that the establishment of mechanical pulp mills can be undertaken on a smaller scale and at a lower cost per tonne than chemical pulp mills. Mills producing high yield pulps from some of these tropical hardwood plantation species, by the processes used above, could provide suitable components for newsprint of adequate quality for use in local markets.

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AID PROJECTS IN SOUTH-EAST ASIA: THE PULPING AND PAPERMAKING POTENTIAL OF TROPICAL HARDWOODS.

F.H. Phillips, A.F. Logan and V. Balodis.

In the past there has been resistance to the use of mixed tropical hardwoods in pulp and paper manufacture but opinions are changing. Some problems in economical utilisation remain but the general view of a few years ago that such materials were unsuitable is not prevalent today. The rapidly increasing use of tropical timbers for pulpwood has been due partly to a shortage of conventional materials but more to an improved knowledge of the properties of tropical hardwoods.

Pulping studies on tropical hardwoods from south-east Asia and the Pacific region have been carried out in research laboratories in England, Austria, North America, Japan and Philippines and elsewhere. Australia has been involved in the south-east Asian area particularly, in addition to recent shorter-term association with pulping projects in India and South America. This involvement has included detailed investigation of Papua New Guinea hardwoods and peat swamp forest and mixed dipterocarp forest resources in Sarawak, Malaysia. Extensive sampling operations were incorporated in the studies and the research programs were planned to produce data to assist the optimum future utilisation of the resources. This approach was considered essential as the increasing use of tropical timbers for pulping, coupled with extensive clearing of forest areas to provide land for agriculture and the harvesting of logs for sawmilling and export purposes, is depleting the worlds tropical forest resources.

It is necessary for those in control of tropical forest resources to ensure that operations are established on a total-use concept to reduce waste left in the forest and after the processing stages. As far as possible pulpwood should be derived from non-commercial timbers, from small and defective trees unsuitable for other processes requiring higher quality and from wood otherwise regarded as waste, such as sawmill slabs, edgings and other offcuts and harvesting residues.

The CSIRO projects have been carried out in conjunction with forestry authorities on mixed hardwood species, forest and sawmill residues (where appropriate) and fast-growing hardwoods for reforestation.

TOPIC 4B/11

PAPUA NEW GUINEA HARDWOODS

In Papua New Guinea (PNG) mixed species from Vanimo, Gogol and Open Bay timber areas, have been tested and the quality of export woodchips has been monitored to assist in determining FOB prices. The potential of fast-growing hardwood species for use in pulping and papermaking has also been investigated extensively. Much of this work has been reported previously at these Conferences e.g. (1) (2) (3) and the recent emphasis which has been placed on high yield pulping was described in an earlier paper at this Conference (4).

Whereas the pulping projects on PNG hardwoods carried out from 1970 to 1976 were funded by the Australian and PNG Governments, the 1977 and 1978 study period was financed by the Commonwealth Fund for Technical Cooperation. Since early 1979 the PNG Government has again financed the research directly They consider that the level of assistance now being provided by CSIRO is of continuing importance as new timber areas are harvested and new plantations are established.

SARAWAK TIMBERS

The forests of Sarawak cover 75% of the total area, hill forests 7,800,000 ha and peatswamp forests 1,400,000 ha. The surveyed hill forests (1,200,000 ha) could yield between 500 and 1000 million cubic metres of pulpwood. The investigation of the technical and economic potential of this pulpwood resource is a highly complex operation because of the large number of species in the hill forests (606 species for trees larger than 20 cm diameter). The peatswamp forests, although not as extensive as the hill forests also contain a large number of species (ca.240) and currently provide the bulk of export logs and sawn timber. Recognising the need for an assessment of these timber resources to determine their potential for pulping and papermaking, the Government of Malaysia submitted a request to Australia for aid funds to finance a pulping project. The Australian Government agreed to finance a project, to be carried out by CSIRO in conjunction with the Sarawak Forest Department, under the Colombo Plan. The investigation of pulpwood quality of *Shorea albida* of major individual species and of species mixtures, from hill and peatswamp forests, now being undertaken is the first step in the process of testing the technological and economic feasibility of an integrated forest products industry.

The most abundant species in the peatswamps, *Shorea albida* is

currently being used for sawmilling, veneer production, and log export. The volume of material avaliable for pulpwood in the form of defective and damaged trees, non-sawlog portions of trees, and crowns is approximately 10 million cubic metres. This supply potentially could sustain a chip/pulp industry in the immediate future. The mixture of *S. albida* residues pulped by the sulphate process appears satisfactory for use in the production of bleached pulps for writing and printing papers. Some packaging materials may also be possible if high strength is not required. The *S. albida* pulpwood resource could be supplemented by other peatswamp species available in the same area.

As well as tests on about 70 individual species of importance from the peatswamp forests, composite chip mixtures representing potential Sarawak pulpwood resources have been tested. These included Padang Forest, Mixed Swamp Forest and Peat Swamp Forest residues. Of these, the former would be suitable for kraft pulping for liner boards and wrappings and for writings and printings. The latter two mixtures would be suitable for a more restricted range of end products including writings and printings and low grade bag and wrapping papers.

The assessment of pulping properties of individual and mixed species from the mixed dipterocarp forests is now being undertaken. Species mixtures representing the probable utilisation plans for these hill forests will be pulped by sulphate and NSSC processes and the quality for papermaking established. An estimate will be made of the export value of various woodchip mixtures as a guide to the viability of establishing export operations.

IN CONCLUSION

It has been accepted that there will be extremes of quality in temperate zone forests and, for improved utilisation, tropical forests must also be recognised as varying greatly. Adequate sampling and testing programmes, close liaison with local authorities and efforts to reduce waste are essential in a responsible approach to assisting developing countries to utilise their natural forest resources. However, as the world's tropical forests are utilised for timber, pulpwood and other wood products or depleted to provide land for agriculture, those who have been accustomed to an over abundance of timber supplies must acknowledge the need for reforestation.

Our aid programmes associated with the pulping of tropical timbers can only succeed if we are able to achieve an acceptance that (1) as far as possible, a total-use concept must be adopted and an integration of industries is necessary to reduce waste in the forest and processing stages (2) a vigorous reforestation programme is necessary to maintain forest resources for the future (3) serious consideration should be given, by all concerned in the development process, to the ecological implications of development and an attempt made to accommodate both ecological and economic requirements and (4) operations should be directed unequivocally towards maximum benefit for the indigenous people.

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ASSESSMENT OF THE QUALITY OF TIMBER RESOURCES FOR EXPORT WOODCHIPS.

F.H. Phillips, A.F. Logan, N.W. Hansen,
H.G. Higgins, J.V. Ward and J.P. Murphy.

In most of the areas in Australia where export woodchip operations have been established the raw material has been obtained from overmature stagnant forests, species unsuitable for other wood using industries, forest and mill waste or as a first stage in the proposed development of a pulping industry. Considerable benefits have resulted from the use of mill waste and from the silvicultural advantages in harvesting hitherto useless stems. The possibility of sawing previously uneconomic logs should also provide benefits in some areas.

That such materials should have been utilised is not unexpected because, traditionally, as technology advances and as supplies of preferred raw materials diminish, industry accepts less desirable supplies for processing. This trend has been evident in the pulp and paper industry over some 150 years with a movement from the exclusive use of a limited number of coniferous species, through the acceptance of select hardwoods to the utilisation of whole trees and mixtures of species. In recent years the evaluation of uncommitted resources, regarded as unsuitable for use, for one reason or another, has led to their economic utilisation in the woodchipping industry. Such studies have included tests on Western Australian species *Eucalyptus calophylla, Eucalyptus diversicolor* and *Eucalyptus marginata* (1) (2) and on *Eucalyptus cypellocarpa* and *Eucalyptus sieberi* from southern New South Wales forests (3). Tests reported on the pulping properties of boxed heart residues (4) showed that the pulping properties of this type of material are similar to sound slabwood containing a mixture of sapwood and outer heartwood. Furthermore, forest residues in a particular region in New South Wales have also been shown as adequate for fine paper production (5).

Investigations have continued on the suitability of various raw materials for conversion to woodchips for export and on chip quality.
These studies include:-

1. Representative samples of woodchips exported from Eden, N.S.W. The forests contain the following distribution of eucalypt species *E. muelleriana* plus *E. globoidea* 29%, *E. sieberi* 28%, *E. obliqua* plus *E. fastigata* 18%, *E. cypellocarpa* 16%, *E. smithii* plus E. radiata 6% and others 3%. In addition about 20% of the wood intake to the chip mill

is in the form of sawmill residues, many from eastern Victoria, and could contain up to 25% *E. nitens*. Unbleached sulphate pulp at a Kappa number of 19-20 was produced from the woodchip mixture (basic density of 615 kg/m^3) with 18 to 18.5% total alkali. Screened yield of unbleached pulp was 44.5% but after bleaching with a four stage process (CEHD) yield was reduced to 41.6%. The brightness of the bleached pulp (88.3%) was very satisfactory. Unbleached pulp at a higher Kappa number (ca 40) had slightly higher tearing strength but the screened yields were similar to those of pulp at 20 Kappa number.

The pulps prepared were considered suitable for the production of writing and printing grades and for use in products such as wrappings and packaging materials requiring reasonably high strength properties.

2. Woodchip mixtures exported from Western Australia. Since the establishment of the chip mill increasing quantities of karri (*Eucalyptus diversicolor*), derived largely from sawmill residues, have been included with the marri (*Eucalyptus calophylla*) in the chip furnish and at present amount to ca 30%. Larger proportions of younger trees are coming into the mill as changes take place in the forest areas available for chip production. These changes led to a need for a reappraisal of the quality of the chips being exported, compared with the study on marri carried out before the mill was operating (2). The screened yield of unbleached sulphate pulp at a Kappa number of 20 was 45.2%. On bleaching, with a CEHD sequence, this was reduced to 42.2%; bleached pulp brightness was 82.7%. The pulp yields are significantly higher than those obtained with marri alone and the presence of karri would account for much of the increase.

The properties of both the unbleached and bleached pulps have been compared with pulps from other Australian forest resources to estimate an equitable export price for the currently produced woodchips.

3. Fire-killed *Eucalyptus obliqua*. A large volume of mature fire-killed timber, mainly *E. obliqua* in a forest area in north-west Tasmania was available for woodchipping. Sulphate pulps were prepared from decay-free, fire-killed wood and evaluated to determine both unbleached and bleached pulp properties.

At any of the alkali levels used, which resulted in pulps with Kappa numbers from 18 to 56, there should not be any upset to commercial cooking control through the inclusion of sound fire-killed wood in

normal export chip mixtures. Screened pulp yield would be expected to drop slightly. The fire-killed sample was disadvantaged by slightly lower unbleached and bleached sulphate pulp quality and required more bleaching chemical to attain a given pulp brightness.

Investigations as described must be a continuing responsibility and will be undertaken, as the need arises, to assist in achieving more efficient utilisation of Australian forest resources. In these recent studies evidence is available to support the use of sawmill waste and forest residues from both large forest-based operations and small mills and to show the viability of including otherwise useless timber in woodchip mixtures. In addition, the projects afford an opportunity to estimate the economic value of these export materials as a guide to obtaining equitable prices for the woodchips.

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PULPWOOD FROM FOREST RESIDUES

V. Balodis, H.G. Higgins, F.H. Phillips,
J. Ward, A. Yuritta and J. Fulton.

Forest residues comprise logging waste (faulty butts, larger limbs and tops, reject sawlog trees), plantation clearing residue, silvicultural residue (malformed or otherwise defective trees) and thinnings.

Plate 1
Logging residue — a small top.

(Ref. 2)

One of the problems with small diameter residues is the cost of debarking which increases rapidly with decreasing log diameter. For example, it may cost up to six times more per tonne to debark 20 than 50 cm diameter logs.

If the cost of bark removal prevents the utilization of small diameter logs and billets, then one alternative is to leave the bark on and pulp it together with the wood. The initial task is to assess the effect of bark on pulping properties and pulp quality. The reduction in pulp quality will depend on the percentage and the type of bark, both of which vary with species, age of tree and with height in tree. This means that each potential pulpwood resource will have to be individually assessed because species composition and tree age will change from one resource to another. The ultimate question to be answered is will the decrease in pulp quality and the possible increase in pulping costs be sufficiently compensated by the potential fibre gain from bark and the saving on debarking cost for a given pulpwood resource.

The northern New South Wales coast, with its concentration of sawmills, is a potential pulpwood resource. It has been estimated that within an economic haulage distance from Coffs Harbour small tops and large branches from logging operations, and thinnings from young stands, represent an annual pulpwood supply of the order of 100,000 cubic metres. Similar material from agricultural and plantation clearing would significantly increase the pulpwood supply. Although these forest residues do not constitute a major pulpwood resource, the utilization of tops would reduce potential fire hazard in the forest, commercial thinning would enable the N.S.W. Forestry Commission to improve stand quality, and the sale of chips could provide foreign exchange earnings up to $2 million per annum. The utilization of this resource will depend on whether the unbarked wood can be used for the production of bleached kraft pulp. To resolve this question, pulping tests were carried out on simulated commercial chip mixtures from thinnings and tops, with and without bark (1).

Sampling

The tops of 75 trees from 13 species were sampled in the Coffs Harbour Forestry District. A 1.2m long sample billet, 20 to 30 cm centre diameter (over bark), was selected from each top. For thinnings, 20 to 30 cm diameter (b.h.o.b.) sample trees were selected at random. The sample billets (one from each tree) were selected in a systematic manner to ensure that all types of bark were represented in the chip mixture. A total of 35 trees from six species were sampled from thinnings. To ensure adequate representation, the sample trees (for tops and thinnings) of any given species were separated by at least 1 km.

Plate 2
Sample billets from blackbutt (E. pilularis) thinnings. Each billet has been selected from a different tree and from a different position in the tree.

(Ref. 2)

Chipping and chip analysis

Prior to chipping, the loose outer bark of the rough barked species was removed with a wire brush. Each group of billets, comprising individual species and sample types (thinnings, tops) were chipped separately on a commercial chipper. The green chips were screened on a Tappi laboratory screen to simulate commercial screening.

The bark content was determined for each species and type of wood, for fines, accept (retained on a 10 mm screen) and oversize (38 mm screen) chip fractions. The bark content of the accept fraction was approximately one half of that in the unscreened chips. From some species, most of the bark was removed either by the oversize screen (*E. grandis*, *E. obliqua*) or the fine screen (*E. acmenoides*, *E. resinifera*, *E. propinqua*); see Table 1.

TABLE1
Distribution of wood and bark in screened chips
(grams per kilogram of oven-dry chips)

Species	WOOD				BARK				Percentage of bark in	
	A*	O*	F*	Total	A*	O*	F*	Total	A*	Total
Sample billets from tops of trees										
Blackbutt (*E. pilularis* & *E. pyrocarpa*)	758	113	27	898	53	22	27	102	6.5	10.2
Brush box (*T. conferta*)	767	77	38	882	46	17	55	118	5.7	11.8
Tallowwood (*E. microcorys*)	785	101	30	916	39	10	35	84	4.7	8.4
Sydney blue gum (*E. saligna*)	805	90	35	930	37	13	20	70	4.4	7.0
Massmate stringybark (*E. obliqua*)	779	58	19	856	65	51	28	144	7.7	14.4
New England blackbutt (*E. campanulata*)	816	44	45	905	37	17	41	95	4.3	9.5
Spotted gum (*E. maculata*)	708	150	30	888	52	27	33	112	6.8	11.2
Ironbark (*E. paniculata*)**	823	51	117	991	7	1	1	9	0.8	0.9
Silvertop stringybark (*E. laevopinea*)	818	49	28	895	42	31	32	105	4.9	10.5
White gum (*E. viminalis*)	824	62	34	920	50	18	12	80	5.7	8.0
White mahogany (*E. acmenioides*)	697	29	63	789	41	13	157	211	5.6	21.1
Flooded gum (*E. grandis*)	802	72	21	895	46	50	9	105	5.4	10.5
Red mahogany (*E. resinifera*)	732	33	39	804	69	26	101	196	8.6	19.6
Sample billets from thinnings										
Blackbutt (*E. pilularis*)	768	76	20	864	75	25	36	136	8.9	13.6
Tallowwood (*E. microcorys*)	795	95	18	908	49	13	30	92	5.8	9.2
Flooded gum (*E. grandis*)	810	64	29	903	64	22	11	97	7.3	9.7
Grey gum (*E. propinqua*)	689	34	140	863	81	7	49	137	10.5	13.7
Ironbark (*E. paniculata*)**	821	74	59	954	21	10	15	46	2.5	4.6
Spotted gum (*E. maculata*)	777	71	19	867	74	21	38	133	8.7	13.3

* A = accept fraction, O = oversize fraction, F = fine fraction (O and F constitute screen rejects)
** Outer bark was removed with an axe from ironbark billets

(Appita 32 (1): page 36, 1978)

Species composition of mixtures

The species composition of tops was based on the weighted sawlog volume of the 1974/75 annual log cut in the N.S.W. North Coast Forestry Districts. The 13 most common species were included in the mixture of tops, the major species bieng:- *E. pilularis* (21.4%), *E. microcorys* (13.9%), *Tristania conferta* (13.2%) *E. saligna* (8.0%), *E. obliqua* (7.7%), *E. campanulata* (7.1%) and *E. maculata* (5.2%). The thinning mixture was confined to the six most common species of thinnings, of which *E. pilularis* (50%) and *E. microcorys* (25%) represent the bulk.

Three sets of duplicate mixtures, with and without bark, were prepared to represent blackbutt (*E. pilularis*) thinnings, all thinnings and all tops.

Pulping, bleaching, papermaking and testing.

The mixtures were pulped by the kraft process. The degree of delignification (Kappa number) was controlled by changes in initial alkali concentration while keeping all other pulping variables constant.

The screened pulps (Kappa number 20) were bleached by a chlorine-alkali extraction-hypochlorite-chlorine dioxide (CEHD) sequence to a pulp brightness between 86 and 88%.

Bleached handsheets (four beating points) were tested for a range of strength and other properties. Besides the standard tests, the sheets were also tested for surface properties (vessel picking tendency and surface roughness) and optical properties (brightness and opacity).

Results and discussion

The most significant wood, pulp and paper properties are summarized in Table 2. Briefly, the presence of bark slightly reduces unbleached pulp yield per unit weight of chips, but its inclusion will significantly increase the total fibre resource. For example, one tonne of o.d. wood from blackbutt thinnings will produce 512 kg of screened o.d. pulp, but if 11% of bark is included, the 1124 kg of chips will yield 547 kg of pulp. On the debit side, 5 kg of additional alkali will be required to pulp the chips to kappa number 20. The presence of bark has a negligible effect on bleaching chemical requirements, fibre loss on bleaching and pulp brightness. The pulps containing bark require more beating to reach a freeness of 250 Csf than wood pulps, but strength and other properties are rather similar for both types of pulp.

The loss in pulpwood quality due to the inclusion of bark is nearly balanced by the increased fibre yeild. For example, in the thinning mixture, if we allow for increased freight costs because of the reduced basic density, and for reduced unbleached and bleached pulp yield, the loss is approximately $4 per o.d. tonne of chips. However, one tonne of wood plus bark chips will contain only 924 kg of wood and the extra 76 kg of wood is worth c.$3 to $4. Consequently, if the wood fraction in the mixture were sold and the bark included as a bonus, the price for the wood fraction would be similar to that obtained for chips from debarked wood (1).

Table 2

A comparison of pulping and papermaking properties of forest residue mixtures with and without bark. (Ref. 1 and 2)

Property	Blackbutt thinnings		All thinnings		Tops		N.S.W. eucalypt chips
	Wood	W + B	Wood	W + B	Wood	W + B	
PULPWOOD							
Percentage of bark	0	11.0	0	7.6	0	5.6	0
Basic density (kg/m^3)	606	565*	649	618*	644	621*	615
ON O.D. CHIP BASIS							
Alkali (%)	13	13½	13½	13¼	14½	15	16
Total yeild (%)	53.2	50.7	51.9	51.6	50.6	48.2	45.7
Screen rejects (%)	1.7	1.0	1.9	1.9	2.5	2.4	<0.1
Loss of fines** (%)	0.3	1.0	0	0.1	0.3	0.4	0.7
Screened yield (%)	51.2	48.7	50.0	49.6	45.8	45.4	45.0
SCREENED PULP							
Kappa number	20.2	20.1	20.4	20.4	20.2	19.2	22.8
BLEACHING (CEHD)							
Fibre loss (%)	7.0	6.3	6.0	7.4	5.6	6.7	6.4
Pulp brightness	88.0	86.4	87.8	87.4	86.4	85.8	88.4
PAPER PROPERTIES AT 250 Csf							
Beating revs (PFI Mill)	2490	3240	2540	2750	3080	3880	3450
Bulk (cm^3/g)	1.55	1.63	1.66	1.67	1.73	1.72	1.60
Breaking length (km)	6.6	5.8	5.7	5.5	5.6	5.4	6.3
Tear Index (mNm^2/g)	9.5	7.9	9.0	9.0	8.0	8.4	8.8
Opacity (%)	65.7	67.3	66.0	66.8	67.0	67.6	69.2

* Estimated by assuming that density of bark is 60% of that of wood
** Calculated from total yield by subtracting screened yield and screenings

In general, pulpwood from thinnings is superior to that from tops: - higher yield, lower alkali requirement, easier to beat and probably stronger pulp. However, the higher bulk of the pulps from tops is an advantage in printing papers. All the pulps have adequate strength properties for fine papers, and the pulpwood quality of these forest residues compares favourably to commercial N.S.W. eucalypt chips (Table 2).

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AN ELECTRONIC TEMPERATURE AND HUMIDITY MEASURING INSTRUMENT.

by J. de Yong and R. McNamee.

Requirements for the measurement and control of air temperature and relative humidity are many and varied. Air-conditioning for human comfort and efficiency may provide for temperature control with or without a rather coarse humidity control. On the other hand, environments with closely controlled temperature and humidity are required for the manufacture, processing, storage and testing of materials and products. Also special research projects often need accurately known and controlled ambient conditions. Research associated with papermaking and the testing of paper is an area of close humidity and temperature control. This is because paper, a man-made assemblage of fibres derived from wood or other plant sources, or more technically a hydrogen bonded network of cellulosic fibres, is particularly sensitive to the moisture content of the air surrounding it. The testing of paper to assess its physical properties must therefore be carried out in a carefully controlled atmosphere as specified by a recognised testing authority. In Australia, the standard atmosphere for paper testing is defined by Appita Standard p 415m-73, as 20 ± 1°C and 65 ± 2 per cent relative humidity. The instrument to be discussed was developed to monitor this standard atmosphere. It can measure atmospheric humidity in a room to an accuracy of ± 0.5% within a 10% span. The normal range is 60% to 70%, at room temperatures between 17.5°C and 22.5°C, but these ranges may be shifted to suit other applications. The spans may also be widened with a consequent loss in accuracy, e.g. doubling either the temperature or the relative humidity range will reduce the accuracy to ± 1.0%.

Currently an Assman wet and dry bulb psychrometer is specified in the Appita Standard. This instrument has two mercury-in-glass thermometers, the bulb of one being maintained dry, while the other is covered with a wet sleeve. A fan is used to draw air from the room over both thermometers. The moisture content of the air determines the rate of evaporation of water from the wet sleeve, and hence the decrease in temperature of the wet bulb. The two temperature readings are converted to a relative humidity value by the use of standard psychrometric tables or graphs. These are based on the standard psychrometric equation, which may be derived as follows:

Relative humidity may be defined as the ratio of the actual, or partial, vapour pressure of water vapour in air, to the saturation vapour pressure of water vapour at the air temperature, expressed as a percentage.

$$\text{i.e. } RH = \frac{p^{11}}{p} \times 100 \text{ per cent} \quad \text{--------(i)}$$

The partial vapour pressure of water vapour in air may be related to the saturation vapour pressure of water vapour at the wet bulb temperature by the formula.

$$p^{11} = p^{1} - aP\,(t - t^{1}) \quad \text{---------(ii)}$$

where p^{11} is the partial vapour pressure (in millibars) of water vapour in the air at the dry bulb temperature

p^{1} is the saturation vapour pressure (in millibars) of water vapour at the wet bulb temperature

a is a coefficient with the value 0.66×10^{-3} per millibar per ^{o}C

P is the atmospheric pressure in millibars

t is the dry bulb temperature in ^{o}C

t^{1} is the wet bulb temperature in ^{o}C

Hence relative humidity can be expressed, for wet and dry bulb measurements, as

$$RH = \frac{p^{1} - aP\,(t - t^{1})}{p} \times 100 \text{ per cent} \quad \text{-------(iii)}$$

where p is the saturation vapour pressure (in millibars) of water vapour in air at the dry bulb temperature.

In the process of controlling atmospheric humidity, some cycling of the humidity level about the control point always occurs. Because of the non-linear response of paper to such cycling, its properties may be affected, and hence it is desirable to continuously record the relative humidity of a test atmosphere. As the Assman psychrometer is a manually read instrument, with the need for tabular evaluation of the measured temperatures, it does not provide facilities for automatic recording. Thus a method was sought which would provide for recording as well as for reliability in calibration.

As in most fields of measurement technology, a number of methods are available from the simple hair hygrograph to sophisticated techniques such as infra-red absorption, attenuation of microwaves, or changes in refractive index of air. A brief review of methods together with considerations which led to retaining the choice of wet and dry bulb psychrometry as the preferred method are discussed in references (1) and (2). Psychrometers are relatively cheap and simple when compared with other humidity measuring instruments and, if they are correctly designed and fitted with good calibrated temperature sensors, careful attention to the condition of the wet sleeve is all that is needed to maintain their stated accuracy.

To provide recording facilities, electrical temperature sensors are a logical choice. Again a selection must be made from thermocouples, temperature dependent resistors, thermistors, and temperature sensitive integrated circuits. Because of the basic need for calibration stability, temperature dependent platinum resistance elements are the most satisfactory. Extensive theoretical studies of the thermodynamics of wet and dry bulb psychrometry have provided a number of criteria which, when satisfied, establish an absolute humidity measurement from wet and dry bulb temperatures according to equation (iii). The geometry of the instrument was therefore designed to fulfil these aerodynamic and thermodynamic requirements, and consultation with Dr. R. Wylie at the National Measurement Laboratories confirmed the design in terms of his specification for a reference psychrometer. As indicated in reference (2) the psychrometric tables for such a narrow range show a nearly linear relationship between wet and dry bulb temperatures and relative humidity. The application of a three variable regression technique to these tabular values yields the coefficients of a linear equation of the form:

$$RH = 7.86\ t^{1} - 6.99\ t + 80.4 \text{ ------(iv)}$$

Electronic circuitry is therefore provided to produce a voltage output for relative humidity as well as wet and dry bulb temperatures, in accordance with equation (iv). Electronic components were selected for maximum stability, and a subsitution method of in built calibration of the electronic circuitry is provided, so that with calibrated platinium resistance temperature sensors repeated relative humidity calibration is not required. The instrument thus combines the established and fundamental method of wet and dry bulb psychrometry with electrical temperature sensing, and modern electronic signal processing techniques, to provide a digital panel meter display of either temperature or

relative humidity, as well as continuous analogue outputs of all three quantities for both recording and control purposes.

As this instrument is now in commercial production, a leaflet giving technical details and specifications of the current unit is attached to this paper.

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DEWAR ELECTRONICS

ELECTRONIC PSYCHROMETER

GENERAL

This instrument was originally developed by the C. S. I. R. O. Division of Chemical Technology to provide the paper manufacturing industry with an instrument which would accurately monitor the air temperature and relative humidity in paper testing laboratories.

Further joint development has resulted in the electronic psychrometer now available which gives the same high accuracy and stability of the original concept, but with added facilities and options.

Applications for this instrument are however, not limited to paper testing laboratories. Other industries which should find this instrument of interest include: food industries, textile manufacturers, printers, packaging manufacturers, environmental control engineers and any other applications where an accurate readout of air temperature and relative humidity is required.

PRINCIPLE OF OPERATION.

The well known and accepted principle of the wet and dry bulb aspirated psychrometer is used in this instrument. Hence, provided that correct thermodynamic criteria are satisfied, only temperature calibration is required to establish an absolute measurement of relative humidity. The wet and dry thermometers and the corresponding derived voltages are appropriately summed to give an output in terms of per cent relative humidity. Either dry bulb temperature, wet bulb temperature, or relative humidity are displayed by switch selection on a three digit panel meter, and voltages corresponding to these quantities are continuously available for recording and control purposes.

TECHNICAL DETAILS.

The standard instrument has a single range with the following measurement specifications:

	Range	Accuracy	Display	Analoque Output
Dry bulb temperature	17.5 C – 22.5 C	±0.02 C	17.5 – 22.5	0 – 1V DC
Wet bulb temperature	13.5 C – 18.5 C	±0.02 C	13.5 – 18.5	0 – 1V DC
Relative humidity	60% – 70%	±0.5%	60.0 – 70.0	0 – 1V DC

Inbuilt calibration of the instrument is provided in the form of two three decade digital potentiometers. An out of range alarm monitors the relative humidity signal and provides a visual and audible alarm if that condition is reached. A low water alarm also provides visual and audible alarm of that condition. A common alarm cancel button will silence the audible alarm.

It should be noted that the readout of dry bulb and wet bulb temperatures will maintain a high accuracy of reading over a wider range since the platinum thermometer's change with temperature is substantially linear, (although they are calibrated at the span quoted). However, due to the linear approximation technique used to compute the R. H. reading, its accuracy will not be maintained outside the span quoted.

The instrument can be supplied calibrated to other ranges if required, or a number of ranges can be provided in the instrument, thereby maintaining the accuracy of the relative humidity reading over a wider range.

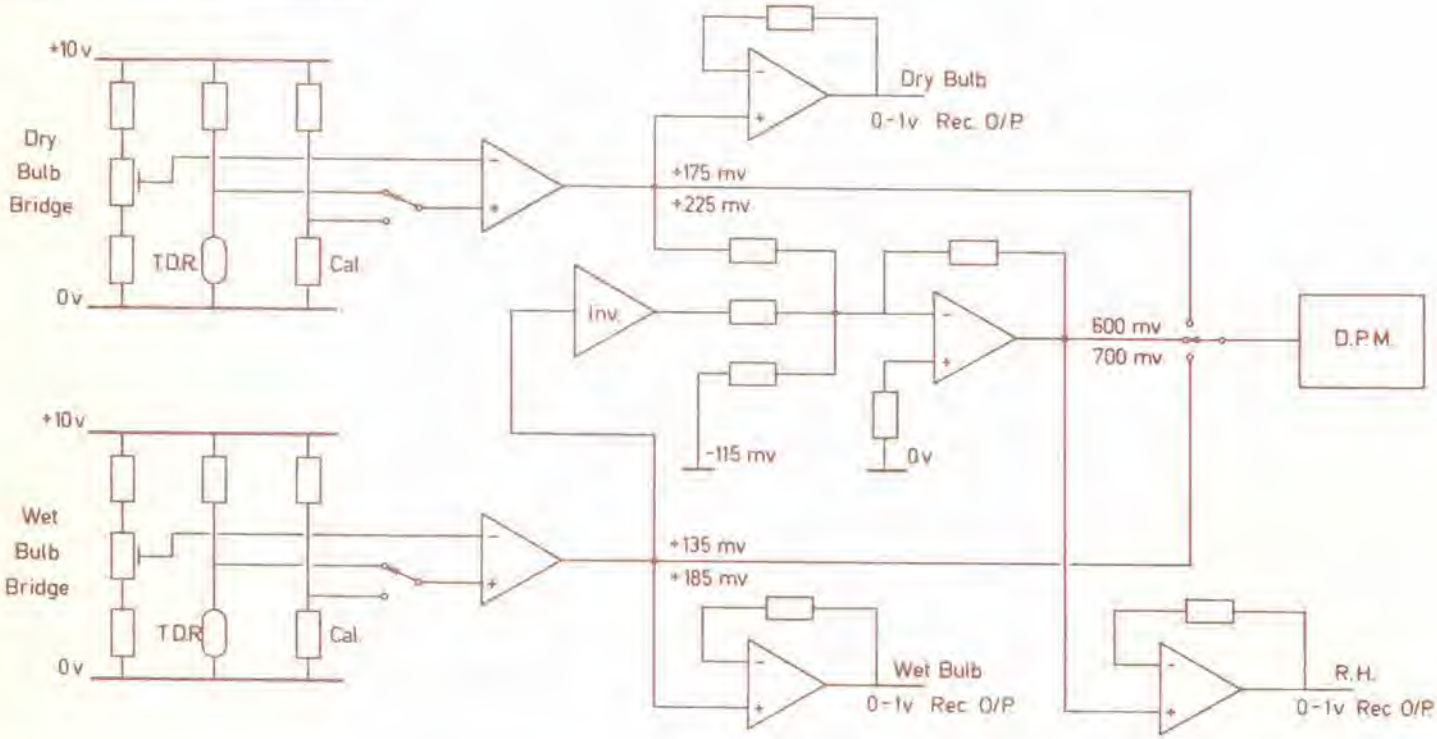
The electronics of the instrument is incorporated into the right hand side hinged cover assembly. All controls are arranged in a recessed area of this cover and are clearly identified. The circuitry employed uses highly stable integrated operational amplifiers throughout which are powered from a stablilsed power supply. The power source for the wheatstone bridges is a precision reference supply with excellent stability characteristics.

The fan used to aspirate the air monitoring tunnel has been selected for its suitable airflow characteristics and life expectancy.

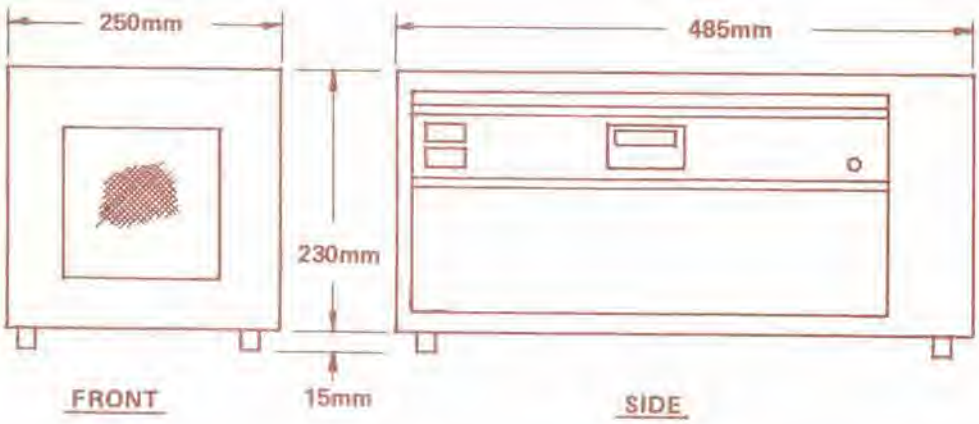
As standard the instrument operates from a 240V AC 50Hz supply.

On the left hand side of the instrument there is a hinged cover which, when opened, reveals the water storage and feed system for the wet bulb thermometer. There is capacity to hold approximatley one litre of distilled water which would allow for continuous operation of around seven days under normal conditions. Replenishment of water can be carried out very simply without interupting operation of the instrument. If required, an option can be ordered to allow connection of an external water source so that continuous operation is maintained which may be essential if it is used for control purposes.

BLOCK SCHEMATIC DIAGRAM



DIMENSIONS



DEWAR ELECTRONICS

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THE INVESTIGATION OF SOME NON-CONVENTIONAL PULPING METHODS

P.J. Nelson and A.F.A. Wallis

ABSTRACT

In accordance with one of the recommendations made at the FORWOOD Conference, a number of non-conventional pulping methods were studied with the aim of developing a process which would be economic on a small scale and produce kraft quality pulp. Hydrotropic pulping was examined with the objective of raising the quality of the pulps produced but this goal could not be attained. Delignification by this method was shown to be an acid-catalysed reaction and when the pH of the pulping liquor was increased to improve the pulp quality the heating times became impracticably long. Pulping with monoethanolamine gave pulps in good yields with properties in the strength range of kraft pulps. However, the consumption of monoethanolamine was uneconomically high and attempts to find a large scale use for the lignin residues to offset the high cost were unsuccessful. The third pulping method investigated was that in which delignification was effected by heating wood in glycol solutions of salicylic acid derivatives. The quality of the pulps produced by this procedure were inferior to those from the kraft process and attempts to increase the quality were not successful.

INTRODUCTION

One of the research recommendations made at the FORWOOD Conference of the Australian Forestry Council was that a pulping process suitable for a small-scale pulp mill should be developed. Any such process must be capable of producing kraft quality pulp without polluting the environment. The kraft process is currently one of the most important pulping processes throughout the world but the complexity and cost of the chemical recovery process is a major disadvantage. The presence of sodium sulphide in the pulping liquor leads to the formation of gaseous sulphur-containing products which can only be removed by installation of very expensive pollution abatement equipment. For these reasons a kraft mill has to be operated on a large scale to keep the unit cost of the pulp at an economic level.

One of the major research efforts in the pulping group at the Division of Chemical Technology over the past few years has been directed towards finding a pulping process which would meet the FORWOOD recommendation. The possibility

of using the lignin removed from the wood as a byproduct and the development of a process with a simple recovery system were two objectives of these investigations. A number of pulping procedures were studied and the three most closely investigated were hydrotropic pulping (1,2,3), pulping with monoethanolamine (4,5), and pulping with glycol solutions of salicylic acid derivatives (6).

HYDROTROPIC PULPING

Hydrotropic pulping utilizes the phenomenon that concentrated aqueous solutions of salts of certain organic sulphonic and carboxylic acids are capable of solubilizing lignin when wood samples are heated with these solutions. The spent liquor can be used a number of times until it is saturated with lignin. Dilution of the saturated liquor results in precipitation of the lignin which is available for utilization as a by-product or can be burned as a fuel. Concentration of the diluted liquor gives a solution which can be re-used as a pulping liquor. The pulping procedure has a number of advantages in that the hydrotropic agent is not consumed by chemical reactions and the only loss is that due to process operations. The principal disadvantage is that the pulp quality is lower than that from the kraft process. One of the main aims of the investigation was to find a method of improving the quality of the pulp.

Sodium 2,4-dimethylbenzenesulphonate was used as the hydrotropic agent during the study because of its ready availability. However, a more desirable agent would be one derived from lignin and this aspect was studied by Bland et al (3). The principal reason for the lower quality of pulp prepared by hydrotropic pulping is that the pH of the liquor (initially 7.0) decreases to about 3.2 during pulping of *E. regnans* wood due to formation of acidic material from the wood.

Removal of potentially acidic groups such as acetyl groups by pre-treatment of the wood using neutral sulphite pulping conditions was an effective way of increasing the pH of the liquor and of raising the quality and yield of the pulp. Addition of a base at the beginning of a cook was studied using sodium hydroxide, sodium sulphite, triethylamine, triethanolamine and urea, and in all cases the use of the modified liquor gave a superior quality pulp but required longer heating times to achieve the same degree of delignification. In a series of experiments designed to maintain the pH within narrow ranges throughout the cooks, small amounts of sodium bicarbonate were added at intervals during pulping of the wood. The data relating to these experiments are summarized in Table 1. To prepare a pulp with a similar Kappa number the cooking time had to be increased considerably when the pH range was raised to a higher level. The pulp prepared using 10 per cent sodium bicarbonate had inferior papermaking properties compared

to a kraft pulp. The lack of success in preparing a high quality pulp from any of the modified hydrotropic pulping procedures meant that this procedure was unlikely to be a substitute for the kraft process.

TABLE 1

DATA FOR PULPS FROM CONTROLLED pH PULPING OF *E. REGNANS* WOOD

Per cent $NaHCO_3$ (wood basis)	Time at 170° (h)	Pulp Yield (%)	Rejects (%)	Kappa No.	pH Range at 170°	Freeness (Csf)	Handsheet properties (60g/m² oven dry grammage)		
							Bulk (cm^3/g)	Tear index (mNm^2/g)	Breaking length (km)
0	1.5	49.4	0.7	58.6	3.0-3.4	400	1.45	6.2	4.9
						250	1.26	5.8	6.3
10	2.75	49.7	0.2	52.0	4.3-5.35	400	1.39	7.5	6.2
						250	1.24	7.2	7.7
12	4.5	49.9	1.3	48.1	5.4-6.2	400	1.41	8.9	6.5
						250	1.23	8.5	8.5
19	5.0	49.2	3.3	52.7	5.9-6.7	400	1.35	9.4	5.5
						250	1.24	9.6	8.4

PULPING WITH MONOETHANOLAMINE (MEA)

Pulping with an organic solvent is attractive in that the solvent can be recovered by distillation and the dissolved wood components are left as a residue and thus available for utilization. A preliminary survey of organic solvents showed that the ethanolamines appeared promising because of their good pulping action and their ability to maintain the pH of the pulping medium above 7. *E. regnans* wood chips were readily pulped when heated in boiling monoethanolamine (MEA) (170°C) at atmospheric pressure. A longer heating period was required to pulp *P. radiata* wood chips. Data relating to pulping of wood from these two species are given in Table 2. The yields of the pulps were higher than those prepared using the kraft process and the strength properties were in the same range as those of kraft pulps. *P. elliottii* wood was more difficult to pulp and a temperature of 200°C and pressure vessels

had to be used to produce pulps with low lignin contents.

TABLE 2

MEA Pulping at 170°

Sample	Cooking time (hr)	% Pulp yield	Kappa No.
E. regnans	1.0	70.9	76
" "	1.25	66.7	57
" "	2.0	64.2	38
" "	3.0	65.1	22
" "	4.0	61.8	17
P. radiata	5.0	64.8	67
" "	7.0	64.9	55
" "	10.0	63.3	38

Recovery of MEA from spent liquors was effected by distillation and it was found that during pulping of *E. regnans* wood the consumption of reagent was 26 per cent and with *P. elliottii* wood the amount used was 36 per cent. The high consumption was due to the decomposition of MEA into acetaldehyde and ammonia at its boiling point and also its reaction with some of the wood components. Studies with lignin model compounds suggested that MEA demethylates the aromatic methoxyl groups in lignin with the formation of N-methyl derivatives of the reagent (7). These studies also showed that MEA reacts with catechol groups and with p-hydroxybenzyl alcohol groups. It undergoes condensation reactions with aldehydes and ketones and it is probable that this is the way it combines with the polysaccharide fraction of the wood.

One way of offsetting the cost of the high consumption of MEA would be to use the residual lignin as a replacement for phenol in phenol-formaldehyde resins. The amino groups in MEA lignin might permit crosslinking by reactions analogous to those which occur in urea-based resins. This aspect was investigated by Bland, Menshun and Willis (8) who found that the reaction of MEA lignins with formaldehyde was slow and there was no evidence for the formation of crosslinked insoluble products. All attempts to find large scale

uses for the distillation residues were unsuccessful and this meant that pulping with MEA would be uneconomic because of the high consumption of pulping agent.

PULPING WITH GLYCOL SOLUTIONS OF SALICYLIC ACID DERIVATIVES

The delignifying action of solutions of salicylic acid derivatives in ethylene glycol was first reported by Schwenzon (9) who used match stick sized samples in his work. Pulping of commercial sized wood chip samples of *E. regnans*, *P. radiata* and *P. elliottii* was studied to determine whether high quality pulps could be prepared by this method. The advantages of a pulping medium which does not contain metal ions or elements other than carbon, hydrogen and oxygen would be considerable because waste material could be burned without the problem of polluting gases or inorganic residues.

A pulp with a low Kappa number was prepared by heating *E. regnans* wood chips in a three per cent solution of aspirin in glycol at 170^{0}C. The use of salicylic acid instead of aspirin resulted in a lower pulp yield. Solutions of methyl salicylate or glycyl salicylate in glycol were not as effective delignifying agents and required higher temperatures and longer reaction times to produce pulps with low lignin contents. *P. radiata* wood was more difficult to pulp than *E. regnans* wood. *P. elliottii* wood was not easily pulped by this method as long reaction times at 195^{0}C gave pulps with high Kappa numbers.

The acidic nature of the pulping liquor resulted in the quality of the pulps being similar to those from the bisulphite process. Several modifications to the procedure were attempted in an effort to raise the pulp quality. Triethanolamine was added to the liquor to reduce the acidity but the pulping rate decreased considerably and it was difficult to prepare a pulp of low Kappa number. Alkali pre-treatment of *E. regnans* wood prior to pulping did not increase the pulp quality and a longer heating period was required. The delignification was an acid catalysed process and anything which decreased the acidity of the liquor reduced the pulping rate.

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PARTICLEBOARD BONDED WITH MOISTURE RESISTANT ADHESIVES

P K McConchie and B R Page

ABSTRACT

Actual test values for eight commercial variants of Australian-made Class 1 Particleboard flooring were compared with overseas products and the effectiveness of AS 1859 glue bond quality and bond durability tests assessed. The AS 1859 tests were less predictive and less effective than internationally used test procedures. This report therefore advocates a re-assessment of AS 1859 and AS 1860 in the light of this evidence and an acceptance of international test procedures and accepted usage areas such as flooring wet areas.

PROPERTIES OF AUSTRALIAN MADE PARTICLEBOARD FLOORING

Single samples of eight commercial Class One Particleboard Flooring products were purchased from the market place in August 1978 and tested according to various procedures and the results presented in Table 1. It would however be statistically invalid to categorise each product according to these results since normal production variables could be much larger than the apparent differences between each test result. Factors in the wide range of test results included resin type of which phenolic (PF), modified wattle tannin (TF) and modified melamine were represented.

The Two-Hour Boil test varied slightly from the V-100 test in that samples were air-dried before testing. The BS Cyclic-Delamination and V-313 test were synonomous. The TRU test (developed by the Timber Research Unit, CSIR, South Africa) dipped test samples (225 x 150mm) in water to a depth of 20mm for one day, oven-dried at 70°C for one day and repeated the cycle as required or until significant delamination occured. Wet and dry edge swells were recorded.

One could argue that a glue bond quality type test should distinguish those products with low delamination resistance and high irreversible swell. Sample 7 fared poorly in the simulative V-313 and TRU test yet had best indicated results in the AS Glue-Bond Quality and Thickness Stability tests. Similarly, one could argue that bond durability of particleboard was effectively measured by strength retention and swell during boiling water soaks. Conflicting results were sample 7 which failed V-100 and V-313 but passed AS Bond Durability and sample 1 which passed V-100 and V-313 but failed the AS test.

TRU test has also indicated that panels 4 and 7 could suffer excessive swell and delamination at board edges when exposed leading to some loss of integrity at tongue and groove joints.

COMPARISON WITH OVERSEAS STRUCTURAL PANELS

Beech et al (1) and Dinwoodie (2) described the performance of particleboard when exposed for 1, 2 and 7 years. Space does not permit presentation of the results but quick inspection showed Australian panels to generally have higher Internal-Bond Retention in the V-100 test (exceptions panels 3, 7) and lower Internal-Bond Retention in the V-313 test. Adhesive types tested by Princess Risborough Laboratory were PF, MF/UF, sulphite liquor and tannin.

A similar program of work in the USA (3) has tested various PF boards for resistance to natural weathering for 6 and 12 months and in various accelerated aging procedures. The Australian panels appeared to have less thickness swell and equivalent Internal Bond Retention (exceptions panels 3, 7) in the test of closest comparison, the Canadian 2-Hour Boil test.

Other significant results were the low swell and high strength retention of PF and MF/UF panels after 50 cycles of one week at each of 30% and 90% relative humidity (1) (2) and the correlation of test results with two year weathering (1). The V-313 and V-100 tests showed significant correlation (0.1% and 1% level depending on property).

SPECIFICATIONS FOR PARTICLEBOARD PANELS

Carroll (4) provided a very interesting discussion of plywood standards and the inherent differences in the various test philosophies. The performance philosophy required tests which permitted innovation in the manufacturing process and usually lead to prolonged simulative tests which required elaborate equipment. This conflicted with a manufacturer's desire for simple, rapid feedback but if specialist knowledge was used to devise a simple rapid test, this led to intuitive suspicion of "unrealistic", non-simulative tests particularly exclusion tests for particular adhesives (e.g. we don't boil Houses). The classic example of an exclusion test based on specialist knowledge was the 72 Hour Boil Test which admitted PF boards but excluded MF/UF and UF bonded plywood and therefore, a simple glue bond quality test (vacuum pressure soak-dry), was sufficient to test resistance to delamination.

Similarly, the US approach to flakeboards specified phenolic type resins (equivalent to an exclusion test). If this was done, then glue bond quality was easily measured and Lehmann (3) suggested one cycle of the VPS-Dry test and for other uses (siding), a cyclic wetting-drying test using moderate temperatures. 1 or 2 cycles of any accelerated aging test was thought to be more severe than 6-12 months exposure, a period which generally surpassed usual construction practice.

TABLE 1 - PROPERTIES OF CLASS 1 PARTICLEBOARD FLOORING MADE IN AUSTRALIA

	PROPERTY		UNIT	PARTICLEBOARD FLOORING SAMPLE								STANDARD	TEST REQUIREMENT
				1	2	3	4	5	6	7	8		
MECHANICAL	Thickness		mm	19.0	18.0	18.6	19.7	21.9	20.2	19.9	18.8	AS 1859	
	Density		Kg/m^3	674	709	705	664	672	720	751	700	AS 1859	Lot Mean > 640
	Modulus of Rupture		Kpa	20.0	24.6	19.1	21.4	20.6	26.7	15.1	20.8	AS 1859	Lot Mean > 16.0
	Modulus of Elasticity		Kpa	2664	3362	2543	2920	2180	3779	2119	2987	BS Draft	Lot Mean > 2750
	Impact Strength		mm	693	627	777	785	868	818	577	652	BS Draft	Lot Mean > 525
	Internal Bond		Kpa	855	615	600	553	720	655	463	615	AS 1859	Lot Mean > 500
	Surface Soundness		Kpa	1801	1593	1016	1188	1164	2080	1119	1314	BS Draft	
	Screw Holding, Edge		N	775	588	850	600	875	613	550	975	BS Draft	
	Screw Holding, Face		N	950	975	1025	1067	1350	1050	975	1075	BS Draft	
WATER RESISTANCE	2 Hour Swelling		%	0.9	1.2	1.2	1.7	0.9	2.1	1.6	1.7	DIN 52364	
	2 Hour Absorption		%	10.2	13.5	11.3	24.8	14.1	17.6	15.9	13.4	DIN 52364	
	24 Hour Swelling		%	3.6	4.8	4.9	6.7	5.2	8.1	5.2	5.3	DIN 52364	
	24 Hour Absorption		%	23.1	31.5	24.7	46.9	38.4	45.3	40.9	31.7	DIN 52364	
	Surface Water Absorption		g/m^2	82	85	90	349	146	180	246	690	AS 1859	Lot Mean < 200
	Thickness Stability		%	6.9	7.9	7.8	7.6	9.8	9.4	8.8	10.3	AS 1859	Lot Mean < 12
DURABILITY	Glue Bond Quality	Wet MOR	Mpa	10.7	13.8	10.8	11.3	12.6	13.3	10.0	15.8	AS 1859	
		Retention	%	53.5	56.1	56.5	52.8	61.2	51.8	66.2	53.0	AS 1859	Lot Mean > 45
	2 Hour Boil	Internal Bond	Kpa	495	483	220	465	665	447	130	415	V-100	>150
		Retention	%	57.9	78.5	35.6	84.1	92.3	68.2	28.0	67.5		
		Wet Swell	%	16.1	10.7	21.3	14.4	13.3	15.6	14.2	12.8		
		Dry Swell	%	7.8	4.6	11.0	6.2	7.3	8.6	4.7	11.3		
	Bond Durability	Wet MOR	Mpa	3.7	10.7	1.5	7.6	8.3	11.2	9.9	11.5	AS 1859	
		Retention	%	18.5	43.5	60.2	35.5	45.1	43.6	52.3	36.8	AS 1859	Lot Mean > 35
		Wet Swell	%	18.5	12.6	20.8	10.2	15..	15.3	15.2	13.7		
	Cyclic Delamination	Internal Bond	Kpa	353	140	127	237	400	160	0	340	BS Draft	Lot Mean > 250
		Retention	%	41.2	29.9	21.2	42.8	55.6	24.4	0	39.0	BS Draft	
		Swell	%	1.3	0	4.4	3.4	3.0	4.3	5.1	4.0	BS Draft	Lot Mean > 8
	TRADA Test 10 Cycles	Wet Swell	%	6.1	6.6	7.8	16.9	11.1	10.0	13.4	6.0		
		Dry Swell	%	1.6	2.2	1.9	9.7	4.6	6.5	6.4	2.7		
		Cycles to Delamination	No.	>10	>10	>10	6	>10	>10	2	>10		

European specifiers however have accepted a wider range of adhesive types and allowed more manufacturing innovation based on their wider experience of PF, TF, Isocyante, MF/UF bonded panels. While they recognised that MF/UF bonded were more affected by long term outdoor exposure and were more affected by fungal attack, Europeans were prepared to accept that MF/UF bonded panels could withstand high humidity and temperature cycling. They therefore accepted simple test methods such as the V-313 test in the UK, Scandinavia and France and the V-100 test in Germany (and now New Zealand) for products intended for protected interior use. For more severe applications, more prolonged simulative testing could be required such as the TRU test in South Africa and the Xenotest Type 1200 and Fungal Cellar Tests in West Germany (certification of all wood products, new adhesives and preservatives by the Federal Material Testing Laboratory (5).

Usage areas for products such as the UK Type III, improved moisture resistant particleboards, were moisture resistant furniture, panels exposed to short-term weathering (platform flooring), wet areas such as bathrooms, toilets, and laundries and flatroofs where complete ventilation could not be provided (cold roofs). These were areas where the EMC could exceed 20% for prolonged periods but not areas prone to fungal attack or persistant damp conditions (6). Similarly NZ Type B panels can be used in wet areas in housing.

The deleterious effects of fungal attack on particleboard, particularly that bonded with carbamide resins, has been recognised and predictive laboratory tests developed (7) (8) (9). However, experience overseas including New Zealand, has demonstrated the safe and successful use of the product in all flooring areas including wet areas. Even UF (Class 2) panels have generally performed satisfactorily with failures being due to excessive moisture conditions since joists and bearers were also rotted, a condition aleviated by proper building practice. The only exclusion in wet areas could apply to UF panels only since these panels suffered strength loss when exposed to conditions of high humidity.

Fungicide treatment was therefore applicable to those grades of particleboard intended for use in fungus prone areas.

DISCUSSION

Particleboard was the newest of the panel products and an important one, more particleboard was used in Australia than plywood and hardboard combined and newer variations being developed (MDF, waferboard, oriented strandboard, composite board) would certainly promote increased interest and demand. Evidence from Australia and Overseas strongly indicated the suitability of particleboard bonded with moisture resistant or durable adhesives for more extensive use in building construction. This was strong argument for further research and development effort to bring the level of knowledge and information to that existing for alternative products.

Particleboard was a particular wood based product requiring its own tests and European experience would indicate that V-100, V-313 and TRU tests were more predictive indicators of the resistance to weathering and high humidity than existing AS 1859 tests. It therefore seemed opportune that AS 1859 and AS 1860 be re-assessed in the light of recent overseas and local experience. Some suggested areas for review were:

(1) Widenning the scope to include structural uses and product variations.

(2) Inclusion of test methods for structural and special properties.

(3) Closer relationship with ISO specifications.

(4) More effective glue bond quality and bond durability tests.

(5) Use of particleboards with "improved moisture resistance" in wet areas and other high moisture environments.

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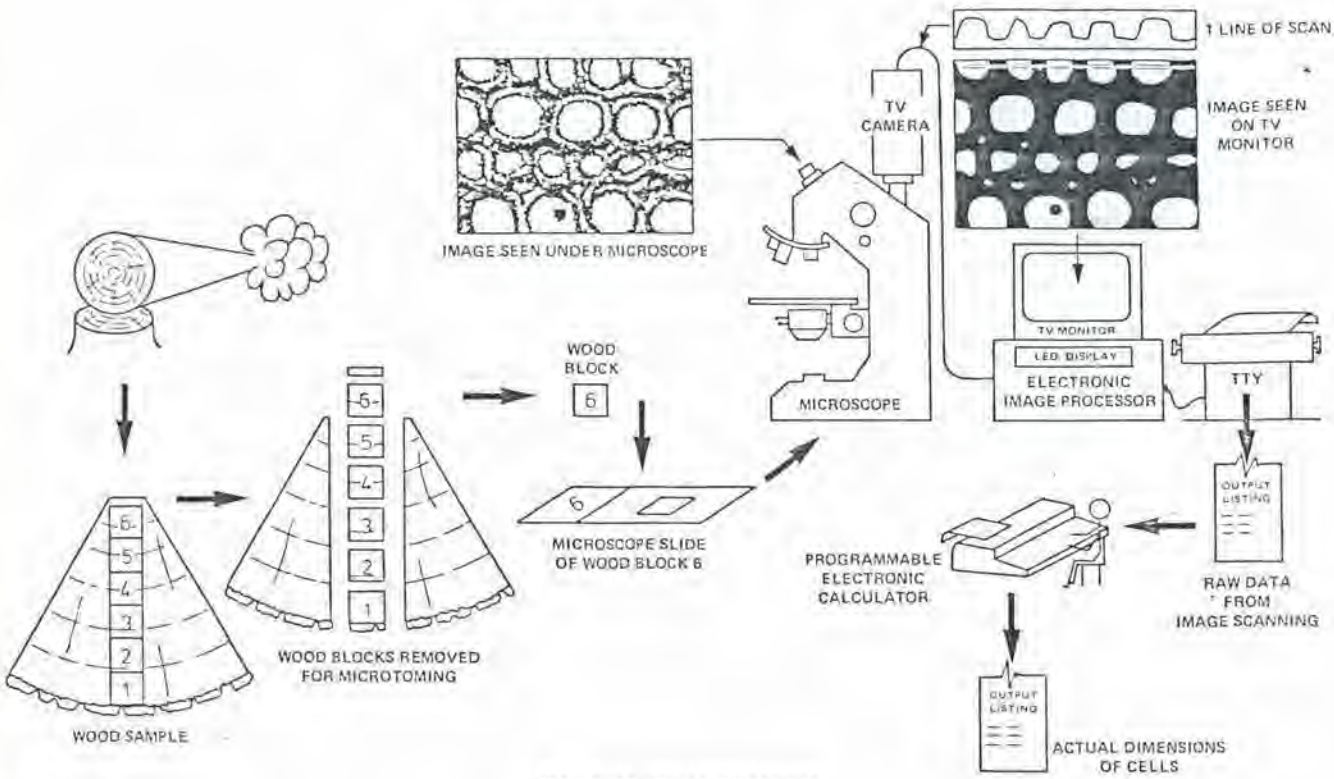


PROCEDURE USED FOR MEASURING CELL DIMENSIONS OF WOOD

FIG. 1.

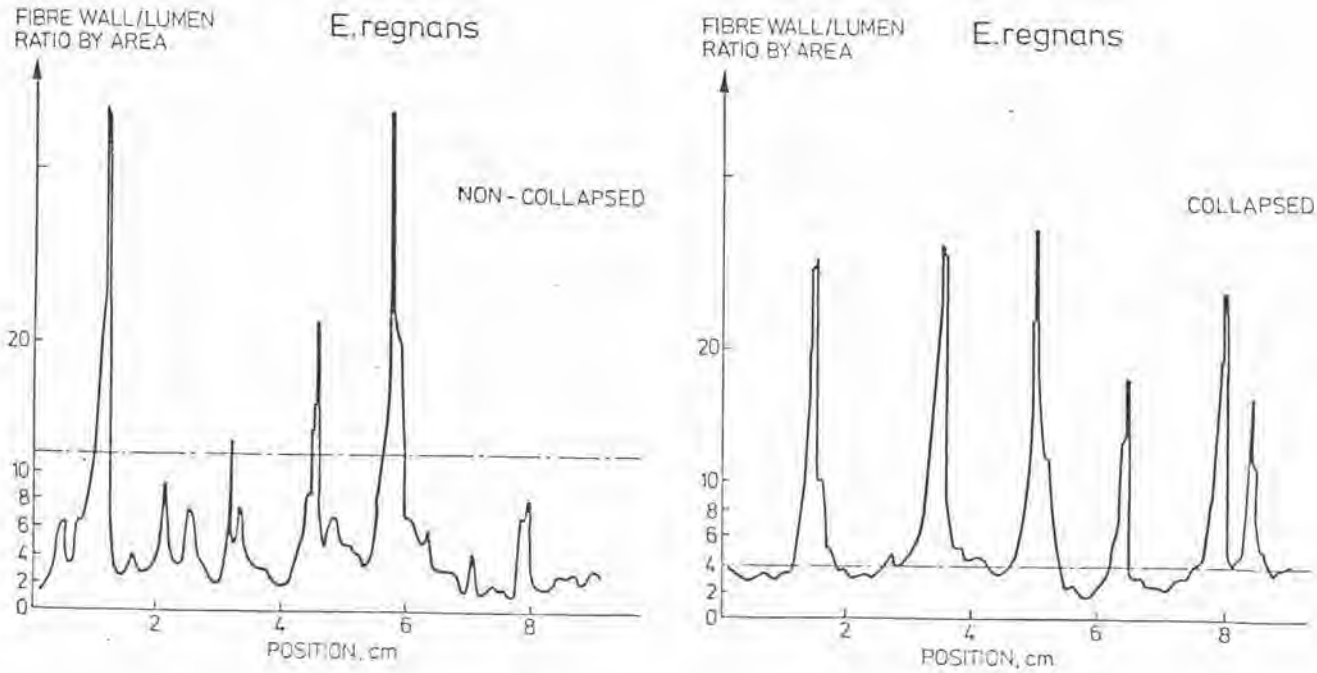


FIG. 2. Typical appearance of the wall to lumen area ratio of the wood fibres for non-collapsed and collapsed samples. The broken horizontal line through each graph indicates a typical LW_{10} value for each sample.

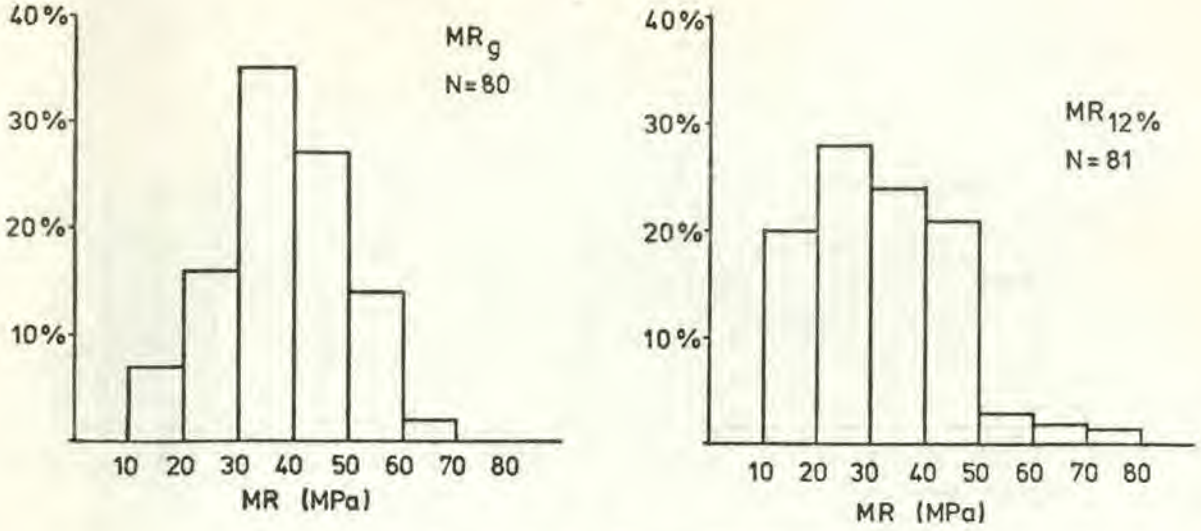


Figure 3. Relative frequency histograms of all the Modulus of Rupture values for the green and air dried samples.

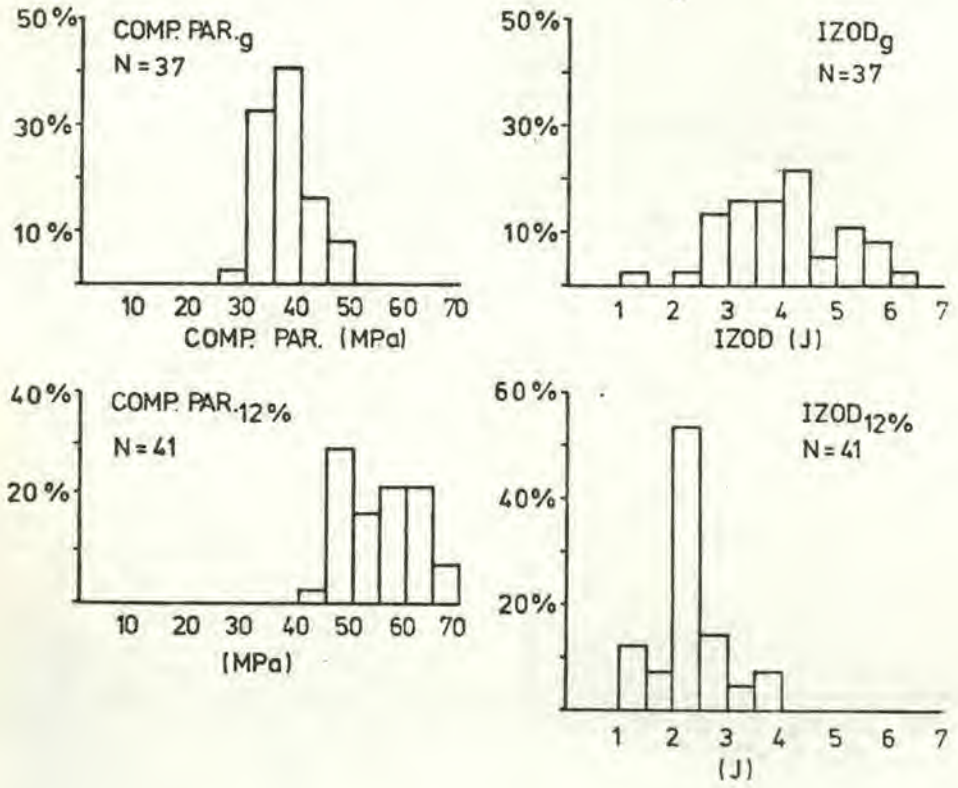


Figure 4. Relative frequency histograms of the compression parallel and Izod values for both the green and dry states. (Swansbel material only).

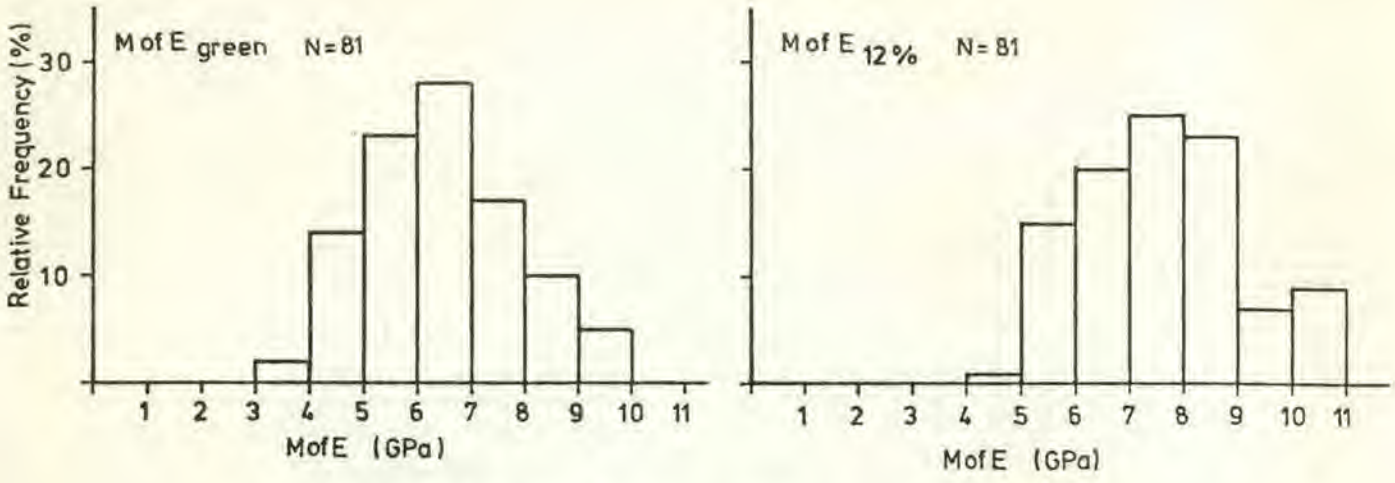


Figure 1. Relative frequency histograms of Modulus of Elasticity values for both the green and air dried samples.

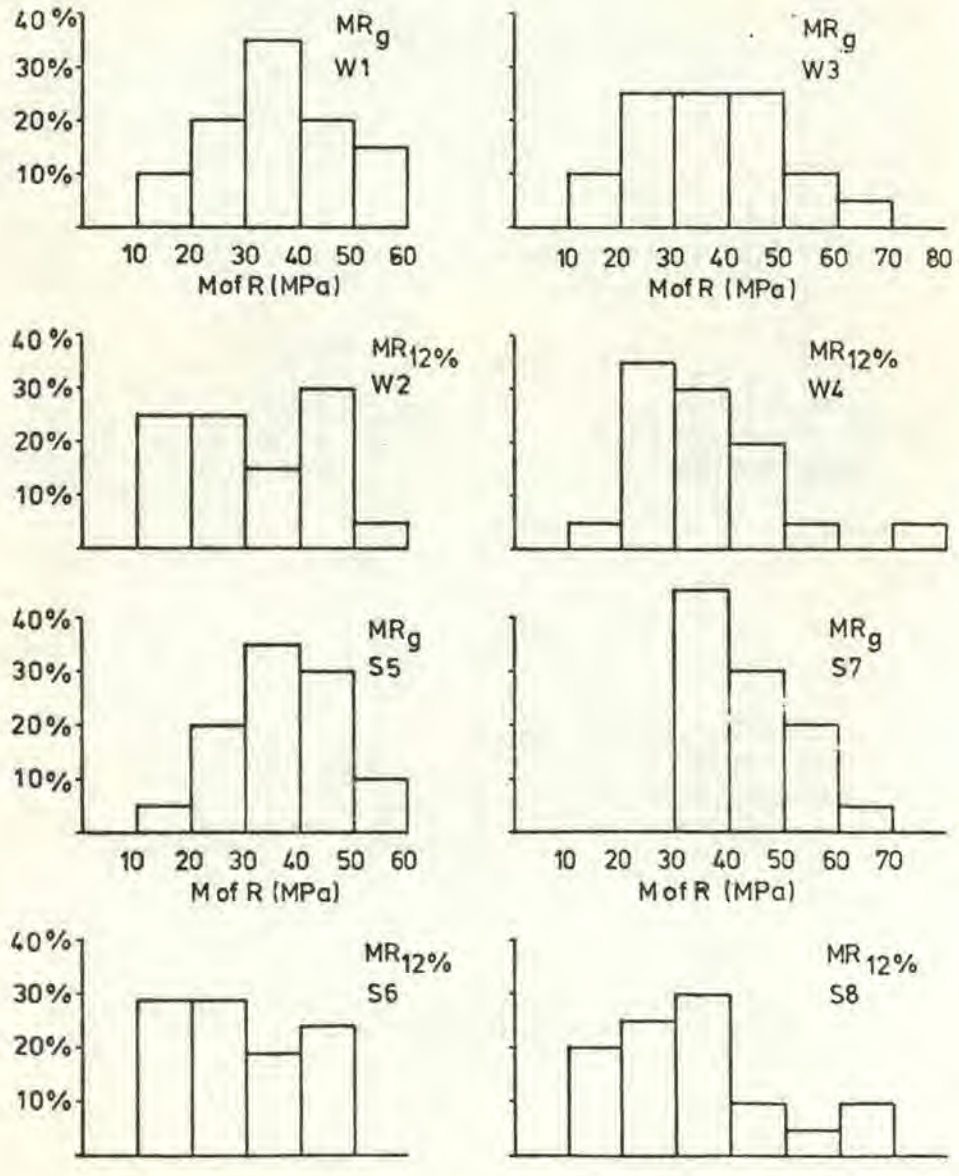


Figure 2. Relative frequency histograms of Modulus of Rupture values for each group tested. See Table 1 for individual group descriptions.

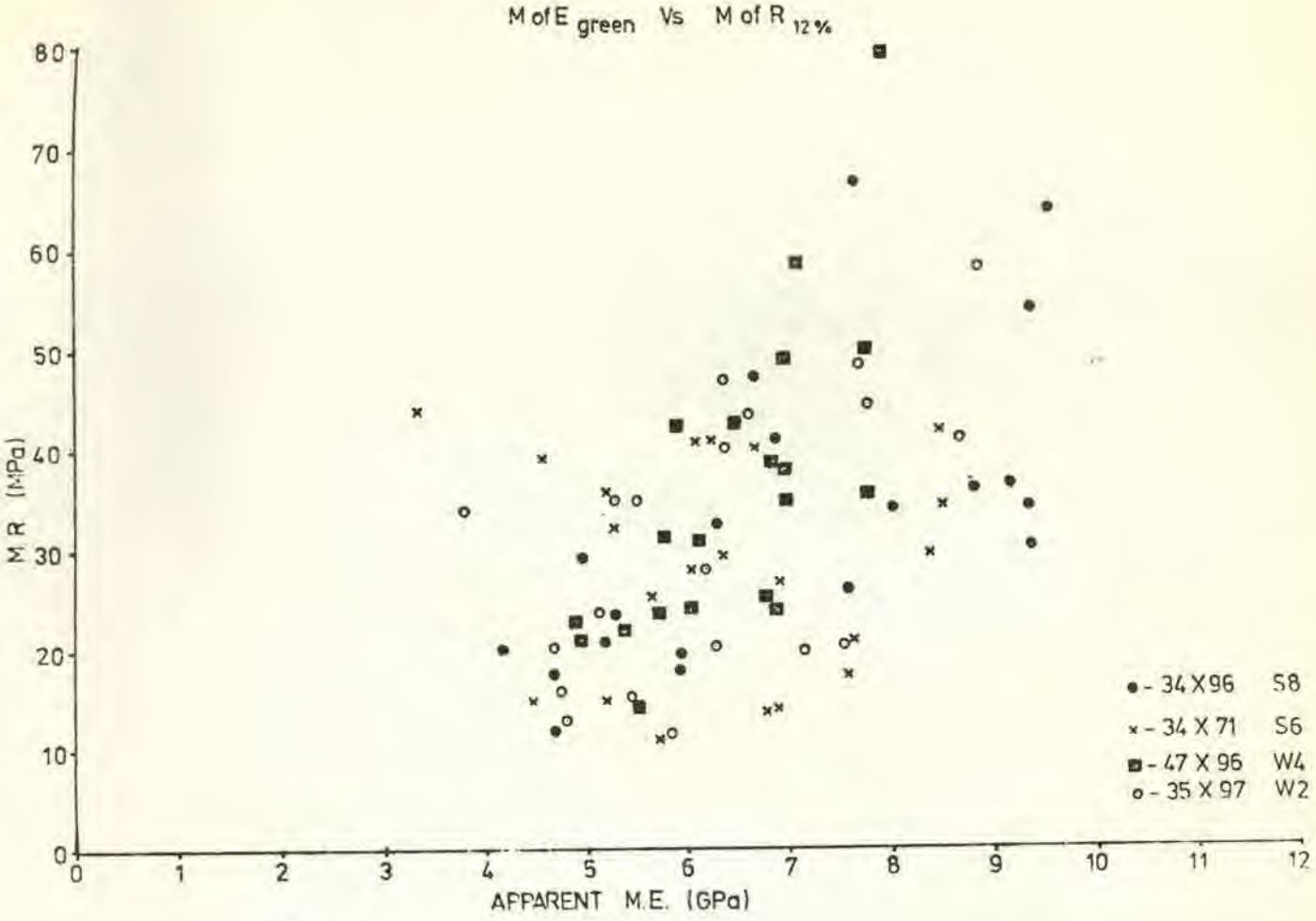


Figure 5.

Plot of Modulus of Elasticity (measured green) Vs Modulus of Rupture (determined dry) for all the samples tested.

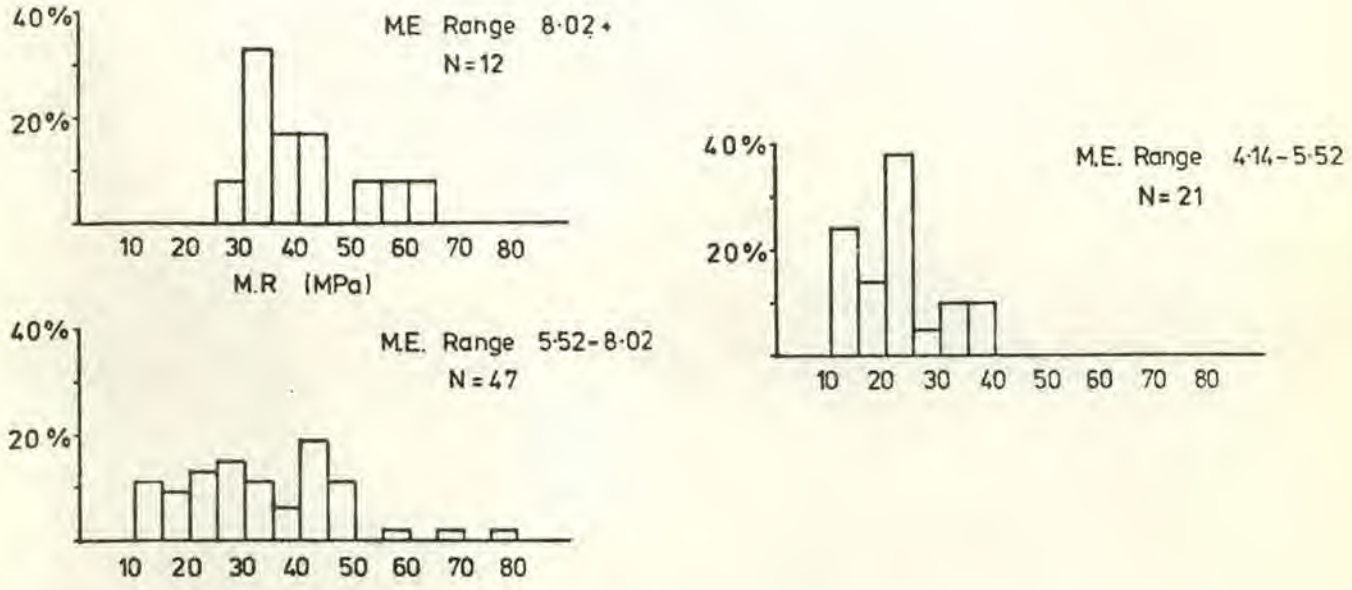
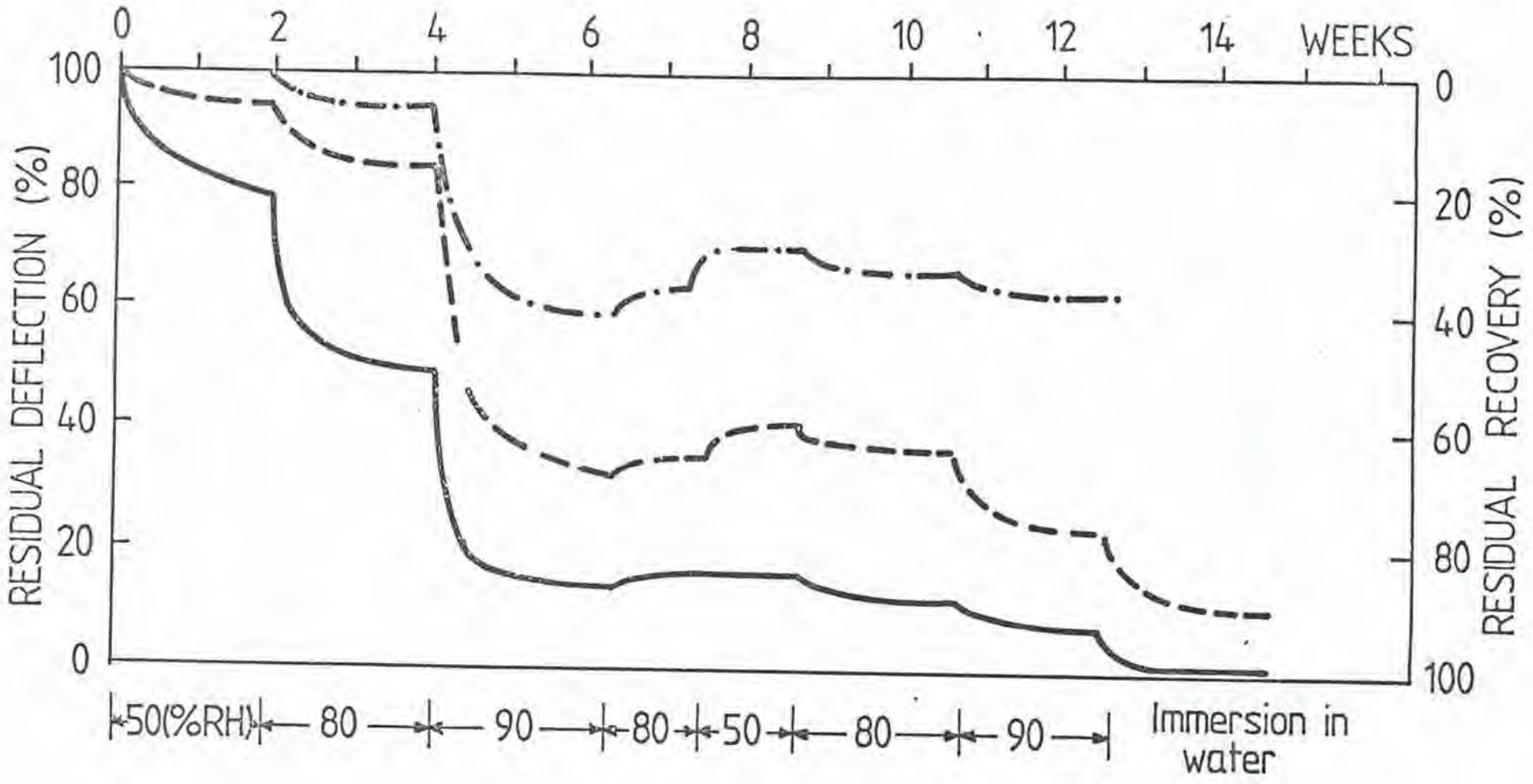


Figure 6. Relative frequency distribution of values of Modulus of Rupture (12%) for samples with Modulus of Elasticity (green) (GPa) values within the indicated range.



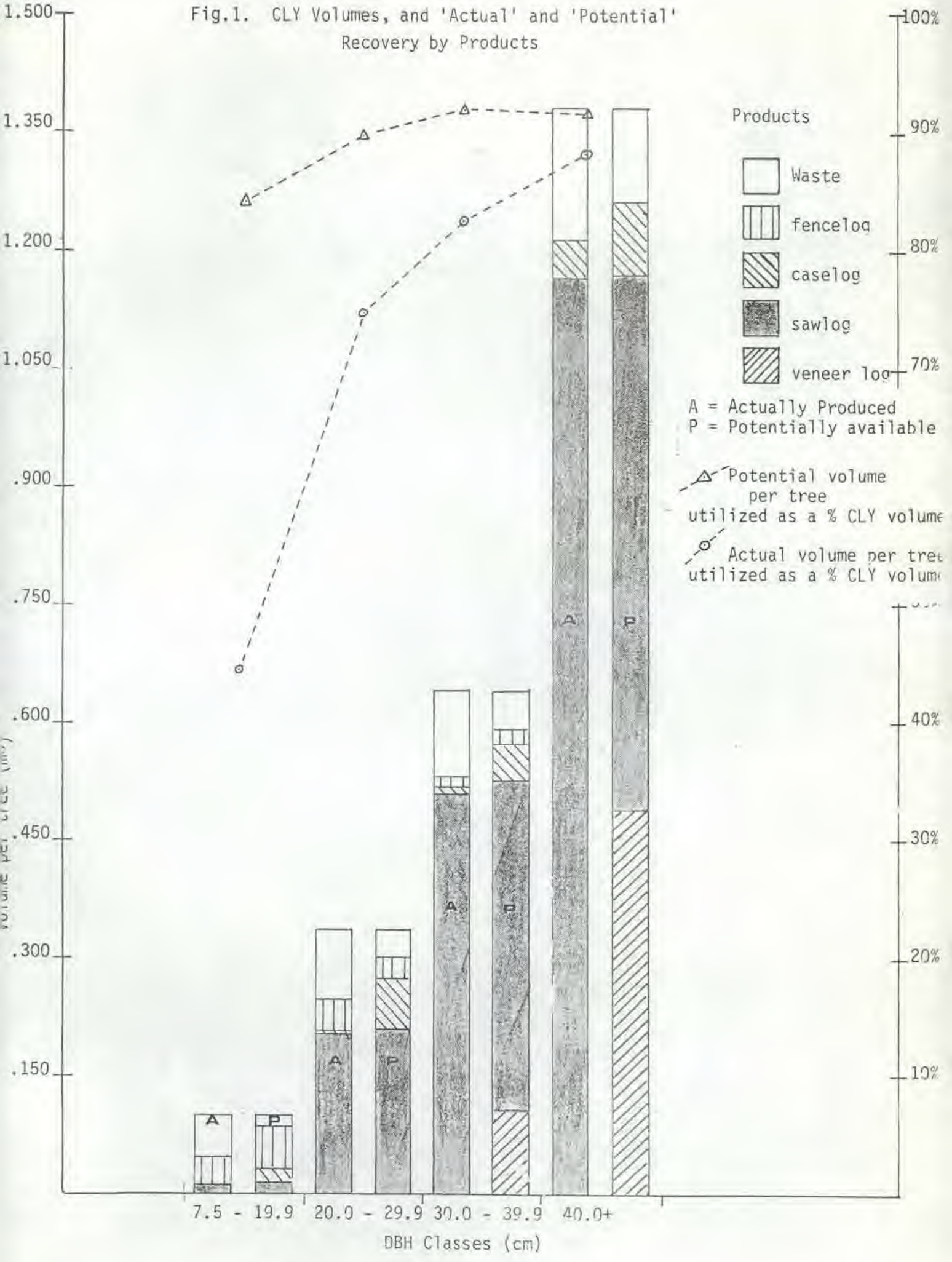
after drying at 25°C

temperature raised to 80°C for one day after eight days drying at 25°C

temperature raised to 80°C for one day at the beginning of drying (specimens not left to recover at 50% r.h. nor immersed in water)

FIG. 1 - Influence of the temperature during drying under stress on the recover of deflection during a sequence of humidity changes (*P. radiata*)

Fig.1. CLY Volumes, and 'Actual' and 'Potential' Recovery by Products



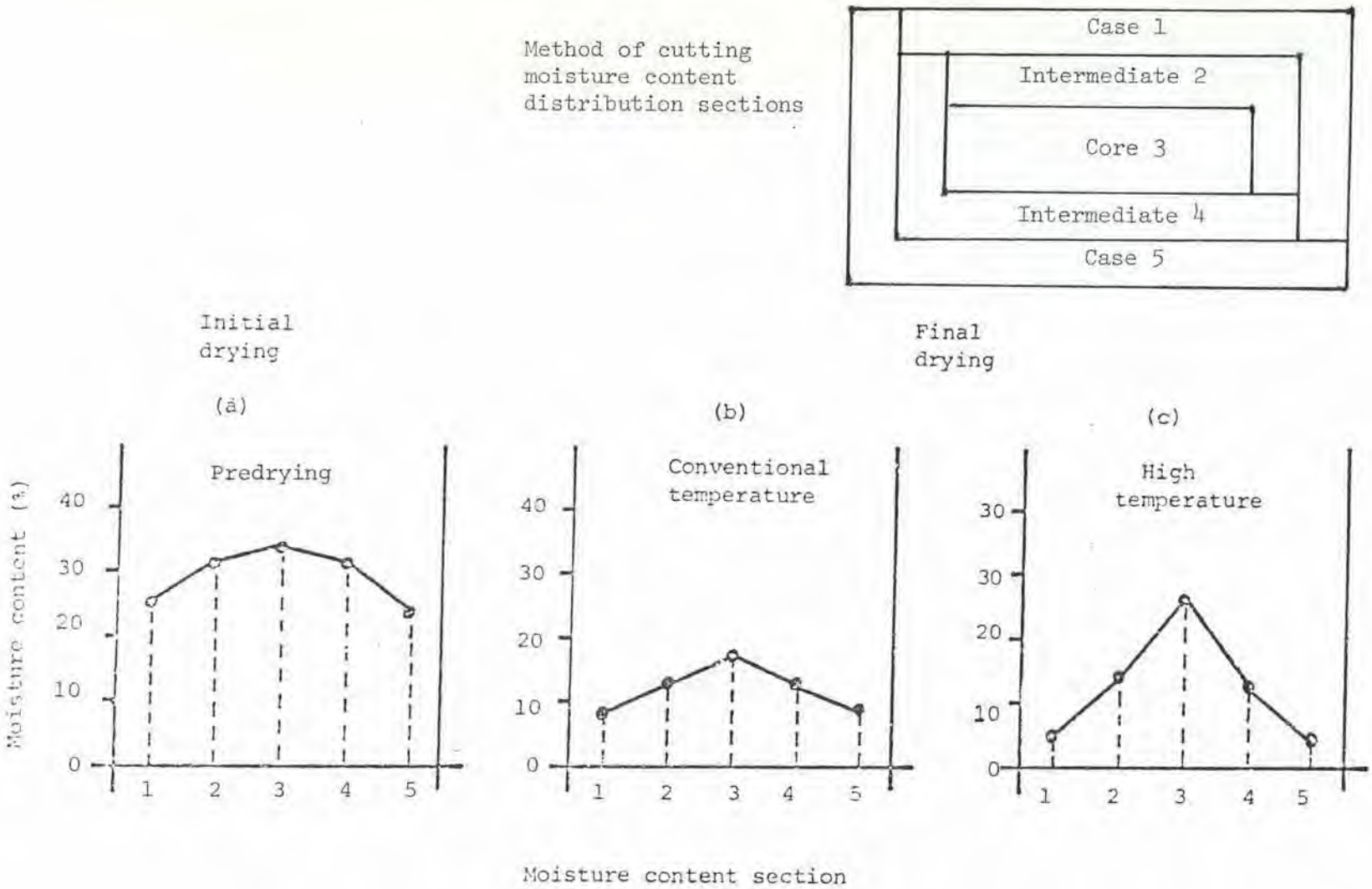


FIG. 1. Mean moisture content distribution in boards after each drying process

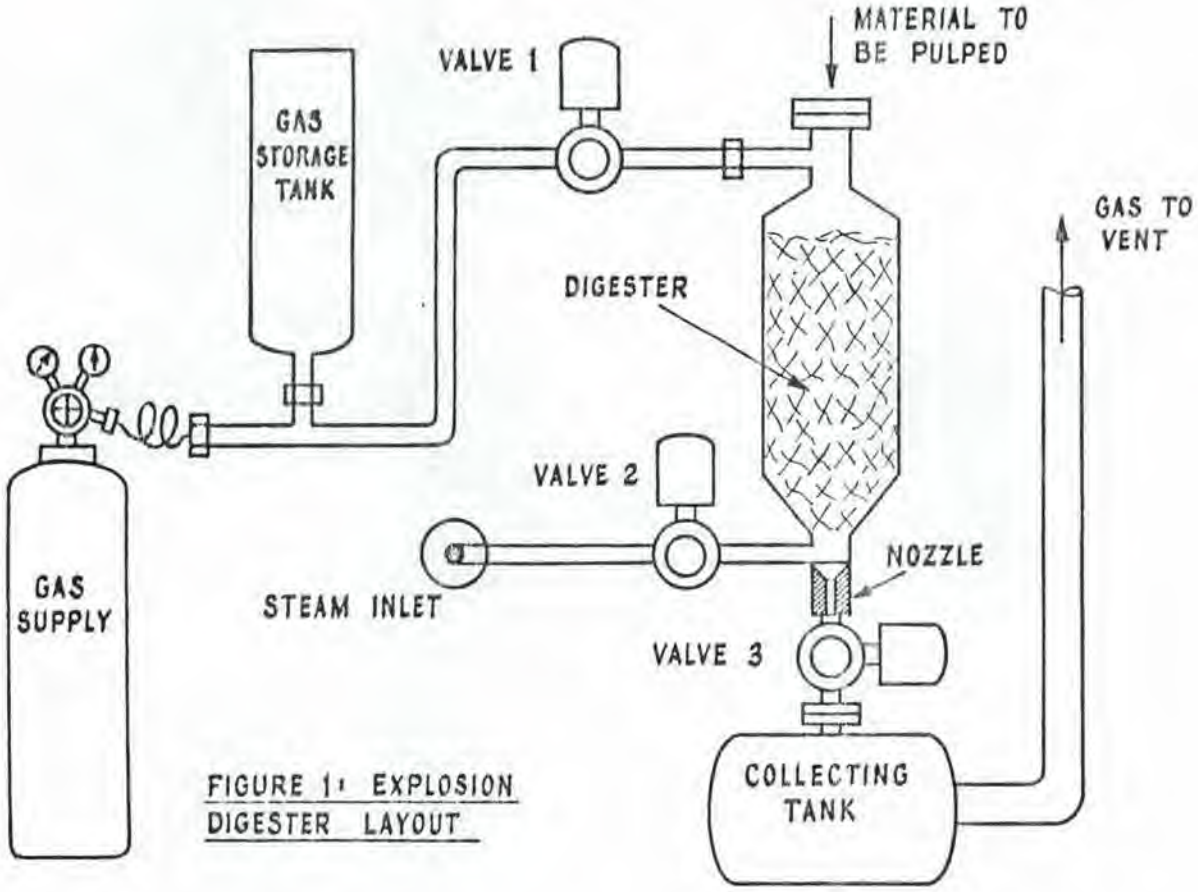


FIGURE 1: EXPLOSION DIGESTER LAYOUT

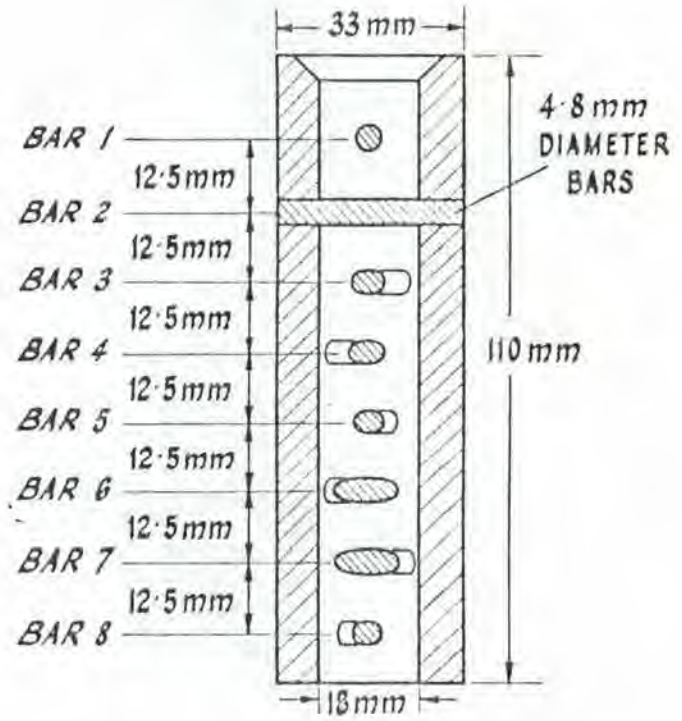


FIGURE 2 CROSS SECTION OF 8 BAR DIGESTER DISCHARGE NOZZLE

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OPENING ADDRESS

BY DR F A BLAKEY
CHIEF, CSIRO DIVISION OF BUILDING RESEARCH

Opening speeches at conferences like this are frequently a confused mix of platitudes. At best they are witty but hardly memorable. Like the curtain raiser at football or if you prefer it the overture at an opera they are intended to give people time to settle down before the real business starts. This will be rather different.

I suspect that this is the most difficult, and perhaps the most important speech that I have ever had to make (and I have made a fair number). Inevitably it will be taken as a policy speech, and for this reason I shall read it, to be sure that I know what I have said.

Although I have known most of you now for some years, today I speak for the first time as Chief of the Division to a major representative gathering of the timber products industry. While Roy Muncey was around, because of his interest and background it was agreed that he would keep the main responsibility in this area, and while the Executive dithered for months over the appointment of a new Chief there was no incentive to get involved. Now there is no escape and I am very much aware that I have a lot to learn and no time to do it because the problems are here and now.

I am also very much aware that the goodwill which is quite strong between most of the building and construction sector and this Division, has been very thin in the area of timber since 1971. I am going to do my best to try to restore

the confidence of the timber products industry in this Division but I know it is going to be a long slow job and I hope I have long enough. It could be greatly shortened if you will make the effort to have more frequent contact with me and the appropriate research staff.

I can assert quite positively that I had no part in the merger of 1971, that I thought it was a stupid idea then and I still do, but the only thing that would be more stupid now would be to try to put the clock back and unscramble the egg. There have been far too many changes in the general political and commercial environment for that to be really possible now. We have had the collapse of the housing industry, the fuel crisis, environmental politics etc. none of which will go away quietly.

In the merger I was left to try to calm the first giant wave of the discontent while Roy went overseas. With the usual one or two exceptions, I believe the staff are now content - perhaps a little nostalgic, those of the old teams that still remember South Melbourne - but broadly content. I should like to leave your industry in about the same state but I am somewhat at a loss to know where to start. Of course, if the industry is prepared to cooperate and provide some pointers I shall do my best to follow.

Some of you may have seen the policy which I set out in a recent issue REBUILD. It was based on a position paper on Research for Building and Construction which I prepared for the

Australian Science and Technology Council. This Council advises the Prime Minister on science policy. It was very general, dealing with broad issues of productivity, standards and resources. I believe that this is the sort of overall view of an industry that any Chief and his senior staff should have. I have already been slammed by two timber groups because there was no mention of timbers, quite ignoring the fact that there was also no mention of steel, concrete, bricks, plaster, plastics, aluminium, stone, and so on.

As I said, it will be a long slow job.

The difficulty is of course that those who have attacked my attempt at a policy are not really looking for a mention of timber, but of "their" particular timber. It prompts me to ask is there no basis on which the different components of the timber industry can unite to help us make forest products an even more significant force in the building and construction sector.

This presents no new situation however because, equally, there is no building industry. There is a building and construction sector of the economy, a statistical concept which includes hundreds of industries. How can one choose between the contending claims of the different hardwood, pine, plywood, particleboard, and all the others? - as we shall have to choose because the days when we could take on everything are over. We are in an era of declining government expenditure, declining resources and governments that want evidence of value for

every dollar they spend. We have lost over twenty percent of the staff we had at our peak, and I fear that there will be more losses. The timber area has lost of course, but nothing so much as bricks, ceramics, plaster and paint which have been wiped out of our program. Numbers can be twisted of course, but the conservation group for one, has not dropped in numbers since 1972. Productivity, if you will accept numbers of reports as a measure has risen, if anything.

I believe we must develop a market-minded approach, using the information that comes from the work of our operations economic group and a major collaborative study with the Australian Industrial Research Group.

We must also have a look at some of the projects that have been on our books for a long time. If we have made no real progress in twenty years perhaps we should stop throwing good money after bad and release staff to turn to other areas which you can help us define, and, which might be more productive. Certainly there are some problems, like the cracking of concrete which cannot be completely solved and it is a waste of money to try any longer. I have no doubt this approach would be automatic in private industry.

My friend, Geoff. Anderson, told me after he was appointed Chief of EBS that he found that people spent a lot more time thinking about his statements than he ever did before he made them. If you are determined to find in what I have said, something that proves again that CSIRO is neglecting the timber industries, I am sure you will find it - but it will be your idea not mine.

Gentlemen. I ask for a fair go and bid you very welcome to the 19th Forest Products Research Conference.

REPORT OF THE WOOD PRESERVATION COMMITTEE (1977-1979)

Prepared by H. Greaves (Chairman)

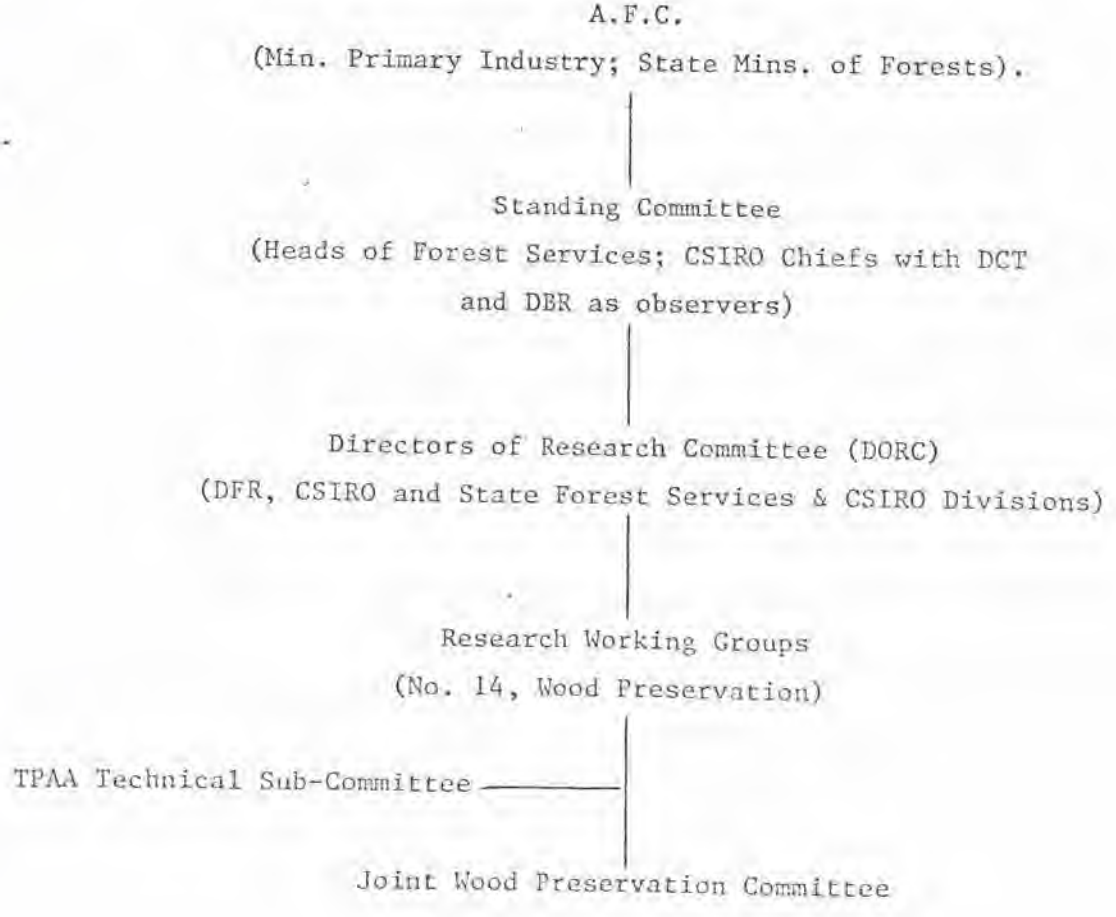
Since our last Conference the Wood Preservation Committee (WPC) has met with the usual frequency, being convened in July 1977 at Brisbane, February 1978 at Melbourne, October 1978 at Sydney, and in May 1979 we met for the first time outside Australia at the Forest Research Institute (FRI), Rotorua, New Zealand. The Committee was enlarged by invitation in 1976, to include Dr. A. J. McQuire of FRI and now consists of the following members:

Mr. W.A. Clifford (Victorian Forests Commission), Secretary & Convenor
Mr. K.V. Cokley (Queensland Department of Forestry)
Dr. H. Greaves (Division of Building Research), Chairman
Mr. R.S. Johnstone (Forestry Commission of NSW)
Mr. C.R. Levy (Department of Primary Industry, Office of Forests, Papua New Guinea)
Dr. A.J. McQuire (Forest Research Institute, New Zealand Forest Service).

Meetings usually consist of two days in closed session, where research in preservation and preservation matters are discussed, followed by a further two days in open session with members of the Australian wood preservation industry. These latter meetings - sometimes refered to as Joint Wood Preservation Committee (JWPC) - involved the former Technical Sub-Committee of the Timber Preservers' Assocation of Australia, represented by Messrs. J.H. Foxton, J.D. Price, S. Retter, and B.R. Rumball. With the restructuring of TPAA Committees, it remains to be seen whether the WPC will meet with the re-constituted Technical Committee or with any of its Working Groups.

The main Committee itself has been subject to some reorganisation since the last report to the 18th Forest Products Research Conference. At the Brisbane meeting Dr. Da Costa announced his intention to retire the following year and to devote his remaining time with CSIRO to writing up a number of his outstanding research projects. The same meeting duly elected Dr. Greaves as Chairman of the WPC, and thanked Dr. Da Costa for his major contributions during his many years of association, both indirect and direct, with the Committee. I feel sure this, the 19th Forest Products Research Conference, would want to join with the WPC and the JWPC and record their thanks too. The Brisbane meeting also saw the New Zealand member, Dr. McQuire, attending for the first time, together with an invited CSIRO guest worker, Dr. John F. Levy of Imperial College, London.

At the October 1978 meeting in Sydney a further, more drastic reorganisation of the WPC was discussed. The Committee had been 'invited' by Standing Committee of the Australian Forestry Council (AFC) to form Research Working Group # 14 of the AFC, thereby becoming responsible to the Directors of Research Committee (DORC) of AFC. Liaison from WPC (as AFC/RWG # 14) to DORC would be through a Co-ordinator; in our case Mr. J.F. Nicholas, Assistant Chief of DBR. It was pointed out that the WPC as set up at the 10th Forest Products Research Conference in 1961 would not cease to exist, "rather that the members..... have been asked to undertake a dual role". Unfortunately AFC Research Working Groups operate under guidelines which appear to be inappropriate for the normal, and highly satisfactory, modus operandi of WPC. In particular our open sessions with the Industry (as the JWPC) are not specifically catered for within these guidelines although membership of the WPC was extended to the PNG and New Zealand delegates within the proposed framework of RWG # 14. After consideration of these and other issues and although some doubts were expressed in Sydney by WPC members, it was announced in March 1979 that the WPC had become formally constituted as Research Working Group No. 14 under the auspices of the Standing Committee of the Australian Forestry Council.



The first meeting of RWG No. 14 was the Rotorua meeting in May this year*

The Committee has continued in the tradition of broad and frank discussions on many topics of research as well as on the day-to-day preservation problems confronting both industry and Government. It was explained at the Brisbane meeting that our deliberations were two-way, in that there has been a tendency for a majority of agenda items at the JWPC meetings to be tabled by the non-industry members; subsequently a marked increase in TPAA involvement took place at the other meetings. It is to be hoped that the formation of Working Groups within the TPAA will not affect this trend.

The Rotorua meeting was poorly attended by the Australian-based WPC members, but nevertheless it was a valuable opportunity to meet with preservation researchers from FRI and with the NZ preservation industry. Drs. Greaves and McQuire were interviewed on radio specifically to comment on trans-Tasman collaboration on wood preservation matters. In particular it was felt that Australian standards should have some input from NZ preservationists (and, of course, vice-versa.)

The subject of standards, notably AS1604 and AS1605, has received a good deal of attention by the Committee. As a result of our lobbying with the Assistant Chief of DBR and liaison with Bill Keating (DBR's representative on the Timber Standards Board) the whole issue of preservation standards received favourable consideration by the Association; Committee TM106 was formed. Unfortunately this Committee has spawned such a range and number of sub-committees that it is doubtful whether real progress, particularly on AS1604 and a standard for light organic solvent preservatives (LOSP), will be made in the short-term.

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* Since this time there has been further discussion on the AFC Standing Committee decision apropos the Forest Products Research Conference Committees, and there is now a recommendation before Standing Committee that the WPC (& Joint Timber Seasoning Committee) be asked to act as Technical Advisory Groups to AFC, rather than as Research Working Groups.

LOSP deliberations have figured prominently on the agenda at all meetings of the WPC and JWPC. These types of preservatives represent a most important development on the Australian preservation scene. It is critical that the best and most relevant research and technical data available be used in assisting this development. There has been a good deal of discord in this respect between the major WPC and JWPC interests, and it is with disappointment that I record a comment of a prominent industry-man that the TPAA do not have to take cognisance of the deliberations of the WPC. Happily these differences in attitude have not reflected on other topics or agenda items, and I am confident that much benefit will be derived all round at future meetings of your Committee.

A synopsis of discussion topics is presented as follows:

PRESERVATIVES
- LOSPs
- CCA
- PCP
- TBTO
- Chlorinated hydrocarbons
- Alternatives
- Synthetic pyrethroids
- PECCs
- Cu naphthenate
- AACs

TREATMENTS
- Water repellents
- Double diffusion
- Groundline maintenance
- Surface coatings
- Remedial preservation
- Treatment methods
- Pine heartwood

LEGISLATION
- Specifications
- Standards & revisions
- NSW Timber Mark. Act
- Quality control
- Imported timber
- Health & pollution aspects
- Standards of preserv. supplies
- Law of liability

BIODETERIORATION
- Dry rot
- Termites
- Anobium in radiata
- Dutch elm disease
- Marine borers
- Soft rot
- General decay
- Sapstain

COMMODITIES
- Sleepers
- Log cabins
- Glulam beams
- Particleboard glue protection
- Plywood preservation
- Playground equipment
- Composite products
- Poles
- Piles

TESTING
- Analyses & procedures
- Non-destructive (Shigometer; X-rays etc.)
- Field tests
- Laboratory screening & tests
- Fungal cellar

MISCELLANEOUS
- Durability ratings
- Out-of-ground exposure
- Fire ratings
- Survey of treated timber
- IRG on Wood Preservation
- AFC Research Working Groups
- Strength properties of CCA treated timber
- Decay of pine

Forest Products Research Conference

Joint Timber Seasoning Committee

1. Details of Meetings

Since the last Conference four meetings have been held; on October 12, 1977 at CSIRO Division of Building Research, Highett; on June 1, 1978 at North Coast Sawmills, Queensland as part of a field tour of southeast Queensland seasoning facilities; on February 23, 1979 at Travelodge Motel, Tullamarine and on September 12, 1979 again at the Division of Building Research, Highett following a field tour of Gippsland sawmills.

2. Membership

Membership of the Committee is currently as follows:

Mr. F.J. Christensen, CSIRO Division of Building Research

Mr. J. Clark, Tasmanian Timber Promotion Board

Mr. R.M. Cowan, Woods and Forests Department of SA

Mr. D. Gough, Queensland Forest Service, Department of Forestry

Mr. J.N. Hartley, Wood Technology and Forest Research Division, NSW Forestry Commission

Dr. W.E. Hillis, CSIRO Division of Building Research

Mr. A.C. Hogarth, Allen Taylor Limited, NSW

Mr. E.P. Lhuede (Secretary), CSIRO Division of Building Research

Mr. P.E. Marshall, Wood Technology Consultant, Murwillumbah, NSW

Mr. B.A. O'Brien, Forest Products Association of WA

Mr. M.W. Page, CSIRO Division of Building Research

Mr. B.L. Rumball (Convenor), Radiata Pine Association of Australia

Mr. F.C. Straker, North Coast Sawmills Pty. Ltd., Queensland

Mr. P.J. Wilkinson, Wilkinson Timber Industries, Queensland

Mr. J.M. Willington, APM Wood Products Pty. Ltd.

Addition to membership was made at the 8th meeting when Messrs. Wilkinson, Hogarth and Christensen were invited to join the committee. Mr. Willington was invited to replace Mr. Jim Alexander who is no longer active in the wood products area. Messrs. O'Brien, Clark and Gough replaced former committee members from their respective organisations. Total membership now stands at 15.

3. Committee Discussion

A wide range of topics concerned with timber seasoning were discussed and the more important of these are briefly outlined below.

(a) W.E. Hillis reported further work related to softening points of green *P. radiata*. The times and temperatures required to obtain softening or plasticization for wood of given moisture content, the effect of long term heating on stability, and the measurements of softening points of wood from various localities were all fully discussed.

The question as to whether plasticizing needed to be carried out at high or low relative humidity was not resolved over the course of the four meetings. Further, the need for presteaming as opposed to rapid air heating as a preliminary to kiln drying still remains to be studied. Both an experimental and a basic research approach to the problem is required.

(b) The need to carry out investigations on the drying of CCA-treated *P. radiata* had been stated and J.N. Hartley reported an extensive experiment being undertaken to obtain data on drying times and degrade. The work had not been finalised in October 1979 but high variability of final moisture contents in redried material were being encountered. F.J. Christensen reported on a joint project which compared degrade in high and low temperature dried treated radiata, and this is reported fully under Topic 4A/9 of this Conference.

The suggestion was also made that the Queensland Forest Service could be involved in the work in covering the ranges of moisture contents during the initial drying that had not been included in the Division of Wood Technology's programme.

(c) It was reported in June 1978 that the firm of N.J. Hurll had been licenced to build the continuous softwood drying kiln and for a unit to process 5 m3/h a cost of $350,000 was indicated. In September 1979 a higher figure was stated and was considered to be realistic for a "first-off" design. Members indicated that a detailed economic analysis of a continuous kiln integrated into a mill production system was still required. Industrial acceptance of this kiln could be enhanced by development of an intermediate scale of drier and funds were being sought to build such a unit.

A low cost continuous hardwood kiln designed by Campbell and Fricke was built at Leongatha in Victoria and its performance has been monitored. There are indications that more of these kilns will be constructed.

Interest developed over the four meetings on the solar heating of kilns and Gough reported that two were now operating in the Brisbane area. Details of their cost and performance have been provided to the committee and application of solar heating to a Leongatha type kiln is being considered. A number of dehumidifiers have been installed in sectors of the industry but there appears to be some lack of understanding of their operation and the extravagant claims made by suppliers have been viewed as serious misrepresentations.

(d) The need to establish a case for the high temperature seasoning of heart-in radiata studs was discussed at the sixth meeting and at the ninth meeting a copy of the code which had been introduced by the RPAA was distributed. There was extensive comment on the details of the code. In a related area Christensen reported the results of seasoning trials with early thinnings of *P. radiata* and the results paralleled the findings of Willington *et al.* in relation to a high percentage production of low strength material.

(e) Concerning hardwood seasoning, Hillis reported the work of Ilic of the Division of Building Research who had developed a microscopic scanning technique whereby a measure of the ratio of fibre wall area to lumen area could be used to differentiate between collapse and non-collapse prone eucalypts.

Page and Christensen respectively reported on the use of ultrasonics and pre-freezing treatments which had been applied to Tasmanian hardwoods as check-alleviating pretreatments in kiln drying. The results were generally of a negative nature although much of the experimental work was confounded by the difficulty of obtaining material that would check during experimental trials. Aspects of this work are covered in Topic 4A/10 of this Conference and in other publications. Further work of investigating the extent of seasoning degrade in Tasmanian eucalypts has been planned but not pursued to the present time.

Discussion of other projects was concerned with seasoning of brushbox panelling, development of improved schedules for southern Queensland hardwoods, and establishing seasoning data on *E. agglomerata* and *E. laevopinea* for the New South Wales hardwood industry.

In summary, the major research developments discussed by the committee since the last Conference were:

(a) whether presteaming was necessary to achieve acceptable in-service stability of Radiata Pine

(b) the requirements for drying CCA-treated Radiata Pine

(c) developments with solar kilns, the continuous hardwood and softwood kilns and the use of dehumidifiers

(d) seasoning and properties of juvenile Radiata Pine

(e) reduction of checking in Tasmanian eucalypts.

4. Extension of Committee's Work

A problem continues to exist with extending the discussion and information transfer that is being effectively accomplished within the Committee. The increase of the membership has to some degree extended the number of people associated with the detailed discussions but a further dissemination of the information is possibly not being accomplished. Minutes of the committee meeting have been extensively reported and it has been intended that these would be given adequate circulation through trade associations and company circulation lists.

5. Merger with the Australian Forestry Council

A possible formalising of the Joint Timber Seasoning Committee as a working party of the Australian Forestry Council was foreshadowed at the sixth meeting and at the seventh meeting the Conservator of Forests (Queensland) Mr. W. Bryan, as a member of the Standing Committee invited the Committee to join other Research Working Groups of the Australian Forestry Council. He suggested that the following advantages would be available to the committee:

(a) it would have a voice to the Forestry Council

(b) it would have formal recognition

(c) the views of the group would be integrated with those of others working in the general forestry research area.

After discussion the majority of the committee accepted the offer with the following provisions:

(a) its activities were not to be restricted From current levels

(b) the committee's opinions were to be heeded in matters of meeting frequency and membership, and

(c) if a research director was to be appointed for the committee he should be involved in seasoning practices or research.

At the eighth meeting guidelines for Research Working Groups of the Australian Forestry Council were discussed and found to be unsatisfactory to the Joint Timber Seasoning Committee. A major objection was whether the committee could function in a dual role of a research working group of the Australian Forestry Council and as the Joint Seasoning Committee of the Forest Products Research Conference. There was concern that the free interchange of information that had been achieved between industry and research bodies within the committee would be impeded by becoming a Research Working Group. The secretary of the Standing Committee of the Australian Forestry Council was notified that the guidelines were not acceptable and alterations were suggested. His reply in September 1979 indicated that the Standing Committee appreciated that the Joint Timber Seasoning Committee would not accord with the conventional research working group concept and that a new advisory role should be defined. At the time of preparing this report the matter had not been finalized.

6. Recommendations of the Committee

The committee considers that a successful exchange of information between researchers and industry is being obtained and that a useful background to the requirements of industry is being achieved as a result of these meetings. Such information may not be as effectively obtained or extended in the absence of the committee. It adequately maintains liaison between research bodies and the Forest Products Research Conference.

For these reasons it is recommended that the Joint Timber Seasoning Committee continues for at least two more years.

The committee sees no disadvantages in developing ties with the Australian Forestry Council, but it maintains that the best interest of industry and research will be met by maintaining independence in relation to frequency of meetings, membership and line of responsibility. It recommends that the present degree of independence be retained.

November 8, 1979.

REPORT OF STRUCTURAL TIMBER EVALUATION COMMITTEE

(Prepared by W G Keating, (Convenor))

At the 18th Forest Products Research Conference it was agreed that an attempt be made to co-ordinate work in the field of strength grouping of Australian timbers. The need for such an approach was at that time becoming apparent as some inconsistencies had arisen based on data available from the three forest products research laboratories.

Accordingly, in November 1977 the first meeting of the Structural Timber Evaluation Committee (STEC) took place. Present were representatives from CSIRO Division of Building Research, NSW Forestry Commission Division of Wood Technology and Forest Research and Queensland Department of Forestry.

The purpose of the meeting was to form a Standing Committee that would

(i) review the strength grouping and stress grading of species and mixtures of species;

(ii) be recognised by the Standards Association as the reference body to supply technical information as required by Standards Committees dealing with structural timber;

(iii) prepare rules for strength group classification;

(iv) make a systematic review of the strength grouping of all Australian timbers;

(v) make arrangements for the continuing consultation on matters relating to the classification of structural timber and the pooling of data; and

(vi) prepare draft standards for the evaluation of structural characteristics of timber and timber structures.

It was decided that items (iii) and (iv) above would receive the immediate attention of the committee and that an approach be made to the Standards Association to publish the resulting information in the form of a Miscellaneous Publication.

Two more meetings were held and a considerable amount of correspondence exchanged before SAA document MP45-1979 was issued. This document lays down the rules for assigning strength group classification for 640 species. This is the first time in Australia that such information has been made readily available.

MP45 has some novel aspects. For example, it indicates how a classification may be made when the three properties, modulus of rupture, modulus of elasticity and maximum crushing strength do not all have the same classification for a particular species and it introduces the concept of provisional strength grouping based on density alone and/or limited mechanical test data. The appendices to the document draw attention to the importance of sampling, the standard methods for testing small clear specimens and the corrections required for adjusting test results from seasoned material to 12 per cent moisture content.

MP45-1979 is regarded as a source document which will be used as the basis upon which other information will be presented. For instance, the committee has agreed that its next task in order of importance will be to allocate strength groups to the mixtures of species as commonly appearing on the Australian market. It also feels that the tabulation of additional information such as shrinkage and density for as many species as practicable could be most useful.

WOOD BIOLOGY COMMITTEE REPORT

(Prepared by W E Hillis (Chairman))

This comment is prepared on the behalf of those members who participated in the Group's meetings at the previous two Forest Products Research Conferences.

1. The Group is gratified that the Organising Committee of the 19th FPRC has adopted its suggestion to organise the Conference in the format which IUFRO has found to be the most successful of those tried. It enables continuity of interest and also facilitates expansion of discussion of interests when that is required. This is particularly relevant at this stage as overseas there is increasing attention to wood quality.

2. At the 1975 FPRC it was recommended (in brief) that a multi-disciplinary project team be formed to advise on the coordination of the planning of relevant research into regrowth eucalypt forests for wood production with W.E. Hillis as convenor.

The proposal was discussed with, and enthusiastically received by Dr Day and his colleagues of the Division of Forest Research, CSIRO. An outcome of these meetings was the preparation of the book "Eucalypts for Wood Production" edited by W.E. Hillis and A.G. Brown, authored by 33 leading workers from CSIRO, State Forest Services and industry, and published by CSIRO. Its completion was considerably delayed for reasons beyond our control. It was launched in late September 1978 by Senator J.J. Webster the Minister for Science & Environment who showed interest in the work. Already 1100 copies have been sold, and the format and content have been highly praised locally and internationally. It appeared at a peak of interest in eucalypts. However, the book is only part of the programme. It provides a summary of authoritative data to facilitate the selection of priorities concerning all aspects of the establishment and utilisation of eucalypt plantations and forests.

3. At the 1975 FPRC it was recommended that a working group concerned with wood quality evaluation be established. Owing to activities concerned with the preparation of "Eucalypts for Wood Production" no action was taken in that period.

At the 1977 FPRC, this Wood Biology Group recommended that a Wood Quality Research Group be formed with W.E. Hillis as convenor. The FPRC itself recommended that among other groups a Wood Quality Research Group be formed.

The Convenor began action after the 1977 Conference. The matter was considered by the DORC of the Standing Committee of the AFC. The convenor has not been informed of the decisions or discussions of that Committee and consequently cannot report to this Conference.

At this point it could be noted the forest products industry is the 4th largest in this country and the third largest employer in the manufacturing industries. Accordingly, the raw material sustaining this industry must be understood. Increasingly and rapidly the forest products industry is becoming dependent on a raw material the quality of which is changing in character because of changing imports and particularly because of changing forest practices altering the resource being offerred to the forest products industry. This industry has limited knowledge about the material it is receiving more and more from both the intensively managed pine plantations and eucalypt forests that are being used more completely than formerly. This is a serious and urgent situation. Some adjustments will be necessary both by foresters to produce the most suitable wood and bark possible under the conditions existing and some adjustments will be necessary by the industry to efficiently convert the "new" wood into the most highly valued product so that it remains competitive.

The Australian forest products industry must know where it stands with its future resources and without delay. As a result of discussions held over several months, W.E. Hillis and Professor E.P. Bachelard of the Department of Forestry, The Australian National University have inaugurated a Technical Consultation on Australia's current and future materials of the forest products industry under the auspices of the ANU and the IWS. It will be held May 4-8, 1981 in Canberra and will be strongly oriented to the problems the industry is encountering with the quality of the "new" raw materials and their products and how industry, foresters and wood scientists can together alleviate the prioritised problems.

This Consultation will meet the suggestions of the Wood Biology Group in its report of 1977.

19th FOREST PRODUCTS RESEARCH CONFERENCE

FIRE RETARDANT COMMITTEE

(Investigating the fire performance of untreated and treated wood and wood-based products)

REPORT
by

J. Beesley - Convenor

ABSTRACT

This Committee was reconstituted at the 18th Forest Products Research Conference with a membership enlarged to include industry representation.

The Committee met once during 1977 and twice during 1978. For personal and financial reasons it failed to hold meetings during 1979 but is pleased to be able to point to the work instigated by the N.S.W. Timber Development Association which has resulted in the piblication of a statement on the Early Fire Hazard Properties of Timbers and Plywoods.

The Committee has had involvement with the Standards Association of Australia, the Forest Products Research Advisory Panel, the Interstate Standing Committee on Uniform Building Regulations and others in its endeavours to promote timber as a building material.

INTRODUCTION

The 11th (1963) Forest Products Research Conference set up the Fire Retardant Committee as a means of ensuring that there was adequate communication between CSIRO and the two States with timber marketing legislation. The most notable achievement of that Committee was the publication of Division of Building Research Technical Paper No. 6: The Early Burning Properties of Australian Building Timbers. At the time, this was the first and only authoritative publication containing hard data on the burning properties of these timbers obtained in accordance with an Australian Standard.

At the 18th (1977) Forest Products Research Conference this Committee, which had not been particularly active over the preceding couple of years, was re-constituted with an increased representation from the Division of Building Research (Mr. Keith Martin, in addition to the Convenor), a representative from the Timber Preservers' Association of Australia (Mr. J.D. Price) and Mr. Noel Roscoe of the N.S.W. Timber Advisory Council. The other members of the Committee are: Mr. J.J. Keough, Co-opted member, Experimental Building Station, Mr. R.S. Johnstone, Forestry Commission, N.S.W. and Mr. K.V. Cokley, from the Queensland Department of Forestry. May I take this opportunity of expressing my personal appreciation to all these gentlemen for their useful and constructive contributions to the deliberations of the Committee?

In re-establishing the Committee, Conference agreed that it would still have power to co-opt, that it should meet as often as necessary but at least once in every 6 months and that its objectives should be:

The acquisition of basic data on the burning properties of Australian timbers and wood-based products;

The development of a 'screening test' for fire-retardant treatments;

Advising the forestry departments of New South Wales and Queensland on acceptable standards for fire-retardant treatments for timber, as required under State timber marketing legislation;

The planning and oversight of investigations into the use and effectiveness of fire-retardants, their mode of action, their inter-action with wood preservatives and related matters;

To investigate the burning characteristics of fire-retardant-treated timber and wood-based products and of the decorative finishes used on them; and, finally,

To identify research needs and to initiate or instigate the appropriate research.

These objectives are sufficiently comprehensive to include all the problems and challenges to which the Committee is likely to need to address itself in the foreseeable future.

MEETINGS.

Since last Conference, the Committee has held three formal meetings, one in September, 1977, the others in February and August, 1978. For a number of personal and financial reasons it did not meet formally during 1979 but has conducted some business by correspondence during that period. In addition, although the Committee lays no claim to the credit, the Timber Development Association of N.S.W. has just published an extensive listing of the Early Fire Hazard Properties of Timbers and Plywoods. This listing incorporates data from tests already published by the Division as Technical Paper No. 6.

The highlights from these three meetings could be summarised thus:

MELBOURNE, September, 1977 -

The meeting reviewed the history of the Committee and the Australian Standards relevant to its work, namely:

AS 1530 - Fire Tests on Materials and Structures,

AS 1604 - Preservative-treated timber, veneer and plywood,

AS 1608 - Preservative-treated farm fencing timber.

The Committee noted that AS 1608 made reference, incorrectly, to 'Fire Retardant' preservatives and to 'Fire Retardant treated' posts (Tables 8.1 and 8.2).

It then reviewed the building regulations relevant to the fire behaviour of timber and wood-based products, with special reference to the Australian Model Uniform Building Regulations, the Dwelling Design and Construction

Handbook prepared by the Department of Environment, Housing and Community Development, and to 'Ordinance 70' of New South Wales.

The commercial fire-retardant treatments approved under the State legislation of New South Wales and Queensland was summarised and, finally,

An outline was given of the investigations sponsored by the N.S.W. Timber Advisory Council during which it was agreed that the T.A.C. would be invited to extend its programme to allow for 'screening tests' on 3 timber species already under investigation and that other timber industry organisations would be invited to contribute to, or participate in a co-ordinated series of burning tests.

The meeting concluded with the observation that neither log cabins nor 'A-frame' buildings using round timbers appeared to be adequately provided for in Australian Standards and a proposal that the effect of oil-borne preservatives (and particularly, Light Oil Solvent Preservatives) and water-repellant preservatives on the burning properties of timber should be examined.

SYDNEY, February, 1978 -

An important decision of this meeting was that circulation of the Committee's Minutes (and other proceedings) would be unrestricted unless otherwise decided for specific items.

It was noted that the title 'Fire Retardant Committee' had caused some confusion with outside inquirers and, as only the Forest Products Research Conference has the power to alter the Committee's title, it was resolved to include the following notation under the title:

"Investigating the fire performance of untreated and treated wood and wood-based products"

'A-frame' Constructions: The Committee was concerned that existing building codds tended to exclude timber from this type of construction because wood is a combustible material - an attitude which appeared to be both illogical and detrimental to the use of timber.

Australian Standard AS 1530, Part 4: The Committee agreed that the Standard should specify, and that testing authorities should require a matched sheet of the face plywood from each fire-door tested to be retained (by the testing authority) as a reference sample.

Mention was made of the possibility of conflict, in N.S.W. and Queensland, between the building codes and the State timber marketing legislation. In both States, neither piece of legislation appears to recognize the existence of the other!

A recommendation was forwarded to the Forest Products Research Advisory Panel to the effect that timber interests should be more adequately represented on committees formulating building codes and regulations.

A proposal was advanced that Building Surveyors should receive advice on sources of information on the burning properties of building materials during their training 'in language they can understand', If introduced into formal training courses, this would give staff from E.B.S. better opportunities for making contacts with building surveyors and with industry.

BRISBANE, August, 1978 - (Two-day Meeting).

The Committee was somewhat flattered to be housed in the V.I.P. Conference Room of the new Executive Building in Brisbane, AND to be welcomed on behalf of the Minister of Forests, and the Conservator of the Forestry Department, by Mr. Alan Gardner. This meeting was also attended, in whole or in part, by two other members of the Forest Products Research Branch as well as Kevin Lyncolgn (Plywood Association of Australia) and Dick Adams, Queensland Depart. of Local Government.

Research Working Groups, Australian Forestry Council Standing Committee - Being aware that the Wood Preservation Committee and the Joint Timber Seasoning Committee of the Forest Products Research Conference had been 'appointed' Research Working Groups of A.F.C., the Fire Retardant Committee deputed the Convenor and Keith Martin to discuss this possibility with others in the Division. No definite conclusion has been reached. Conference might like to comment.

It could be of interest for Conference to know that fire resistance tests on fire doors, and similar structures, performed overseas would be acceptable to Australian authorities, provided details of the test methods and the results could be examined and were considered adequate.

Australian Standard AS 1604: Preservative-treated sawn timber, veneer and plywood - Standards Association has set up a committee to review this Standard and others dealing with the preservative treatment of wood and wooden components. This SAA committee sub-divided its task amongst a number of sub-committees including one on fire-retardant treatments. Over the ensuing couple of months, the Fire Retardant Committee prepared a submission to SAA indicating that no reliable rules had been established which could be used as a guide in forecasting the effectiveness of a potential fire-retardant chemical in timber of different species and offered a proposal for inclusion in the FOREWORD or COMMENTARY of appropriate standards - copy attached.

Building Regulations - All Uniform Building Regulations have well-established fire resistance rating requirements for structures and components

and, currently, all U.B.R. Committees are introducing or have introduced general restrictions on building materials according to their behaviour in the test for early fire hazard (AS 1530, Part 3). Since commercial interests require some prior notice of impending changes in these regulations which might affect the acceptability of certain materials or components in a building, it was resolved that the Fire Retardant Committee would endeavour to maintain a current register of these restrictions.

AS 1530, Part 3, Revision(Keith Martin, Chairman) - The Committee was informed that AS 1530, Part 3: Test for early fire hazard properties of materials was being revised; no changes in the test method were envisaged but the revision would include a more detailed description of the test apparatus and method because laboratories other than the Experimental Building Station were seeking NATA registration for the test. The new Standard would include a section on interpretation of test results, specifically to guide building surveyors and U.B.R. committees.

In response to a request for an 'authoritative statement' on the use of early fire hazard indices, KEOUGH and MARTIN agreed to prepare a statement which was published in REBUILD of December, 1978.

Research and Investigations - Preliminary tests have indicated that after reasonable post-treatment drying, Light Oil Solvent Preservatives made very little difference to the burning properties of the timber;

there was a need for a simple, inexpensive 'bench-top' test which manufacturers of fire-doors and the like could use to screen out ineffective treatments so that full-scale testing could be restricted to units which could be expected to satisfy a stipulated requirement;

progress was reported on tests sponsored by the N.S.W. Timber Advisory Council - since available in published form.

Publications available to the Committee at this meeting included:

*Dept. of Construction, Technical Information Branch, FIRE INFORMATION, 1978

* Martin, K.G. et al. SMALL SCALE FIRE ASSESSMENT OF INTUMESCENT PAINTS, D.B.R. Reprint No. 809

* Ramsay & McArthur COMBUSTION CHARACTERISTICS TESTS FOR CELLULAR PLASTICS Part 2: A New Propagation Test ... D.B.R. Report, 1977

* Ramsay & Souprounovich THE OXYGEN INDEX TEST, Part 1 D.B.R. Report 1976

1 Martin & Dowling ASSESSMENT OF FIRE PERFORMANCE OF PLASTICS-FACEDHARD-BOARD LININGS D.B.R. Report, 1978

In spite of its failure to meet quite as often as desired by the previous Forest Products Research Conference, this Committee has functioned effectively. Its deliberations have demonstrated that there is an interface between the research establishments and industry where co-operation and communication can serve a useful purpose and achieve a worthwhile result and it is my strong recommendation that this Committee should continue to function without any material change to its terms of reference and I seek a Conference resolution to that effect.

* * *

J.Beesley
Convenor

CSIRO

DIVISION OF BUILDING RESEARCH

P.O. BOX 56 HIGHETT, VIC. 3190 GRAHAM ROAD TELEPHONE 950333 TELEX AA 33766 TELEGRAMS BUILDRESEARCH MELBOURNE

FOREST PRODUCTS RESEARCH CONFERENCE

Fire Retardant Committee

Investigating the fire performance of untreated and treated wood and wood-based products.

THE INCLUSION OF FIRE-RETARDANT TREATMENTS IN AUSTRALIAN STANDARDS.

INTRODUCTION

AS 1530, Part 3- 1976: Test for early fire hazard properties of materials, makes provision for measuring four parameters, namely:

(a) Tendency to ignite
(b) Heat developed after ignition
(c) Tendency to spread flame
(d) Tendency to produce smoke.

This Standard does not take cognisance of the tendency of some materials to continue burning after the source of ignition has been removed or to continue a slow combustion process after flaming has ceased - a phenomena which may be called 'after glow'.

AS 1608, Part 1 - 1974: Preservative-treated farm fencing timber, softwood timber; is the only relevant Standard in which reference is made to 'Fire-retardant waterborne preservatives' (Table 8.2). In fact, this is a mis-nomer and steps have already been taken to amend the heading to read: Waterborne preservatives intended to prevent afterglow.

Building regulations are more concerned with the safety of persons than the preservation of property. Hence regulations tend to give more emphasis to rate of flame spread and smoke production than to the capacity of the treated timber to survive fire. The preservatives intended to prevent after glow, mentioned in AS 1608, are of more value in the latter regard than the former, but different formulations could behave differently. Therefore, in prescribing preservatives intended to reduce the propensity of wood to burn, spread flame or produce smoke, some clear definition of the objective is necessary.

C...../2

Finally, no reliable rules have yet been established which can be used as a guide in forecasting the effectiveness of potential fire-retardant chemicals in timber of different species, or at different loadings in the one species.

PROPOSAL - *The concensus of opinion within the Committee is that the subject of fire-retardants is too complex for inclusion in a general Standard on wood preservation but it would not be inappropriate to incorporate the following in the FOREWORD, or a COMMENTARY:*

"No preservative shall be accepted as a fire-retardant preservative or treatment unless, when tested in accordance with the provisions of AS 1530, Part 3 - 1976: Test for early fire hazard properties of materials, the treated timber shows a significant improvement in behaviour over that of untreated comparable timber of the same species, in which case it may be accepted as a fire-retardant treatment for the timber species tested and for index numbers no better than those achieved in the test.

Fence posts impregnated with some CCA-type preservatives have a tendency to continue glowing after exposure to fire until only ash remains. To a degree, this drawback can be overcome by the use of specially formulated preservatives designed to reduce after glow, without detracting from the capacity of the treated posts to resist decay or insect attack. However, even these preservatives will not prevent treated posts from burning in hot fires. "

COMMENT

At present, too little data has been accumulated from burning tests on preservative-treated timbers to justify the application of results on tests on one timber to other species. Users of timber impregnated with preservatives intended to modify its burning properties should be made aware of the possibility that the effectiveness of the treatment could change with time especially if exposed to the weather or humid conditions.

1st November, 1978.

J. BEESLEY
Convenor
Fire Retardant Committee

CSIRO

DIVISION OF BUILDING RESEARCH

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P.O. BOX 56, HIGHETT, VIC. 3190 (GRAHAM ROAD) TELEPHONE 930333 TELEGRAMS BUILDRESEARCH MELBOURNE

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J.Be

1st August, 1978

FOREST PRODUCTS RESEARCH CONFERENCE

Fire Retardant Committee

(Investigating the fire performance of untreated and treated wood and wood-based products)

MEMORANDUM TO: Mr. C.D. HOWICK
Secretary,
Forest Products Research Advisory Panel
HIGHETT

At its last meeting, my Committee spent considerable time discussing the consequences State Building Regulations can have on the use of timber and, indirectly, on the bouyancy of the timber trade as a whole. In fact, as an example, the proposed amendment to the Victorian Regulations, Clause 1332 - Limitations on Use of Materials (which has not been proclaimed) was cited.

It was the opinion of our Committee that timber-oriented interests should be more adequately represented on committees formulating building codes and regulations. Further, it was considered that this matter was one for consideration by your Panel rather than by representatives of the industry - or my Committee. In passing, might I mention, that my Committee must plead gross ignorance of the persons and procedures by which building regulations are proposed, amended or promulgated. It would appear that these regulations, which affect the living of so many of us, are prepared with (unnecessary?) secrecy and that any change in the procedures will need to be initiated at Ministerial level.

I have had referred to me, from the Minutes of the last FPRAP meeting, Item 8 (d) - Hardboard Industry, with a request for an authoritative statement on the limitations of fire retardants. I would like to submit this request to my Committee which next meets on 9th-11th August.

Meanwhile, as an interim statement, could I propose that the action of fire retardants is to increase the time to ignition, raise the temperature of ignition, reduce the flammability of treated materials and to reduce or prevent the tendency of some substances to continue burning after the source of ignition has been removed. A fire retardant may act in any or all of these manners. The degree to which it is effective is, of course, another question.

I do not need to remind your Panel that, in N.S.W. the Timber Marketing Act and, in Queensland, the Timber Users' Protection Act, require prior approval of the treatment before timber treated with a fire-retardant can be marketed as such. I am unaware of degree of improvement needed to merit an approval of the treatment.

J.BEASLEY

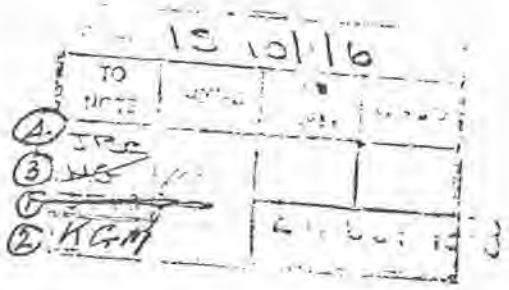
ISCUBR

THE INTERSTATE STANDING COMMITTEE ON UNIFORM BUILDING REGULATIONS

BS 64/16/I (IP.11)

16th October 1978

Mr J. Beesley,
Convenor,
Fire Retardant Committee,
C.S.I.R.O.
Forest Products Laboratory,
P.O. Box 56,
HIGHETT. Victoria 3190



Dear Mr Beesley,

TIMBER MARKETING ACTS
Your IS 10/1/6 of 1st August

The ISCUBR Subcommittee considered your letter at a recent meeting.

Since the timber marketing acts in New South Wales and Queensland were originally drafted as consumer protection legislation they stand apart from the building acts. It is not clear therefore what action by ISCUBR is proposed. It is noted that the Australian Capital Territory requires timber imported into the Territory to conform with the requirements of the N.S.W. Timber Marketing Act. Clause 28.9a - (8) of the Building Manual reads -

> "TREATMENT OF TIMBER - Timber imported into the Australian Capital Territory shall have been treated in such a manner so that the timber is of a standard required by the Timber Marketing Act of New South Wales".

Building regulations in other Administrations do not specifically nominate such an Act.

The Subcommittee has as a result of your letter taken action to investigate an amendment to AMUBC, requiring the tests contained in clause 16.19/Specification No. 8 (copy enclosed), should be carried out by certified laboratories listed in AMUBC, similar to those listed in clause 20.2 - (1).

Thank you for your interest in AMUBC. Should your Committee wish to raise any further matters with ISCUBR please let me know.

The Secretary, ISCUBR Experimental Building Station,
P.O. Box [illegible]

TRENDS IN TIMBER ENGINEERING RESEARCH

R. H. Leicester

ABSTRACT

This paper presents an overview of trends in timber engineering research, with an emphasis on topics of particular significance to Australia. An historical survey of this research indicates that it can be classified into well defined eras, each one concerned with a particular type of research. Detailed discussion is given on the current era of research, one concerned largely with research in the laboratory; and on the next research era, one that will probably be dominated by research into the effects of human factors on the building industry. A few prognostications on the characteristics of long-term research trends are also given.

PROLOGUE

In deciding to settle Australia, one of the primary motivations of the British government was to obtain a new source of timber following the loss of access to North American forests after the War of Independence in 1783. A House of Commons investigation committee, set up to discuss the settlement of Australia was given conflicting opinions as to the suitability of the timbers therein. Captain Cook, who had explored the east coast of Australia in 1770, believed that "most of the trees in this Country are of hard and ponderous nature and could not be applied for many purposes". However, the committee was more inclined to accept the opinion of Joseph Banks, the botanist who had accompanied Cook who stated that the timber of Australia "appeared to me to be fit for all purposes of House building and Ship building" and suggested that Botany Bay would be the best site for establishing a penal settlement.

The first settlers arrived in Botany Bay in January 1788 and their adventures with the local timbers began almost immediately. A lively description of these happenings has been given by Cox and Freeland (1969). About the only timber in the vicinity of the Bay was Sydney red gum, *Angophora costata*, a timber with rotten heart. The leader of the expedition to Botany Bay, Captain Arthur Phillip, wrote that the wood of the tree "has a very bad quality....(it) splits and warps". The expedition surgeon, White, wrote somewhat more forcefully, "How any kind of house.....can be raised up, the timber being so very bad, it is

impossible to determine..... I do not know of any one purpose for which it will answer except for firewood, and for that it is excellent; but in other respects it is the worst wood that any country or climate ever produced." Similar comments were written by many other settlers. Probably the low point in morale was reached when a small hospital, constructed in green timber and completed in July, was found by November to be "bungled up and in a tottering condition".

However, as exploration parties moved out into areas surrounding the first settlement, several useful timbers were found. These included blackbutt, the stringybarks and ironbarks. With time, the settlers became increasingly impressed by the straightness, strength, durability and low flammability of these timbers. By the turn of the century, the settlers had learnt to handle the peculiarities of these hardwoods so well, that in 1807 ex-Governor Phillip Gidley King, in an official submission to a Board of Commissioners in England, was moved to extol the virtues of Australian timber in such glowing terms as to consider them to be "equal to any wood in the world".

In many respects, the experiences of these early settlers foreshadowed the characteristics of the development of timber technology in Australia. At first acquaintance, the timbers of Australia appear to have poor characteristics, but in fact are found to be excellent for structural purposes when handled correctly. However, as most of these timbers differ in their characteristics from those utilised in other developed countries, the necessary technology for their effective utilisation had to be developed within Australia.

INTRODUCTION

The following commences with a brief historical survey of past eras in timber engineering research. This is done to provide an insight into the nature of research trends. It would appear that we are near the end of an era associated largely with laboratory research and will shortly commence a new one in which research will be related to studying the human factors that influence the building industry. These two eras will be discussed in some detail. The paper concludes with a few prognostications on some possible characteristics of long term trends in timber engineering research.

AN HISTORICAL PERSPECTIVE ON RESEARCH

RESEARCH THROUGH CONSTRUCTION (1750-1900)

Prior to 1900 most knowledge on timber structures was obtained largely through trial-and-error in the field, without benefit of laboratory experimentation or the use of effective structural theory. For example, in North America, many notable bridges were constructed, some as early as 1785, prior to the

publication in 1847 by Squire Whipple of the first text on the theory of bridge construction (Schneider 1905). These bridges included the 556 foot long bridge over the Amoskeag river, commenced on the 3rd of August 1772, "at which time the timber was growing, and the rocks dispersed in the river", and completed less than two months later on the 29th September. Probably the most spectacular bridge to be constructed without benefit of a sound structural theory was the Colossus over the Schuylkill river. Built in 1812, this bridge was a shallow arch, spanning some 340 feet. A rough profile of this bridge is shown in Fig.1.

We are told that these early builders were "practical men who had no knowledge of the strains produced on the various members of a structure by exterior forces but who were men of unusual constructive ability and sound judgement,.... experimenting with models and profiting by previous failures..... Structural systems were invented before their theory was developed," (Schneider 1905). "These pioneers....thought with vigor and were not fettered with the trammels of science before they were capable of exerting their mental faculties to advantage", (Cooper 1889). The calibre of these builders is illustrated by the career progressions of Rufus Graves, who in 1876 constructed a shallow arch bridge of 236 feet span across the Connecticut river. He "studied divinity, graduated at Dartmouth College, became a merchant, then a bridge builder, then an officer in the United States Army, and finally a physician", (Cooper 1889).

Through a process involving many trials and careful observations, these early timber engineers discovered numerous effective principles of construction, not the least of which was that protection of primary members from the direct effects of the weather, as is the case for example in covered bridges, ensures their durability for some 100 years. There is little doubt that most formal engineering research has not been directed to assising brilliant innovators such as these pioneer engineers. Indeed, it may be important to consider whether current research, because it is communicated in codified formats, is inhibiting the innovators. If so, it must act as a constraint to the possibility of giant strides in research progress, a hallmark of the early days of timber engineering.

THE FIRST ERA OF LABORATORY RESEARCH (1900-1940)

The first formal investigations on the structural characteristics of timber were undertaken during the period 1900-1940. Information obtained and concepts developed during this research form the basis of most existing timber engineering design codes. In Australia, the development of timber technology was strongly influenced by research at the Forest Products Laboratory at Madison, U.S.A. Examples of such research that still influence current Australian

Standards are the work by Wilson (1921) and Newlin and Johnson (1924) on the effects of natural defects, the work on columns by Newlin and Gahagan (1930), and the work on bolted joints by Trayer (1932).

Unfortunately, most of the research of this era was not carried out in sufficient depth or in a suitable format to be applied within the context of modern timber technology concepts. Consequently, much of this research will be repeated in the future. However, it served its purpose well, and will probably never by equalled again in terms of cost effectiveness.

THE ERA OF THEORETICAL RESEARCH (1940-1955)

During this period, timber was used for very sophisticated structures such as aircraft and high performance sea craft. In these applications, a high degree of quality control was used to ensure that the structural timber was defect free, homogeneous and with well defined properties. As a result, the timber behaved as an ideal material, and research scientists, particularly those from the Forest Products Laboratory at Madison, were encouraged to derive theoretical solutions for a great variety of structures constructed with orthotropic materials. A good example of this is the work on the buckling of plywood plates (March et al 1942-1950).

This theoretical work has proved to be an extremely useful base for timber technology over the years. It is likely to remain so for the foreseeable future, even though structural timber will not, in general, have ideal properties.

Finally, it may be instructive to note that even in the case of timber structures constructed under very careful conditions, it was sometimes difficult to obtain agreement between experimental observations and predictions based solely on linear orthotropic elasticity. The outstanding example of this was noted in experiments to measure the buckling strength of axially compressed plywood cylinders. In order to explain the poor buckling strengths observed in laboratory tests, it was found necessary to introduce into the analysis, concepts concerning imperfections and variability (March et al 1956, Horton and Durham 1965).

THE ERA OF ACADEMIC RESEARCH (1955-1970)

After World War II, timber was little used for high performance craft and interest in timber engineering was increasingly concerned with civil engineering applications such as houses and bridges. Because these do not require a high structural efficiency, it is acceptable and usually cost-effective to utilise timber containing large natural defects. The quality control exercised by the associated building industry is meagre, often even to the extent that the exact

species of timber utilised is not known.

Many structural timber research scientists of this research era failed to recognise the significance of these changes in the material and associated industry, and as a result much of the research of that period was of little practical value. For example, research concerned with the treatment of natural defects as being equivalent to holes in orthotropic material, elasto plastic strength theories of timber beams, and the "fibre-support" concept, will remain little more than of limited academic interest.

However, during this period there were quite a number of useful developments in Australia related to the structural utilisation of timber. This included the development of a very effective mechanical stress grader (Huddleston and Anton 1967, Anon 1972), and a strength classification system (Pearson 1965, Kloot 1973) and associated timber framing code (Standards Association of Australia 1971)that were sufficiently extensive to cover the wide range of timbers utilised in Australia. Of the laboratory research in Australia, probably the work that will have the greatest long term impact is that related to the effects of changes in moisture content on the deformation of timber (Armstrong and Kingston 1962).

THE SECOND ERA OF LABORATORY RESEARCH (1970-1980+)

This period has been marked by intensive laboratory studies, aimed at providing reliable design information for structural design codes. In Australia this has included studies on creep buckling, fracture mechanics and structural reliability topics (Leicester 1971, 1972). Overseas research which has probably had the most impact on the Australian scene are the numerous and extensive studies by Madsen on the characteristics of structural timber (Madsen, 1975, 1978, Madsen and Barrett 1976, Madsen and Nielson 1976).

THE NATURE OF RESEARCH TRENDS

In the review of research on timber engineering during the past 200 years, it was found that in each era, research has been related predominantly to just one of the three domains, denoted as the domains of theory, laboratory and building, shown schematically in Fig. 2. This is probably because these domains are concerned essentially with different types of objectives. However, the domains are in fact closely interrelated and research should reflect this fact if it is to be fully effective. During the next research era, the focus of attention is likely to be on the building domain, because of the large gaps in knowledge here that have arisen through many years of neglect by research scientists.

Fig. 1 Profile of the "Colossus" bridge

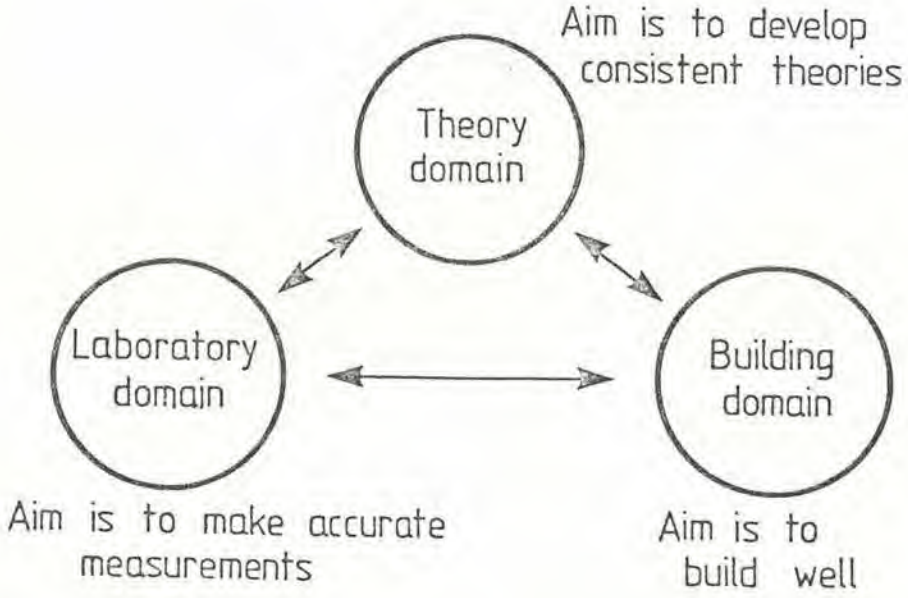


Fig. 2 Basic research domains

CURRENT TRENDS IN RESEARCH

GENERAL

The following are brief discussions on some areas of timber engineering research that are of current interest to Australia.

CHARACTERISTICS OF STRUCTURAL TIMBER

Many, if not most, of the design rules in current timber engineering codes are based on the structural characteristics of small clear pieces of timber. During the past decade it has become apparent that such a procedure can lead to considerable error because of differences between the characteristics of structural lumber and small clear timber specimens.

An example of this is illustrated in Fig. 3, which shows some strength properties of Southern Pine timber. It is seen that the relative values of the average tension, bending and compression strength are different from small clear timbers, large clear timbers and structural lumber containing natural defects. Moreover, the relative strength values for structural lumber vary with the grade of timber.

A similar effect is illustrated in Fig. 4 which shows that the influence of moisture content on full size structural lumber is different from that on small clear specimens. Equally important is the fact that for structural lumber the effect of moisture content on the 5-percentile strength level is different from the average effect. The significance of this difference lies in the fact that design strengths are related to 5-percentile rather than average values. A similar difference is found with respect to the effect of the duration of load on strength as shown in Fig. 5. Examples such as these have shown that it may be necessary to test structural lumber in large samples to derive design parameters related to strength.

In addition to testing large samples, it is now known that there are many instances where the size of the structural element has an important influence on its strength (Leicester 1973). Two examples of this are shown in Figs. 6 and 7. A related effect discussed by Bohannon (1966), illustrated in Fig. 8, is that the method of loading may also have an effect on the nominal strength of structural elements.

To date, only the simplest structural characteristics of timber have been studied in sufficient detail to provide design information as reliable as that available for the more commonly used structural materials such as steel and reinforced concrete. It is quite possible that some current ideas on more complex structural characteristics, such as buckling strength, are in considerable error.

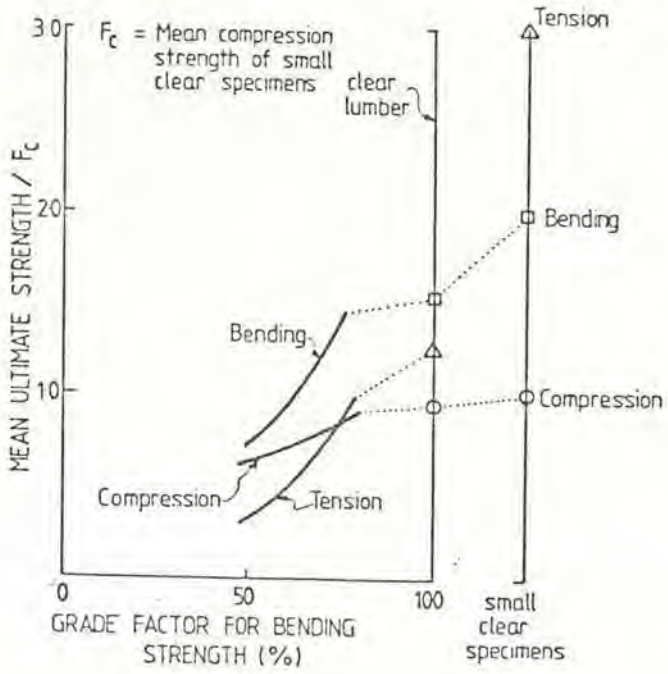


Fig. 3 Effect of grade on the strength of dry southern pine (after Doyle and Markwardt 1966, 1967)

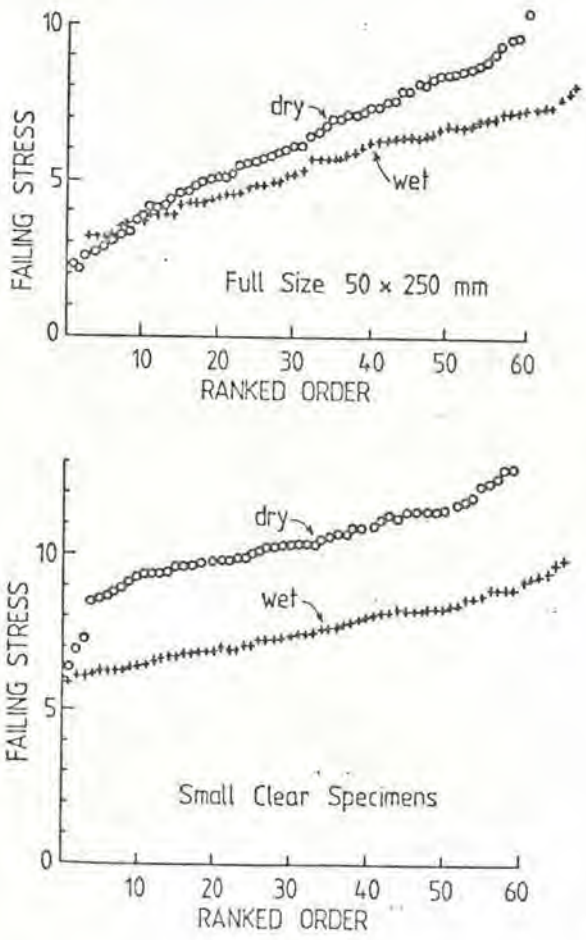


Fig. 4 Effect of moisture content on the bending strength of Douglas fir (after Madsen 1972)

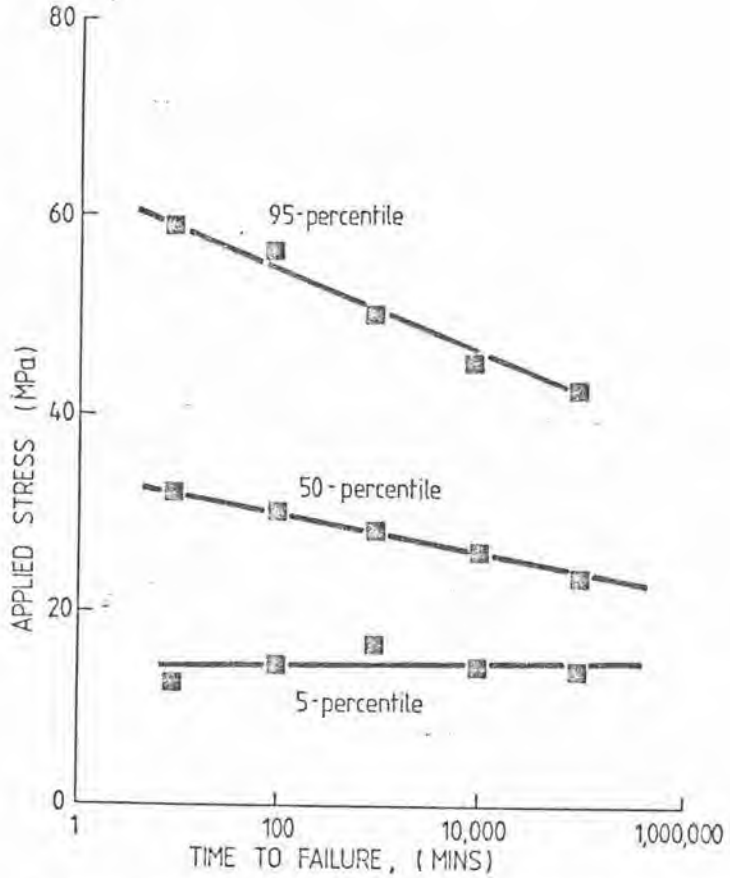


Fig. 5 Bending strength of dry hem-fir subjected to ramp loading (after Madsen 1971)

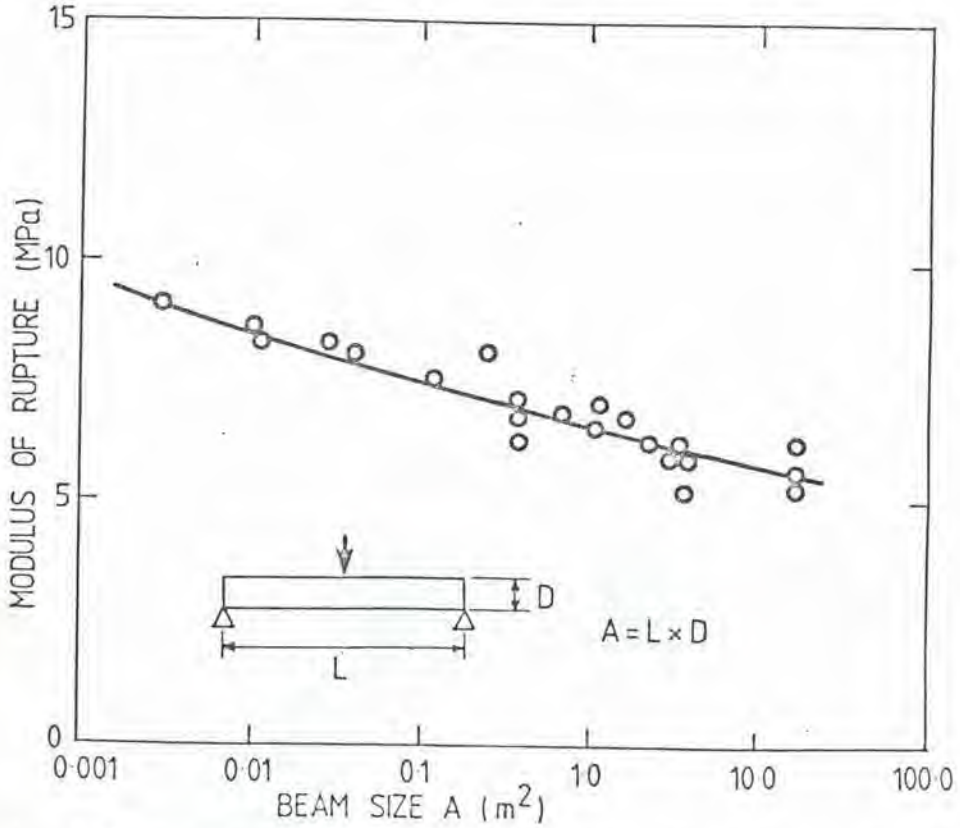


Fig. 6 Effect of size on the bending strength of dry softwood timber beams (after Bohannon 1966)

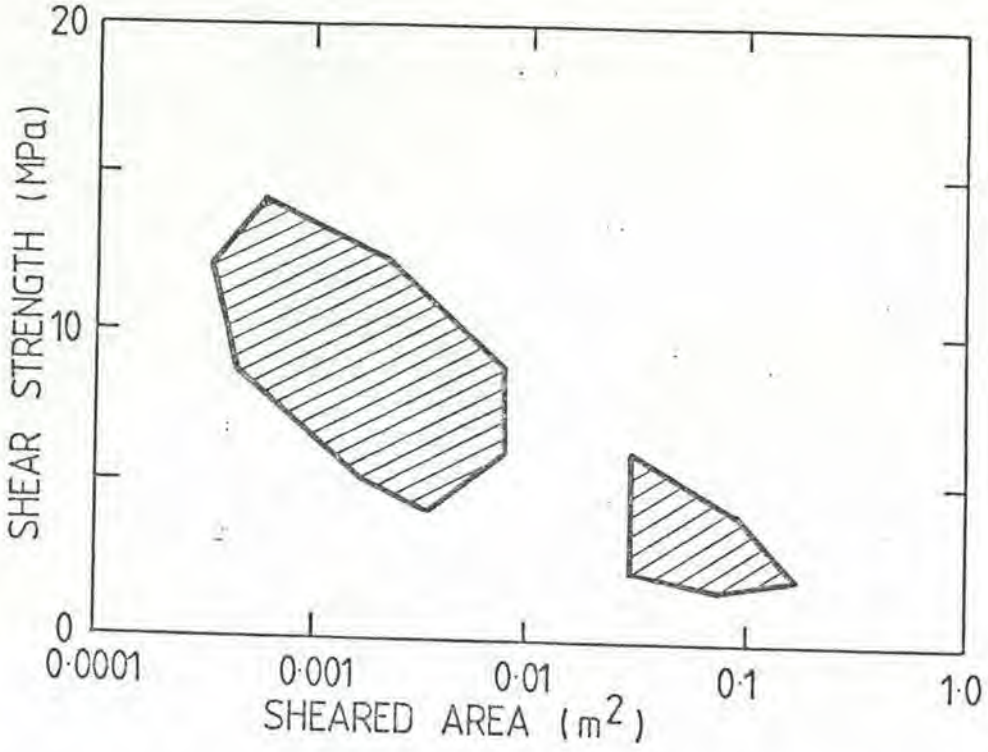


Fig. 7 Effect of size on the shear strength of timber beams and glued joints (after Keenan 1974)

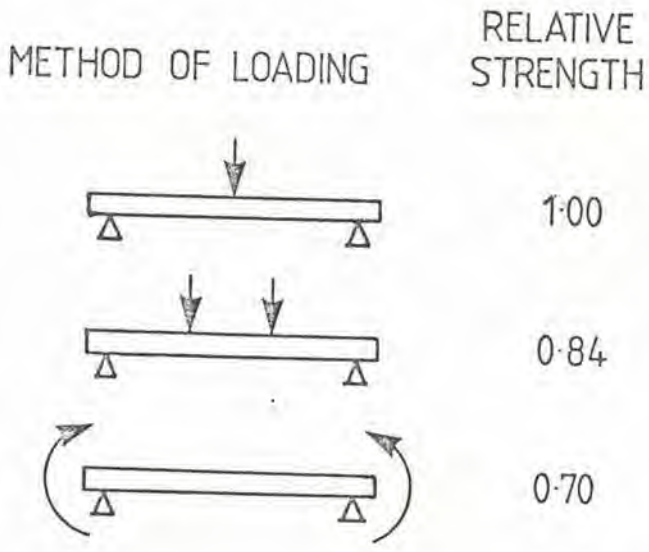


Fig. 8 Effect of loading configuration on the nominal bending strength of dry slash pine (CSIRO data)

TIMBER GRADING

Two methods of grading timber for structural purposes are currently in use. Neither is completely satisfactory.

The most commonly used method is visual grading, which is based essentially on the measured strength in bending of small clear specimens of timber, together with a visual assessment of the effects of naturally occurring defects. Although this method has been in use for almost half a century, it is only in the last decade that attempts have been made to measure its effectiveness. These in-grade measurements, particularly those made by Madsen (1978), have revealed considerable deficiences in the visual grading method. Particularly disturbing is the fact, illustrated in Fig. 9, that the strength of visually graded timber may show significant variations from one mill to another and even from time to time within the same mill. Possibly this indicates that there are significant strength parameters that are not considered in the visual grading process. One example of this is the influence of log diameter as shown in Fig. 10.

The second method of grading frequently used is mechanical stress grading. This method is based on the correlation between local stiffness and bending strength. It is in general more effective than visual grading; but because high costs and sophisticated technology are required for its application, mechanical grading is applied only to a few species in Australia, and then only to a very small range of timber sizes. Furthermore, there are some inherent limitations in the method. One is that the correlation between stiffness and strength may not be adequate for grade sorting purposes. This occurs for example with timber from young radiata pine trees (Anton 1979). Another limitation is that the method cannot detect localised defects such as occurs with some types of decay and compression shakes.

Because of the limitations in current grading methods, and because there is a wide range in the strength properties of timber, there is considerable incentive to develop other methods of grading. One method that has recently been investigated in Australia is based on proof testing the structural lumber (Leicester 1979). This method has the advantage of low cost and considerable flexibility, but suffers from a loss in efficiency due to damage to the lumber during the grading process. However, it is excellent for detecting localised defects and may eventually prove useful as one component of a hybrid grading system.

METAL CONNECTORS

Because of the desire to market new metal connectors soon after they have been developed, there is a demand for rapid methods of assessing the structural

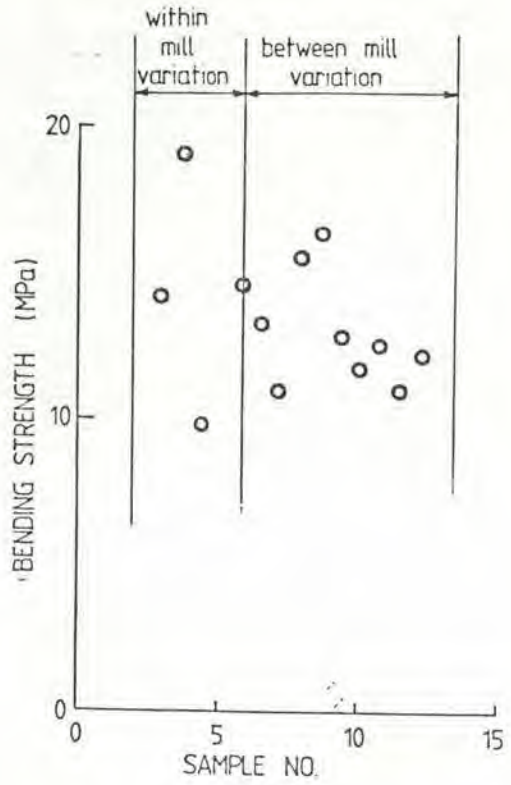


Fig. 9 · The 5-percentile bending strength of No. 3 structural grade hem-fir (Madsen, private communication)

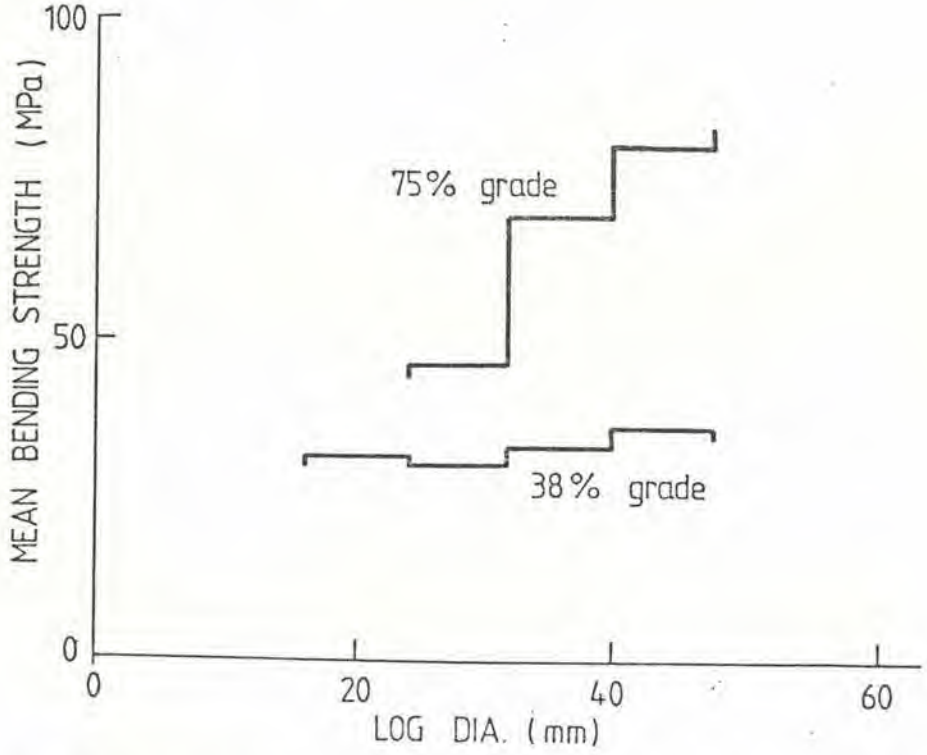


Fig. 10 Effect of log diameter on the strength of dry radiata pine (CSIRO data)

properties of connectors. The Australian Standard AS 1649-1974 (Standards Association of Australia 1974) is intended for this purpose. However, with usage over the years, several deficiencies in this Standard have become apparent. One difficulty is that it does not specify a method for the strength assessments of groups of timber. In addition, it has no rational basis for the load factors specified, and there is some doubt on its effectiveness for the assessment of joint performance under long duration and repeated loads. A considerable amount of further research will be required to remedy these deficiencies.

One problem that arises in the use of metal connectors is that in practice it is very difficult to guarantee the occurrence of clear material at joint locations, a common requirement in most design codes. Consequently, there is a strong incentive to investigate the influence of natural defects on the performance characteristics of joints. Research on this topic is currently under way in Australia.

STRUCTURAL RELIABILITY

Some early attempts to estimate the uncertainty characteristics of structural timber were based on the properties of small clear specimens (Wood 1958). Because these properties differ from those of structural timber, the early estimates were in considerable error. During the past decade there has been an increased interest and research on the structural reliability of timber structures arising from a desire to provide consistent safety not only between the various members of timber structures, but also between structures constructed with various materials, and more recently even between structures constructed in various countries. An excellent discussion on the choice of a consistent set of load factors for such a wide range of situations is given in the Recommendations of Loading and Safety by the Nordic Committee on Building Regulations (1978).

In applications of probabilistic concepts, structural timber is characterised by large coefficients of variation and the occurrence of occasional severe defects such as poorly glued finger-joints. Rational methods for coping with these situations are available (Leicester 1976b). A pioneering effort in Australia has been the use of sturctural reliability concepts to derive load factors for assessment procedures based on proof and prototype testing (Standards Association of Australia 1975).

GROUPING SYSTEMS FOR STRENGTH CLASSIFICATIONS

In order to utilise effectively the hundreds of timber species available in Australia for structural purposes, it has been essential to develop methods of grouping timber with respect to their structural properties. The current

system, together with the methods used for classifying timber therein have been described in detail by Leicester and Keating (1980).

The current grouping system for structural timber properties are given in the Australian timber engineering code AS 1720-1975 (Standards Association of Australia 1975) and were first developed by Pearson (1965). These systems are sufficiently wide to include most of the world's timbers. Pearson also developed simple methods for classifying timber into these systems. These simple methods have since been refined and formalised in the SAA Miscellaneous Publication MP 45-1979 (Standards Association of Australia 1979c). One such method is based on mechanical tests of small clear specimens of timber and another is based even more simply on density measurements alone. Using these methods some 2000 species of the world's timbers have been strength grouped (Leicester and Keating 1980). These include the following:

Africa	700 species
Australia	630 species
South East Asia	362 species
South America	190 species

Systems for grouping timber with respect to their joint strength properties have been developed by Mack (1978). These groupings are based on timber density. Examples of the strong relationships between timber density and connector characteristics are shown in Fig. 11.

STRUCTURAL STABILITY

Possibly the least satisfactory aspects of current timber design codes are the recommendations concerned with the design buckling strength of timber elements and structures. These arise because of complexities associated with the analysis, testing and codification of buckling phenomena. Simple linear elastic theory is inadequate to describe the buckling strength of any but a few simple structural elements (Leicester and Pham 1979). In addition, there have been few in-grade measurements on the buckling strength of timber elements. Some examples are reported in the paper by Leicester and Pham cited above. Probably the only published data on creep buckling strength is that shown in Fig. 12.

The buckling strength of gable-ended trussed-roof systems remains of considerable research interest. Baldwin and Ransom (1978) have reported that of the one million domestic truss roofs constructed in the U.K. some 700 cases of failure have been reported; most of which have been associated with inadequate bracing systems.

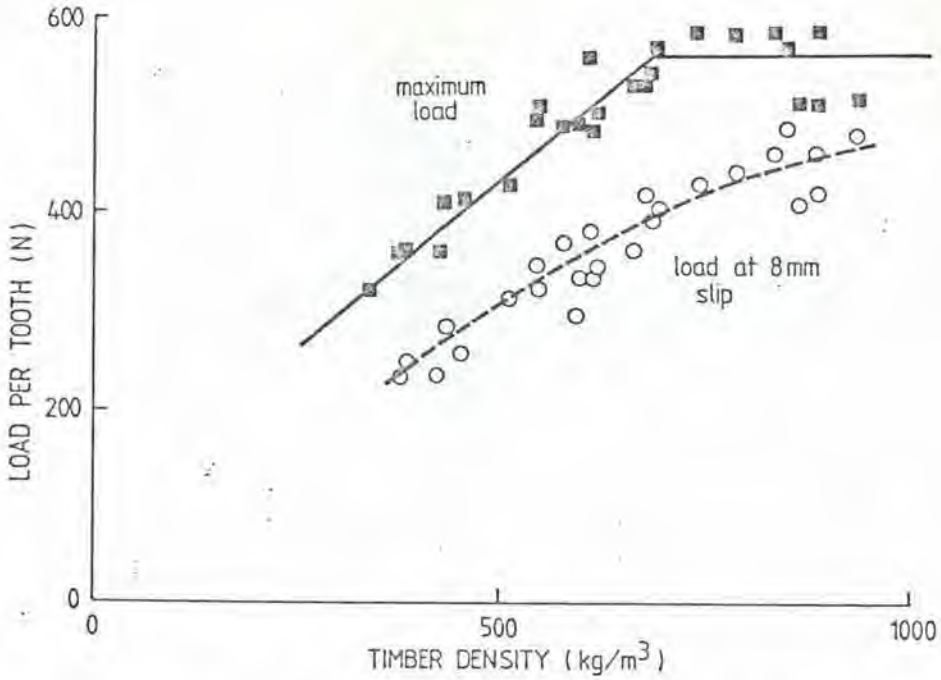


Fig. 11 Effect of density on the characteristics of a toothed plate connector joint (Schuster, private communication)

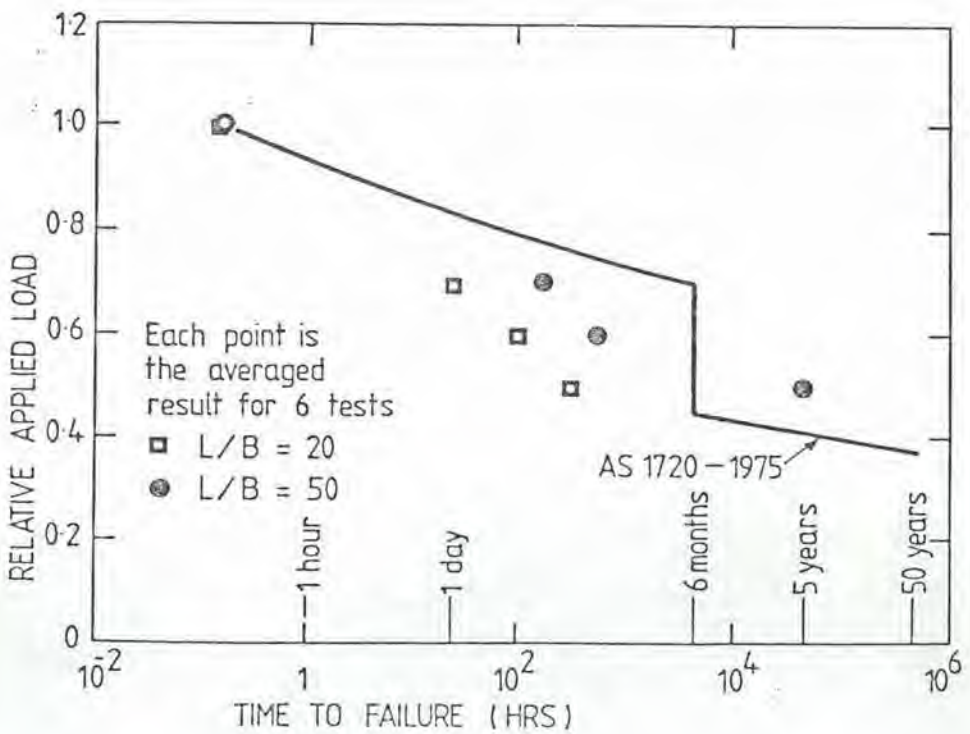


Fig. 12 Effect of load duration on column strength (after Leicester 1972, based on private communication from Pearson)

There is one particularly dangerous characteristic of gable-ended trussed-roof systems that does not appear to be generally appreciated. It is the fact that the form of diagonal bracing traditionally used in the roof planes of these systems cannot cope with unsymmetrical buckling modes unless the trusses are also braced in the ceiling plane. This is illustrated schematically in Figs 13 and 14 which show the essential structural systems in the roof planes that resist the lateral buckling forces of a single truss. For the case of symmetrical buckling shown in Fig. 13, the roof frame provides the complete restraint system required; by contrast, for the case of unsymmetrical buckling, shown in Fig. 14, the side support walls are required to resist a set of unbalanced forces. In Australia there have been several instances of roof failure occurring in this type of unsymmetrical mode. A failure of this type reported in the U.K. is illustrated in Fig. 15.

Apart from the buckling mode described above, there are several other significant characteristics of roof-truss systems that are not widely known. One is that the bracing and roof rafters act together to form a shell that transmits vertical loads laterally to the gable-end walls, and in the process apply additional forces to the bracing. Another feature of truss-roof systems is that the friction forces acting between the rafters and truss top-chords can provide very effective restraints against buckling of the top-chord (Leicester 1976).

GLULAM

The design procedure for glulam, given in the timber engineering code AS 1720-1975 (Standards Association of Australia 1975) is directed towards Australian conditions. Because glulam in Australia is fabricated from a great range of species, the design procedure used is essentially that of solid wood with minor modifications to account for the effects of laminating. This is in contrast to most other design codes which usually give design recommendations only for specific layups of glulam fabricated with specific species. Furthermore, the scope of AS 1720-1975 includes glulam fabricated from thin timber veneers. This form of glulam is extremely strong and reliable and has considerable potential for major structures (Anon 1976).

Difficulties experienced with glulam have been concerned largely with fabrication. These have been sufficiently serious that at some time or other glulam has been discredited as a structural material in most States of Australia. Fortunately, there have been no disasters of the same magnitude as some of those reported overseas (Fox et al 1976).

Current difficulties are associated with the glueing of laminae, the occurrence of the occasional defective joint in the laminae, and the occurrence of

vertically stacked joints in random layups. Also severe delamination and checking are found to occur in glulam used in exposed locations. This is probably because exposed glulam in Australia is not impregnated with an oil based preservative, a treatment which would appear to be essential for their satisfactory performance (Huggins and Aplin 1965).

FIRE RESISTANCE

There is a considerable demand for a computation method to assess the fire resistance of timber structures. This is required not only for new buildings but also for old ones which may have to be assessed for a change in end use.

The fire resistance of solid timber sections is quite good and has been extensively studied. In a typical building fire, the wood chars slowly at a rate of about 0.5-1.0 mm/min but is otherwise largely undamaged. An effective computation method to design against this effect is given in the British Standard BS 5268 (British Standards Institution 1978).

By contrast, the performance of joints fabricated with unprotected metal connectors is poor. This is due largely to the softening of wood at low temperatures and the ensuing loss of connector bearing strength. Examples of poor connector performance in standard fire tests are shown in Fig. 16. Obviously the development of new fire resistance connector systems is important to the general development of fire resistant timber structural systems.

FUTURE RESEARCH TRENDS RELATED TO THE BUILDING DOMAIN

GENERAL

As mentioned earlier, much of the effective research in the near future is likely to be related to the building domain. The following is a brief discussion on some aspects of the building domain in which research has already commenced.

MATERIAL AVAILABILITY

Current indications are that new types of structural timber will become available for utilisation. This may occur with great rapidity and for some types perhaps only briefly. In Australia, the forcasts are for the utilisation of new species, smaller diameter logs (both softwoods and hardwoods), regrowth hardwoods, and spasmodic imports of mixed tropical hardwoods (Hillis 1979, Page 1979). Similarly, metal connectors are expected to be developed in great profusion. In order to use these building components effectively, rapid and simple techniques must be developed for assessing, grading and classifying them.

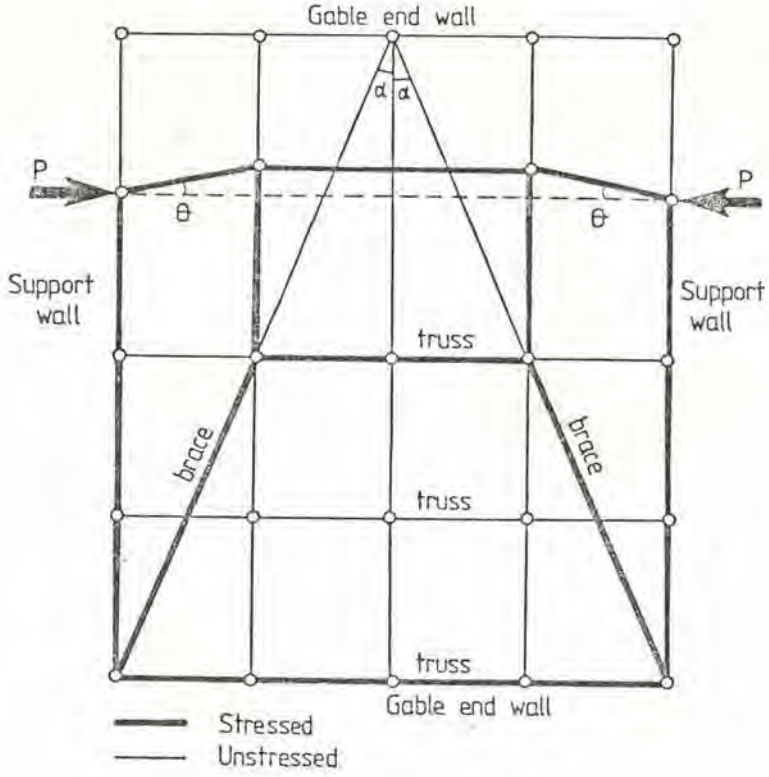


Fig. 13 Resistance by a diagonal bracing system to the symmetrical buckling of a truss-roof system

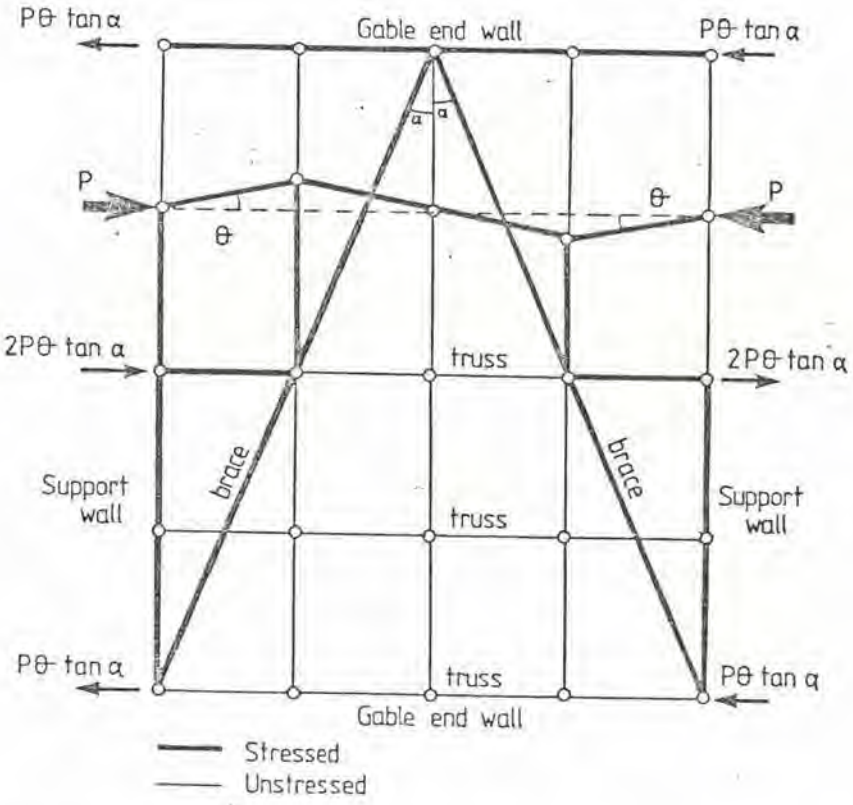


Fig. 14 Unbalanced forces arising from the anti-symmetrical buckling of a truss-roof system

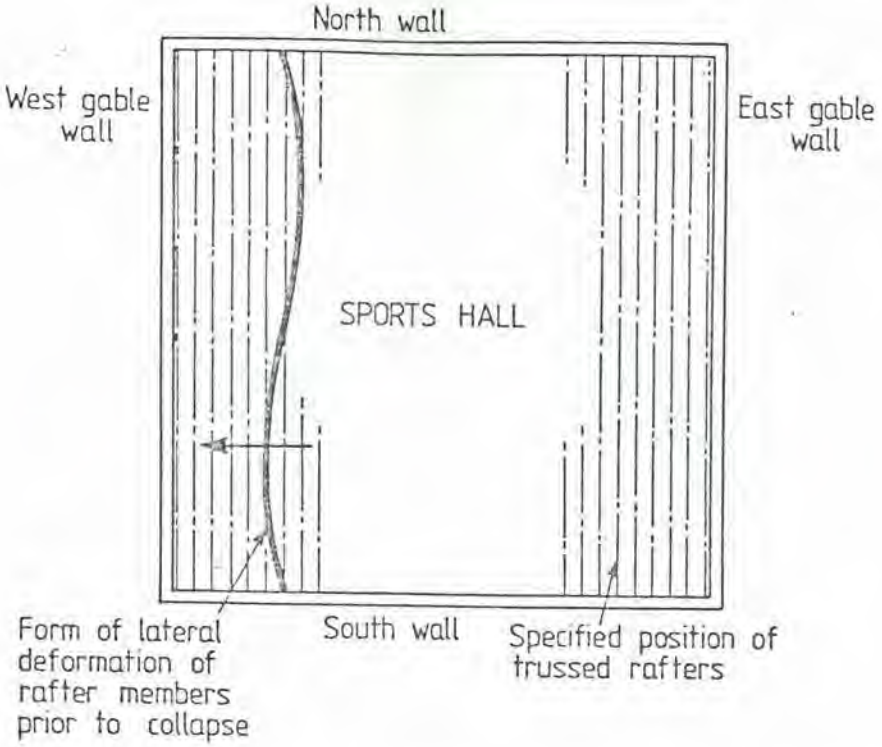


Fig. 15. Failure mode of a school sports hall roof at Birkenhead (after Menzies and Grainger 1976)

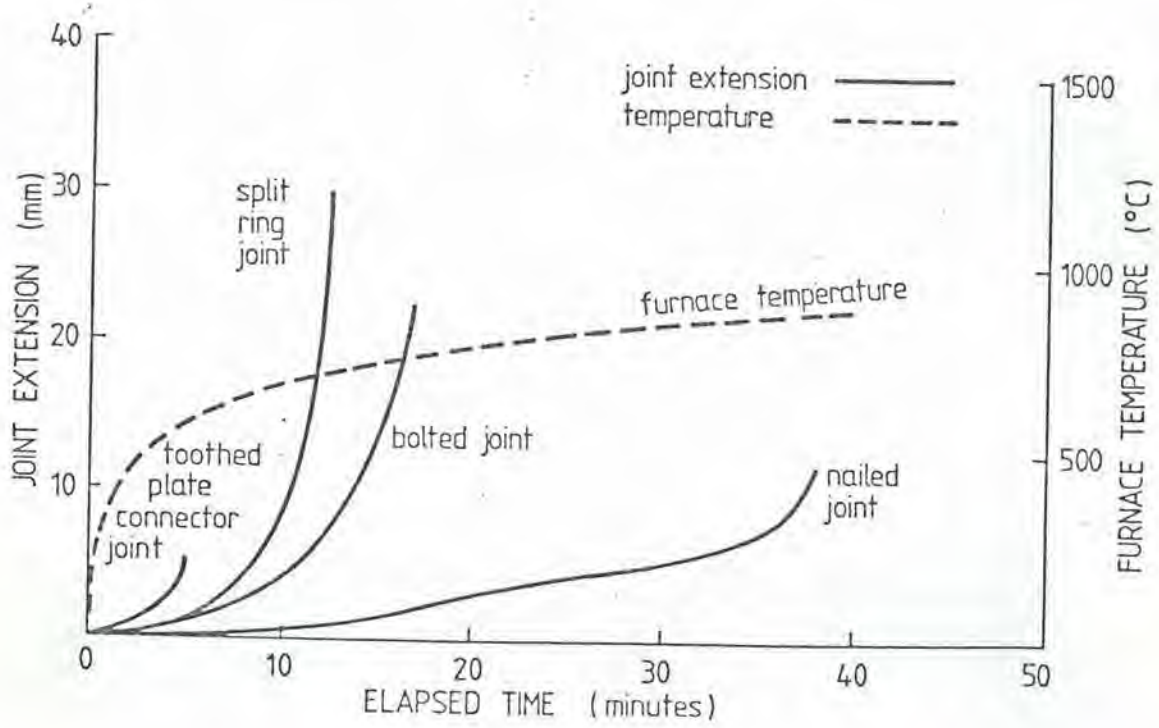


Fig. 16 Joint performance in a standard fire test (after Leicester et al 1979)

Difficulties are anticipated in deriving methods for the assessment of long term performance characteristics.

FABRICATION CAPABILITY

It will be necessary to modify current design procedures to bring these into line with the fabrication capabilities of the timber industry. Due account should be taken of the fact that the occasional finger-joint will be defective, some metal connectors will be located at timber defects, vertical stacking of joints will occur at times in glulam beams, and for timber situated in decay hazard locations, the reliability of preservation treatments is of an order of magnitude poorer than is the usual target reliability for structural strengths.

HUMAN RESPONSE

The serviceability of a structure, such as for example the serviceability related to stiffness, is dependent not only on material properties but also usually on human response to structural environmental factors (Onysko 1970). In the past, research emphasis has been placed on material properties because these are closely related to the marketing problems of the timber industry. However, the biggest uncertainties in design for structural serviceability are those related to human response (Leicester and Beresford 1977), and accordingly it is appropriate that more emphasis be given to this area in future research.

HUMAN JUDGEMENT

Human judgement plays a major role in many aspects of timber utilisation, most significantly perhaps in the visual grading procedure. Surprisingly there have been very few studies made on this topic. One such study was undertaken by Leicester (1979) in connection with a project related to proof grading. The purpose of the study was to measure the ability of a timber grader to choose the weaker of two defect locations in timber selected at random. It was found that in about 20 per cent of the choices, grading operators made an error and that for these cases the differences in strength between the paired defect locations had the frequency distribution shown in Fig. 17. In this figure, the notation R_{max} and R_{min} are used to denote the maximum and minimum strengths respectively, of the paired defect locations.

HUMAN ERROR

Some structural failures undoubtedly occur because of extreme load events or poor material properties. However, a more obvious cause of structural failure is human error. It is now generally believed that most structural failures

occur because of human error and that failure rates are related to the factor of safety roughly as indicated in Fig. 18. Notionally, there are several ways in which the failure rate due to human error may be reduced. These include a change in the factor of safety, the use of proof testing, improved inspection and checking procedures and the use of error-proof design (Nowak 1979). The practical difficulty of implementing these suggestions lies in lack of a suitable data base. The study by Wymond (1977) on the frequency of types of errors that occur in the construction of dwellings in Victoria is one of the few studies of human error in the Australian construction industry.

CODIFICATION OF RESEARCH INFORMATION

The application of research findings into building practice is usually made through Standards and Codes. The construction of Codes is now a subject of research in its own right and includes such sophisticated topics as the use of decision logic tables (Standards Association of Australia 1979a). Of more direct consequence to research in timber engineering is the fact that essentially Codes must have a simple format. As a result, many complex factors, such as crookedness and nonlinear effects, that are known to have an effect on structural performance, cannot be specified directly in design Codes and indirect methods must be found to introduce their influence. A discussion on this aspect, with respect to the codification of design rules for buckling strength, has been given by Leicester and Pham (1979).

BUILDING REGULATIONS

Building regulations frequently form a barrier to the implementation of research findings. For example, research findings on the fire resistance of timber cannot be applied if the regulations forbid the use of combustible materials. One response to such an obstacle is to develop and promote the use of Codes of practice based on fire resistance performance rather than on material properties.

In Australia, one particularly effective aspect of timber technology has been the development of strength grouping systems. The use of these systems separates problems related to timber technology from those related to building regulations. For example, the timber framing code AS 1684-1979 (Standards Association of Australia 1979b) through a set of Tables for only eight stress grades, enables the usage essentially of all green structural timber for the hundreds of species marketed in Australia. Consequently, if a structural timber is reassessed to a new grade, this does not alter its acceptability for domestic construction. The only effect usually will be that the sizes required must correspond to a different set of tables in AS 1684.

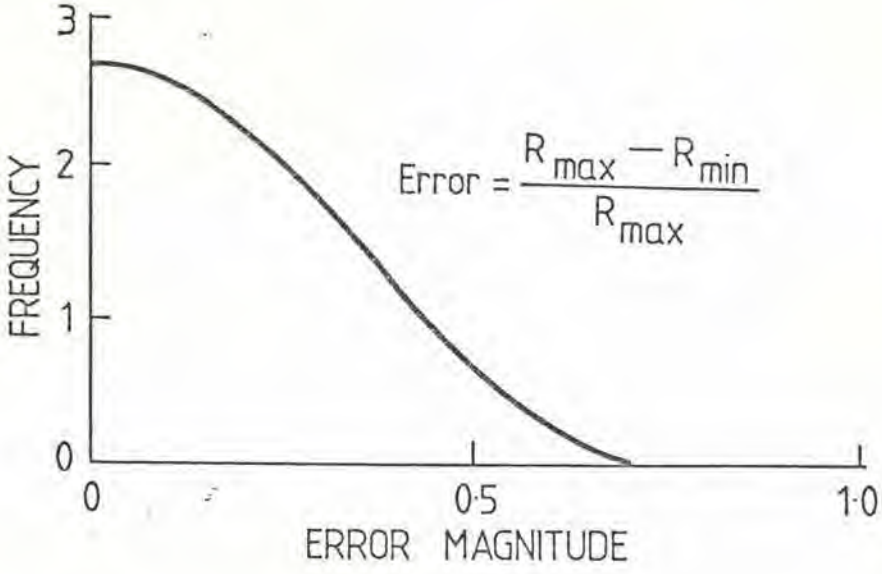


Fig. 17 Frequency distribution of grading operator errors for radiata and slash pine (after Leicester 1979)

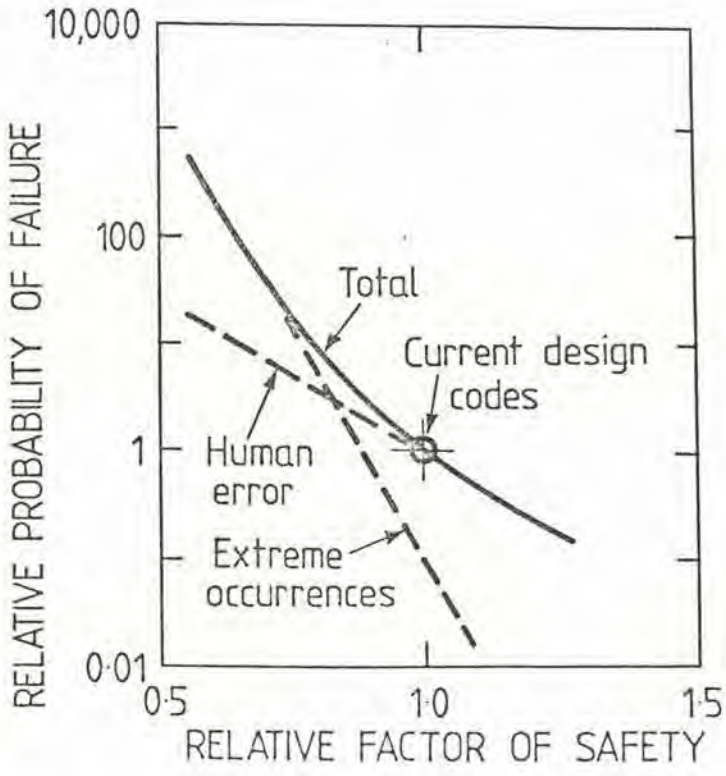


Fig. 18 Effect of factor of safety on the probability of failure (after Allen 1976)

LEGAL ASPECTS

Since Codes and Standards, the usual vehicles for the implementation of research findings, are frequently incorporated into building regulations, legal matters often have an indirect but marked influence on research. For example, the concept of a target structural failure rate, a keystone of research on strength, is difficult to use in legal documents and so it has become essential to develop alternative equivalent but legally acceptable concepts such as that of the safety index (Nordic Committee on Building Regulations 1978).

There is an urgent need to undertake research directly related to the matter of legal responsibility and liability in the event of a structural failure. Current difficulties arise because the building process involves many groups of people such as researchers, material suppliers, designers, builders, national regulatory authorities and local building authorities. Largely because of this, the legal implications of failure are not very clear except in cases which involve obvious breaches of common law duty in failure to exercise reasonable care, or breaches of statutory duty on non-compliance with the terms of a statute (Fryberg 1976). Many of the difficulties which arise could probably be avoided through the use of suitable quality control and structural design systems.

INTERNATIONAL STANDARDS

International Standards, such as the proposed ISO Structural Timber Design Code (CIB Working Group W18 1979), will obviously be of considerable benefit to international trade and to assistance for developing countries. In particular, the use of internationally accepted systems for grouping timber according to their structural properties, will facilitate the transfer of technology software from one country to another. For example, the United Nations Industrial Development Organisation has in preparation a set of standard designs for wooden bridges which is based on only eight strength classes; and yet it is applicable to the commonly available species of India, the Pacific Region and South-East Asia (United Nations Industrial Development Organisation 1980).

The development of international structural utilisation standards requires research into several special areas. This includes a study of the differences between the structural characteristics of timber from forests of the various regions of the world (Leicester and Keating 1980) and the differences in safety level that would be appropriate to differences in socio economic factors.

THE LONG TERM FUTURE OF TIMBER ENGINEERING RESEARCH

In the past, timber engineering research has proceeded in eras associated with one of the three basic research domains indicated in Fig. 1. It is quite possible that this will continue in the future. However, because of the increasing efficiency of communications between research laboratories around the world, it is likely that the essential research targets in each era will be met rather more quickly than in the past, so that the length of an era may be less than a decade, possibly as short as five years.

The type of research undertaken in any particular era will probably depend on developments in the technology of the building industry in general and not specifically on developments occurring solely in the timber industry. In particular, the building industry's trend towards frequent product development could lead to notable changes in the format of research. In the past, the thrust of research has been directed to assisting the structural designer. In the future it may well be biased to assisting regulatory authorities, whose main concerns will be with product appraisal methods. The development of the Australian appraisal system, ABSAC (Anon. 1978), is an indication of this trend.

Finally, it is of interest to note the observations of Serry (1979) on the future of engineered timber. Serry has suggested that in the future the usage of board products such as particleboard, plywood and hardboard will decrease because their production is energy expensive. On the other hand, the use of solid timber will increase. The reason for the latter is that although the production of solid timber is currently labour intensive, particularly with respect to quality control and grading requirements, the manpower effort required in the future will be considerably reduced through the use of microprocessor facilities. Some of the necessary interface equipment for this, such as for example an electronic slope of grain indicator (Machlauchlin et al 1973), is already being developed. This interesting speculation by Serry, if correct, will undoubtedly influence the course of research. However, it may need to be slightly tempered by the possibility that in many instances buildings board material introduced primarily to act as a lining, will also act simultaneously as an effective structure.

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TIMBER ENGINEERING IN NEW ZEALAND - A REVIEW

G.B. Walford

ABSTRACT

Many efficient and economically competitive light-industrial buildings are being built in New Zealand. Of particular interest are those using glued laminated members joined by nailed predrilled or punched steel plates.

In-grade bending tests on radiata pine show that size has a large effect on strength, that the increase in strength on drying decreases with increasing defect size, and that the traditional derivation of basic working stresses from small clear specimens, while substantially correct for 100 x 50-mm members, is optimistic for larger sizes.

Differences between the Australian and New Zealand timber design codes are discussed. The major difference is that in New Zealand, strength data are based on the 5-percentile exclusion limit, rather than on the 1-percentile.

INTRODUCTION

Time and space do not allow me to cover all aspects of timber engineering in New Zealand at this conference, so I will discuss only major developments, and others which represent significant differences of opinion between Australia and New Zealand. On a more general note I wish to express pleasure at the amount of research done on timber engineering in Australia, research that has formed the basis of our codes of practice for both structural timber design and light frame construction. This is a consequence of similar building practices, a similar philosophical approach in design, widespread use of the same species (radiata pine), and the use of the same stress-grading machine in both countries, but it nevertheless means that I can with sincerity express real appreciation.

Significant development has been made, I believe, in moment-resisting connections for large timber members, such as occur in portal frames and multi-storey timber buildings. Also in the area of in-grade testing and the derivation of design data from the results obtained.

Areas of difference exist between the New Zealand and Australian design codes in spite of the fact that AS 1720 was used as a model for the revision of the NZ timber design code. These differences will be discussed in this paper.

RECENT TIMBER CONSTRUCTION

A detail of heavy timber construction that appears to be unique to New Zealand is still being used in portal frame single-storey structures, the largest of which is 7900 m^2. The detail is a joint between vertically laminated column and rafter members in which alternate laminations interleave in the joint area and are glued. Theoretically, such cross-laminated construction should fracture at the gluelines due to the shrinkage difference along and across the grain but this has not happened, even in members up to 2 m wide. The largest portal frame of this type has a span of 23 m. The reasons given by Hill (1) for the choice of timber in the four examples he describes are: because of the corrosive environment, because it was tolerant of differential settlement, because it was marginally cheaper but gave much greater fire resistance.

A recent amendment to NZS 1900 Chapter 5 "Fire resisting construction and means of egress" allows the construction of buildings with timber floors and structural systems up to four storeys in height. The design implications involved have been studied (2) and it is concluded that structural requirements are relatively easy to satisfy but the design is strongly influenced by the need to achieve required fire ratings on boundary walls and structural elements. Nevertheless Carter Holt Holdings Ltd have recently built themselves a new head office of four storeys in glued laminated timber. In this building seismic resistance is provided by reinforced masonry shear walls.

Several glulam arch structures are under way at the moment, each worth about $150,000 for the glulam alone. Typically these are three-pin circular arches of 50 to 60 m span similar to those in hangars at the Auckland International Airport and described some time ago (3). Interest in timber construction is being spurred by purely economic factors - it is becoming cheaper to build single-storey buildings in timber than in other materials. A recent (1/11/79) article in the Auckland Star describes a container depot built of steel and goes into great detail extolling the advantages of steel construction. It appears that steel producers are feeling the competition.

Truss construction and design have developed, with the largest span in trusses built of 50-mm thick radiata being 31 m (4). This is for a fertilizer

works and another 31-m extension is planned. A further 40-m span extension to this building is also proposed, reaching a height of 40 m and carrying a conveyor at the apex. An important part of this development has been the use of correct erection procedures. An interesting feature has been the combined use of glulam and Gang-Nails in trusses.

Pole construction has become a common feature in house building and in warehouses and is an example of a trend towards "mixed" timber construction in which poles, glulam, trusses, plywood, and sawn timber are all used.

Finally, it needs to be mentioned that the Ministry of Works and Development is designing main highway bridges using glued laminated beams and nail-laminated decks.

MOMENT-RESISTING CONNECTIONS

The principle of the North American glulam rivet has been used successfully in New Zealand for knee joints in portal frames except that plain or galvanised nails have been substituted for the specially shaped hardened-steel glulam rivets. One Auckland firm reports that it has won more than 15 design-and-supply contracts this year for glued laminated portal frames using nailed-on pre-drilled steel plates at the apex and knee joints. Some of these have been made for export to the Pacific Islands as they have the advantages of being compact to ship and being simple to erect with unskilled labour. The idea has also been used to provide simple on-site connections between concrete columns and timber trusses.

Three variations on this theme can be identified:

(a) 2-mm steel plate with 3.15 x 30-mm nails. The plate is punched with a pattern of holes spaced 50 mm along rows which are on average 9 mm apart and staggered in a random manner. This product has the trade name "NAILON PLATE". The basic load per nail is 340 N in green radiata pine.

(b) 3-mm steel plate with 4 x 50-mm nails. The plate is punched with a pattern of holes spaced 40 mm along the rows which are 10 mm apart and staggered 20 mm. This pattern was developed from tests (5) done at the Central Laboratories of the Ministry of Works and Development. From these tests a basic load of 443 N/nail in dry radiata pine was deduced according to AS 1649 but based on the 5% limit, not 1%.

(c) 6-mm steel plate with 3.55 x 70-mm nails. The plate is drilled with a pattern of holes spaced 25 mm along rows which are 20 mm apart and staggered. The basic load per nail is 300 N in dry radiata pine.

Some cyclic testing of joints with 3-mm steel plate has been done (5), giving the typical load-deflection curve shown in Figure 1. This work is being extended to joints loaded in bending to provide design data in relation to the ductility requirements in NZS 4203 (Loadings code) for earthquake-resistant structural frameworks.

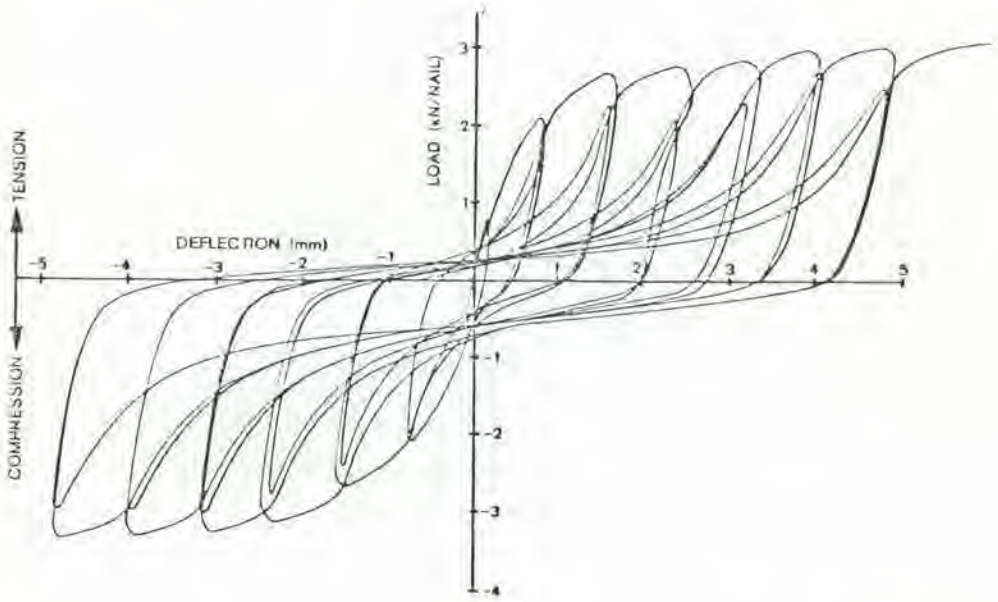


FIGURE 1 LOAD/DEFLECTION CURVE FOR CYCLIC LOADING OF A TIMBER JOINT USING NAILED STEEL PLATES

IN-GRADE TESTING

In a project (6) that was undertaken primarily to assist in trade negotiations with Japan, in-grade bending tests were done on radiata pine from several forests throughout New Zealand. Two sizes, nominally 100 x 50- and 200 x 50-mm, were tested in third-point bending with a span/depth ratio of 15, and in both green and dry conditions.

The following properties were measured:

(a) Bending strength (Rj) with the worst visual defect located on the tension edge;

(b) Modulus of elasticity (Ej) as above;

(c) Grading modulus (Ep) measured on the flat over a span of 914 mm under a central point load;

(d) Visual grade according to New Zealand rules.

Table 1 summarises the results obtained for timber from Kaingaroa forest which contains the bulk of New Zealand's resource of radiata pine.

TABLE 1

Properties of Visually Graded Radiata Pine from Kaingaroa Forest

	Nominal size:		100 x 50			200 x 50		
	NZ grade:		Eng.	No.1F	No.2F	Eng.	No.1F	No.2F
Condition	Property	Unit						
Green	No.		106	192	174	60	74	36
	$\bar{R}j$	MPa	33.3	22.0	16.5	27.8	19.7	15.7
	5% Rj	MPa	19.9	11.8	9.6	13.4	11.8	8.1
	$\bar{E}j$	GPa	7.96	6.53	5.65	7.74	6.35	5.51
	$\bar{E}p$	GPa	8.46	6.56	5.40	8.17	6.33	5.21
Dry	No.		32	56	52	96	87	44
(15% m.c.)	$\bar{R}j$	MPa	47.0	29.6	22.3	33.8	23.3	20.4
	5% Rj	MPa	25.6	13.4	10.7	17.4	11.3	9.5
	$\bar{E}j$	GPa	10.3	8.00	7.42	9.11	7.42	6.63
	$\bar{E}p$	GPa	9.61	7.05	6.41	8.29	6.41	5.53

In Table 1 the 5-percentile value of Rj has been calculated by ranking and is a non-parametric estimate with 50% confidence.

These data show that:

(a) The effect of size on strength is greater than is allowed for in current design codes;

(b) The increase in strength on drying reduces with increasing defect size.

The basic working stresses, derived largely from Table 1, for radiata pine are given in Table 2. These stresses will be published in NZS 3603, due for publication in December 1979.

To derive basic stresses from in-grade data, the procedure in ASTM D2915 (7) has been adopted except that:

(a) Data are adjusted to a permanent load duration;

(b) Stresses for timber in the dry condition are adjusted to a mean moisture content of 16%;

(c) Strength values are based on the 5-percentile estimate with 75% confidence.

TABLE 2

Basic Working Stresses for Visually Graded Radiata Based on In-grade Testing (MPa)

	Grade	Size	Bending F^1b	Compression F^1c	Shear F^1s	Bearing F^1p	MoE E
(a)	Timber used green						
	Engineering	≤ 150 x 50	7.7	5.4	0.85	1.82	8 800
		> 150 x 50	6.8	5.1	0.85	1.82	8 100
	No.1 Framing	all	5.0	4.3	0.85	1.82	6 500
(b)	Timber used dry (16% annual mean m.c.)						
	Engineering	≤ 150 x 50	9.4	8.7	1.32	2.99	10 500
		> 150 x 50	8.3	8.2	1.32	2.99	10 000
	No.1 Framing	all	6.0	7.1	1.32	2.99	8 000

Adjustment to permanent load duration means that Table 4 in ASTM D2915 is replaced by the following: (D2915 values in parentheses)

Modulus of elasticity	1.00	(1.00)
Bending strength	0.45	(0.475)
Tensile strength	0.45	(0.475)
Compressive strength	0.60	(0.526)
Shear strength	0.45	(0.244)
Bearing strength	0.70	(0.667)

To estimate the 5-percentile with 75% confidence from 100 or more values, the ith value is taken when the data are ranked in ascending order and i is given by:

$$i = n^{1.066}/34.1 \quad \text{where } n = \text{number of tests.}$$

For 30 or more but less than 100 values, the estimate shall be the jth percentile obtained from a 3-parameter Weibull distribution fitted to the data where j is given by:

$$j = n^{1.066}/(0.341(n+1))$$

MACHINE STRESS GRADING

The approach to mechanical grading in New Zealand differs from the approach in Australia in that:

(a) Machines are programmed for particular species (in fact only radiata pine and Douglas fir) rather than using a single program for all species. This simply reflects the fact that in New Zealand we do not have to cater for a multitude of species as in Australia.

(b) Machine programs have been developed to produce a grade with properties as similar as possible to those of No.1 framing radiata pine which represents the bulk of our domestic market. This is done to avoid conflict between visual grading and machine grading interests within the timber industry.

(c) Allowable stresses for machine-graded timber have not been calculated using a regression against grading modulus but by means of the in-grade testing approach which provides a common basis for both methods of grading.

It is noteworthy that, at a seminar on stress-graded timber held in Rotorua in May 1979, engineers expressed a need for a grade with properties as high as was possible from the timber available.

The machine programs and basic stresses in bending for timber for the domestic market are given in Table 3 although currently no timber is being machine graded for that market.

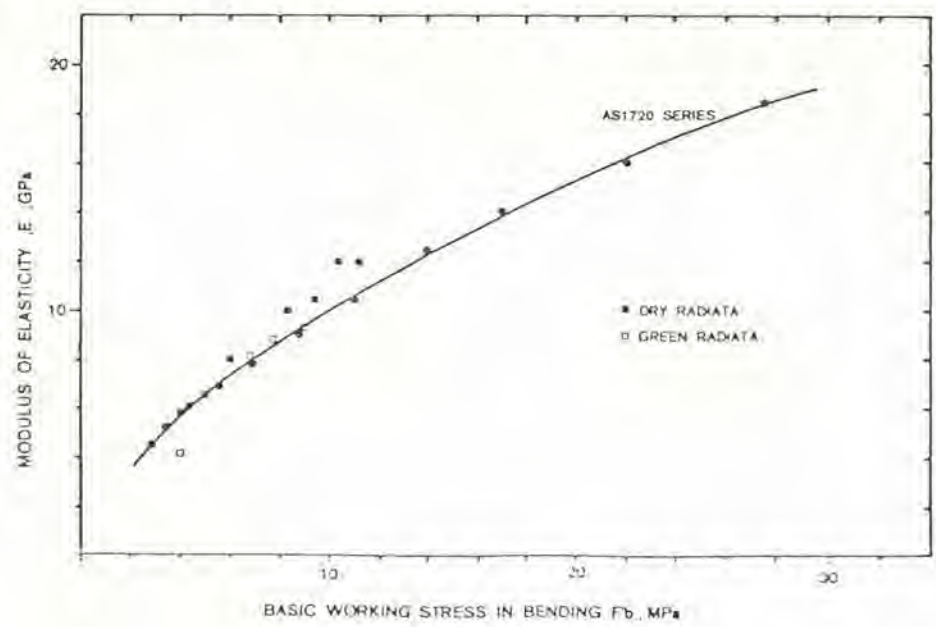
TABLE 3

Basic Working Stresses for Machine Graded Radiata (MPa)

Grade	Min. Ep (GPa)	Size	Bending F^1_b	Compression F^1_c	Shear F^1_s	Bearing F^1_p	MoE E
(a) Timber used green							
F11	8.05	≤150 x 50	9.0	5.8	0.92	1.97	9 300
		>150 x 50	7.7	5.4	0.92	1.97	8 700
F6	3.64	all	5.0	4.3	0.85	1.82	6 500
F4	2.88	all	4.0	3.9	0.78	1.07	4 100
(b) Timber used dry							
F11	9.65	≤150 x 50	11.3	9.7	1.43	3.23	12 000
		>150 x 50	10.3	9.2	1.43	3.23	12 000
F6	5.23	all	6.0	7.1	1.32	2.99	8 000
F4	4.26	all	4.0	5.7	1.21	2.75	5 800

As with visually graded timber, an effect of size has been introduced into the stresses. Figure 2 shows the relationship of Fb to E for New Zealand radiata pine compared to the series used in AS 1720 and shows that while green radiata substantially agrees with AS 1720, dry radiata has relatively higher stiffness.

FIG 2 RELATIONSHIP OF Fb AND E VALUES COMPARED TO SERIES USED IN AS1720



Multiple linear regression analysis of bending strength and stiffness against the following variables has been done, with results as shown in Table 4.

(a) Knot area ratio (KAR) - the projected cross-sectional area of all knots occurring in a length equal to the width of the piece, expressed as a percentage;

(b) Margin knot area ratio (MKAR) - as above but considering only the 25% of the depth on the tension edge;

(c) Density (D) - oven-dry weight/volume at test of the wood with the resin not extracted;

(d) Ring width (RW) - the average ring width along a radial line drawn through the centroid of the cross-section.

TABLE 4

Multiple Linear Regression Analysis of Dry Radiata pine

Constant term	Coefficients				
	Ep (GPa)	MKAR (%)	KAR (%)	D (kg/m^3)	R^2
(a) Modulus of rupture, Rj (MPa)					
-4.28	5.19				0.55
14.03	4.28	-0.265			0.71
18.89	4.01	-0.231	-0.129	Not sig.	0.72
(b) Modulus of elasticity, Ej (GPa)					
1.66	0.899				0.82
2.45	0.861	-0.0111			0.83
1.42	0.926	-0.0195	0.0313		0.85
0.45	0.866	-0.0198	0.0290	0.0035	0.85

In Table 4 it is seen that the addition of values for MKAR improves the prediction of bending strength by an appreciable margin over that given by Ep alone. This means that a visual override on machine-graded timber is a practical proposition for exacting structural applications, such as glue lamination. It also supports the provision in the draft New Zealand code for machine grading of timber (NZS 3618) that places restrictions on the size of knots intersecting an arris in the F6 grade.

DESIGN CODES

AS 1720 was used as a model for the New Zealand timber design code NZS 3603. The same format and working-stress design method is used and several appendices have been quoted verbatim. Significant differences exist as follows:

(a) Stresses in NZS 3603 are quoted for particular species because with only two species of structural significance there is no need for species grouping.

(b) Stresses, loads, and factors affecting strength in NZS 3603 are based on the 5% exclusion limit. This is in line with the draft international code for structural timber design (8) in which it is recommended that characteristic timber strength values be based on the 5% exclusion limit. It was found that stresses derived from in-grade tests and based on the 5% limit and given in Table 2 are higher and lower for the 100 x 50-mm and 200 x 50-mm sizes respectively than the stresses derived from small clears data and based on the 1% limit. Therefore the derivation of basic working stresses remains as is, i.e., based on the 1% limit, 95% confidence, normal distribution assumed.

(c) The material constant rho for use in evaluating stability factors for beams and columns in AS 1720 has been deleted. Again, with only two species of significance this constant was considered to be an unnecessary refinement.

(d) The interaction formula in AS 1720 for combined bending and compression forces has not been adopted but the simple formula

$$\frac{fc}{Fcx} + \frac{fb}{Fbx} \leq 1.0$$

has been adopted on the grounds that this gives satisfactory truss designs which are usually governed by combined bending and compression in top chords.

(e) In NZS 3603 a fifth joint group has been introduced, J5, to provide for New Zealand-grown Douglas fir and for laterally loaded fasteners in radiata pine. As with the timber stresses, joint loads are based on the 5% limit which has meant an 11% increase over the equivalent values in AS 1720.

(f) In NZS 3603 provision is made for the design of structures to be built of green timber but it is assumed to dry out before full dead-plus-live load occurs. Dry stresses (except for shear) are used with green dimensions which are reduced 2½% to allow for shrinkage.

AS 1649 (9) is referred to in NZS 3603 with the following modifications:

(a) Joints shall be assembled wet (m.c. greater than 30%) and tested dry (m.c. 16 $\pm$ 2%), except that for specific uses joints may be assembled dry and tested dry or assembled wet and tested wet, provided that the moisture contents are representative of those in the timber during its expected use.

(b) Fasteners that are intended for use under a loading condition other than than provided for in AS 1649 shall be tested in such a manner as to represent that loading condition (e.g., cyclic loading).

(c) For category C fasteners tests shall be arranged to:
(i) induce maximum effects in the plate-timber connection;
(ii) induce maximum effects in the plate.

(d) Basic working loads shall be determined at the 5-percentile load based on a lognormal distribution. Values of k listed in AS 1649 Appendix B Clause B4 shall be replaced by the following:

No. of tests	n	10	11	12	14	16	18	22	26	30
Factor	k	1.90	1.88	1.86	1.82	1.80	1.78	1.76	1.74	1.73

(e) The basic working loads determined by the procedures set out in Section 6.0 of AS 1649 shall be modified to represent the basic working load for the fastener when used in a timber having a density equal to the reference density for that species. The reference density for radiata pine and Douglas fir shall be as set out in Table 5. The basic working load at test shall be modified as follows:

$$\text{B.W. load} = \text{B.W. load at test} \left[\frac{\text{Average density of tested joints}}{\text{reference density}} \right]^{\frac{1}{2}}$$

TABLE 5

Reference Densities

Type (kg/m^3)	m.c. (%)	Radiata pine	Douglas fir
Basic	-	410	400
Nominal	12	434	430
Nominal	16	428	423
Nominal	20	423	416
Test	12	486	481
Test	16	497	491
Test	20	508	500

Although the Australian code CA38 was used for the original draft of the New Zealand light timber framing code, NZS 3604, the final document bears little resemblance to it. To discuss the differences fully would require a conference in itself but as a general comment existing practice was taken as the basis of NZS 3604 whereas CA38 appears to have engineering design as its basis.

CONCLUSION

Efficient and economically competitive light industrial buildings in New Zealand are being built using glued laminated members connected by nailed predrilled or punched steel plates. The moment-resisting properties of such joints under cyclic loading is under study.

In-grade bending tests have revealed a large size effect on the strength of radiata pine but the derived basic working stresses based on the 5% exclusion limit are little different from those previously established from results of tests on small clear specimens and based on the 1% exclusion limit.

A change to the 5% exclusion limit as the basis for strength data has been made throughout the New Zealand timber design code with consequential amendments being applied to AS 1649 for the derivation of fastener loads.

Stresses for machine-graded timber are given for particular species (as are stresses for visual grades in New Zealand) and are derived by an in-grade testing approach rather than by regression against modulus of elasticity.

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19TH FOREST PRODUCTS RESEARCH CONFERENCE

USER NEEDS IN TIMBER ENGINEERING RESEARCH

P A Campbell

ABSTRACT

Australia with its hardwood economy and a significant timber research organisation, has the opportunity of becoming an industrial leader amongst the dominantly hardwood countries of the Southern Hemisphere. There is need for much more information on timber to be made available and this includes information on our species, on timber identification, on timber technology and on timber design. Preservation technology is one of the weakest areas and current methods are not very suitable for hardwoods and so there are opportunities here. There will be a need to expand full-sized testing of timber to cope with new plantations and especially the small wood lots which should produce more variability. Consideration should be given to the management problem of setting up task force research teams to solve industry problems and the committment to Standards committees needs to be strengthened. Australia's opportunities for industrial leadership will rely heavily on the maintenance of DBR as a world leader in research and development of timber technology.

INTRODUCTION

Australia is in a unique position in the world of timber. We are the only industrialised nation which has a dominant hardwood economy and also substantial timber research facilities. There is an opportunity to use this combination to develop skills and new industries to serve the Southern Hemisphere countries which are also on hardwood economies. Much of the technology from the Northern hemisphere has been developed to serve large timber industries processing softwoods and this is not always valid for the generally smaller hardwood based industries which predominate in the Southern Hemisphere.

With oil and probably other resources increasing in real cost, the long term prospects of timber appear good. But to develop the full potential of timber in Australia and overseas, the industry is going to

have to change from a dominantly craft to a mainly engineering type industry. The difference between these lies in skills and quality control.

Timber engineering in Australia has a long way to go before it achieves the reliability and hence, credibility of its counterpart in N America. So research and development work should be directed towards the better use of our timber and the results measured accordingly.

INFORMATION

New information can cause changes in technology by encouraging new uses or more confidence and so one material or method is replaced by another. As has been noted elsewhere (1), information on steel and concrete is fairly universally applicable but this is not the case with timber where the methods used may vary with species, climate, building practice, etc. So any country wishing to develop timber has to spend rather more on producing information than would be the case with most other building materials. There are a number of deficiencies in Australia.

THE USES, PROPERTIES AND CHARACTERISTICS OF AUSTRALIAN TIMBERS

CSIRO has already produced an excellent manual of this kind for African timbers and there is an expressed demand for a similar volume for our own timbers. Probably most of the information is available but it is scattered and not easily accessible to those not committed to timber development or research. Such a manual could do much to encourage the wider use of some of our lesser known species and the better use of our major species.

SPECIES IDENTIFICATION

Apart from a dozen or so species, most of the others are difficult to identify on site. Mixed or unknown species cannot be readily used with confidence other than for simple structures such as house frames. For other uses there is a need for reliability of properties such as durability, permeability for treatment and shrinkage. Moreover strength groups cannot be checked on site (except for mixed species) unless the species

can be identified. A system of end use classification as suggested by Keating (2) and in which species are grouped for certain end uses does not lend itself to quality control on site. It is generally not very practical to send samples off to the laboratories for identification and so there is a need for a users guide to species identification which could be used for preliminary identification of species on site. Without this, the user is dealing with a craft industry, not an engineering industry. Even if end use classification systems can be developed, there is need for some system of checking quality after the timber has passed through sub-contractors, main constractor and been incorporated in a structure.

HANDBOOK ON TIMBER TECHNOLOGY

There is no handbook in this area for designers along the lines of similar books on concrete which "tell it all including warts". There are some books directed at the industry and technicians which omit information for designers such when not to do use certain species or methods. For example, there is a need to make clear that pressure treatment is not very reliable for most species in the sawn condition. There is a strong tendency in trade literature and some standards to skate around or avoid direct statements which might affect the short term usage of timber. Such is not the case with concrete where confidence is given to designers by telling where problems may arise. It is not surprising that many designers are wary of using timber. A handbook in this area, possibly following the concrete model, would be very valuable for designers and would be useful for teachers in technician courses where the level of technology appears rather stagnant. It would need to be written for people to use rather than to study.

HANDBOOK ON TIMBER DESIGN

Most structural engineers in Australia do very little timber design and if it is the desire of the industry to encourage the wider usage of timber in major structures, then designers should be encouraged by the provision of a handbook which enables them to get into the Code more easily. Again this would also encourage more lecturers to teach timber design.

It is suggested that publications such as those listed above could make a very significant contribution to converting timber from a craft building material into an engineering material which is more widely accepted both by designers and teachers at several levels.

TIMBER PRESERVATION

This appears to be the weakest area of timber technology. Weakest in the sense that it is the area in which a knowledgeable designer has the least confidence. The dominant technology, pressure treatment been developed to suit the permeable softwoods of the N Hemisphere and vigorously promoted over the world. Considering that the method is unable to reliably treat the heartwood of most species and the sapwood of 40% of the species in Australia, it is a remarkable example of the powers of promotion. There are a number of problems such as afterglow and soft rot with CCA salts which are not so well promoted. As designers become more aware of the deficiencies of the pressure treatment methods, confidence will wane. Another factor is that recent changes in the law of liability may make a designer liable for six years from the time a defect becomes noticed rather than six years from the time of construction. So poor treatment may rebound on the designer ten years after construction.

There is a need to take a look at the whole process of protecting wood with a view to developing better technologies which suit the majority of species which cannot be effectively protected by pressure means when used in the sawn state. One candidate technology is hot double diffusion. There is an opportunity for a new industry for Australia because here, the motivation should be greater than in most other countries.

Related to this is the topic of quality control of treatment. The lack of simple facilities for checking penetration and retention does not give designers too much confidence and encourages them to ask just how much quality control (as distinct from process control) is exercised

at treatment plants. So we need better or simpler methods of quality control.

The natural durability of timber is probably as reliable a method of ensuring long life as most treatment methods. But natural durability is defined in very vague terms - ground contact in the average capital city- is one phrase used. Overseas information suggests that the life of a durable species in a temperate climate might be ten times that of the same species in a termite area and so it would be helpful to define durability in terms of end uses in various parts of the country. There is a lot of craft information which is not too reliable and scientific experience which is being lost through retirement as it has not been recorded. There should be a much better examination of the various durability properties of timber.

Much timber is protected with paints and stains. But it is not possible to exercise any quality control of these as the constituents are unknown. It is known that the formulation for a particular product may be changed to meet the requirements of different authorities and market price changes. Madison has developed some stains and published these and it is suggested that these are probably more reliable than unknown formulations from the paint industry. It is suggested that DBR should develop stains to suit Australian needs.

Work is being done on the detection of soft rot. There is need to develop electronic or other methods of locating insect attack. There is considerable concern about the major infestation of Cryptotermes brevis in Brisbane. Detection of attack may be exceedingly difficult and it would be a brave man who would guarantee a building in the susceptible zone, to be free from attack. It would be well worth while to examine the possibilities of designing an instrument to locate holes in timber.

STRUCTURAL TIMBER

The recent visit of Borg Madsen has highlighted the importance of large scale testing of full sized timbers. We face a number of future

problems. The rapid development of woodlots encouraged by taxation policy and Forest Commissions is going to lead to many small lots from diverse growing areas and grown under a variety of conditions coming onto the market place and being sold with the products of the large plantations. Past experience tells us that these will be more variable than plantation timber. There may also be a drift downwards in strength properties arising from indifferent husbandry. We cannot anticipate with any confidence, that timber from the large plantations of radiata in NSW will necessarily have the same properties as that currently marketed. We have a similar problem with regrowth hardwoods and also with plantation hardwoods grown out of their original environment.

Professor Madsen has made it very clear that testing of small clears is not very reliable and so it is important that the programme of testing full sized samples continues.

Associated with this is the further development of machine and proof grading systems. These do tend to emphasize the structural properties only of the timber under test and there is a need to look at grading in a wider context to include shrinkage, durability and the ease of effective protection.

A significant factor of most design is creep. But we do not have too much reliable design information on this and the figures used in the timber Code are less accurate than most of the other data. This is an area for further research.

With increasing emphasis on whole tree utilisation, we should be looking at the structural properties of the whole range of board products so that designers may use these with more confidence.

SEASONING

For the user, there is the simple decision to accept or reject timber on site after examining its moisture content. One piece of equipment

which could significantly improve seasoning would be a cheap moisture meter. The craft nature of most of the timber industry inhibits the acceptance and use on the shop floor of moisture meters. They are not conditioned to spend $200 on a delicate instrument and neither are designers so inclined. The developments of the electronic industry over the past decade are such that it is quite possible to produce a robust moisture meter using microprocessors. This has not been done because the electronics industry has no understanding of the timber industry and the timber industry in the main, is not too good at looking at opportunities from other technologies. Here is a chance for some entrepeneur. The target price would be $25!

There is some very interesting work going on at Madison on timber stabilisation and perhaps our needs are much greater than those of the USA. This is work which should be pursued. We can expect plastics derived from petrochemicals to rise in price and it is worth considering stabilised wood as a valid substitute in some cases.

CONCLUSIONS

The way the research findings are transferred into industry is of particular importance to Australia as the models are not the same here as in the USA and other large industrialised countries. There, large commercial organisations can carry substantial in-house R & D staff and it is these who effect most of the transfer of science into technology. Such large organisations are very rare in Australian owned industry and this will probably be a permanent feature. So we have the well known syndrome of original work being taken up overseas rather than in Australia.

With limited resources we should be directing these to helping Australian industry in preference to adding to the world fund of knowledge and subsidising overseas companies. One aspect of assisting local industry is that the structure of a research organisation should

be set up or be able to cope with a task force or mission oriented approach to research and development. Once a research body divides itself into very rigid knowledge compartments, it may be suitable for fundamental research but it usually loses the capacity to look at total problems which is what industry needs. Researchers who are seconded to a task force for a year or so may also be concerned that their career in their specialised section may be jeopardised. So research organisations which seek the support of industry should be asking whether their structure has sufficient flexibility to serve industry.

One of the main interactions of DBR with industry is through the various Standards Committees. These fulfill a very valuable function and is one where DBR has special skills. It is also an area where DBR is seen to assist industry and is therefore an activity which should be encouraged rather more strongly.

I started by saying that Australia was in a unique position in the timber world, not only to help ourselves but also to assist other countries by developing new technologies which we might export. Central to this opportunity is the existance of one of the best timber R & D organisations in the world. We should keep it that way.

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2. Keating W G 1979, A System for End Use Calssification of Timbers, J Inst Wood Sc Vol 8, No 3, pp 105 - 108.

RESEARCH ON TIMBER FASTENERS

J. J. Mack

ABSTRACT

A revised system has been developed for the classification of Australian timbers into four groups for the purposes of the design of mechanically fastened joints. The system covers timber in the green and dry conditions independently and species are grouped according to their basic or air-dry densities.

Research on nailed joints has shown a very high correlation between their mechanical properties and timber density. As a result of data obtained from tests on joints in species covering a wide density range, basic working loads have been determined for nailed joints in green and dry timber in accordance with the new grouping system.

An empirical method has been developed for calculating the displacement of a nailed joint under load which embodies the concept of a stiffness modulus as a material constant. Correction factors have been determined for various durations of loading.

Preliminary studies have been made on the mechanical properties of bolted joints and have indicated that current working loads may require some revision.

INTRODUCTION

The earliest recorded research on timber fasteners of which the author is aware is a paper published by Clay (1) in 1894. Clay discussed the withdrawal resistance of nails and the lateral strength of joints with nails and drift bolts and compared the "new" round nail with the then standard cut nail.

Since then, a considerable amount of research has been carried out in many countries on mechanically fastened timber joints. Nailed joints have been given the most attention, whereas bolted joints have been almost disregarded since Trayer (2) published his results from an extensive series of tests with North American timbers. Little detailed research has been made overseas on modern special fasteners such as toothed plate connectors.

While much of the information gained from overseas research can be used as a guide to the design of joints for Australian conditions, results cannot always be directly utilized because of differences between species characteristics. Softwoods, frequently in the dry or semi-dry condition, are

predominantly used in building construction in Europe and America. On the other hand, the Australian practice of a general use of green hardwoods with a much wider density range has demanded different techniques in the design of structural joints. Even the indigeneous and plantation-grown softwoods are mostly different in growth characteristics.

The need for research on mechanically fastened timber joints is due to the fact that such joints when under load involve complex mechanisms in both the fastener and the timber and the present state of the art does not readily permit the analysis of strength and load-displacement characteristics from basic engineering principles.

That there is no universally accepted philosophy for the determination of working loads for joints is largely because of a lack of knowledge of precisely how a joint acts under different kinds of loading, i.e. dead, live, wind. Different views are held on the magnitude of allowances which should be made for variability, which can be very high, and type of loading, and of the test load on which the working load should be based. With Australian hardwoods used green, there are the additional problems inherent with splitting and collapse after assembly of the joint. With a view to unify the situation in Australia, a Standards Association of Australia (3) standard, AS 1649-1974, describes methods of test and determination of working loads for various types of joints. Working to this standard has shown that improvements could be made but at least it is a step towards standardising the evaluation of mechanical properties of timber fasteners and joints using what are considered to be reasonably satisfactory methods of analysis.

The research on timber joints at the former Division of Forest Products and at the Division of Building Research, C.S.I.R.O., during the last 25 years can be described as having the following main aims;

(i) To determine the mechanical properties of joints made with the more common types of fasteners and the more commonly used Australian timbers.

(ii) To examine the applicability of overseas findings as regards effects as such variables as fastener diameter, timber thickness and moisture content, and number of fasteners and to determine the effects of these variables.

(iii) To examine the behaviour of timber joints under various conditions of loading.

(iv) To develop suitable procedures for the determination of working loads.

Most of the above has been on nailed joints, being the most common in domestic timber construction. Properties of joints with some other types of fasteners

have been examined in only very limited testing.

This paper summarises the more important results from the ongoing research and points out some of the areas which require further investigation.

SUMMARY OF RESEARCH ON TIMBER JOINTS

GROUPING OF SPECIES FOR JOINT DESIGN

The classification of species into a small number of groups according to their strength properties for purposes of structural design has proved successful in providing a limited series of working stresses for solid timber. When the current seven-group system was introduced to replace the four-group system originated by Langlands and Thomas (4), it was decided to retain the four-group system for the classification of species for joint design. With some minor exceptions, species retained their same positions in the system and working loads determined by Langlands and Thomas for the various fasteners generally remained the same, a few small changes being made in the light of some additional experimental data.

It must be remembered that this four-group classification was made on the basis of strength properties of solid timber. In considering a revised grouping system for the design of joints, it would be desirable for this to be compatible with the new seven-group strength classification. However there are problems in attempting this. Firstly, any method of species classification which is based on a number of strength and related properties often has to be a compromise because the various strength properties of a species do not always all indicate the same group. Trying to place species in the same system on the basis of their strengths with various jointing devices such as nails and bolts, not to mention as yet undeveloped new types of fasteners, would often be an even greater compromise, and in some cases could give rise to serious anomalies. Secondly, relatively few species have been systematically tested with all types of fasteners and test data available are insufficient to support an accurate classification into the finer seven-group series, whatever the means of grouping adopted.

Examination of the grouping of species for joint design in the SAA Timber Engineering Code (5) showed that species are roughly classified according to their basic densities. Since it has been found by several research workers that the strength properties of joints with most mechanical fasteners are reasonably well correlated with density it was decided to continue with a density classification for a revised grouping system for joint design but with a more rational series of density limits for the four groups. At the same time a system was

devised for grouping with dry timber based on air-dry density.

The new classification proposed by the writer (6) is given in Table 1.

Table 1

Classification of Species into Groups for Joint Design

Green Timber		Seasoned Timber	
Species Group	Minimum Basic Density for Group kg/m^3	Species Group	Minimum Air-dry Density for Group kg/m^3
J1	750	JD1	940
J2	600	JD2	750
J3	475	JD3	600
J4	380	JD4	475

It will be noted that the ratios of the group limits for each moisture condition are in the ratio of 1.25:1, making for a more or less uniform distribution of species among the groups. The ratio of the air-dry density to the basic density of corresponding groups is also 1.25:1, this being the average ratio of densities of the major Australian native and plantation-grown species.

Although species are now being grouped on the above density basis for general purposes of joint design, it may be necessary as more test data becomes available to re-locate certain species in consideration of their strength characteristics with specific fasteners.

RESEARCH ON NAILED JOINTS

(a) Withdrawal Resistance of Nails. One of the more important properties of a nailed connection is the withdrawal resistance of the nail and a considerable amount of research has been carried out world-wide to examine this property. Tests have indicated that generally overseas findings are applicable to Australian timbers, but the magnitude of effects such as those of moisture condition and seasoning after driving may differ considerably.

The working loads for nails in withdrawal given in the SAA Timber Engineering Code were largely based on overseas data and corrected for the higher density of Australian hardwoods according to a density relation given in U.S. Department of Agriculture Wood Handbook (7).

Recent analysis of data obtained from an extensive series of withdrawal tests on plain steel nails in green and dry timber of a number of Australian species covering a wide density range has shown a very high correlation between with-

drawal resistance and both basic and air-dry density. Permissible loads for nails in green and dry timber have been now determined (8) with a greater reliability than previously possible for the new group system from the density regressions obtained from these tests. Allowance has been made for the deterioration during drying of withdrawal resistance of plain nails driven into initially green timber.

(b) Lateral Strength and Stiffness of Nailed Joints. The load v. displacement curve for a nailed joint has been shown quite positively to be curvilinear even at very small displacements (9, 10). Despite attempts by several research workers in this field, a theoretical definition of this curve in terms of fundamental elastic and rheological properties of the timber and nail has not been entirely successful.

An examination by the writer of load v. displacement curves obtained from tests on nailed joints in a number of species with several nail diameters showed that the curves could be reduced to a common basic curve irrespective of species, nail diameter and moisture condition and that this basic curve could be represented by an empirical exponential equation thus:-

$$R = (0.128\delta + 0.68)(1-e^{-3\delta})^{0.56} \qquad (1)$$

where R = load ordinate of the basic curve
$= P_\delta / P_{2.5}$
P_δ = load at displacement δ, $0 < \delta < 2.5$ mm
$P_{2.5}$ = load at displacement of 2.5 mm

Analysis of test curves also showed that the load at any given displacement can be related to the nail diameter raised to the power 1.75. Thus, the complete expression for the load v. displacement curve for a joint with any given set of values of the joint parameters, i.e. species, nail diameter, moisture condition etc., is:

$$P_\delta = 0.165\, d^{1.75} M_N R \qquad (2)$$

where d = nail diameter, mm
M_N = stiffness modulus for nail joints, $N/mm^{1.75}$

The modulus M_N is a basic material property and has a discrete value for any set of conditions, i.e. species, moisture condition, type of nail, etc. It is conceptually identified with modulus of elasticity and is defined as the value of the load function $Q = \dfrac{P_\delta}{0.165 d^{1.75}}$ per unit value of the displacement

function R, i.e.

$$M_N = Q/R \qquad (\text{cf M of E} = \frac{\text{stress}}{\text{strain}}) \qquad (3)$$

This modulus has been evaluated for nailed joints in green and dry solid timber of a number of species with plain low-carbon steel nails. A nomogram, Figure 1, has been prepared for the solution of equation (2).

Thus a satisfactory, albeit empirical, method has been developed whereby the displacement of a nailed joint can be estimated for any applied load up to a displacement of 2.5 mm. The accuracy of the estimation is better than 5 per cent, which is adequate for normal engineering design purposes.

The next step was to determine working values of the stiffness modulus for use with the revised grouping system. From tests with a number of species covering a wide density range, it was found that there is a very high correlation of the modulus with density. Thus working values of the modulus for short-time loading were calculated for the species groups from the density regressions.

Although much research is still required on the effects of long-duration loading on the behaviour of mechanically fastened timber joints, the small amount of data obtained by the author (11) indicates that for nailed joints, at loads close to the basic working load, the displacement of joints which season under load is conservatively about 10 times the initial displacement. At lower loads, the proportional increase in displacement under long-duration loading is demonstrably less. It may then be calculated from the empirical equation relating load to the displacement and stiffness modulus that this corresponds to an apparent reduction in the modulus of about 60%. Thus for green timber,

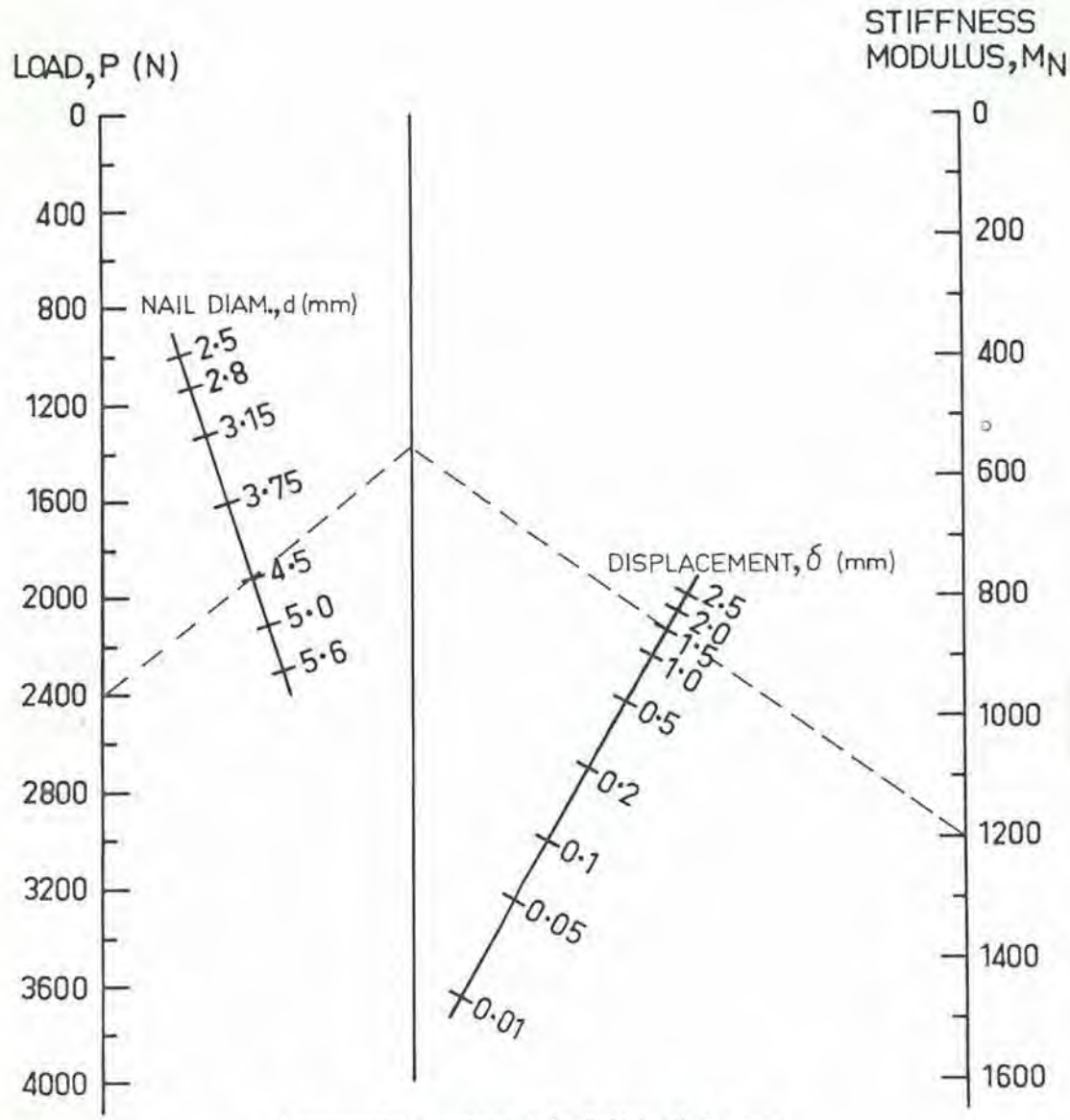
stiffness modulus for loads of long duration = 0.4 x modulus for short-duration loading.

Limited data suggest that with dry timber, the displacement under long-duration loading increases to about 5 1/2 times the initial displacement, corresponding to an apparent decrease in stiffness modulus of about 45%, so that

Stiffness modulus for loads of long-duration = 0.45 x modulus for short-duration loading.

There is a complication however, when considering the value of the stiffness modulus for loads of shorter duration.

An extensive series of tests have been carried out to examine the behaviour of nailed joints under repeated applications of loads of relatively short-



Nomogram for the estimation of nailed-joint displacement.

Example: Given load per nail = 2400 N
Nail diameter = 4.5 mm
Stiffness modulus = 1200 $N/mm^{1.75}$
Then displacement = 1.5 mm

duration ranging from periods of a few minutes to a week with like periods of no-load conditions. At the time of writing, the data obtained from these tests have not been fully analysed but it is evident that even if a load is applied for only short periods at a time but often enough, the cumulative displacement may correspond to that reached if the same load is constantly maintained for the same overall period of time.

Corrections, similar to the above for long-duration loading, to group stiffness modulus values have thus been determined for loads of intermediate durations.

Other papers presented to this Conference will describe research which has been carried out to examine the behaviour of nailed joints under a variety of schedules of repetitive loading, with a view to formulate the performance of nailed wall cladding.

The recent systematic testing of nailed joints mentioned earlier has also provided data on their maximum strength for a large number of species and again it was found that there is a very high correlation between maximum load and the timber density. On the basis of this correlation, a revised set of basic working loads has been determined to coincide with the new grouping system for the design of mechanically fastened timber joints.

For the determination of these basic working loads and the design value of the stiffness modulus for each of the strength groups it was necessary to re-examine the method of this determination. The method finally established is fully discussed in a publication by the author (12).

RESEARCH ON BOLTED JOINTS

Until recently, little or no research had been carried out on bolted joints in Australian timbers. Working loads given in the SAA Timber Engineering Code were largely based on the work of Trayer mentioned earlier and on working loads given in British and American design standards.

Tests have now been carried out with five Australian species using three bolt diameters and a limited range of joint geometries. The species were chosen as being representative of species at the low end of the density range of each of the joint strength groups.

At the time of writing, the data obtained from these tests have not been analysed. Although it is evident that some adjustment to currently recommended working loads may be necessary and that it would be advisable to extend this research, the results indicate that present design data for Australian timbers is reasonably adequate.

RESEARCH ON OTHER FASTENERS

During the 1930's, a series of tests were carried out on joints in Australian timbers using split rings and shear plate connectors. The results of these tests were never published but were used to prepare working loads and other design data which are still current. An attempt is now being made to re-analyse the data in the light of the revised species grouping system and to examine in closer detail the load v. displacement characteristics of these fasteners.

During the last decade or so a multiplicity of special fasteners and connectors have been developed. Probably the most important of these is the toothed-plate connector which is made in a wide variety of forms and dimensions. This connector was developed overseas mainly for use with softwoods and its use with initially green Australian hardwoods has presented some difficulties such as problems associated with driving the teeth into the harder timbers and high shrinkage and collapse during drying after placement. Some research has been carried out to formalise working loads published by manufacturers and developed from overseas data and to examine long-duration loading effects. It has been established that load v. displacement characteristics of toothed-plate connectored joints are similar to those of an ordinary nailed joint and can be formulated in a like manner. Currently, a research programme is investigating the relation between the strength properties of these connectors and timber density. It appears from results obtained to date that with some forms a high strength v. density correlation does in fact exist. However, with other forms, the strength of the connector itself is the controlling factor and the properties of the joint are the same for all timber species. A similar series of tests is being made with angle-shaped connectors from a variety of manufacturers.

It is believed that in general, research on special fasteners, which frequently are made to patented or registered designs, and the determination of specific working loads, is the responsibility of the manufacturers. However, it is beyond their capabilities to carry out tests with a wide range of timber species. Consequently it has been proposed that with the revised grouping of species for purposes of joint design which is based on a density classification, it is in general only necessary to test a fastener with a species which is representative of those at the lower end of the density range of each group. This of course assumes that a high strength v. density correlation exists for the fastener.

FUTURE RESEARCH REQUIREMENTS

Although working loads and general design data for the more common types of fasteners are now provided with a higher degree of confidence in their reliability, there is no doubt that there are considerable gaps in our knowledge of the duration of loading. Nailed joints in solid Australian timbers, in regard to both axial

and shear forces on the nail, have now been fairly well researched in respect of their performance under static types of loading and some indication has been obtained of their performance under loads of other duration. However, extension of this latter aspect is required.

There is a world-wide dearth of information on the strength properties of joints in plywood with mechanical fasteners. However, it is likely that a relatively short research programme could provide a reasonable comparison with solid timber joints.

These are major areas of research. There are numerous small avenues of research which could be treated in an ad hoc manner by small laboratories. It is envisaged that there will be an increase in manufacturer research as already indicated by the number of applications to the Australian Building Systems Appraisal Council Ltd.

SUMMARY

As a result of the research on nailed joints, reliable data is now available on the performance of these joints in Australian timbers and has been taken into account in a revision of the SAA Timber Engineering Code. Not only have basic working loads for nailed joints been reviewed in the light of a revised system for the classification of Australian timbers for purposes of joint design, but an empirical method has been developed for estimating their displacement under various durations of load.

While other types of fasteners such as bolts and toothed-plate connectors have received some attention, it is clear that more work is required with these types as it has been demonstrated that overseas design information is not generally applicable to Australian conditions.

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REPORT BY WORKING GROUP NO. 1 - WOOD QUALITY

(Leader: W E Hillis)

The Plenary session concerned with this Group's activities was attended by over 50 delegates.

1. Discussion of Papers

These were grouped into dry wood features 1/2, the behaviour of wet wood under different conditions 1/5, 2/19, 1/1, 1/4, juvenile wood 1/1 and extractives 1/6, 1/7, 3/14. There were also two contributions 1/1/C and 1/2/C.

2. Report of Working Group No. 1

On the basis of discussion of the above papers and the proposal to establish a Wood Quality Working Group, the assessment of future research effort, its priorities and planning, the following report was prepared.

Concern was expressed at the long delay in forming a Study Group devoted to the quality of juvenile and mature woods of the nation's resources. Formation of a Wood Quality Group was discussed but no consensus was reached on the terms of reference. There is a need for additional liaison between research workers and various relevant research working groups.

3. Identification of National Research Programmes

(a) The investigation of growth stress, its causes, extent, effects on utilisation and its amelioration, especially with respect to young eucalypts.

(b) The investigation of juvenile wood, its structure, causes, properties and means of processing for optimal utilization.

(c) The investigation and assessment of gross wood defects other than (a) and (b).

(d) The determination of the causes of variation in clear wood properties in regrowth eucalypts and how such variation affects utilisation.

(e) The development of methods of quick assessment of inherent timber defects such as collapse, and brittle heart and for wood and bark properties.

(f) The determination of technical criteria for the designation of timber and bark quality for particular end-uses and the adjustment of the qualities of the products.

(g) The investigation of the relationship between forest management practices and basic wood properties and the incidence of defects.

REPORT BY WORKING GROUP 2
WOOD ENGINEERING

(Leader: R H Leicester)

1. ASSESSMENT OF GRADED TIMBER

The following resolutions were made with respect to the assessment of the structural properties of graded timber:

(i) The STEC* group is to produce recommendations for criteria to be used in the assessment of the structural properties of graded timber and in particular the procedures applicable to the assessment of structural test data;

(ii) The STEC group is to provide recommendations for a program to assess the structural properties of graded timber. This program is to involve both members of the STEC group and members of relevant timber industry associations; and

(iii) This Forest Products Research Conference working group is to inform the Standards Association of Australia that it is their considered opinion that for the immediate future the assessment of graded timber not be considered as a Standards Association project. Rather it should be considered primarily as a research project in which any useful results will be communicated to the relevant Standards Committee.

2. FIRE RESISTANCE OF STRUCTURAL TIMBER

This Forest Products Conference working group is to convey to the Standards Association of Australia a request that in the current revision of the Australian Standard 1720, the SAA Timber Engineering Code, that an additional Part be drafted related to the fire resistance of timber members. This Part is to be modelled to the British Standard BS 5268: Part 4: Section 4.1:, the Code for Practice for the Structural Use of Timber. Part 4 - Fire Resistance of Timber Structures. Section 4.1 - Method of Calculating Fire Resistance of Timber Members.

3. DEFORMATIONS OF TIMBER STRUCTURES

STEC is to set up a committee to co-ordinate and collate information on the long duration characteristics of timber structures. Both experimental and in-use structures are to be considered, and particular attention is to be paid to the climatic factors that should be recorded.

4. CRITICAL ENGINEERED STRUCTURES

A committee comprising members of the STEC and TAG** groups are to collate and analyse information on structural deficiencies that are important in the design of critical engineered structures. In particular, the committee should pursue the frequencies, reasons and possible remedial actions for these deficiences.

* STEC - Structural Timber Evaluation Committee

** TAG - Technical Advisory Group

REPORT BY WORKING GROUP 3, WOOD PRESERVATION

(Leader: H Greaves)

Although fewer papers on wood preservation and allied subjects were presented at this Conference when compared with previous Forest Products Research Conferences, the time allocated for our deliberations was far too short. With this in mind, papers, communications, reports, etc. were grouped into major topics to produce the following agenda:-

1.	Poles	1. Soft rot; general and related studies; control measures 3/1, 3/3, 3/4, 3/17.
		2. Non-destructive defect detection 3/2, 3/6
		3. E.S.A.A. 3/7
		4. Pigment emulsified coloured creosotes in SECV poles 3/6/C
2.	Treatments	1. CCAs 2/21, 4A/9
		2. Brucising 3/15
		3. For sleepers 3/16
		4. Douglas fir treatability 3/7C (1/1/C?)
3.	Testing	1. Field and laboratory tests against termites 3/10, 3/11
		2. IRG Cooperative tests 3/8
		3. Of natural products for insect repellent & control 3/12, 3/14, 3/2/C
4.	Techniques	1. Laboratory screening 3/4/C, 3/5/C
		2. Any other business
5.	General	1. Drywood termites 3/13, QDF reports
		2. Overseas entomological research 3/3/C
6.	Any other business	1. Invited paper 2/3
		2. Assessment and identification of research priorities
		3. Dissemination of results.

It was clear that an in-depth discussion could not be accommodated on all items, and thus our main attention was divided between: ground-line maintenance treatments for poles; barrier-protective systems for poles; techniques for non-destructive defect detection (this is developing into a most important research area, especially when viewed in the context of erroneously condemned poles with their concomitant high replacement costs); strength and checking properties of CCA treated wood; termite field testing; and drywood termites, with particular reference to the fumigation programme in Brisbane, as outlined to the meeting by Alan Gardner, QDF.

The invited paper 2/3, 'User needs in timber engineering research' by P.A. Campbell received some attention. It was particularly noted that the author's comments on communication between research and industry were very valid, and perhaps a means of facilitating more effective exchange would be to re-constitute the Forest Products Newsletter. At this point, the Chief of DBR, Dr. F. A. Blakey expressed the view that he would be happy to reconstitute the Newsletter 'if the demand is there'. He further added that some attention would need to be given to the Newsletter's format, it's production, it's contents, etc. The Working Group were enthusiastic in their response to Dr. Blakey's offer. Furthermore, the Chief of DCT, Dr. H.G. Higgins added that he would wholeheartedly support Dr. Blakey should the Newsletter by resurrected.

Dr. Higgins also commented on the need for research in controlled biodeterioration. He suggested that expertise at DBR could be directed along the lines of examining such areas as microbial alcohol from wood wastes, etc. These areas are already on DBR's research programme within the Conservation & Biodegradation Section's mandate, but pressures of more preservation-oriented problems have resulted in little progress on such studies as controlled biodeterioration. Collaboration between DBR & DCT on these matters could be more fruitful.

The meeting then considered additional research effort and priorities, beginning with three recommendations from Bruce Rumball representing the Radiata Pine Association of Australia:

(i) Impermeable heartwood The RPAA believes this matter requires research attention since it'could run the industry into a lot of problems'. Support for research in this area was also expressed by Keith Cokley and Wal Smith of QDF, the former suggesting a consideration of treatments to confer dimensional stability and weatherproofing, while the latter saw a need for effective treatment of such wood particularly for use in water cooling towers.

(ii) Light organic solvent preservatives Again the RPAA thought this area required further research and some priority should be given to it. Mr. Retter of the Timber Preservers Association of Australia agreed, but commented that the preservation industry have mostly met the RPAA's requirements in this area, as set out at the 16th Forest Products Research Conference. Further 'improvements' could lead to significant rises in costs. Again QDF personnel supported this aspect of preservation as a priority area.

(iii) Alternatives to pressure treatments This was the third research priority of the RPAA, and once more it was supported in principle by the meeting. There was some disagreement on Mr. Rumble's specific request for double diffusion studies especially since quality control would represent a real difficulty from both research and commercial view points. Mr. Cokley and Mr. Barnacle of DBR mentioned Boultonising, and hot and cold dipping was a further discussion point raised by QDF. Some suggestion was made about the need for research on improved pressure treatments, as opposed to alternative pressure treatments.

(iv) Preservatives for flooring used in platform construction It was felt (QDF) that too little attention is being given to water- and rot-proofing of different flooring materials which are presently being used in modern construction techniques.

(v) Out-of-ground durability ratings Mr. Gardner (QDF) spoke about the need for research in this area, and informed the meeting that QDF were setting up a field test to help fill this need. He received support for the suggestion that DBR also consider this topic as a research priority.

The meeting closed with much discussion of the effectiveness and present *modus operandi* of TM 106. (See report of the Wood Preservation Committee). In particular it was suggested (Rex Johnstone, and others) that the numerous sub-committees were losing sight of the primary goal, i.e. to revise AS 1604 especially. The Group recommended that the Timber Standards Board should be lobbied with a view to placing TM 106 back on the path of developing urgently needed preservation standards in the short term. A reduction or amalgamation of the 21 sub-committees would be a good start.

REPORT BY WORKING GROUP 4A
DRYING AND CONVERSION

(Leader: M W Page)

The Working Group on Conversion and Drying met and considered eleven papers and three contributions. These embraced the research areas of log storage, log grading, sawmilling, saw blade behaviour, and seasoning. It should be noted, however, that these considerations covered only approximately 40 per cent of the research activities in the total conversion field. It is recognised that in a conference of one week duration, if parallel sessions are to be avoided, then discussions must unfortunately be restricted.

The work on storage of coniferous logs under water spray was encouraged, particularly in view of the proneness of pine plantations to windthrow, but it was suggested that the possible diffusion of bark extractives into the wood, which may adversely affect pulping characteristics, should be examined.

The substantial beneficial effects of log grading by electronic log scanning and decision-making systems was noted in relation to *P. radiata* harvesting in the A.C.T., while the research into the influence of log characteristics on the economics of sawmilling regrowth eucalypts was considered to offer important assistance to foresters in determining optimum rotation ages and is to be encouraged.

The group was asked to consider the need for research into saw blade behaviour and the view was accepted that while investigations of the mechanism of noise generation by saw blades may be of academic and long term interest, industry did not need such research at the present time. On the other hand, it did need expanded research into tooth profiles, sharpening techniques, assessment of bluntening, saw kerf reduction, tensioning techniques and overall saw blade efficiency.

The group also noted that the paper on energy requirements in sawmilling represented only a small proportion of the work currently being undertaken on energy generation from forest-based industry residues and that this work is increasing.

Five papers and three contributions on seasoning were discussed, indicative of the considerable interest and activity in this area. Further, the group fully endorsed the recommendation of the Joint Timber Seasoning Committee that this Committee continue its present role at least until the next Forest Products Research Conference.

Appreciation was expressed for the recently successful research into the redrying of preservatively treated *Pinus radiata* and the drying of 100 mm thick material of the same species. Considerable interest was also expressed in the development of a continuous high-temperature dryer and its likely industry application. The continuing difficulties in drying collapse susceptible ash eucalypts, particularly backsawn material, was noted and work to identify refractory material prior to drying was supported. Other seasoning aspects in which further research should be considered as a matter of priority are:

(i) the need or otherwise for pre-steaming in the drying of pine

(ii) the development of solar powered kilns, and

(iii) the drying by dehumidifiers.

It was also believed that some further work on the constant rising temperature method of drying should also be carried out.

On the problems of dissemination of research results the industry members present at the group meeting were critical of DBR's present methods in the Forest Products' area and spoke strongly in favour of reintroducing the Forest Products Newsletter. The view was expressed that industry had lost a much valued communication that had been tailored specifically to their needs. The suggestion was also made that there should be greater opportunity for temporary transfer of research personnel between local industry and CSIRO, and vice versa.

REPORT BY WORKING GROUP 4B
FIBRE UTILIZATION

(Leader: H G Higgins)

The group endorsed the recommendation of Working Group No. 3 (Fibre Utilization) of the 18th Forest Products Research Conference (1977), and decided to continue with the approach to the Standing Committee of the Australia Forestry Council that a working group be set up on "Fibre Utilization, Energy and Chemicals".

With regard to the recommendation of Working Group No. 3 of the 18th Conference in relation to improved communication between people working in the area of cellulose fibre composites, it was considered that collaboration in adhesives, in particular, should be intensified.

On the question of forest inventories, Mr Harries proposed that the forest services should be encouraged to:

1. include total wood fibre production potential with a view to its possible use for energy generation, material for chemicals etc., not committed to existing or planned forest-based industries, and

2. extend studies of forest productivity to low grade forests and former forest land now marginally economic or uneconomic for agricultural production.

Some opposition was expressed on the grounds that:

1. such a decision might be taken to imply a policy directed to vastly increased forest utilization with possible deleterious environmental consequences.
2. the forest services are already fully committed.

However, the opinion was also expressed that there could be advantage in extending the forest inventory to include a reasonable fraction of managed low-grade forest.

In the absence of sufficient consensus of opinion around this question, the resolution lapsed.

The various topics were discussed under the following headings: energy, composite materials (particleboard, fibre-cement composites, sawdust-cement, hardboard, reconsolidated wood (Scrimber)), pulping (tropical hardwoods, residue utilization, non-conventional pulping), chemicals and instruments.

The discussion on energy was tied in with the discussion on Mr Harries' inventory proposal and covered the use of woody materials vs other materials such as other sources of biomass and coal for energy raising.

In the area of composites differences in testing for reliability and for predicting long-term performance were recognized and aspects of both were discussed in relation to the various materials under this heading. There was concern that tests prescribed in the Standards should be regularly updated in the light of new knowledge. There was also discussion of the long-term durability of wood fibres in cement matrix materials. Some effects of wood species on hardboard properties were also mentioned and it was noted that the hardboard industry might benefit from the knowledge being gained in TMP processing.

In the discussion on the pulping, the costings for wood and wood plus bark chips were clarified, and the pulp quality of fire killed material and the effects of density on the uses of tropical hardwood pulp received further attention.

The development of locally derived tannin resins was seen to be of growing importance in the light of the increasing costs and possible shortages of synthetic resins, particularly those derived from petroleum. It was suggested that perhaps eucalypt chips might replace radiata pine bark in some horticultural uses to make more of the bark available for use in adhesive production.

The costs of the electronic psychrometer were explained in terms of the small number of units and the precision and the capability of the instrument for both humidity measurement and control. It was noted that the use of this instrument is being written into the Standard for the control of Paper Testing Rooms in Australia.

COMMUNICATIONS

Topic 1/1/C	The Quality of Douglas Fir Grown in N.S.W. and its Potential Use. M. Ghali
Topic 1/2/C	Dark Heart, Stained Wood and Its Utilisation. M. Ghali
Topic 2/4/C	A Development of a Mathematical Function for the Strength Grouping of Species. M. Ghali
Topic 2/5/C	Architects Inspection Service Education Course. J. Beesley & L.D. Armstrong
Topic 3/2/C	Host-Produced Odours Attract Elm Bark Beetle. J.R.J. French & P.J. Robinson
Topic 3/3/C	Resume of Entomological Research in Forest Products Laboratories in U.S.A., Canada, U.K., Japan and Malaysia. J.R.J. French
Topic 3/4/C	The Use of X-Rays in Laboratory Termite Studies J.W. Creffield
Topic 3/5/C	Laboratory Culture of *Neotermes insularis*. J.W. Creffield & C.D. Howick
Topic 3/6/C	The Use of Pigment Emulsified Creosote in the SECV for the Impregnation of the Sapwood in Poles. J.B. Murrey - SECV
Topic 3/7/C	Treatability of Local and Imported Douglas Fir Heartwood. C. W. Chin
Topic 3	Statement on *Cryptotermes brevis* Control in Queensland. A. Gardner
Topic 4/A/3/C	Moisture content of Kiln Dried Sawn Radiata Pine, Including the Effects of Final Steaming and Conditioning. J. Hartley
Topic 4/A/4/C	Notes on a Dehumidifier Kiln Operating in Queensland. D.K. Gough

Topic 4/A/5/C	Demonstration Solar Timber Kiln, Queensland Department of Forestry D.K. Gough
Topic 4/B	Some Effects of Wood Species on Hardboard Properties. J.L. Pascoe
Topic 4/B/4	Simulated Exposure Tests on Particleboard Flooring - Supplementary Note. G.N. Christensen & Razali Abdul Kadir
Topic 4	Comment:- Extension of the Use of Particleboard in Dwelling Construction K.R. Bootle (Forestry Commission of NSW)

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The Grading of 13-year old Radiata Pine

by

A. Anton

Paper presented at 19th Forest Products Research Conference

Melbourne, 1979.

FORESTRY COMMISSION OF N.S.W.
Wood Technology and Forest Research Division
Sydney 1979

THE GRADING OF 13-YEAR-OLD RADIATA PINE

A. Anton

ABSTRACT

An investigation on scantlings produced from 13-year-old radiata pine trees has shown:

(i) A very low correlation (r = 0.36) between stiffness and strength.

(ii) A lower relative stiffness for a given strength, when compared with results obtained from testing scantlings obtained from mature radiata pine trees as produced commercially.

(iii) If the existing grading programmes are used to machine stress grade scantlings obtained from 13-year-old (first thinnings) radiata pine trees approximately 50% of them will be rejected.

(iv) Approximately 95% of the pieces involved in this study had a strength value (M.R.) in excess of that required to place them in to the F5 grade although their stiffness was well below that assigned for the existing F5 commercially available mechanical grade.

A comparison of results obtained from small clear samples taken from the abovementioned scantlings has shown a substantially lower value in mechanical and physical properties when compared with those reported in the literature for mature radiata pine produced under normal practices.

INTRODUCTION

This paper presents the results of a pilot investigation on scantlings produced from 13-year-old radiata pine trees. The aim of this investigation was to:

- evaluate whether existing machine stress grading (M.S.G.) programmes for softwoods which include imported species, slash pine and mature radiata pine, are suitable for grading scantlings obtained from 13-year-old (first thinnings) radiata pine trees;
- assess the relationship between modulus of elasticity (M.E.) and modulus of rupture (M.R.);
- assess other properties and compare them with those known for radiata pine scantlings obtained from mature trees.

MATERIAL

The material for this investigation was selected from a representative sample of 13-year-old radiata pine logs converted into scantlings, following existing mill practices, in the Australian Forest Industries mill, Myrtleford, Victoria. One hundred and twenty lengths of timber representing the average timber quality produced from the abovementioned logs were involved. The timber was high temperature seasoned, dressed and of the following sizes.

Cross-section

60 pieces	35 ± 1 mm x 70 ± 1 mm
60 pieces	35 ± 1 mm x 90 ± 1 mm

Length

Approximate length 2.44 metres as normally produced for studs.

TESTING

The material was processed through the "Computermatic" timber grading machine and deflections along the length of the graded timber as monitored by the grading machine were automatically recorded using the "Mnemotype" (5) a facility developed by the Wood Technology and Forest Research Division for this purpose.

The grading machine was programmed to discriminate four useful grades and a reject grade, using the normal programme card for 35 mm radiata pine.

Details of the programme used and recoveries for the various grades as defined by the modulus of elasticity ranges are given in Table 1.

TABLE 1

Machine Programme and Grade Recovery for 13-year-old Radiata Pine

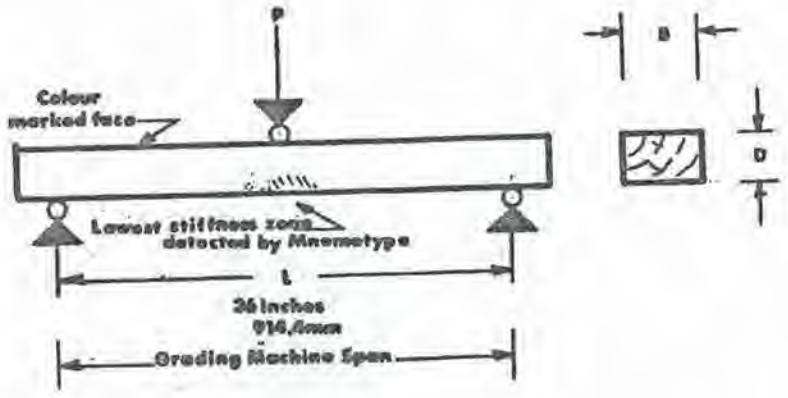
Grade	Colour code	Modulus of elasticity range GPa	Recovery			
			35 x 70 mm		35 x 90 mm	
			Number of samples	%	Number of samples	%
F11	Purple	11.58-max	0	-	0	-
F8	Green	8.27-12.19	0	-	0	-
F5	Black	5.52-8.58	0	-	2	3
F4	Red	4.14-5.65	19	33	25	42
Reject	Bleached Yellow	min-4.21	40	67	33	55
		Total	59	100	60	100

As the timber passed from the stress grader the zone of least stiffness was colour-coded by the machine and the deflections as measured along its length were recorded by the Mnemotype (5) for that piece of timber. This facilitated the determination of the weakest zone for which (M.E.) and (M.R.) were to be

evaluated on the scantling size.

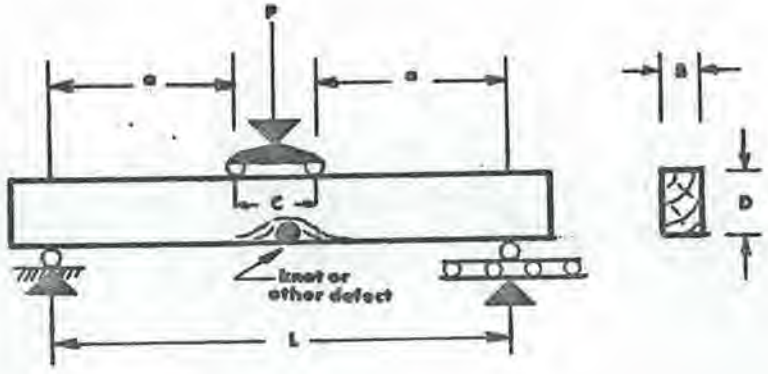
DETERMINATION OF APPARENT MODULUS OF ELASTICITY (M.E.)

Modulus of elasticity for a scantling was determined from deflections measured on the flat over a span of 914.4 mm (36") when simply supported as a plank with the lowest stiffness zone or obvious defect placed under the load. The span, the end conditions and direction of loading were identical to those of the stress grading machine as shown below.



DETERMINATION OF MODULUS OF RUPTURE (M.R.)

Modulus of rupture was determined from the maximum load recorded when testing the scantling to destruction as a joist by four point bending, as shown below, with any obvious strength reducing defect placed in the worst possible orientation, that is, a defect near the edge would be placed on the tension side.



where L, C, a are as shown in Table 2 for the two cross-sections.

TABLE 2

Span and Loading Conditions for the Determination of Modulus of Rupture

Cross-sections	L	C	a	Remarks
35 x 70 mm	100 mm	300 mm	350 mm	The spans and loading conditions are so determined to ensure that the effective length to span ratio is not less than 1 in 14.
35 x 90 mm	1300 mm	300 mm	500 mm	

During the destructive testing a detailed description of the natural features responsible for the initiation of failure were recorded.

PRESENTATION AND ANALYSIS OF DATA

Experimental data for modulus of elasticity (M.E.) and modulus of rupture (M.R.) were plotted in Fig. 1. The statistical relationship between (M.E.) and (M.R.) is given by the correlation coefficient r = 0.36. The linear regression of (M.R.) on (M.E.) is described by the following equation.

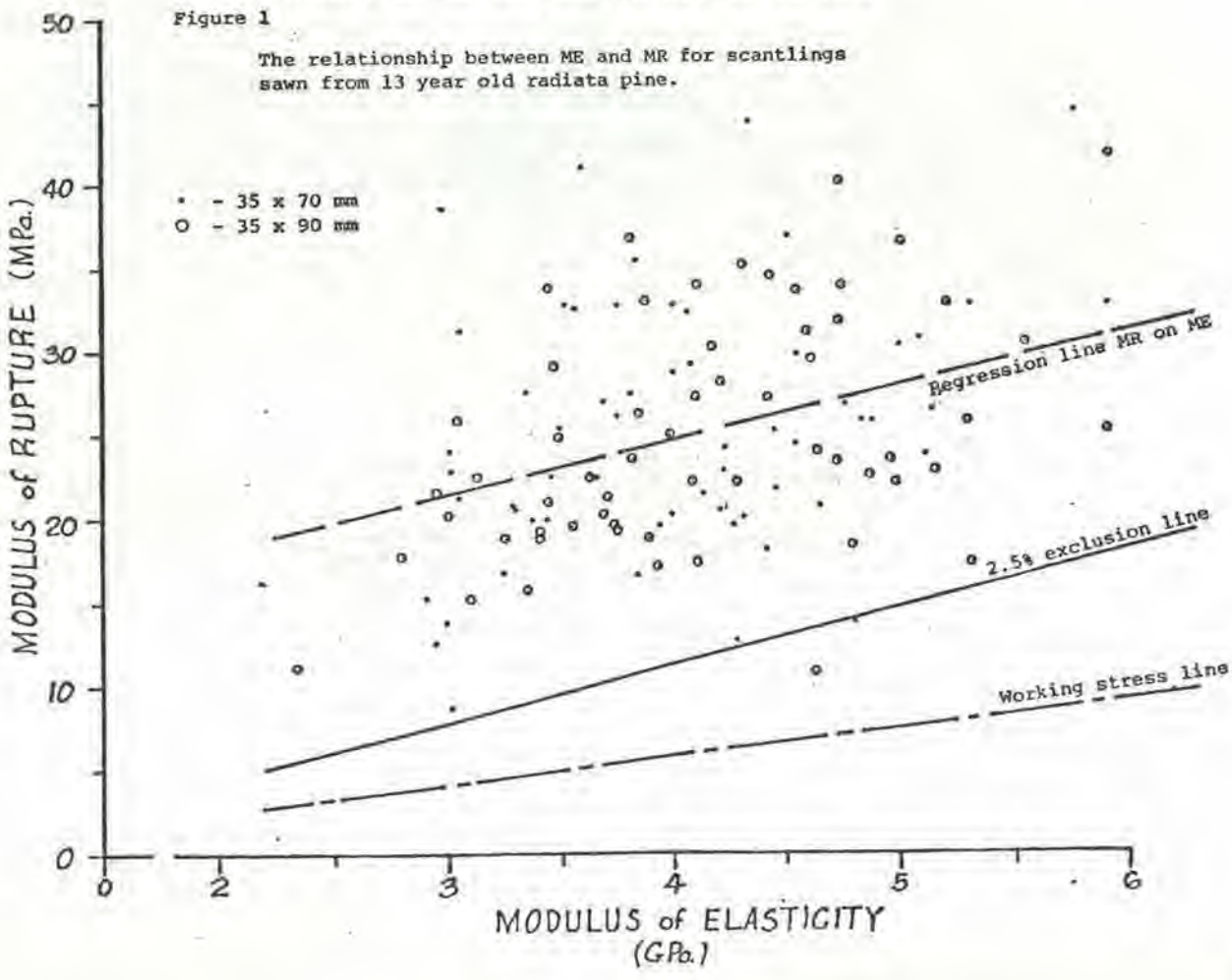
$$(M.R.) = 3.373 \times (M.E.) + 11.20 \text{ MPa}$$

where

(M.E.) is in GPa and (M.R.) is in MPa

Figure 1

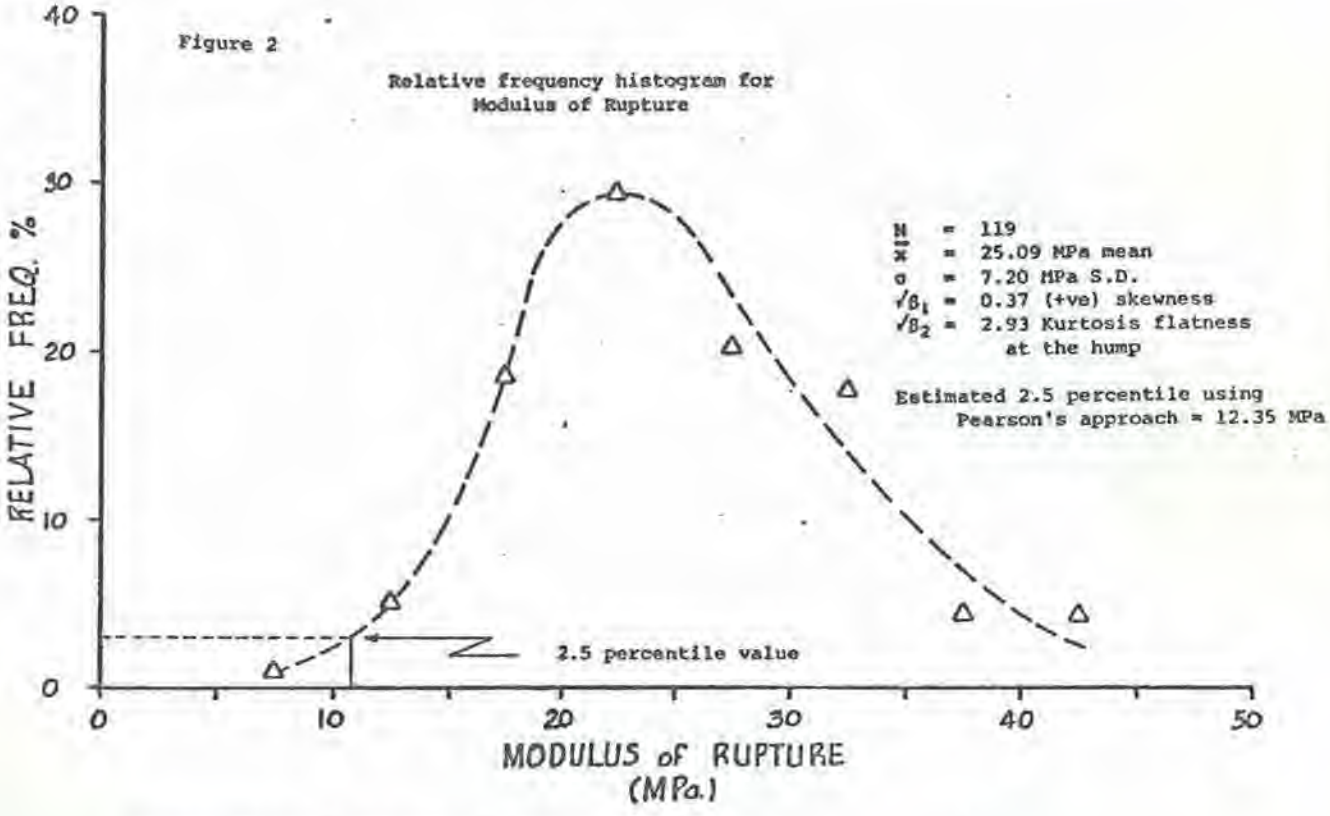
The relationship between ME and MR for scantlings sawn from 13 year old radiata pine.



Although the linear regression approach may not be the best way of describing the (M.R.) on (M.E.) relationship, it is sufficient to establish a working stress line and compare it with that for mature radiata pine.

Because of the nature of the timber under consideration it was considered desirable to analyse the results obtained as describing an individual population for which working stresses have to be determined (3).

The relative frequency histogram of (M.R.) is shown in Fig. 2. The parameters describing the data are listed and have been used to estimate the low 2.5 percentile value which is the limiting value (F_1) used to derive basic working stresses after being modified for factors related to long term loading (F_t) and uncertainties (F_u). These factors traditionally are 9/16 and 4/5 respectively.



Hence Basic Working Stress = $F_1 \times F_t \times F_u$

= 12.35 x 3/16 x 4/5 MPa

= 5.56 MPa

A Working Stress of 5.56 MPa may be assigned to scantlings obtained from 13 year old radiata pine trees.

Figure 3 shows the summary of the results for the same data as in Fig. 2 and Fig. 4 the graphical approach in estimating the 2.5 lower percentile value. Figure 4 is a magnification of the low end of the cumulative frequency curve of Fig. 3.

Figure 3

Cumulative frequency curve for strength of Scantlings obtained from 13 year old Radiata pine trees

N = 119

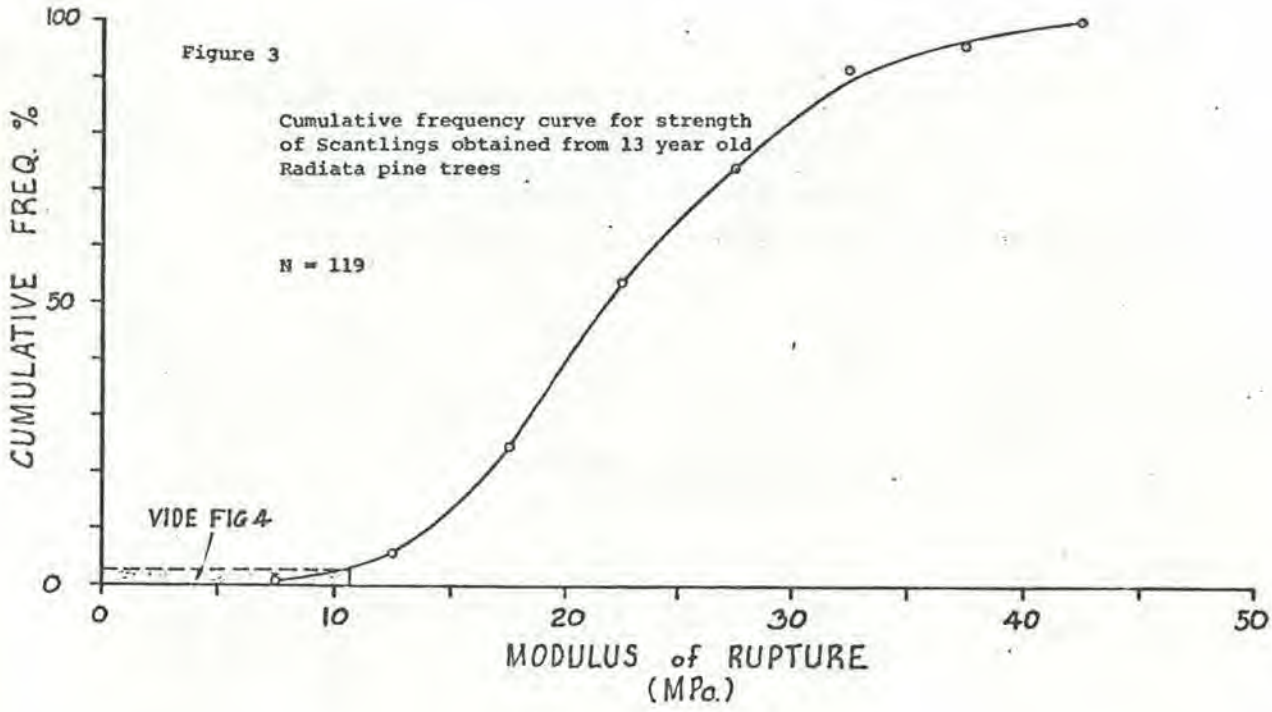
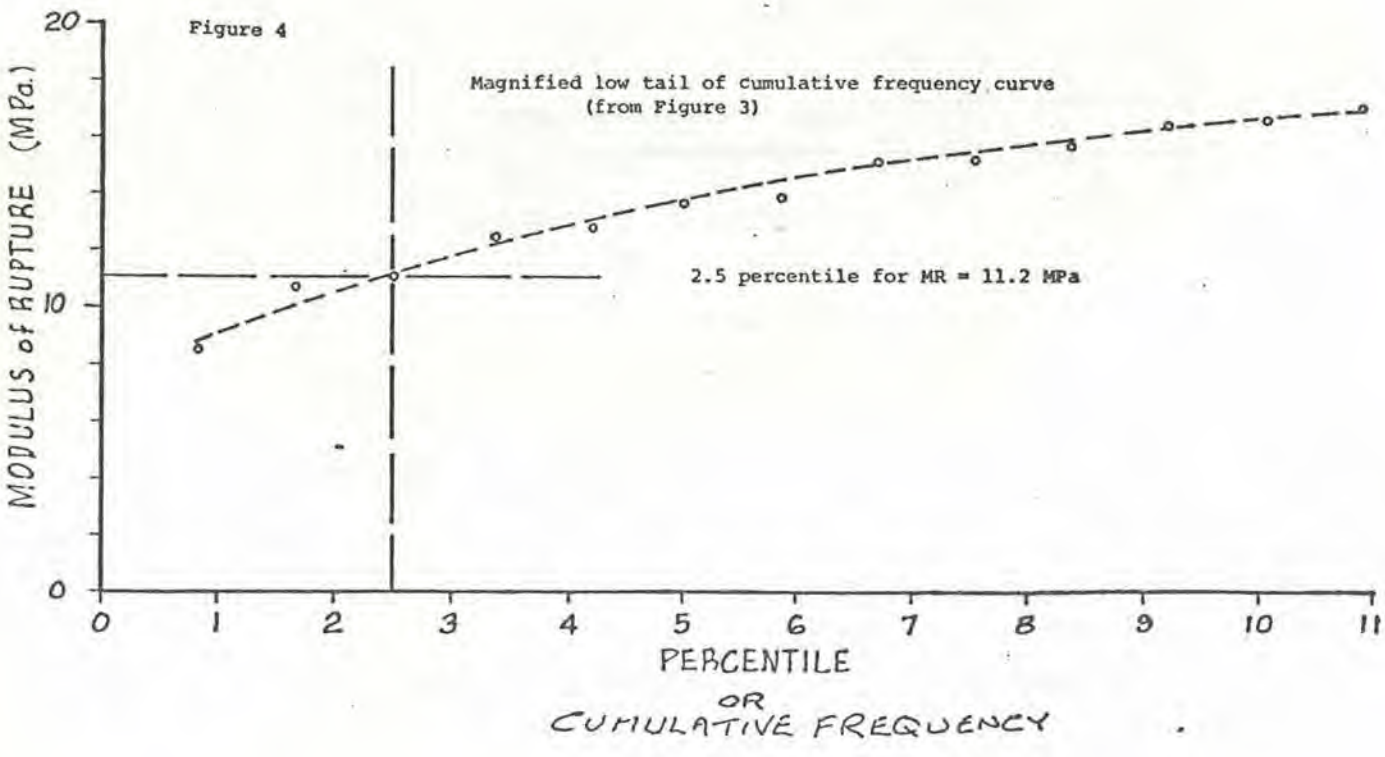


Figure 4

Magnified low tail of cumulative frequency curve (from Figure 3)



CLEAR SAMPLE PROPERTIES

A summary of test results for small clear specimens obtained from the scantlings is given in Table 3 below as well as in the relative frequency histograms Figure 5.

TABLE 3

Clear Sample Properties

	Izod (J)	M.R. (MPa)	Shear (MPa)	Comp. II (MPa)	Density(*) kg/m^3	Moisture content(+) %
No. of samples	114	112	114	111	115	342
Mean	4.10	60.97	10.09	30.52	407.63	11.67
Coefficient of variation	47%	18%	14%	14%	9%	14%

(+) oven-dry method.

(*) determined from shear samples.

Coefficient of variation is the standard deviation as a percentage of the mean.

Table 4 compares the mean values of the results for small clear samples obtained from this study with those published by Ditchburne et al. (2) involving clear specimens taken from 235 trees statistically representative of the distribution and volume of sawn production from mature radiata pine in Australia.

TABLE 4

Mean Values Obtained from Testing Small Clear Specimens

Material	Moisture content %	Density kg/m^3	Modulus of elasticity GPa	Modulus of rupture MPa	Comp. II to grain MPa	Shear MPa	IZOD values J
Mature radiata pine	12	535	11.75	89.0	49.3	11.5	7.9*
13 Y.O. radiata pine	11.76	407	6.20+	60.9+	30.5	10.0	4.1
% Difference Ø		-24	-47	-32	-38	-13	-48

* IZOD values from CSIRO Tech. Paper No. 25 (6).

\+ In this study values of (M.R.) and (M.E.) were determined from bending (centre-point) tests over a span of 280 mm, the cross-section of the specimens being 20 mm x 20 mm.

Ø Percentage difference is calculated with reference to mature radiata pine.

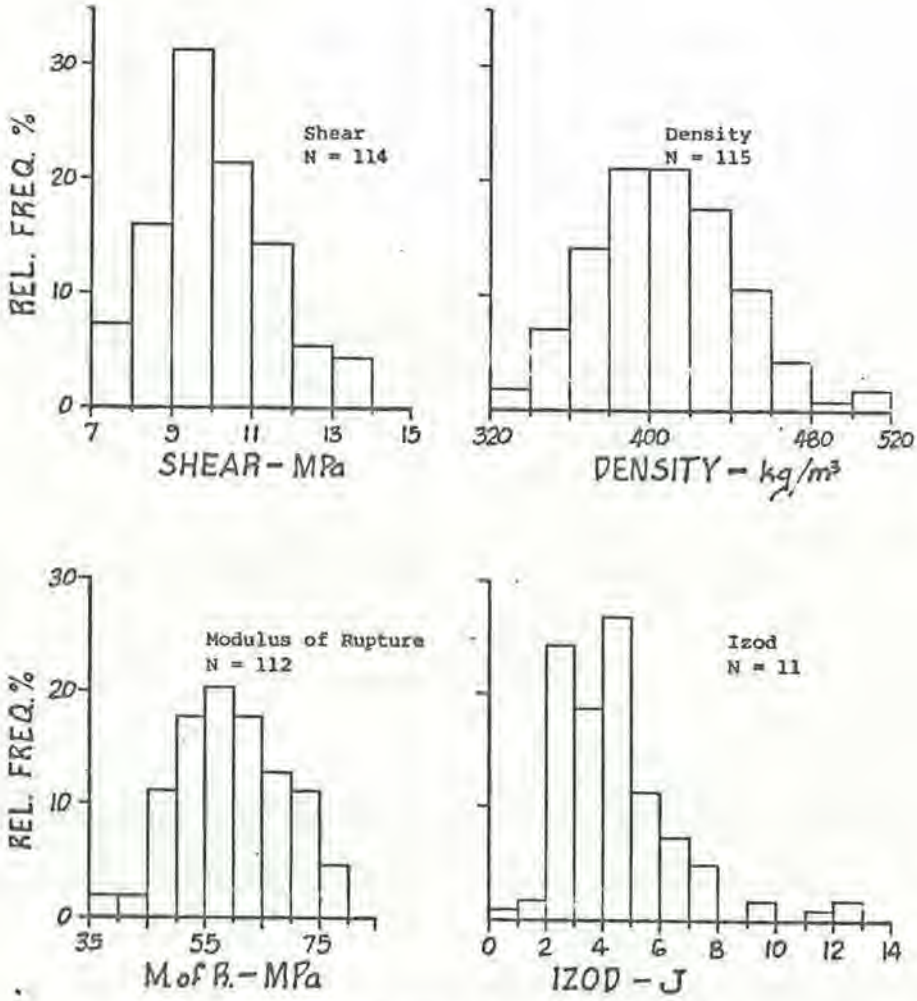


Figure 5. Relative frequency histograms for shear, density, modulus of rupture and Izod determined from small clear samples of 13 year old radiata pine.

Approximately 98 per cent of the scantlings obtained from 13-year-old radiata pine trees had a strength value (M.R.) in excess of that required to place them into the F5 grade although their stiffness was well below that assigned for the existing F5 mechanical grade.

Mechanical grading uses stiffness as a strength indicator. If the existing grading programmes which have been developed for mature radiata pine are used to grade material obtained from 13-year-old radiata pine trees approximately 50% of them will be unjustifiably rejected (Table 1).

If strength is the only parameter under consideration the present grading programmes are not suitable for scantlings produced from 13-year-old radiata pine trees because the material will be rejected on low stiffness. The results from the tests performed on both scantlings and the clear samples obtained from them indicate that the material is strong enough. Consequently it would be reasonable not to mechanically grade the material but to produce a one purpose grade such as an F4 stud grade by excluding only unusual visual defects which do not meet the general pattern.

The utilization of 13-year-old radiata pine scantlings by industry and tree producers should also be influenced by other technical aspects not covered here such as dimensional stability and drying problems.

It is of interest to note the lower values obtained from clear samples in this study for various properties when compared to those reported for mature trees as shown in Table 4 and in particular for modulus of elasticity where a 47% difference was found.

ACKNOWLEDGEMENTS

Mr. N. Cowley carried out the experimental work under the supervision of the author as a trainee forestry student and prepared a comprehensive report (5).

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DC 621.3673

DETECTION OF DEFECTS IN STANDING POLES BY X-RAY TECHNIQUES

by

W. D. Gardner, R. S. Johnstone, W. Pitt

Paper submitted to 19th Forest Products Research Conference, Melbourne, 1979, Topic 3/2.
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Chief of Division

Date 14/9/79

I'O File 663/wt

FORESTRY COMMISSION OF NEW SOUTH WALES
Wood Technology & Forest Research Division
Sydney

Admin 5 - 1979

DETECTION OF DEFECTS IN STANDING POLES BY X-RAY TECHNIQUES

W. D. Gardner, R. S. Johnstone, W. Pitt

ABSTRACT

The application of x-ray techniques to wood pole inspection procedures has been evaluated. Internal defects were accurately identified using x-ray inspection methods. These methods and their possible influence on the safety and economic aspects of wood pole utilization are discussed.

INTRODUCTION

Wood poles are subjected to attack by termites and wood decay fungi, resulting in the development of internal defects. These internal defects, depending upon their size and location within a pole, can significantly reduce its strength. For wood poles to be safely and economically used, it is necessary to detect and quantify these defects so that their influence on pole strength can be assessed.

In Australia, the internal condition of most wood poles is determined by the traditional sounding and boring pole inspection methods. To improve the accuracy and reliability of pole inspection methods, various instrumental inspection techniques, including those based on x-rays, have been evaluated. The successful application of x-ray inspection techniques to wood poles was first reported in 1940 (1) and at regular intervals thereafter (2, 4, 5, 8). These techniques have not been adopted by pole using authorities in Australia, mainly because of the increased cost over the traditional sounding and boring inspection methods, possible problems of interpreting the film radiographs, and the size of the earlier equipment.

Advances in x-ray equipment and technology, and changes in the economics of wood pole utilization, indicated that a re-assessment of x-ray inspection techniques was warranted.

Thirty four poles that had previously been condemned as unserviceable by pole inspectors using traditional sounding and boring methods, were re-inspected using x-ray inspection techniques. Radiographs were obtained both on film and x-ray sensitive paper, and an assessment of the pole condition was based on an interpretation of these radiographs. The poles were removed from service and the accuracy and reliability of the x-ray inspection techniques was compared to that of the traditional sounding and boring techniques.

Interpretation of radiographs

The appearance of a radiograph obtained from x-raying a pole will indicate the intensity of the radiation that has passed through the pole and been exposed on the x-ray sensitive medium (film or paper).

Variations in the intensity of the radiation will result in changes to the film density of the radiograph. The greater the intensity of the radiation striking the film or paper, the greater the film density of the radiograph. The intensity of the radiation, and hence the film density, is

dependent upon the density and the thickness of the timber through which the radiation passes, the distance between the focus of the x-ray source and the film or paper (F.F.D.), the voltage at which the x-ray source is used, the current applied to the x-ray source, and the time of application. The product of current (mA) and time (in minutes) is the exposure (mA minutes). By working with stepwedges of various timber species, a relationship between these factors has been established, and is represented by the following formula for a focus to film distance of 1 metre using Agfa D-7 film.

$$TT = 1.38\ kV + 3.54\ mA\ min - 0.19\ TD - 76.37\ FD + 333.9$$

($R^2 = 0.73$, coefficients for each of the independent variables were significant at less than the 1% level.)

where FD = film density
kV = tube voltage in kilovolts
mA min = exposure in milliamp minutes
TT = timber thickness to be x-rayed
TD = timber density

For any pole of a known species and thickness, and using a known voltage and exposure, the film density of the radiograph can be predicted. If the cross section of the pole is sound there will be an even reduction in film density from the outside to the centre as shown in Figure 2.

The presence of internal checks will be indicated by a small zone of higher film density if the check is aligned with the direction of x-ray transmission. This is illustrated by Figure 3.

The presence of degrade due to termite attack is indicated by increased film density and a distinctive mottled effect due to the presence of termite galleries when compared to a sound pole of similar size and species, x-rayed under the same conditions. The film density will vary according to the type of attack as illustrated in Figures 4 and 5. The film density in the radiograph in Figure 4 is less than in Figure 5 due to the presence of wet termite frass and mud.

The presence of fungal degrade is indicated by an increased film density and patchy appearance due to the partial destruction of the wood by the fungi. This is illustrated in Figure 6.

Equipment and test methods

A Philips K140 portable x-ray system was used. This equipment was composed of a K140 tubehead capable of operating at tube voltages up to 140 kV, and a control unit to allow regulation of tube voltage (up to 140 kV), tube current (up to 5 mA), and with automatic timing facilities. This equipment was powered by a 1 kVA portable motor generator.

The radiographs on film were obtained using Agfa D-7 x-ray film in 425 x 110 mm format. This film was pre-packed in reuseable light-proof black plastic envelopes, and commercially processed after exposure. Agfa Structurix IC Paper was used in a format of 400 x 40 mm. These sheets were obtained from 400 x 300 mm sheets, and each sheet was wrapped in black polythene to exclude light. The paper radiographs were developed in a Structurix IC processor after exposure.

Each pole was x-rayed at the ground line as shown in Figure 1.

Figure 1

The x-ray sensitive film or paper was taped to the backing board, and the x-ray tubehead was positioned so that the focus to film distance (FFD) was 1 metre. Lead numerals were fixed to each radiograph before exposure to provide identification after development. Lead strips were placed on the side of each pole to aid identification of the pole extremities in the radiographs.

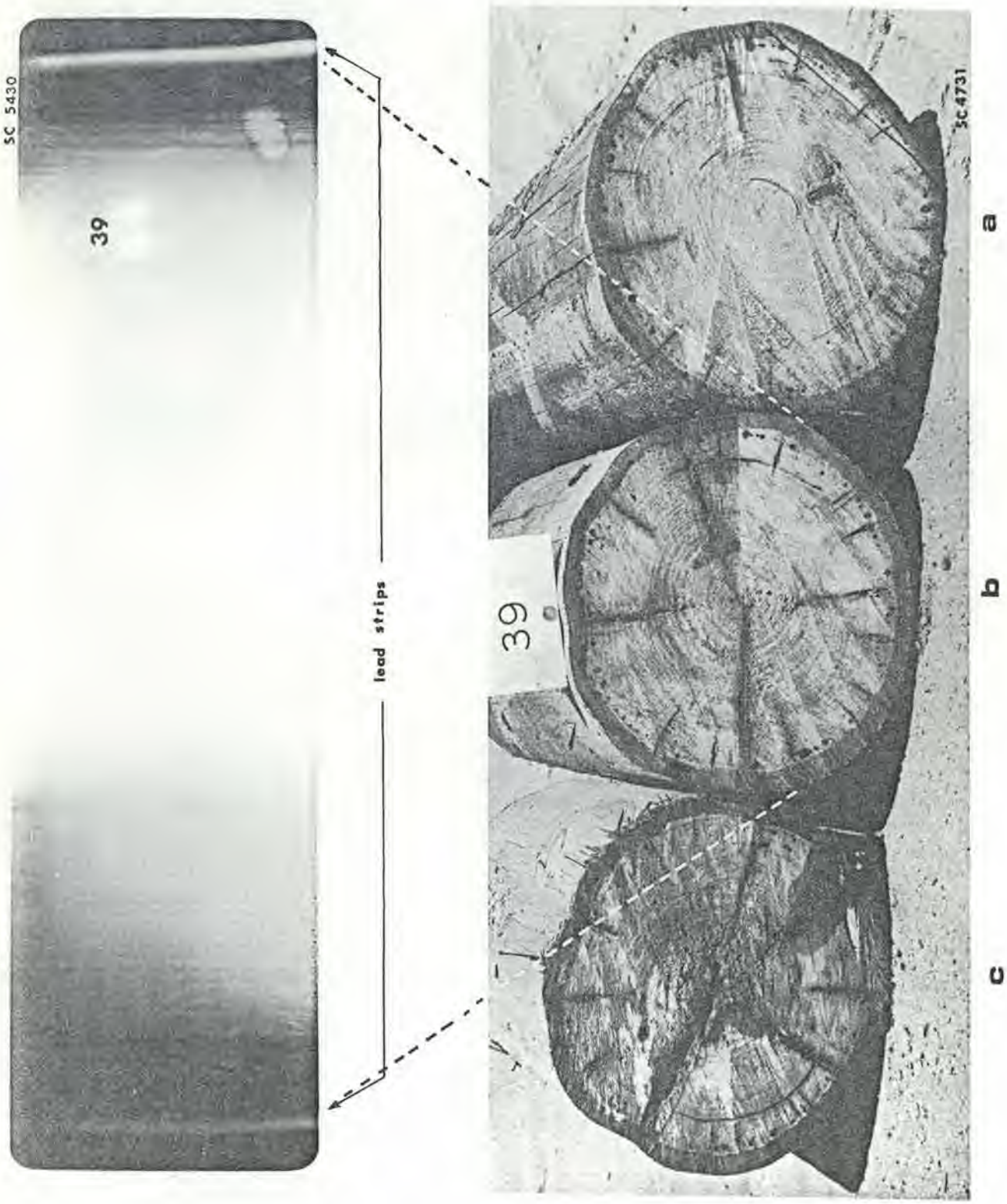
An exposure of 4 mA for 60 seconds (4 mA minute) at 110 kV was used for the Agfa D-7 film. The Agfa Structurix IC paper was exposed for 4 mA minutes at 80 kV. These exposures were selected from a laboratory evaluation using pole sections of a similar diameter (approx. 300 mm) and a selection of stepwedges that had been x-rayed using the Agfa D-7 film and Structurix IC paper with a F.F.D. of 1 metre.

After development, the radiographs were examined and the internal condition of the poles was assessed based on an interpretation of the radiographs. The poles were considered as unsuitable for further service if more than 60% of the original pole cross section was degraded by either termite or fungal attack. This allowed a 230 mm centrally located defect to develop in a 300 mm diameter pole before the pole was condemned as unsuitable for further use.

The 34 poles that had been x-rayed were removed from service. Each pole was sectioned at three points as illustrated in figures 2-6. Section (a) was originally 500 mm below the ground-line, section (b) was 25 mm above the groundline and section (c) was 700 mm above the groundline. The radiographs in figures 2-6 were obtained by x-raying at the ground line - i.e.

FIGURE 2. Radiograph of a sound pole

This radiograph shows the even reduction in film density from edges to centre typical of a pole containing only sound timber.



through section (b).

After sectioning, the poles were examined for degrade due to fungal and/or termite attack, and rated as condemned if more than 60% of the original cross section had been degraded as outlined above.

Results and Discussion

The results obtained by the three inspection techniques - traditional sounding and boring, assessments from film radiographs and assessments from paper radiographs are compared in Table 1 to the pole condition assigned after removal and sectioning.

TABLE 1

Pole inspection results

Inspection method	Unserviceable poles		Serviceable poles	
	Correctly assessed	Not detected	Correctly assessed	Incorrectly condemned
Traditional	12	0	0	22
X-ray film	12	0	20	2
X-ray paper	7	5	22	0
After sectioning	12	-	2	-

After sectioning, 22 poles were rated as being in a serviceable condition. These poles had been prematurely removed from service following their condemnation after inspection by traditional sounding and boring techniques. The remaining twelve poles had been correctly condemned as unserviceable by these traditional methods.

Interpretation of the film radiographs yielded correct assessments for 32 out of 34 poles, including all 12 condemned after sectioning.

Interpretation of the paper radiographs was less accurate, and five of the poles condemned after sectioning were not detected. This was due to the lower sensitivity and definition of the paper radiographs when compared to the film radiographs. The use of this and similar x-ray sensitive papers for such work is not recommended until the sensitivity and definition of the radiographs is sufficiently improved to enable accurate predictions of pole condition to be obtained from their interpretation.

The accuracy of the traditional sounding and boring pole inspection methods has been reported by several researchers including Zucker (1), Shaw (3), Truman (4), Johnstone (5), Owen & Pitt (6). Zucker, Truman, Johnstone and Stoker (2), also assessed the accuracy of pole inspection by x-ray techniques. A summary of their results is given in Table 2, in terms of the percentage accuracy of the prediction of pole condition.

FIGURE 3. Radiograph of internally checked pole

The presence of the internal check reduced the thickness of timber penetrated by the x-rays and increased the film density. This resulted in the centrally located dark band in the radiograph.

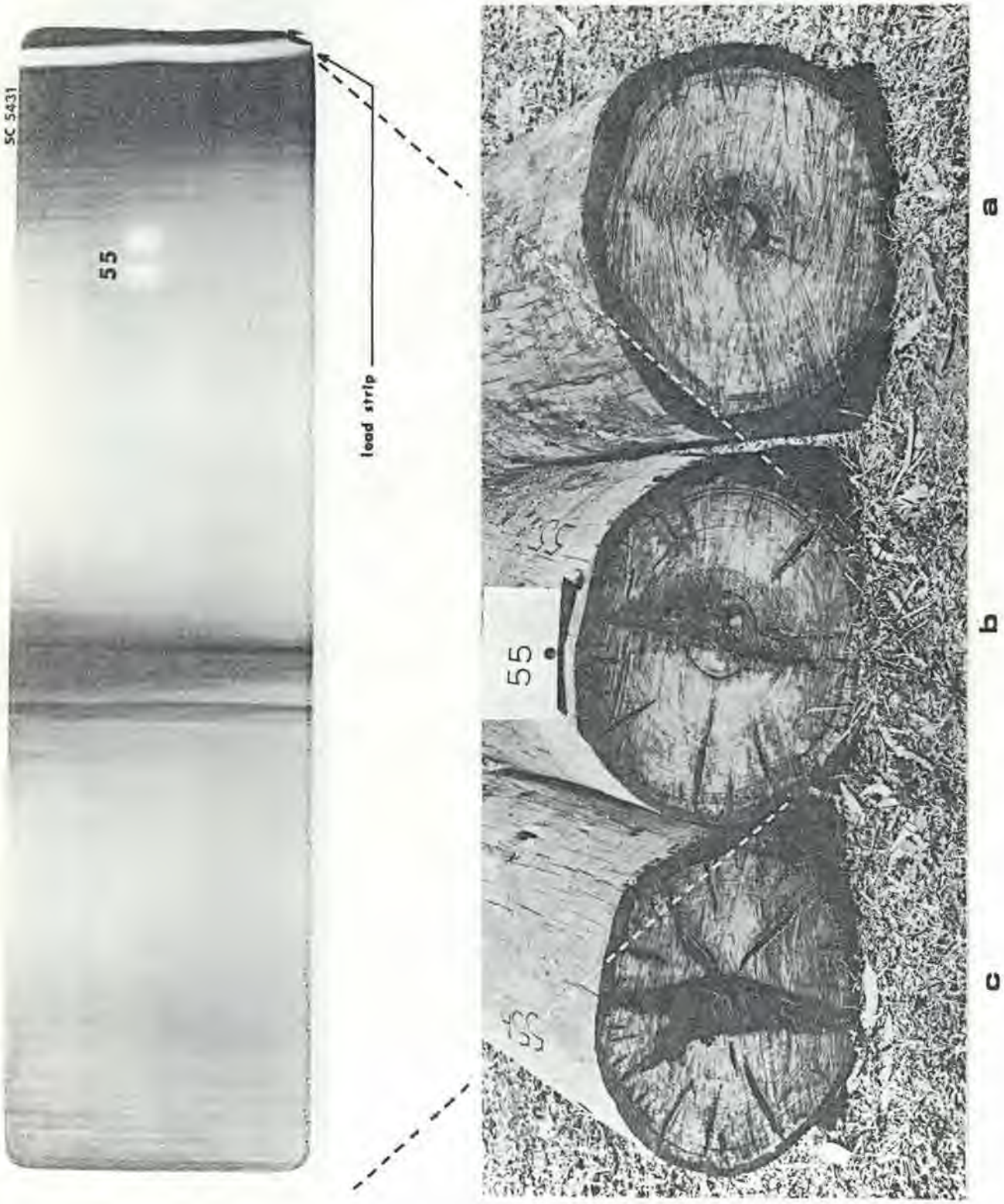


TABLE 2

Percentage accuracy of inspection methods

	Traditional inspection	X-ray inspection	Number of poles tested
Zucker (1)	29	100	300
Stoker (2)	-	78	113
Shaw (3)	45	-	2312
Truman (4)	28	83	33
Johnstone (5)	28	83	18
Owen & Pitt (6)	27	-	23
This study	35	94	34

From the data in Table 2 it is evident that at least 60% of the poles condemned by traditional sounding and boring methods are prematurely removed from service.

The economic consequences of this premature removal of serviceable poles must be considered. With a national wood pole (electricity supply) population estimated at 4 million, and an annual replacement rate following condemnation of 1.7%, approximately 68,000 poles will be condemned and replaced annually. The data from Table 2 indicates that 60%, or approximately 40,000, of these poles will be prematurely removed from service. The total cost of pole replacement including pole purchase, labour, equipment, revenue losses and overheads, is estimated at $500 for an average pole. The premature removal of 40,000 poles represents an expenditure of $20 million annually that the pole using authorities could avoid if x-ray inspection techniques were used.

To effect this saving, it would be necessary to x-ray all poles currently condemned by traditional inspection methods. The cost of the x-ray inspection will vary according to the manner in which the operation is carried out. The pole using authorities could either purchase the equipment and do the inspections with their own staff or contract the work to non-destructive testing companies. The current contract price is approximately $12.50 per pole. The cost at this price to x-ray the 68,000 poles condemned by traditional inspection techniques would be $850,000.

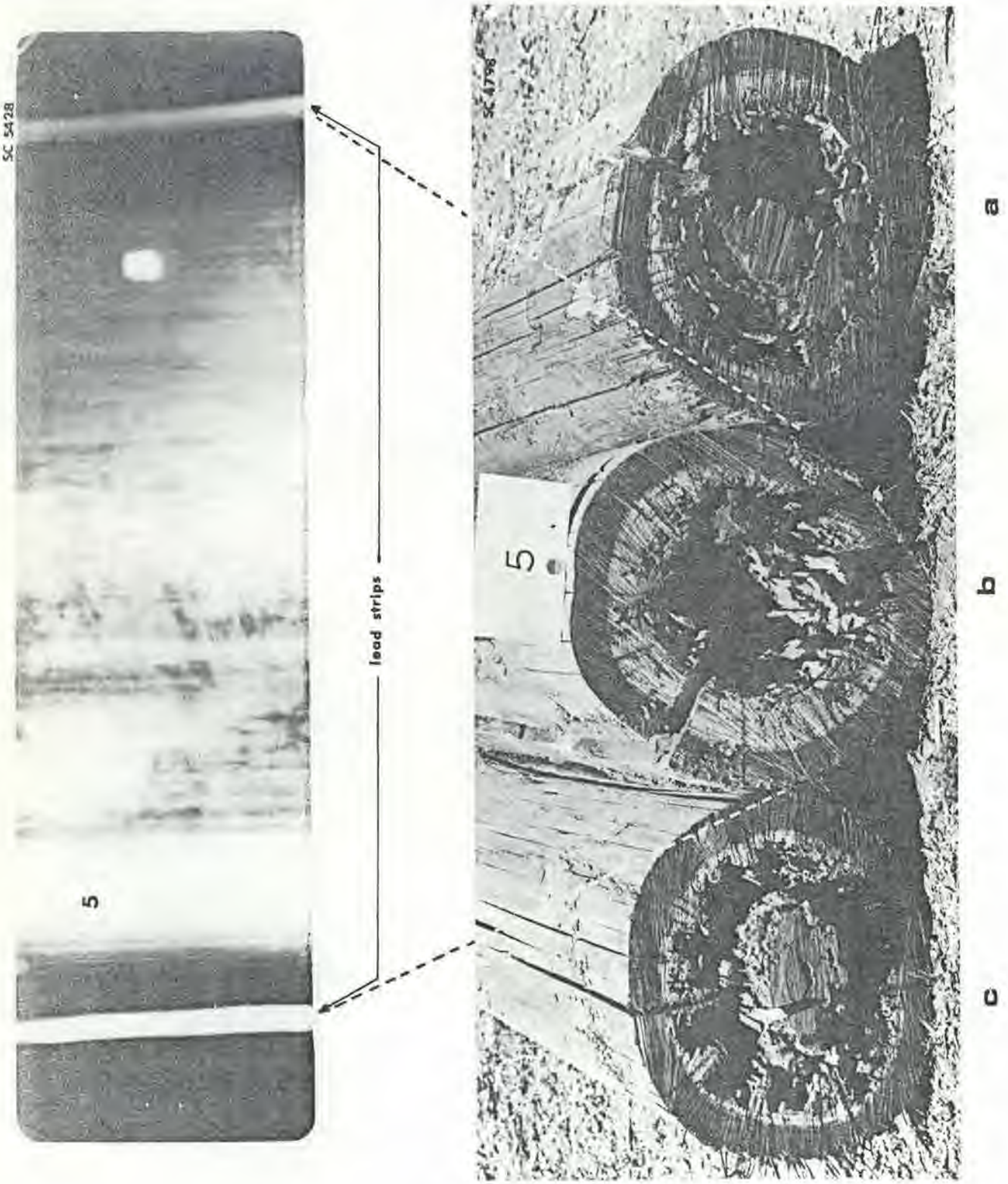
The nett annual national saving in pole replacement costs would be approximately $19 million if only those poles condemned by traditional pole inspection techniques were re-inspected with x-ray techniques.

There are also many defective poles that should be removed from service, but are not detected using the traditional sounding and boring techniques. Based on the total number of poles rejected by traditional inspection techniques, Zucker (1) stated that another 7% should have been condemned, Shaw (3) found an additional 2% and Owen and Pitt (6) 9%.

The failure of these poles in service can result in damage to property and livestock, and such failures have been the subject of major compensation litigation. The presence of defective poles also increases the risk to overhead line staff, and in New South Wales alone, 33 people have been

FIGURE 4. Radiograph of a termite-attacked pole - Type 1

There has been a considerable increase in film density with a distinctive "mottled" effect due to termite galleries. This is typical of termite attack with residual wet workings.



involved in accidents with falling poles between 1961 and 1979 (7). These accidents resulted in 29 people being injured, including 5 fatally. Only 3 of the 33 poles had been condemned as unserviceable and unsafe. The application of x-ray inspection techniques to all poles over a specified "safe" age, say 12 or 15 years, should detect the defective poles that are currently remaining in service. This must increase the safety and economics of wood pole use.

Conclusions

Our research has shown that with modern x-ray equipment and technology, internal defects in standing wood poles can be accurately and reliably detected. The use of x-ray inspection techniques by pole using authorities would significantly decrease pole replacement requirements, resulting in improved economics of wood pole utilization and aid the conservation of a valuable timber resource. The implementation of these techniques will also improve the safety record of wood pole use.

The maximum benefits from x-ray inspection techniques will be obtained if they are applied as part of a regular, programmed inspection operation. This will require a considerable departure from the current concepts and practices of wood pole inspection, and the development of new inspection practices.

The benefits of x-ray inspection make it the ideal technique upon which to develop future wood pole inspection practices.

FIGURE 5. Radiograph of a termite-attacked pole - Type 2

The film density for this radiograph is much greater than that for Figure 4. This is due to the presence of a "pipe" with dry nest material rather than tightly packed wet material.

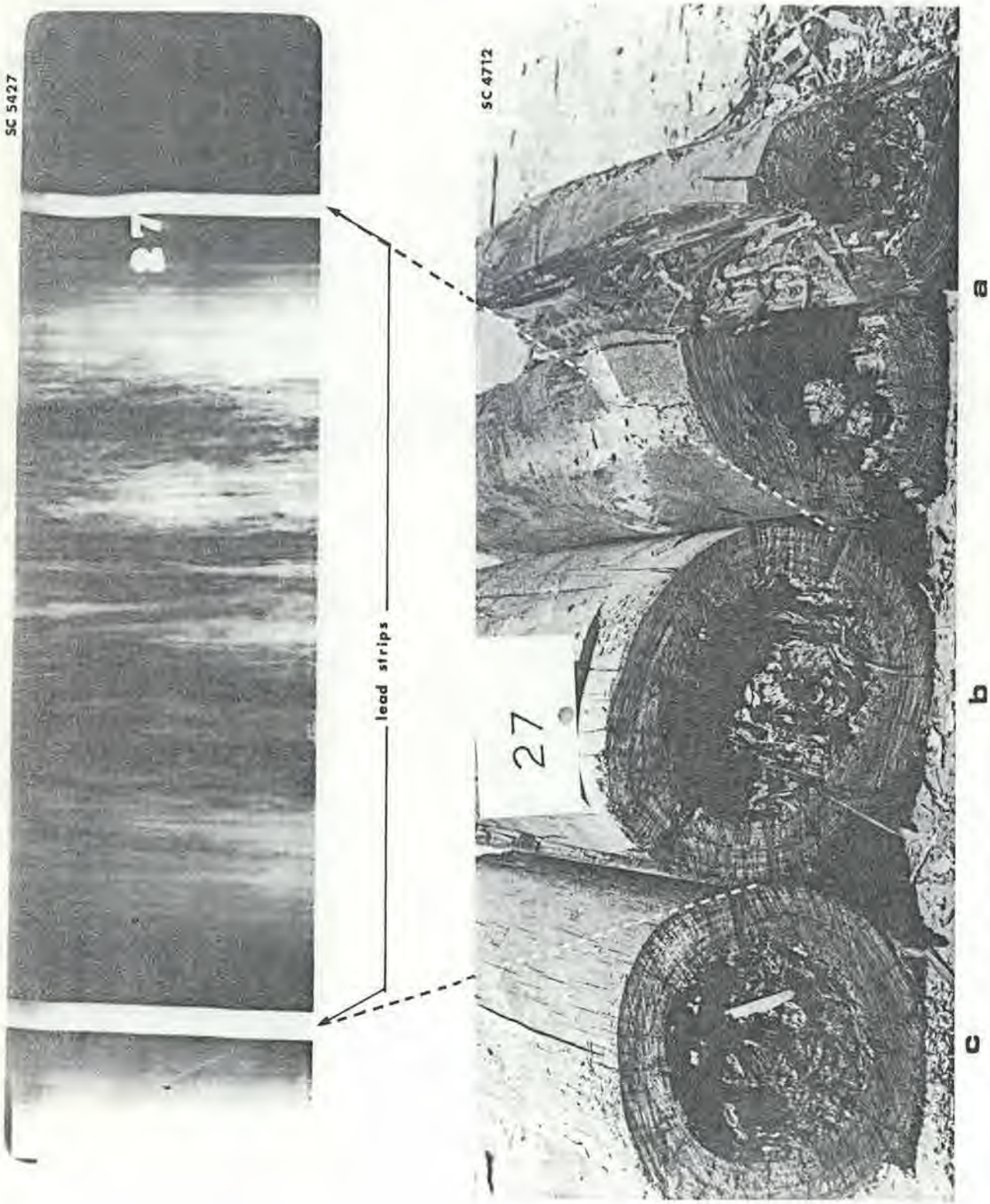
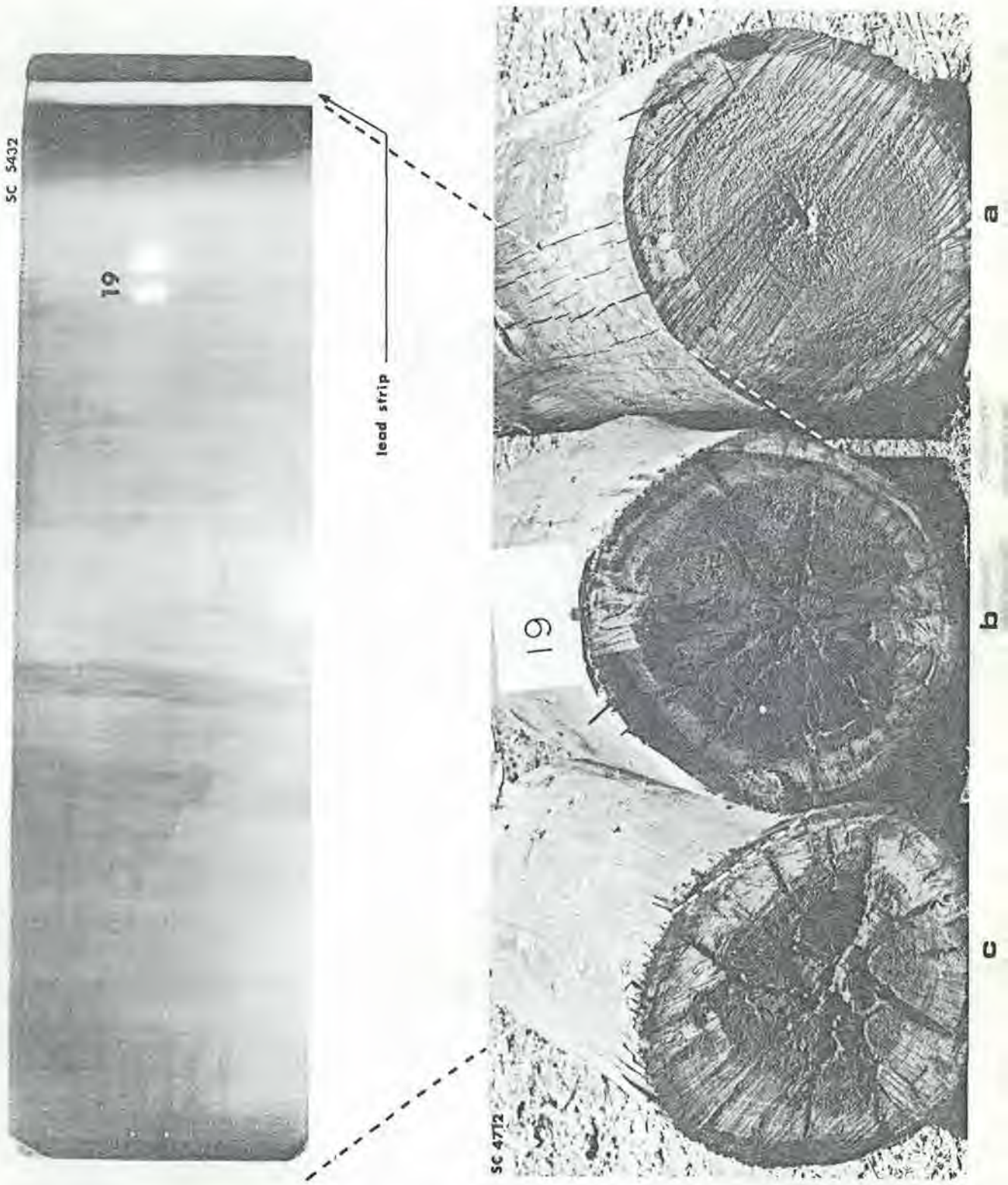


FIGURE 6. Radiograph of decayed pole

This radiograph contains a greater film density than a similarly-sized sound pole, and exhibits the uneven grain effect characteristic of partial destruction of wood matter by fungi.



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